FY 2012 Specialty Crop Block Grant Program – Farm Bill

New Mexico Department of Agriculture

Final Report
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Project Coordinators

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-1477 Project 1: Promoting New Mexico Processors and Growers of Specialty Crops to the Food and Beverage Industry, Final Report

Project Summary

The project was the evolution of prior Specialty Crop Block Grant Program (SCBGP) food services projects. The project built on prior funded "Food Service" projects by expanding marketing and promotional efforts of New Mexico (NM) specialty crops and value-added products across the entire food and beverage industry. The issue and importance of expanding the marketing and promotional efforts was to grow business for processors and growers into new markets including: food and beverage retail operators, food and beverage distributors, food service chains, grocery and convenience stores, and specialty food and beverage retailers.

The project achieved its purpose. The project demonstrated the importance of funding assistance and NMDA expertise for the beneficiaries, thus increasing the growth and competitiveness of New Mexico Specialty Crops.

Project Approach

The project approach was to build on prior food service projects to increase sales and market share of processors and growers of specialty crops. The approach was to grow into new food service and retail markets through product demonstrations, exhibiting at trade shows, participating in special events, and working with the entire U.S. food and beverage industry. The promotional activities started in March of 2013 and carried through May of 2015. The product demos worked with talented, professional, and celebrity chefs. The tradeshows were carefully picked to connect processors and growers to distributors and operators.

The special events promoted New Mexico specialty crops to local food and beverage festivals, regional and national cook-offs, regional and national grocery chains, and culinary media reporters. The special events promoted New Mexico specialty crops.

The Market Introduction Program introduced New Mexico specialty crops to new markets as funding was used for product sampling and new and innovative uses. The funding was critical to enabling processors and growers being involved with the promotional activities (especially trade shows), whereas, they may not have been able to without the assistance. Although the work project needed to be extended, the activities listed in the work plan were completed.

NMDA's expertise, contacts in the food and beverage industry, and promotion of New Mexico specialty crops through the use of the SCBGP funding was critical to the success of the program.

Goals and Outcomes Achieved

The primary goal of the project was to increase the number of markets and market segments for processors and growers of New Mexico specialty crops. As outlined below, the goas were exceeded.

- New food service market goals exceeded the goal by nine markets.
- New retail service market goals exceed the goal by 10 markets.

Goals Established	Actual Accomplishments
Increase new markets in the food service industry by 13	22 new markets-- New markets in the food service industry using New Mexico specialty crops include: Pizza restaurant operators; Indian Gaming and Hotel Operations across the USA; West Texas food service operators; Food truck operators in NM, AZ, and CA; Phoenix and Scottsdale, AZ food services operators; Airline food series concessions; NM college and university alumni across the USA; Southern CA wine distributors; Hotel food and beverage operations in Las Vegas and Reno, NV; Specialty produce to northern CA and southern USA; Food service distributors in: Delmar, CA; Phoenix, AZ; Denver, CO, Dallas, TX; Monterey, CA; Las Vegas, NV; Salt Lake City, UT; Southern Texas; Des Moines, Iowa; Southern Colorado; Anaheim, CA; Chicago, IL; Tucson, AZ; and New Orleans, LA; Albuquerque school districts; and additional Native Indian Food and Beverage operations.
Increase new markets in the retail section by four	10 new markets in the retail sector using New Mexico specialty crops include: Southern CA; Las Vegas, NV; Chicago, IL; Michigan; Texas; Hawaii; and USA web retail venues, ICS Love with Food, ExpoWest, Fuze-SW. New retail markets have been established including: Smith's Grocers, Albertson's Grocers, Specs Distributors, Independent Grocers Association, Walgreens, and World Market Stores.

Activity Highlights

Food Service, Distributor Trade Shows— SYSCO, LaBatt, Ben E. Keith, US Foods, and Shamrock typically promoted specialty crops: red and green chile, pecans, onions, and potatoes.

Food Service Distributor show attendance was 600-1,000 food service operators. Sampling and cooking demos were preformed and approximately 40-60 strong sale leads resulted.
International and Association Trade Shows: Produce Marketing Association (PMA), Global Gaming Expo (G2E), International Pizza Expo (IPE), Texas Restaurant Association (TRA), Efficient Collaborative Retail Marketing (ECRM), Night Club and Bar Show (NCB), National Indian Gaming Association (NIGA), and International Chile Society (ICS).

These activities were usually very large-scale promos that involved many growers and processors.

Average attendance from TRA and ECRM shows was approximately 6,000 attendees per show; attendance for the IPE, PMA, and NCB all ranged from 20,000 to 25,000 per show; and G2E had approximately 50,000 attendees.

The activities included seminar presentations, product demos, networking, and expanding markets.

Beneficiaries

The beneficiaries of the project were the processors and growers of New Mexico specialty crops. The project helped the beneficiaries to grow their business in existing and new markets as shown in the actual accomplishments of goals.

Working to benefit the processors of specialty food and beverage products, creating more demand and thus benefiting the growers.

The exposure and growth into new markets will continue to benefit the processors and growers in the future as New Mexico specialty crops gain popularity, demand, and competitiveness.

Lessons Learned

NMDA through prior projects has helped processors and growers of specialty crops by making contacts, identifying their growth goals, and making them more competitive, especially in the Food Service Sector. This project realized and dealt with promotion and growth into new sectors and markets. The project promotions and activities opened major retail markets. The promotion and activities worked across the entire Food and Beverage supply and service chain.

The project helped New Mexico companies to gain market share out of the state of New Mexico whereas sustainable growth was realized among New Mexico processors and growers and less winning and losing business from each other. We have learned that the business growth potential in the surrounding states has enough business for all to grow substantially.

The project took longer than originally planned since we had some overlapping funds from a previous project and mostly that we took caution to spend the funds most effectively while making sure the New Mexico companies were ready to grow in the new markets.

There continues to be a great need for support through NMDA for New Mexico processors and growers of specialty corps. The funding continues to be vital in helping the companies participate in promotional activities, especially in trade shows. The companies realize the expertise and connections that NMDA has in the Food and Beverage industry. Through the work of the project, NMDA and the New Mexico companies realize the enormous potential business that exists for them in new markets outside of New Mexico.

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-1477 Project 2: Development of Onion Cultivars Resistant to Fusarium Basal Rot, Final Report

Project Summary

Fusarium basal rot (FBR) is a soil-borne fungal disease that causes a disintegration of the onion bulb basal plate (compressed stem) thus killing a plant growing in the field. Once a bulb becomes infected with the fungal pathogen, the disease and the resulting decay it causes cannot be halted. Any plants exhibiting foliage symptoms consistent with the disease must be discarded, thus reducing yield. Soil fumigation, although costly, and crop rotation cycles of five years or more can reduce the frequency of the disease, but will not prevent it from occurring. FBR-resistant cultivars currently do not exist. Since onions have been grown in New Mexico for more than 100 years, many fields have had multiple onion crops in their history. In addition, as agricultural land becomes sequestered into residential development or perennial agricultural crops, such as pecan, the number of fields available for adequate rotation decreases and the rotation time between successive onion crops decreases to three years or less. The FBR pathogen also has the ability to infect other plant species and to survive on dead plant matter in the soil, thus increasing its longevity in the soil and decreasing the benefits of crop rotation.

The disease is particularly damaging to bulbs in storage as the initial decay is difficult to detect but once decay is visible, secondary bacterial pathogens have already entered the decayed tissue. These bacterial pathogens can cause additional decay and spread decay to adjacent bulbs. Any decayed bulbs must be separated from healthy bulbs otherwise entire shipments can be rejected by buyers upon detection of a certain percentage of decayed bulbs at their destination. A rejected shipment not only causes a loss in revenue from those onions, but also incurs additional costs of shipment disposal if another buyer cannot be found. During the grading and re-grading process, decayed bulbs can be removed by hand but this is costly and time consuming. Onions that are resistant to FBR would develop no basal plate decay, would not permit entry to bacterial pathogens through the basal plate, would exhibit fewer decayed bulbs, would require less grading effort, and would save money through fewer discarded bulbs and fewer rejected shipments because of decay issues.

Project Approach

Seed of original, intermediate, and advanced FBR-selected populations and one resistant and two susceptible checks were sown in fields at the Fabian Garcia Science Center (FGSC) in Las Cruces, NM on October 2012. There were a total of 30 entries in the study that were replicated four times. Plants were grown during the fall, winter, and spring months using standard cultural practices for onions grown in southern New Mexico. In March of 2013, cultures of *Fusarium oxysporum* f. sp. *cepae* (FOC) isolates maintained by the program were initiated. In May and June of 2013, bulbs were harvested from the planted populations once plants had reached maturity. After 4 weeks of storage, the basal plate of bulbs was cut transversely and 3.0 x 10^5 spores/ml were applied to the cut surface as a liquid suspension. After 21 days, the basal plate of each bulb was cut again and the basal plate was rated on a scale of 1-9 where a 1 represented no diseased tissue and a 9 represented 70% or more of the plate tissue was diseased. The lack of diseased tissue on basal plates of the susceptible check indicated that the inoculation was ineffective in causing disease.

A new study was initiated to evaluate higher inoculum rates and alternate inoculum delivery methods. In addition to the original spore concentration of 3.0 x 10^5 spores/ml, three additional concentrations

were evaluated; 6.0, 9.0, and 12.0 x 10^5 spores/ml. Two additional inoculum delivery methods were developed in the hopes of increasing disease incidence. Spores at the aforementioned concentrations were either suspended in potato dextrose agar (PDA) or polyacrylamide gel before being placed on cut basal plates. Twelve treatments that consisted of the 3 inoculum delivery methods and the 4 inoculum concentrations were created. Basal plates of 20 bulbs of the susceptible check were cut transversely and the basal plates were inoculated with spores from one of the treatments. A treatment was repeated four times. After 21 days, the basal plate of each bulb was cut again and the basal plate was rated. The treatment in which 12 x 10^5 spores/ml suspended in PDA were applied to the basal plate resulted in the highest incidence of disease and was selected for future inoculations.

Using the information gained in 2012, seeds of original, intermediate, and advanced FBR-selected populations and one resistant and one susceptible check were sown in fields at the FGSC in October 2013 and 2014. There were a total of 23 entries in the study that were replicated four times. In March of 2014 and 2015, cultures of FOC isolate CSC 515 were initiated from infected, frozen wheat straw. Onion bulbs were inoculated with mycelium and spores from these cultures. The pathogen was reisolated from infected basal plate tissues of these inoculated bulbs. Infected bulbs served as an inoculum source for generating fresh inoculum and to maintain pathogen virulence. Small sections of infested basal plate tissue were placed on petri plates of PDA to encourage pathogen growth. After 10 days, spores were rinsed from the plates with distilled water and the resulting spore suspension was saved. These spores were mixed with cooled, autoclaved PDA media to result in a final spore concentration of 12 (2014) or 3 (2015) x 10^5 spores•ml^{-1} of PDA in the poured plates.

From late May to early July of 2014 and 2015, bulbs were harvested from the planted populations once plants had reached maturity. After harvest, the basal plate of all bulbs from the plot was cut transversely and a 1 cm diameter plug of PDA inoculum was applied to the cut surface. Bulbs were placed in black plastic crates and crates were placed in black plastic bags for 3 (2014) or 1 (2015) day(s) to encourage mycelium growth and infection. After 21 days from inoculation, the basal plate of each bulb was cut again and the basal plate was rated. Bulbs, that were rated as a 9, were discarded while all other bulbs were saved to produce seed for the following year. The average disease severity was calculated from the first 20 bulbs selected arbitrarily from the plot. Disease incidence was calculated as the percentage of diseased bulbs. Data were statistically analyzed to determine entry means for disease severity and incidence. Single-degree-of-freedom contrasts were calculated to determine statistical differences between pairs of entry means. These analyses were conducted to determine if selection had resulted in a reduction in disease severity and incidence.

In September 2014, bulbs selected from the first and second generation lines of all seven cultivars were placed into separate locations in a field at the Leyendecker Plant Science Research Center (LPSRC) to produce seed of each line in the following year. In April 2015, those bulbs produced seedstalks and began the flowering process. Crossing cages were constructed and placed over the flowering bulbs. In May 2015, pollinators (honeybees and blue bottle flies) were introduced into the cages to pollinate flowers. These pollinators remained in the cages for 2-3 additional weeks from now once flowering has finished. In July 2015, seed capsules were harvested and seed cleaning was initiated. Seeds of original, intermediate, and advanced FBR-selected populations and one resistant and one susceptible check were sown in fields at the LPSRC in October 2015. There were a total of 23 entries in the study that were replicated four times. This study was initiated to assess the progress made for FBR resistance through

the selection conducted as part of this proposal. The work funded by this proposal will continue until a FBR resistant cultivar is developed.

In both 2014 and 2015, the inoculation method was very effective at causing disease in most bulbs which is very important for selecting FBR resistant bulbs. Both the resistant and susceptible check entries exhibited a high level of disease severity and incidence and both entries could not be distinguished for both traits in 2014. These results suggest that the inoculation method needs to be modified to reduce infection rates and disease development in order to better differentiate between the resistant and susceptible check entries. When the spore concentration and incubation time were reduced, a better discrimination was observed between check cultivars; however, additional modifications to the inoculation protocol are needed for reduced disease infection. Compared to the evaluations performed in 2013 and by previous investigators, the incubation environment and time of incubation is critical to disease formation with this pathogen.

With the high rate of disease development throughout the study, many of the selected populations did not perform well in terms of disease severity and incidence. In addition, the responses observed were not the same in both years. For example, of the seven cultivar populations evaluated in 2014, all three generations of 'NuMex Mesa' exhibited a reduced severity and incidence as compared to the performance of both check cultivars. Unfortunately, this same response was not observed in 2015 as all three generations were similar to the susceptible check in terms of disease severity and incidence. Any observed resistance needs to be present in multiple years to be valuable. The results from this study suggest that the inoculation method used to develop these populations prior to this proposal were ineffective in selecting for FBR resistance. By continuing this work with a selected generation developed using the inoculation protocol developed from this proposal, FBR resistance might be finally realized. In addition, if this developed inoculation protocol proves successful at identifying resistant bulbs, the protocol could be used by other onion breeding programs to develop FBR resistant cultivars.

Goals and Outcomes Achieved

The goal of this project was to develop onion cultivars that are FBR-resistant with a target of one FBR resistant cultivar released by the end of the project. Based upon the evaluations completed in this project, we have not reach the level of FBR resistance to warrant a cultivar release at this time. However, by completing this project, we are closer to releasing a FBR resistant than before the project was started. An additional selection for FBR resistance was made during this project. Modifications made to the inoculum procedure and incubation protocol increase our prospects of developing a FBR-resistant onion cultivar. Through these modifications we were able to make greater progress than if those modifications had not been made. In addition, these new modified procedures can be used by other researchers for plant improvement once the results are published.

Another goal of the project was to increase annual attendance at onion field days by a target of 20 individuals. Field days were held in 2013, 2014, and 2015. In 2013, 28 individuals attended the field day and 45 individuals attended the field day in 2015. While we did not increase the attendance by 20 over this time period, attendance did increase by 61%. We plan to continue hosting annual field days that spotlight the progress we have made in developing FBR-resistant onion cultivars.

Beneficiaries

The main beneficiaries of this research will be the ~100 onion growers, shippers, and brokers in New Mexico who manage 6,000 acres of onions that have a farm-gate value of $50-60 million annually. Onions are an important high-value specialty crop for NM and are one of the most profitable crops grown in NM. The absence of soil fumigation could save $150 per acre. If a 2% loss in yield due to FBR and associated bacterial decay is assumed, gross returns could be increased by $160 per acre. Assuming the same 2% loss in the form of rejected shipments due to decayed bulbs, the cost would be over $400,000. While we were not able to release a FBR-resistant cultivar within the time period of this project, we are closer to that goal as a result of this work. We will continue to work towards developing a FBR-resistant cultivar. Once a FBR-resistant cultivar is released, the profit of the NM onion industry could increase by close to $2.3 million annually. Other beneficiaries of this research are other researchers and commercial plant breeders working to develop FBR-resistant cultivars. The results from this research will hasten their progress towards this shared goal. Additional beneficiaries of this research are the students that were involved in completing this research project. They gained valuable scientific experience that they will apply in their future endeavors. Our research program will also benefit from this research. The results from this research will strengthen our efforts to obtain additional funding to support the continuation of this research.

Lessons Learned

Our project learned to not assume that previously-used inoculation methods were effective in selecting for disease resistance. We also learned to evaluate new inoculation and incubation procedures prior to their implementation on a larger scale. Even though we were not successful in releasing a FBR-resistant onion cultivar, we developed a inoculation and incubation procedure that was effective in reliably causing disease development. This effective procedure will greatly aid us in the development of FBR-resistant cultivars. In addition, this new procedure allowed us to effectively assess the lack of progress made with a previous inoculation procedure. The new incubation procedure developed as part of this project was an improvement over the previous procedure and contributed to high levels of disease infection.

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Additional Information

Publications

Mandal, S. and Cramer, C.S. 2014. Selection progress for Fusarium basal rot resistance in onions, pp. 20-21. In: Proc. 2014 National Allium Research Conf. W. Mininger and H.F. Schwartz (Eds.) Scottsdale, AZ.

-1477 Project 3: GAP and GMP Prep Workshops and Mock Audits,
Final Report

Project Summary

Food Safety has become a major national and international concern. Thus, additional minimum federal safety standards have been implemented over the past few years in order to guarantee consumers that they are receiving the safest food supply possible. Additionally, many stores themselves have implemented their own safety standards to protect themselves and their customers. With this in mind, many retail stores, restaurants, shippers, distributors, and processors are now required to have audits conducted by certified inspectors.

The purpose of this project is to: 1) assist companies with monies to offset the cost of having these audits conducted in order to remain in the market place; 2) conduct mock audits and training for industry and Extension personnel; and 3) maintain and utilize NMDA's three certified licensed auditors who can conduct Good Handling Practices and Good Agricultural Practices audits.

Project Approach

This project served to help New Mexico specialty crop suppliers and manufacturers more appropriately safeguard their product for the protection of the consumer and everyone in the food supply chain. The objective was to provide the tools needed to pass any third-party audit required by a buyer. This was accomplished by hiring a consultant to provide hands-on workshops and mock audits in various locations across the state and by hosting preparatory workshops for small-to large-scale specialty crop growers and manufactures.

These funds also financed continuing education expenses for keeping the two NMDA/USDA certified GHP/GAP auditors current with their training and train a fourth GHP/GAP auditor. By utilizing NMDA's certified auditors, the suppliers' expense is often much less than if they had hired a third-party auditor. (The expenses associated with these training sessions is not passed on to the supplier.) NMDA's auditors attended the workshops and explained the certification process to the industry at no additional cost.

The various workshops and mock audits conducted during this project have allowed New Mexico's specialty crop producers and processors to remain in the marketplace and stay competitive. In 2013 a “Train the Trainer” workshop was conducted for NMSU Extension agents to provide the necessary tools to train producers in creating a food safety plan. The workshop provided an in-classroom mock audit experience. Some of the agents had never experienced any type of mock audit before taking the class. The feedback from the agents expressed the importance of the food safety plans. The representative from Primus lab that provided the information on “Train the Trainer” to the agents also gave a presentation at the NM Organic Farming Conference titled “It’s Coming! Preparing for Food Safety Regulations”. The feedback was very positive and the presentation made producers/processors aware of the food safety guidelines that will be implemented in the future.

At the 2014 Organic Farming Conference a session on FSMA (Food Safety Modernization Act) was conducted by staff from Primus. During the session, the representative from Primus presented an overview of the program and what is expected of producers. At that point, FSMA was in the developmental stages and details of the FSMA program had yet to be communicated by USDA/FDA.

During the mock audits, a pre-test was given to see how knowledgeable participants were on food safety and how third-party audits are conducted. The first mock audit pre-test average score was 74%. Upon completion, a post test was given to the participants to gauge the effectiveness of the mock audit. The post-test average score was 80%. The second mock audit pre-test scores ranged from 11 to 72% and the post test scores ranged from 67 to 88%.

In conclusion, the mock audits and workshops proved to be a valuable tool in preparation for third-party audits. In order for New Mexico's specialty crop producers and processors to remain in the marketplace today, third-party certifications are vital in ensuring the safest food supply to consumers from farm to fork.

Goals and Outcomes Achieved

- Initially, 17 GHP/GAP audits were conducted for 10 different companies.
- With the change in scope of the original proposal, this project has contributed to the successful completion of audits by 13 additional companies throughout NM which were conducted by a 3rd party auditor, and allowed them to remain competitive in the marketplace.
- The initial goal was to assist 20-30 companies. To-date, 23 companies were either GAP/GHP Certified and/or received certification from another 3rd party auditor.
- A "Train the Training" food safety workshop was conducted for NMSU Extension agents to provide the necessary tools to assist producers with a basic guideline for developing a food safety plan. In addition, the trainer spoke at the Organic Farming conference about preparing for food safety regulations (FSMA).
- A mock audit was conducted with participation from Extension, NMDA and Industry. The pre-test was given to see how knowledgeable participants were on food safety and how 3rd party audits are conducted; the average was 74%. After the mock audit, a post test was given to the participants to see how much information was gained; the post-test average was 80%. A second mock audit took place and the pre-test scores ranged from 11 to 72% and after the mock audit the post-test scores ranged from 67 to 88%.

Beneficiaries

- The 23 various NM specialty crops companies that successfully passed GHP/GAP or 3rd party audits.
- The 24 participants which included NMSU Extension staff, NMDA staff, and Industry who gained knowledge of current food safety requirements, the process of preparing for GHP/GAP or 3rd party audits, and the steps taken during an audit.

Lessons Learned

- Regular audits enable the industry to remain competitive in the marketplace and offer the safest food supply to consumers.
- New Mexico had initially delayed the certification process due to FSMA and the impact it would have on 3rd party certifications.
- Conducting on-site mock audits with 3rd party auditing companies has provided NMSU Extension staff and Industry with basic tools to create and implement a food safety plan.

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-1477 Project 4: Promoting Jujubes in New Mexico with Cultivar Demonstrations, Research and Extension, Final Report

Project Summary

Late frost is the number one challenge to apple and peach production in central and northern New Mexico and these fruit crops are highly unpredictable. Most fruit growers without frost protection equipment did not have a crop in 2010 or 2011; in most cases growers are fortunate to have a crop every two or three years. Most of these producers are small acreage farmers (less than 2 to 5 acres) and come from socially disadvantaged backgrounds. Without a reliable year to year crop from which to create income, many become discouraged and abandon the effort. To help those small and socially disadvantaged farmers in New Mexico stay in business, reliable alternative crops are desperately needed.

Jujube is native to China and was imported into the U.S. 100 years ago. With its late season start-up, wide soil and climate adaption, and nutritious fruit, jujube is a good alternative crop in New Mexico. Mature jujube plants are drought tolerant: another advantage given the frequent water deficiencies/drought in the Southwest.

The NMSU Alcalde Center imported over 30 cultivars from China in 2011 and grafted them successfully at Alcalde, NM. After the two year quarantine period, we started the preliminary propagation in 2013, grafted 40 cultivars in 2014, and planted them with replication at NMSU Los Lunas Center and Alcalde Center in April 2015. Plants had 100% survival and over 50% set fruit in 2015, the planting year. We also planted 30 cultivars for a total of 66 trees in 2014 at Alcalde and 39/66 (59%) yielded over 1 lb of fruit and 1/3 (22/66) of trees yielded over 3 lb in 2015, the second year after planting. We hosted three jujube growing habit, pruning and grafting workshops at Alcalde, five jujube fruiting habit and fruit tasting workshops in Las Cruces, Los Lunas and Alcalde plus three fruit tasting sessions at the NM State Fair in 2012-2014 which reached more than 1000 customers. The jujube research and extension activities also appeared in popular media numerous times. Jujube talks at Alcalde Field Day in 2014 and Los Lunas Field Days in 2013 and 2015 reached 150-200 people each time. The jujube session also appeared at PI's Master Gardener training classes across the state which reached 150-200 Master Gardeners each year from 2013 to 2015. At this time, the availability of commercial cultivars is still limited but we have preliminarily identified over 10 promising cultivars and will recommend/release them after we collect more data from the cultivar trials at different locations in New Mexico. We published one jujube review paper and one jujube flowering and fruiting habit paper, four jujube abstracts and two extension publications. The jujube grafting video on YouTube received over 10,600 IP clicks since Oct 2013. All of those will guide future jujube growers and researchers. We got inquiries not only from across the country—especially California and Texas—but also internationally. Growers and home gardeners have started to plant jujubes. A multistate project will definitely boost the popularity of jujube in the US and assist growers nationwide.

Project Approach

Cultivar trial preparation and planting

Over 30 cultivars were imported and successfully grafted at NMSU Alcalde in 2011. After 2 years quarantine, we started to propagate them in 2013 and Dr. Yao grafted every single tree used in this project except for the five commercially available cultivars. We propagated around 100 trees in 2013 as

a test-run and planted 66 to another plot at NMSU Alcalde Center. The rest were used as scionwood and observation trees in situ.

In 2014, even with the unexpected frost damage to rootstock seedlings, we managed to propagate 41 cultivars, with eight trees each of 31 cultivars and four trees each of 10 cultivars. Trees were planted at both NMSU Los Lunas and Alcalde Centers with identical planting of 41 cultivars in April 2015. Trees grew well in 2015 at both locations with over 50% setting fruit during planting year. Within the 2014 planting at Alcalde, 59% of trees (39/66) cropped over 1 lb of fruit and among them, 22 trees yielded 3 lb or more fruit in 2015.

Jujube flowering and fruit habits observation

We observed and studied the jujube flowering and fruiting habits as well as pollen germination from 2012 to 2014 and published the flowering and fruiting part in HortScience 2015, 50(6): 839-846. We found 24 morning blooming type and 32 afternoon blooming type among the 56 cultivars observed. Cultivars Li, Li(2), Redland, Daguazao, Dabailing, Xiangzao and Qiyuexian were self-fruitful while popular cultivar Lang was not self-fertile. The self-fruitfulness information will be helpful for extension personnel and growers for their cultivar recommendation/selections. Jujube cultivars all have a pit (except 'Pitless' with an incomplete one) but not all cultivars have seeds inside the kernel. Cultivars Zhongning, Globe, Jinsi -2, Abbeville, Sept Late and Liuyuexian had filled seeds while Lang, Don Polenski, Junzao and Xingguang had no seeds just an empty sac. Big fruited cultivars like Li, Li(2), Redland, Daguazao, and Dabailing had very low seed percentage. This paper provided basic flowering and fruiting information for cultivars in the US which will be the baseline for further research and guide parent selection in breeding.

Disseminating the knowledge to growers through workshops, media and extension publications

From 2012 to 2015, we hosted at least two jujube workshops each year, with a spring workshop on jujube growing habits, pruning basics and grafting, and a fall workshop on jujube flowering and fruiting habits plus fruit tasting. Jujubes belong to the Rhamnaceae family. Its growing habits differ from most stone or pome fruit from the Rosaceae family. As far as my knowledge, we are the first educational institution in the US to systematically offer jujube growing habits, flowering and fruiting workshops. Our workshops attracted local growers at first, then those from across New Mexico and growers from Texas and California. We also got inquiries from growers across the country and even Canada, Italy and Australia.

In addition to those workshops, we also introduced jujubes through Dr. Yao's Master Gardener training class across the state. Each year, 150-200 Master Gardeners were trained in several counties in New Mexico. We also hosted a jujube fruit tasting session at New Mexico State Fair from 2012-2014 which reached over 1,000 customers.

Due to the shortage of jujube extension publications, we published 'Jujube, Chinese date in New Mexico' in 2012 and 'Jujube Grafting' in 2014. For the grafting, we also made a video version on YouTube which received over 10,600 clicks from distinct IP addresses since it was released in Oct 2013, which indicates its popularity for an agricultural video. One grower from Australia emailed me and mentioned that he learned some new techniques after watching the video.

Our jujube research and extension work also appeared numerous times in popular media in New Mexico such as Albuquerque Journal, Albuquerque Journal North, Las Cruces Sun-News, and Rio Grande Sun (Espanola), etc.

Cultivar evaluation

We have been evaluating jujube cultivars since 2012 and preliminarily identified potential cultivars for New Mexico.

'Li': imported 100 years ago, the most dominant cultivar in the US. Big fruit, nice flavor, self-fruitful, good for fresh eating, mid-season.

'Lang': imported 100 years ago. One of the two dominant commercially available cultivars. Pear shaped, not self-fruitful, OK for fresh eating, good for drying, mid-season.

'Junzao'/'Xiangguang': new importation. Similar to Lang in shape, testing productivity now.

'Shuimen': imported 100 years ago. Medium in size, soft texture. Good for fresh eating and drying. Heavy producer.

'So': imported 100 years ago. Zig-zagged branches, fan shaped plant, short round columnar fruit, sweet and tart, good for fresh eating and drying. Mid-season. Suitable as ornamental-edible landscape.

'Honeyjar': small fruit, curved leaves, excellent fresh eating quality (#1 for fresh eating at Alcalde), precocious (sets fruit in grafting year/planting year), very suitable for home gardeners.

'Sugarcane': olive shape fruit, sweet, medium size, good for both fresh eating and drying. Early mid-season.

'Qiyuexian': recent importation. Early season. Big fruit, good quality for fresh eating, very suitable for northern New Mexico or other areas with short growing season.

'Dragon': recent importation. Contorted plant with hair pin shoot structure. Small pear shaped fruit. Good ornamental plants.

'Dabailing'/'Daguazao'/'Redland': big fruit, good fresh eating quality. Self-fruitful. Mid or mid-late in season. Also good for pie.

'Maya'/'Gaga': recent importation. Small football shaped fruit, excellent for fresh eating. Mid-season.

'Mushroom': Mushroom shaped fruit, good ornamental plant. Mid-season. Dry fruit also keep the mushroom shape.

'GA866': a US cultivar. Tooth shaped fruit. Very sweet, never set heavy in northern New Mexico. Need data from southern locations.

'Sherwood'/'Capri'/'Winter Delight'/'Jing 39': late cultivars, need testing in warmer areas. Sherwood did not set well in northern New Mexico. Did well in California. 'Jing 39' is a new importation. Big fruit. Late in season. Potential for fresh market near Thanksgiving after cold storage.

Cultivar recommendations will be deferred. We decided to hold until we collect more data from other cultivar trial locations.

Role of participants

Shengrui Yao: team leader, conducted all the extension activities and participated in all research activities and wrote extension and research publications;

Steve Guldan: participated in grant, research reports and publications' writing and editing.

Robert Heyduck: participated in nursery tree management after grafting and fruit nutrient analysis in 2014 and 2015.

Junxin Huang: graduate student, participated in jujube flowering habit observation and nutrient analysis in 2014.

Mary O'Connell: Guided Junxin Huang for nutrient analysis in her lab.

Field crew at Alcalde and Los Lunas: daily management of field plots for this project.

NMDA: provided space and table for the NM State Fair jujube promotion in 2012-2014.

Extension agents from Rio Arriba and Dona Ana counties and the NMSU Los Lunas Center assisted in organizing workshops.

Goals and Outcomes Achieved

Established jujube cultivar trials at both NMSU Alcalde Center and Los Lunas Center with 41 cultivars with replications.

Shared the results with growers, researchers, and extension personnel.

Published two jujube extension publications plus a YouTube video about jujube grafting.

Jujube, Chinese date in New Mexico. http://aces.nmsu.edu/pubs/_h/H-330.pdf

Jujube (Ziziphus jujuba) grafting. http://aces.nmsu.edu/pubs/_h/H335/

Jujube grafting on YouTube. https://www.youtube.com/watch?v=fFLwOWe0KQ4

Published a peer-reviewed paper: Jujube (*Ziziphus jujuba* Mill.) flowering and fruiting in the Southwestern United States, HortScience 50:839-846.

Published a peer-reviewed jujube review paper: Past, Present and Future of jujubes, Chinese dates in the United States. HortScience: 48:672-680.

Gave three oral jujube talks at the American Society for Horticultural Science annual meetings plus four jujube posters from 2013-2015.

Gave a talk on alternative fruit crops at New Mexico Fruit Growers Conference with 40 customers in 2014.

Growers/customers reached: The workshops directly had over 200 attendees, the tasting session reached over 1,000 customers, and 500 Master Gardeners in the past three years. The grafting video had over 10,600 unique IP address clicks and the media coverage also reached thousands of readers.

Jujube acreage is still limited but several growers from New Mexico have started to plant jujubes commercially. Numerous home gardeners have planted jujubes in their yards. Growers from Texas and California also contacted us with their cultivar or cultural management questions.

Cultivar recommendations

We have preliminarily identified 10+ promising cultivars (as listed in project approach section). We decided to collect more data from different testing locations and gradually recommend cultivars in several years. (A multistate cultivar trial is urgently needed. Otherwise, our future recommendations will just be based on data from New Mexico.)

We have fulfilled all the goals and outcomes in the original proposal: established the cultivar trials at two locations, one research paper, two extension publications and at least two workshops each year. In addition, we produced one Youtube video with over 10,700 clicks, published a review paper, and reached more audiences with workshops, publications, media coverage and Master Gardener trainings. All those activities brought us national and international recognition for our jujube research and extension work.

Beneficiaries

Jujube growers and home gardeners are among the beneficiaries who can use information we provide to select their cultivars and guide their fruit production. Fruit growers and small farmers also benefit from this project who can use jujube as an alternative crop to diversify their operations, reducing the late frost risk and increasing income. Actually, jujube growers nationwide and internationally all benefit from this project and we did receive inquiries across the country and internationally. The jujube flowering and fruiting habits paper, extension publications and Youtube video are all available to jujube growers internationally. Jujube growers, extension personnel and researchers all benefit from this project. Customers will also benefit with more jujube cultivar choices for different purposes.

Lessons Learned

Late frost damage to seedlings or young trees. In 2014, when we started the propagation- grafting process, we noticed the late frost damage. The low temperature in April killed the bark near the ground on about 20-30% of the seedling rootstock trees. The project was not really affected by this damage since we delayed the grafting and were more selective with rootstocks. It reminds us that in late frost prone areas, growers and nurserymen should be aware of this risk and protect their seedlings/young trees for possible late frost damage.

Cultivar recommendations: we started the cultivar evaluation process when we received the initial cultivars in 2010 and 2011. After 3-4 years observation, we have preliminarily identified over 10 cultivars for recommendation. As for their yield potential and performance in different locations, we do need more data from cultivar trials across the state since Alcalde is close to the borderline for jujube planting with its high elevation and short growing season. So, we decided to delay this process and recommend/release them gradually after several years with more information collected from the cultivar trial sites across the state or potentially in different states.

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Additional Information

Two extension publications and two peer-reviewed papers in attachment.

-1477 Project 5: Developing the Rio Arriba County Local Food System through Centralized Shared Cooler Storage for Rio Arriba Farmers, Final Report

Project Summary

The grant funded a walk-in cooler to be used by Rio Arriba County farmers, the Española Community Market, the Española Farmers' Market and the local food hub for cold storage of local specialty crops. Local farmers and the Rio Arriba Food Policy Council have expressed a need for aggregate shared cold storage within the city of Española, the area's commercial hub. With this piece of equipment, farmers can extend their selling season to the Española Farmers' Market (EFM), a successful and established local farmers' market (1,800 customers per week), and to the Española Community Market (ECM), a local member-owned cooperative. The cooler will also help to grow the local food economy by providing an aggregation point currently lacking for the farmers in this agriculturally rich region. Aggregating Rio Arriba produce in a central location within the commercial hub of Española will help local farmers increase the availability of their local specialty crops. It will also aid wholesale institutional buyers (such as the hospital, local school district, and restaurants) that have expressed interest in purchasing substantial volumes of local specialty crops, but have not had the resources to source locally within the County.

Project Approach

Because Siete Del Norte, another entity in the community, received a large grant to schedule, aggregate, package and market local crops on behalf of farmers, ECM delayed purchase of the cooler until a working relationship and proper agreements could be secured. Siete del Norte joined the ECM board of directors in August of 2013, and the two entities began jointly planning to lease, renovate and co-locate in an abandoned Ford Dealership in downtown Española. An agreement to lease the facility from the City of Española passed City Council in January of 2014 and the County of Rio Arriba was awarded $290,000 by the NM State Legislature to begin renovating the building to house the Española Community Market, Siete del Norte and Moving Arts Española, an after-school dance program for youth. Española Community Market purchased the walk in cooler in October, 2014 and installed it in the "Hunter Ford" building. It is currently in use.

Several items in the work plan were altered as a result of the unexpected, but extremely fruitful partnership with Siete del Norte: 1) because secure indoor space is convenient and available (it is in downtown Española within easy walking distance of both ECM and EFM), ECM purchased an indoor cooler; 2) no shade protection was necessary; 3) electrical costs to run the unit are currently being paid by the City of Española. Because the cooler has only recently been purchased during winter months, the cooler is solely used by ECM to store specialty crops purchased from farmers, and no intern has been hired to log usage. (The cooler is used solely to store specialty crops.)

The partnership has expanded beyond ECM and EFM to include the City of Española, the County of Rio Arriba, Siete del Norte, the Rio Arriba Community Health Council and Moving Arts Española. Siete del Norte has taken on the role of food hub from ECM, allowing ECM to focus on providing a retail outlet for individual consumers of local specialty crops and other agricultural produce. The City of Española has provided low cost space for co-location of ECM, Siete del Norte and Moving Arts Española. The County of Rio Arriba raised $290,000 from the state legislature to develop the project. The Rio Arriba

Community Health Council and Moving Arts Española have sponsored a series of events designed to raise public awareness of the project.

Goals and Outcomes Achieved

The cooler was purchased and installed and is currently in use.

The Española Community Market has seen a steady increase in sales of local products, and has increased the vendors from which it purchases as evidenced by the tables below:

Annual ECM Sales from 2011 to 2014

Year	Sales	Percent Increase Over Previous Year
2011	$ 3,148	No store
2012	$ 61,076	1,840%
2013	$ 98,355	61%
2014	$119,020	21%

Vendors to ECM

Year	Number of Vendors	Receipts to Vendors	Percent increase in vendors	Percent increase in sales to vendors
2011	No data			
2012	41	$18,571	N/A	N/A
2013	55	$32,185	34%	73%
2014	78	$46,606*	42%	45%

*Projected sales based on 11 months data.

In 2014, two of the vendors to ECM were actually farmer coops with multiple farmers as members. This data indicates that while farmer capacity to sell locally to individual customers appears to be increasing, more work needs to be done to increase the consumer market for local produce. While sales have been increasing every year, the number of volunteers has not, indicating that we need to conduct a well-planned marketing campaign to individual consumers who are accustomed to cheap, outsourced food through large chains. The coop has requested the assistance of the County's Economic Development Director for this purpose.

The existence of the cooler assures that ECM will have the capacity to address demand, should this strategy cause a sudden increase in sales.

Beneficiaries

Beneficiaries included local vendors and farmers and local individual consumers of specialty crops.

There has been a 90% increase in vendors (from 41 to 78) to ECM from 2012 to the present. Two of these vendors are farmer coops which aggregate crops from multiple farmers, so in fact, we have more than doubled the number of farmers/vendors from which we procure produce and other food items.

There has been a 151% increase in purchases from those vendors since 2012, while there has been a 3,681% increase in sales to local consumers.

Unfortunately, there has been a steady *decrease* in coop members as the requirements of membership have become more complex than paying a one-time $15 fee: most coop members are asked to support the ECM with a $25 annual fee and by volunteering labor at least four hours per month.

The following table summarizes annual coop membership:

Year	Number of Members	Percent Decrease from Previous Year
2011	264	N/A
2012	242	8%
2013	197	19%
2014	183*	7%

Overall, the ECM has seen a 31% decrease in membership since 2011, probably reflecting: 1) increased request for commitment to the store by members; 2) some drop off because, while food is less expensive than similar coops in Santa Fe and Los Alamos, it is still more expensive than WalMart and Supersave; and 3) because ECM continues to rely on the same demographic to staff the store, the volunteer base is growing tired or aging and dropping off.

This data clearly indicates a need to market the store to people who were not part of volunteer-run coops in the 1970s, and thus require much more effort and education to recruit. If the coop can recruit this new, younger demographic, it will provide an effective outlet for sales of local produce to local individual consumers. The ECM, at this time, is the only entity capable of developing and supplying the market for local food to individual consumers.

Lessons Learned

The most important lesson learned through this project is that, while market capacity is dependent on physical plant, it is not solely dependent on physical plant. While ECM has steadily expanded its hours and days of operation, it has lost some of the volunteer-base necessary to run the store. We continue to rely on an older, primarily Anglo demographic of individuals who are true believers in volunteer-run coops and local food to make the coop run. A significant amount of carefully planned and carefully targeted work will have to go into an education campaign about the benefits of local produce aimed at a demographic that has grown up dependent on chain stores such as WalMart for produce.

The Rio Arriba Community Health Council will be informed of these findings, along with the Rio Arriba County Economic Development Director, and asked to assist to conduct the proposed education and marketing campaign on behalf of ECM. Developing a market for local food among individual consumers may be the single most impactful activity the health council can take to improve the health of Rio Arriba residents as it will both improve eating habits and improve Rio Arriba's economy at the same time.

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Additional Information

Two children from Santa Clara Pueblo participating in a Run-Walk-Ride from Santa Clara to the proposed new site of ECM to draw attention to the benefits of eating locally grown food.

An artist works on a mural painted by children at the site of the food cooler. The mural depicts local farmers at work and is funded by the Northern Rio Arriba Heritage District. It is one of three murals located at the future site of ECM.

A volunteer checks out a customer at ECM.

An ECM Board member awaits a meeting at the store.

Two children prepare an ECM “Healthy Snack Night” meal for their parents at La Tierra Middle School.

Children help prepare a meal using ECM produce for their parents at ECM Healthy Snack Night at La Tierra Middle School. The night is part of an effort to market local foods to individual consumers in Rio Arriba.

-1477 Project 6: Enhancing Hops Production in New Mexico, Final Report

Project Summary

Hops (*Humulus lupulus* L) are used to provide bitterness and aroma to beer. Ratios of α-to β-acids and of the various essential oils form important hops and ultimately craft beer quality indices. Demand for organically produced hops have received attention by regional craft brewers, home brewers, and medicinal herb companies. The trend fits into a larger interest in local food production models. Since 2008, 13 commercial cultivars and several unreleased *neomexicana* crosses made by Todd Bates of Embudo, New Mexico, have been under horticultural trial at the NMSU Agricultural Science Center in Farmington. The later "New Mexico hops" could figure into a specialized niche market. This proposal seeks to further explore feasibility of growing and marketing hops in New Mexico. Main objectives are to 1) expand cultivar evaluations at Farmington and establish a new replicated plot in Las Cruces or Los Lunas, 2) characterize hop cone chemistry of all entries, 3) undertake a more thorough economic/market analysis of producing hops in New Mexico, and conduct an intensive one- to two-day workshop on the opportunities and challenges of small-scale hop production in New Mexico. This proposal fits into the objectives of the NMDA Specialty Crop program of examining potentially new specialty crops.

Background

Hops (*Humulus lupulus* L), used to provide bittering and aroma to beer, are perennial bines reaching up to 18 to 20 feet in a single season. A trellis supports growth. The cones of the female plant are harvested and the bitterness comes from α-and β-acids, phenolic-like compounds. Essential oils provide the overall hop presence and hop aroma. Ratios of α-to β-acids and of the various essential oils form important hops quality indices. The characteristics of hops, like grapes, depend on the growing location. Market volatility in 2008-2009 fueled initial interest in locally grown hops. The Farmington hops trial was established in 2009 with support from NMDA ($5,000). Although hops cone prices have since stabilized, regional interest remains high.

United States craft brewing realized $14.3 billion in retail sales in 2013 (20% growth in sales over 2012) (Brewers Association, 2014). The Pacific Northwest still dominates U.S. hop production and processing with Washington State (e.g. Yakima Valley), producing 79% of the hop crop followed by Oregon and Idaho. Total value of the U.S. hop crop among these three states was $249 million in 2013 (USDA, 2013). Hop strobiles are borne annually on 6 m (20 ft.) tall bines (twining stems) that originate from long-lived perennial rhizomes (underground stems). Hop bines require extensive trellising systems and labor intensive thinning and training management to increase bine vigor and hop cone yield. Hops are easily propagated asexually (to produce clones) by rhizomes which are used to multiply hop-yards of uniform growth, strobile harvest date, yield and chemistry.

New Mexico and Regional Brewing and Hops Production

With an interest in "buy local" campaigns supporting regional agriculture (e.g. New Mexico-Grown with Tradition® and Colorado Proud™). New Mexico and Colorado craft brewers may be interested in purchasing their hops from a local grower as evidenced from recent workshops conducted in Farmington NM and Durango, CO (Rodebaugh, 2013). Previous research at the NMSU-ASC Farmington indicates that some standard hop cultivars grow well in Northern NM, even possessing certain terroir

characteristics. For instance, in Farmington, NM, 'Cascade' attained 9.8% alpha acids and 6.1% beta-acids, higher than values reported in the literature for the same cultivar (ten year range: 5.1 to 8.5 % alpha; ten year range 4.0 to 6.6% beta) when grown in the Pacific Northwest (Freshops, 2014; Lombard,

Acharya, Thomas, & McCarver, 2014). Additionally, hop-yards of New Mexico native *H. humulus* var. *neomexicanus* are being viewed by some growers as a value added cultivar which could be branded to produce craft beer specific to the southwest region (Geiling, 2014; Merchant, 2013). There are about 40 commercial breweries listed statewide on the New Mexico Brewers Guild webpage. Most are clustered in and around Albuquerque and Santa Fe.

Justification for Research

Barriers to small-scale commercial hops production in New Mexico include: 1) limited knowledge on cultivar adaptability across New Mexico growing conditions, 2) limited mechanization of key labor intensive processes such as picking, 3) limited direct marketing schemes for locally produced hops in the state, and 4) limited educational opportunities for New Mexico producers to gain more knowledge on the crop (NEED).

Goals and Objectives

This project originally attempted to:

- Continue to evaluate the agronomic potential of cultivars with the greatest marketability under high elevation and calcareous soil conditions in Farmington. Replicate the trial to lower latitudes in Las Cruces or Los Lunas. Evaluate hops on a low trellis system.
- Determine hop cone chemistry (resins and essential oils) under New Mexico environmental conditions.
- Determine comprehensive economics on developing production and post-harvest systems for hops for multiple markets including commercial craft breweries, home brew supply, and medicinal use outlets (e.g. herbal extract companies).
- Educate growers on opportunities and challenges to hops production.

Project Approach

Original Approach Evaluate agronomics and economics of hops (2012-2013):

- An existing study is located at the NMSU ASC at Farmington (lat. 36° 41' 0" N; long. 108° 18' 36" W; elevation 5,640 ft.) and will be expanded to include ten additional cultivars. New Mexico native hops and cultivars requested by regional craft brewers will receive priority in planting.
- A scaled-down replicated trial was installed in Las Cruces at a private farm (Spring/Summer 2013).
- Analyze cost of production and processing and determine overall market opportunities and constraints experienced in New Mexico (Fall 2012-Summer 2013).
- Conduct a field day to demonstrate production (Summer 2013; Farmington).
- Conduct a one-day intensive workshop on hops production (Summer 2013, Farmington).

Dr. Ron Godin (Colorado State University) will assist. Godin conducted a hops workshop in Grand Junction, CO, in February 2012 with about one hundred in attendance. A basic online tutorial (similar to one produced by the PI http://aces.nmsu.edu/southwestherbs/) will ensure sustainability of educational outreach after the grant has ended.

Expanded Approach:

- Conduct brewer's perception survey to identify market needs and constraints for locally produced hops.
- Conduct virus testing of established research plots.
- Expand workshops in partnership with Fort Lewis Colorado.

Goals and Outcomes Achieved (by quarter)

First Quarter 1 (November 2012-December 2012)

Funds were released in November 2012. Gear up-included beginning to contact potential guest speakers for a July workshop, plan future research plot expansion, and hire a staff person to assist with proposed activities.

Second Quarter 1 (Jan. 2013 – March 2013)

During the reporting period we focused on soliciting guest speakers for the July 2013 workshop. We also ordered certified disease-free tissue culture grown plantlets from Summit Labs (Ft. Collins, CO). Although more expensive than traditional rhizomes used to plant-out new fields, reports indicating that rhizomes were increasingly being shipped infected with stunt-viruses dictated the need to acquire these certified disease-free plantlets. The shipping date for these plantlets was set for June 2013.

Third Quarter 1 (April 2013 – June 2013)

The reporting period saw field activities associated with care and evaluating older hop research plots. Research activities included evaluating plots for chlorosis (yellow of leaves) thought to be associated with iron nutrition and alkaline soils. Foliar analysis used a Minolta SPAD 502 meter to evaluate leaf color. Soil samples were also taken to evaluate soil fertility and chemistry.

Workshop planning continued to escalate. Guest speakers were confirmed. Much effort was devoted to the handling of forms required by New Mexico State University for speaker remittance. The venue, Three Rivers Brewery banquet hall, was secured and logistics finalized.

On June 20, 2013, a new research plot consisting of 9 certified disease-free cultivars was established. The plot was planted in four rows with nine cultivars replicated six times. Drip irrigation lines with 1 gal per hour emitters provided irrigation water. Plants were allowed to grow without trellising for establishment purposes. A similar study of smaller scope was planted in Las Cruces the following week to evaluate hop performance under southern New Mexico conditions.

On June 27, 2013, the PI visited with Hop Union representatives in Yakima, WA. Greater than 90% of the hop production is in the Pacific Northwest, including Yakima, WA. The trip included field and postharvest tours and was very informative as it pertained to traditional hop growing and processing. The trip greatly helped to inform literature reviews of alternative marketing strategies and post-harvest approaches for non-traditional, small-scale production being conducted in other portions of the U.S (outside of the Pacific Northwest) such as Colorado, New England and North Carolina.

Fourth Quarter 1 (July 2013- Sept. 2013)

July 12-13, 2013 workshop entitled "*WHAT's HOP'N: A Symposium on hops (Humulus sp.) production and marketing in the Four Corners Region and New Mexico*" was conducted. July 12 consisted of all-day presentations on marketing and producing hops. Specifically: 1) understanding

brewer's needs and realities (panel discussion by representatives from home-brew supply, small-scale and large-scale craft brewers), hops production and marketing in Colorado, the New England hops experience, New Mexico hops production research updates, economic forecast for hops production in New Mexico and Colorado, New Mexico Native hops production, small-scale hops production lessons. Ample time was built into the program to allow for networking. A member of the NMSU Agricultural Communications Department audiotaped all speaker presentations.

About 40 participants attended. The workshop also received state-wide media coverage through television and newspaper print. The second day of the workshop consisted of a field-plot tour at the New Mexico State University Agricultural Science Center at Farmington. The time was spent covering hop cultivars and trellis construction and gave participants the opportunity to see actual field plots. More networking-time was allocated and the workshop officially wrapped up by noon. The Three Rivers Brewery banquet hall was fully equipped with audio visual equipment and leant well to the facilitation of questions and networking opportunities for hop growers and brewers alike.

Field plot maintenance continued throughout the 2013 growing season. Older research plots were hand harvested beginning in mid-August. Harvesting began in earnest in mid-August. Two staff and about 8 volunteers helped pick the initial flush of harvested plots. Lower yielding plots were hand harvested intermittently between mid-August and mid- September by a research technician. Sub-samples of higher performing cultivars were dried to about 25% moisture content and then shipped for hop cone chemical analysis (Alpha Analytics, Yakima, WA).

A graduate student joined the research team to assist with literature research and economic data analysis in August, 2013. She also began to contact state-wide breweries and one small-scale producer for informal surveys on producer/brewer needs to help inform the conduct of a future elicitation survey to be conducted winter 2014.

First Quarter 2 (Oct 2013- December 2013)

We continued to conduct literature research, conduct statistical analysis on agronomic data generated during the 2013 growing season, build a trellis for 2013 planted hops, and interview craft brewers as part of an economic analysis and continued needs assessment.

Literature research has involved assessing other U.S. regional approaches to hop production and utilization. Because most of the hops production is located in the Pacific Northwest under large-scale production methods, the models employed there do not apply to the more small-scale production nature of producing hops in New Mexico. Other regional models under evaluation that are more appropriate to New Mexico include the New England Hops Alliance, North Carolina model, Colorado model and nano-brewing model. These models are being compiled into a more comprehensive report to be submitted for peer review outlet (e.g. NMSU Research Report or journal article).

Continued agronomic assessment of existing research plots and construction of a new research plot. We continued to assess research plots planted in 2008, 2009, and 2010 during the 2013 growing season which begins in late April and ends mid-October. These established plots are generating useful information that continue to inform this project and future projects. Data generated included chlorosis evaluations using a handheld SPAD meter to measure plant response to high pH (alkaline) soil. We also evaluated yield (fresh weight). Yields are generally trending downward due to the fact that older plots have been treated under low-input, "organic" conditions or the possibility that older plots, established

with rhizomes, may be inoculated with virus now commonly identified in hop rhizomes but received little attention until recently. The plot established in 2013 was done so using certified virus free tissue culture transplants. We began the process of trellis construction which involved purchasing steel pipe poles, wire, and irrigation supplies.

We conducted a second interview of key influentials working in the New Mexico craft brewing industry on November 22, 2013 in Albuquerque, NM. These interviews will inform the development of a

questionnaire that will be sent to the entire New Mexico craft brewing industry and known producers (mostly small-scale) to help guide our understanding of needs and interests related to hops.
The NMSU Hops webpage (http://aces.nmsu.edu/hch/hopsresearch.html) was developed to preserve the July 12, 2013 workshop and field plot content for general public access. Analytics on number of website hits were not tested in 2013 because the site was not publically launched January 2014.

Second Quarter 2 (Jan 2014 - March 2014)

New Mexico Brewers Perceptions Survey

We developed and pilot tested Brewers Perception survey based on interviews with key influential in November-Dec 2013. Specific objectives of this study were to:

- Understand NM craft brewing industry (e.g. hop usage, barrels produced, varietal preference).
- Understand brewers' perceptions and interests of locally grown hops.
- Understand expectations of NM brewers (e.g. hop price, consistency).
- Define opportunities (if any) for local hops production in New Mexico.
- Provide farmers informative data on NM Craft brewers' demands and expectations.

Additional Hops Workshops

The PI presented "Brewers' Realities" at the spring 2014 Hops Workshop hosted by Fort Lewis College (Durango, CO). The presentation focused on comparing large-scale conventional hop farming with small-scale production and what craft brewers expect in terms of hop cone chemistry and purchase price. The presentation also gave an overview of the hop variety trial being conducted in Farmington. Approximately 40 persons attended the all-day event-mainly from southwest CO and northern NM. Attendees were made up of commercial craft-brewers, home brewers, hobby farmers, and small-scale producers.

Hops Virus Testing

With some momentum toward expanding hop cultivation, the question was raised as to whether rhizomes imported into northwest NM and southwest CO between 2009 and 2013 were virus-free. During the winter of 2014, hop rhizomes were collected from research plots in Farmington and Hesperus, CO and tested at the NMSU Plant Diagnostic Clinic for the presence of Apple mosaic virus (ApMV), American hop latent virus (AHLV), Strawberry latent ringspot virus (SLRSV), Tobacco necrosis virus (TNV) and Arabis mosaic virus (ArMV). In one study established in 2008 at the NMSU-ASC Farmington with non-certified virus free material, 50% of 'Cascade' entries tested positive for ApMV and 17% were co-infected with ApMV and AHLV. Strawberry latent ringspot virus, Tobacco necrosis virus or Arabis mosaic virus were absent in tested rhizomes. Certified virus-free (planted in 2013) and *H. humulus* var. *neomexicanus* entries were virus-free of the five viruses we tested for. Establishing hopyards in New Mexico and Colorado with certified virus-free rhizomes or plantlets is critical to avoid the risk of reduced yields and viral transmission into unaffected hop plantings. Plots infected were culled out during the summer 2014.

Third Quarter 2 (April 2014 - June 2014)

New Mexico Brewers Perceptions Survey

We launched the Brewers Perception survey via Survey Console (an online service). The survey was sent out to all commercial craft brewers listed in the New Mexico Brewers Guild. Key components of the survey were:

- Production and hop usage information to identify market trends and how New Mexico's craft brewing industry compares to the national craft-brewing industry. Respondents were divided into categories based on total number of barrels produced per year in order to find market trends. Distribution information was also gathered to identify trends between production and distribution method.
- Hop cultivar usage, amounts, and desired cultivars: the survey gathered hop cultivars currently used, with corresponding volume and desired cultivars among respondents. The data could direct growers into choosing cultivars popular and desired among brewers, as well as, provide an idea of how many kilograms per year brewers are using of each cultivar. The survey indicated the top five hop cultivars currently used by NMBG respondents and most desired hop cultivars. We compared said top five cultivars with the top performing hop cultivars grown at New Mexico State University Agricultural Science Center at Farmington. The usage data was also compared to national cultivar trends.
- Hop source, hop form, and equipment design: the survey gathered source information to understand where respondents obtain their hop supply. Since hop production is centralized in the Pacific Northwest, it's fair to assume the brokers are located in the same region. The survey also gathered the form of hops respondents use: wet/fresh, whole/(dried) baled, and/or pellets. Depending on what form of hops is being used relates to a respondent's equipment design. For local hop producers, pelletizing is expensive, thus the survey asked if respondents were willing to modify their equipment to brew with non-pellet forms.
- Price points and long-term contracts: The survey gathered information pertaining to price points in which brewers would expect from a local NM hop producer. Criterion for the price points was adopted from an unpublished jalapeno pepper consumption survey provided by a team member of this study. Respondents were asked to choose the following: would not buy, would purchase at a 10% premium, would purchase at a 5% premium, would purchase the same price as conventional, would purchase at a 5% discount, and would purchase at a 10% discount. This information could help growers calculate a profit margin to determine their own feasibility of hops production.
- Perceptions and interests: The survey asked perception- type questions to indicate themes among respondents in regards to collaboration between local growers and brewers. Local hops production cannot be sustainable without the support of a market. Growers need to understand the market and its needs/desires before investing in a costly operation like hops production.
  Additionally, the survey asked local perception-type questions to validate a need for continual research on the cultivation of hops as a specialty crop in New Mexico.
- The final question of the survey instrument asked respondents if any other food commodity groups are used to enhance their beer, and if so, to list the items. Growers interested in polyculture farms could incorporate other crops used in beer to expand their operations and increase their profit.

We received New Mexico State University (NMSU) IRB approval June 2, 2014 and IRB modification requests were submitted on June 6, 2014 and on June 11, 2014 after participants alerted the survey team of mistakes.

Preliminary results indicate:

- Most New Mexico brewers contract with large hop suppliers in PNW (e.g. Hop Union), but are somewhat interested in test-brewing with hops grown in New Mexico as long as the price remains the same.
- 'Cascade' is one of the most commonly used and desired hop cultivars by New Mexico brewers. 'Cascade' produces acceptable cone chemistry and yield in New Mexico.
- *H. lupulus* var. *neomexicanus* may have a potential niche market for New Mexico branded beer.
- Appropriately scaled picking, drying, and processing equipment is lacking in New Mexico and needs further investigation.

Full results will be peer review published during the winter 2015.

NMSU-ASC Farmington Hops Trellis Retrofit and Equipment Fabrication

Because hops grow up to 20 ft. in height and the original trellis was established at about 12 ft., we retrofitted the experimental plot trellis to correspond with standard trellis height. Retrofitting involved welding additional pole lengths onto existing trellising and adding additional cabling for support. A mobile scaffolding trailer was also fabricated in order to perform training and harvesting operations on the expanded trellis (Figure 1).

Figure 1. NMSU-ASC Farmington experimental hopyard trellis retrofit and equipment fabrication Spring/Summer 2014.

Fourth Quarter 2 (July 2014- September 2014)

Plot harvesting and hop cone chemistry

Plots were harvested beginning mid-August and ending about mid-September. Yield data will be analyzed during the winter 2014-2015. Hop cone chemistry was undertaken at Alpha Analytics (Yakima, WA). Results (Table 1) of selected cultivars indicate varied alpha (bittering) and aroma profile with good storability (having been previously dried to about 25% moisture content and vacuum sealed before being shipped for analysis).

Table 1. Select cultivar hop cone chemistry.

Sample ID	% Alpha-acids	% Beta-acids	HSI	oil %v/w
M107*	3.1	5.1	0.263	0.52
R1107*	1.6	5.3	0.244	0.47
Nugget	13.8	4.1	0.245	1.22
CTZ	13.7	4.8	0.231	0.55
Teamaker	-0.1	11.8	0.179	0.35
Vangard	4.1	5.4	0.226	0.17
Chinook	12.4	3.5	0.236	0.73
Centennial	7.4	2.9	0.253	0.65
Crystal	4.9	5.6	0.215	0.66
Cascade	7.3	5.7	0.217	0.4
Willamette	3.7	2.3	0.271	0.32

**H. lupulus* var. *neomexicanus*

First Quarter 3 (Oct 2014- December 2014)

Efforts are focused at finalizing data analysis and publishing results of the Brewers Perception survey.

Beneficiaries

Craft brewers in New Mexico and Southwest Colorado who have helped supply information about their needs and interests in purchasing locally produced hops. The 30+ commercial breweries in New Mexico will benefit from the research results as it pertains to hop cultivar cone chemistry and market channel realities.

Producers: We retrofitted our research trellis to reflect commercial hop growing realities (need for taller trellis). We introduced certified virus-free rhizomes and tested older plots for virus infection to raise awareness about the detriments of infected hop-yards. We conducted a series of field days and workshops (many unfunded) to increase awareness of hop production realities and opportunities. We continued to evaluate new varieties including *H. lupulus neomexicanus*. The chemical profiles of these cultivars will aid growers and brewers in hop selections for brewery needs. Craft brewers survey results will aid growers in determining market needs of artisanal beer production systems.

Lessons Learned

Due to the seasonality of the growing season (May-October), agronomic evaluations were not undertaken until the summer of 2013. A new research plot was not planted until late June 2013 until after the arrival of disease-free hop tissue cultured plantlets. Most of the data analysis was therefore delayed until fall/winter 2013. Due to these delays, we requested a one-year no-cost extension which was granted.

The smaller hop trial located in Las Cruces failed, we speculate, because of the extreme heat and lack of oversight by the grower we contracted to work with. Future studies in Las Cruces should be located on one of the NMSU experimental farms and additional funding needs requested to support a technician in southern NM. The PI acknowledged that the funding for this project simply could not support this reality.

After a visit to the Yakima WA area during the summer of 2013, the PI realized the extent and scope of the Pacific Northwest crop. The PI acknowledges that additional funding should support the development and importation of small-scale equipment appropriate for growers outside of large-scale growing operations located in the Pacific Northwest should hops production interest increase in NM. This barrier alone should be a priority for future work.

While the Brewers Survey (once published) will offer insight into marketing needs of craft brewers in New Mexico, the economic analysis (a goal not achieved) is lagging. We need to double our efforts and combine the marketing data with economic data in 2015. A graduate student would be helpful for this task.
We exceeded our expectations on workshops (at least three workshops and two field days). Much of this was not funded by this grant but had shared objectives.

We retrofitted our trellis and fabricated scaffolding (partially funded) in an effort to move toward better managing our experimental hop-yard.

We continue to work with partners to expand research activities. Future needs are primarily marketing and small-scale equipment. Future research efforts will expand into malted barley in order to take a more comprehensive view of craft brewing needs in NM.

We thank the NMDA and USDA for generously funding this program and assisting us with questions along the way.

Contact Information

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Additional Information

Published Articles, Abstracts and Articles Appearing in Popular Press:

Lombard, Kevin A., Beth LaShell, Franklin J. Thomas, Jason French and, and Todd Bates. 2014. Hops virus testing: Significance and implications for establishing hop production in New Mexico and Southwest Colorado. NMSU Cooperative Extension Service, College of Agricultural, Consumer and Environmental Sciences (In Press).

Lombard, K.A., K. McCarver, F.J. Thomas, R. Acharya, T. Bates. 2014. What's Hop'pening in Northwest New Mexico? Hops (*Humulus lupulus*) trials summary 2009 to 2014. American Society for Horticultural Sciences. July 28-30, 2014. Orlando, FL. HortScience 49(9):S318-319 (Abstr.).

Rodebaugh, Dale. 2013. Braving the cold to learn more about what makes hops tick. Oct. 12, 2013. Durango Herald. Url: http://www.durangoherald.com/article/20131012/NEWS01/131019821/-/News01/Braving-thecold-to-learn-more-about-what-makes-hops-tick

McElroy, Ashley. 2013. Farmington farmers experimenting with growing hops. July 13, 2013. Featuring work with hops and hops workshop hosted in Farmington, NM. KOB Eyewitness News 4 hops. Url:http://www.kob.com/article/stories/s3096438.shtml

Rodebaugh, Dale. 2013. Time to hop to it? July 11, 2013. Durango Herald.

Moorman, Jane. 2013. NMSU to host alternative crop workshop. The Deming Headlight and other newspapers. June 6, 2013. Url: http://www.demingheadlight.com/ci_23406636/nmsu-host-alternative-cropworkshop?source=most_viewed. Featuring hops and an upcoming workshop hosted July 12 and 13 in Farmington, NM.

In Preparation:
Winter 2014-2015: Finalize a comprehensive study report to be submitted winter 2015 to peer reviewed NMSU Research/Cooperative Extension report and/or journal article. This will include an economic and marketing analysis through survey of the craft brewing industry of New Mexico, field plot data, and literature review.

-1477 Project 7: Fresh Market Green Chile Market Development and Promotion, Final Report

Project Summary

The initial purpose for this project was to increase market share of New Mexico Green Chile and ultimately create a new demand for consumers seeking new tastes and culinary applications. The incorporation of new and different marketing strategies was critical in capturing new markets. The project was a continuation of the 2012 SCBG New Mexico Green Chile Promotion project. It was also an extension of continued market development into targeted markets and expansion directed at gourmet food purveyors.

Project Approach

Technical assistance and educational seminars were provided in efforts to maximize targeted markets effectively. Chile Boot Camp 101 provided retailers historical data, common misconceptions of green chile, event planning, roasting and preparation strategies, cross merchandising, promotional materials, and education outreach for consumers. Proper training and education of store personnel conducting demonstrations was an integral component in establishing a one-on-one connection with the consumer. A total of 11 Chile Boot Camp 101 trainings were performed. These events occurred in:

- Seattle, WA
- Las Vegas, NV
- Atlanta, GA
- Los Angeles, CA
- San Antonio, TX
- Newark, NJ
- Pittsburg, PA
- Columbus, OH
- Houston, TX
- Dallas, TX
- Des Moines, IA

The promotions were conducted at Kroger, Smith's, Fareway, Wakefern, Fresh Market, Whole Foods Grocer, and Frieda's distribution. These chain stores represented at least 90 stores. Alumni Events were performed in:

- Annapolis, MD
- Alexandria, VA
- San Francisco, CA
- San Diego, CA
- Phoenix, AZ
- Atlanta, GA

In addition, one restaurant/alumni event was performed in Austin, TX. Education outreach was also expanded in the form of our "Get your Fix" DVD's which provided consumers with chile roasting instructions and green chile recipes. NMDA also provided support to NM shippers with point of purchase materials that included "Get Your Fix" caps. These caps were worn by store personnel during the chile season.

Goals and Outcomes Achieved

The Green Chile promotion had a desired impact on industry. With an increase in market expansion and an increase in the number of stores, processors and producers were positively impacted. Even though the target of gourmet restaurants was not met, the one event that occurred in Austin, TX was deemed very successful.

The nine new regional markets created was well beyond the target mark of four. Ultimately over 90 stores throughout various regions invested and participated in the New Mexico Green Chile Promotions surpassing our target of 24 stores. Through marketing strategies taught by NMDA via Chile Boot Camp 101, the new markets will ultimately increase demand and future sales for seasons to come.

The establishment of Alumni events proved to be very successful. The six alumni events surpassed the target mark of three and continues to be a high demand event. The alumni event allows ex-New Mexicans the opportunity to feel at home and purchase chile. Reuniting with former classmates and roasting chile makes for a popular event that attracts not only former New Mexicans but new interested buyers. These popular events are greatly appreciated by alumni and prospective customers throughout the United States.

Beneficiaries

The rise of new markets and higher demand has resulted in a substantial growth of annual retail sales, positively impacting the chile producer, processor, and retailer.

These events have created a win/win situation where New Mexico alumni offices can provide their membership with sources for New Mexico green chile and the participating stores benefit from not only the immediate sales, but the opportunity to gain the ex-pats as regular customers as well.

Lessons Learned

The project had positive results. As expected, the green chile is a gourmet product that grows business. As a result of our boot camp trainings, committed retail stores took advantage of the opportunity and increased storewide profits tremendously.

The primary lead for the project retired in 2014 resulting in a few constraints that led to a couple of cancellations. Several trainings and promotions that had been scheduled due to short notice and personnel resources, were cancelled and rescheduled for 2015.

NMDA staff regrouped and added a new marketing specialist to become the new lead for this project.

Contact

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-1477 Project 8: Landrace Chiles: Protecting and Maintaining Part of New Mexico's Heritage, Final Report

Project Summary

This project was developed to support the production of NM landrace chiles (*Capsicum annuum*). These uniquely New Mexican specialty crops were developed through many generations of selection by farming families in northern New Mexico and are recognized by consumers for their excellent quality. While these varieties are genetically distinct from commercial chile cultivars, there is evidence that cross-pollination has occurred between the landrace chiles and commercial cultivars, potentially threatening the distinction of these varieties. This project provided training and materials needed for growers to maintain and improve the genetic purity of their chile lines and produce high quality seed. In additional, data was generated to categorizing and describe the different chile landraces. This information will be compiled in an Extension bulletin that will be available for use by growers in publicizing and selling their chile products.

Project Approach

A training curriculum was developed on basic chile breeding and seed production.
This information was presented at three workshops in three different counties selected because landrace chile cultivars are grown in these areas. The project was carried out through a partnership with the Extension Agents in the targeted counties including: Tony Valdez, Taos County; Patrick Torres; Santa Fe County; and Newt McCarty, Valencia County. Each county Agent provided a meeting space to hold the training, as well as publicizing the events to the targeted clientele in their counties. The Taos Workshop was presented on May 21, 2013 from 6-8pm at the Taos County Extension office, 202 Chamisa Rd, Taos, NM; the Santa Fe Workshop was presented on May 23, 2013 from 6-8pm at the Santa Fe County Extension office, 3229 Rodeo Rd, Santa Fe, NM; and the Los Lunas Workshop was presented on August 28, 2013 from 6-8pm at the Valencia County Extension office, 1036 Miller Rd.

In addition, personnel from the New Mexico State University Los Lunas Agricultural Science Research Center assisted with the project by hosting the NM Landrace Chile Field Demonstration and the replicated field trails. The Landrace Chile Field Day was conducted on August 29, 2013. Participants in the three trainings, as well as the general public, were invited to attend this event. Participants were shown the different aspects of the different landrace chile varieties, as well as instances were genetic non-uniformity was apparent. Participants were also encouraged to sample and comment on fruit from the different entries.

The replicated trials conducted under this project consisted of a randomized complete block design with three replications of the following NM Landrace Chiles: *Alcalde, Casados Native, Chimayo, Cochiti Pueblo, Econdida, Isleta Pueblo, Jarales, Jemez Pueblo, Puerta de Luna, San Felipe Pueblo (2 lines), San Juan Pueblo 'Tsile', Santo Domingo Pueblo, Velarde, and Zia Pueblo.*

Seed was planted in the greenhouse, and then transplanted to the field at the Los Lunas Ag. Sci. Research Center on May 9, 2013. The two key quality parameters of red chile, heat and extractable pigment, were analyzed. Heat level (SHU) was tested by high-performance liquid chromatography (HPLC), and extractable pigment (ASTA) through the American Spice Trade Association's method 20.1. Fruit size and pericarp thickness were also measured. This data was combined with information obtained from yield trials performed in 2011 and 2012 to add fresh and dried weight yield compared to

the commercial chile cultivars 'NuMex Big Jim', 'NuMex 6-4' and 'NuMex Sandia'. Although analytical analysis of flavor was out of the scope of this project, participants (18 attendees- many individuals who had expressed an interest in attending did not, likely in large part because of the distance to Los Lunas) of the field day were encouraged to sample the different chile lines and provide feedback. Not surprisingly, the flavor of the landrace chiles was generally preferred to that of the commercial cultivars.

Goals and Outcomes Achieved

The three workshops were completed with approximately 12-15 participants at each session. Participants in the workshops had an increase in knowledge from a pre-test score of 53.9% to a post-test score of 74.0%.

Plant and fruit characteristic data was collected from the 2013 landrace variety trial, although laboratory results are still in process. Information obtained is currently being compiled into a Cooperative Extension Bulletin. Once completed, this information will be provided to targeted counties to aid in consumer awareness of the landrace chiles. Long term impacts, including production of genetically uniform, high quality landrace chile seed and greater awareness of these cultivars by consumers is anticipated, but would need to be assessed in future seasons.

Recommendations to growers include: The NM landrace chiles tend to be higher in pungency than the commercial chile cultivars analyzed, with the exception on 'NuMex Sandia'. While high pungency is not necessarily bad, the landraces were also much more variable in their pungency compared to the commercial cultivars. The trait may not be acceptable to customer; most would like to know whether they are purchasing a mild, medium or hot product. Several of the landrace chile varieties also expressed noticeable fruit phonotypic variation. Another important finding involved the harvested yield. Conventional wisdom in NM dictates that the landrace chiles have a much lower yield than the commercial varieties. While this was true of fresh weight, several of the landraces provided dry weight yield equivalent to the commercial cultivars. For red chile production, dry weight yield is the critical parameter for crop profitability.

The landrace chiles have great potential to increase in value as a specialty crop for northern New Mexican growers. They represent a unique product that already enjoys a reputation for great taste. However, additional efforts must be employed to work with the germplasm to achieve more consistent heat level, profitable dry yield, and fruit consistency without sacrificing flavor. By improving the genetic purity of the seed, particularly if accompanied by a marketing project, commercial demand could be expected to increase. The landrace chiles could provide increased income to growers in northern NM.

Beneficiaries

The participants in the training workshop showed an increase in knowledge regarding protocols for uniform seed production of landrace chile cultivars, as well as basic information on saving seeds from other vegetable crops. However, the long-term beneficiaries will include consumers and enthusiasts of landrace chile, and ultimately, the families and communities who produce and protect the landrace chiles.

Lessons Learned

We anticipated that it would be challenging to get a large number of target participants to the trainings.

This goal was greatly bolstered through the collaboration with the county Agents. We met our target minimum of 10 participants at each training, however we know that many individuals who grow and save seed from landrace chile cultivars were not able or interested in attending. A key benefit of this program was to initiate and increase understanding in landrace chile seed protection efforts. The program raised awareness that genetic mixing has been a problem, as well as the great diversity in landrace chile cultivars available.

Originally we had planned to grow our landrace chile cultivar variety trial at a participating grower's field. We found that due to economic circumstances and lack of water availability, the grower could not produce chile in 2013. We relocated the variety trial to the Los Lunas Agriculture Science Center, however the issue points to the dire straits of the long-time farming families in northern New Mexico. Crops that have been grown for hundreds of years, and that are unique to communities and families are in imminent danger of being lost as families cease growing crops.

Finally, it became clear from interactions during the workshops and field day that much more work in seed saving education needs to be done. Participants wished to learn more, and expressed a desire in expanded efforts in seed saving as part of the growing trend of locally grown, quality produce. Two counties in particular have indicated interest in beginning 'seed libraries', where growers can procure seed, but then also contribute part of their seed harvest back to the library. While the overall concept of a seed library is worthy, if seed is collected from plants in which purity is not enforced, the material in the seed library may soon become worthless. Protocols from vegetable to vegetable type vary greatly; more in-depth training is needed for landrace chiles but also other vegetables.

Contact Person

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-1477 Project 1: Promoting New Mexico Processors and Growers of Specialty Crops to the Food and Beverage Industry

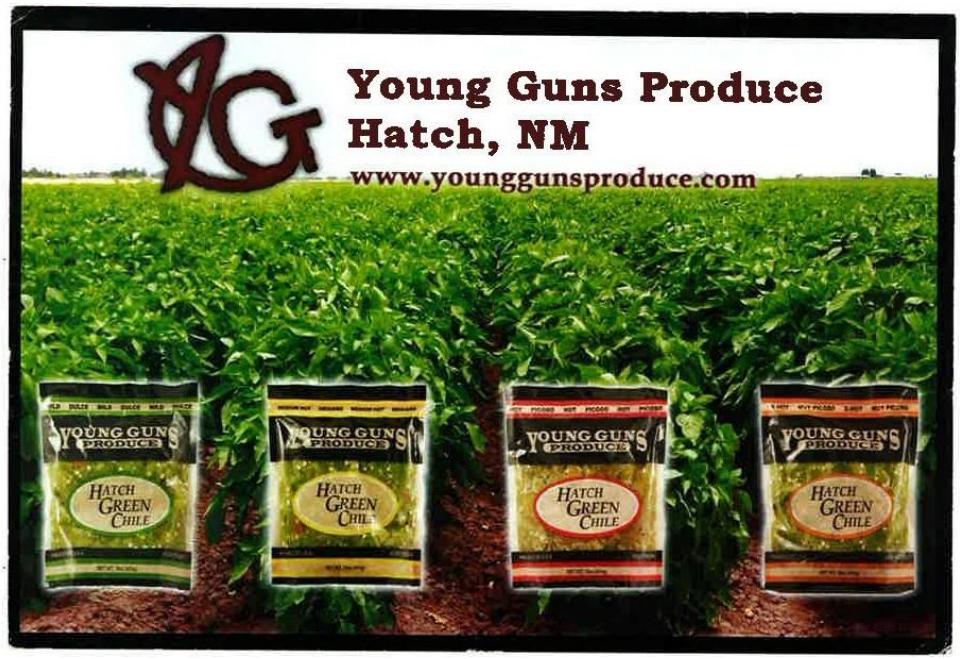
International Pizza Expo, Las Vegas, NV. 2015.

Chef Taste Challenge, New Orleans, Louisiana. 2015.

Hatch green chile display in Arlington, VA. August, 2015.

Dennis Hogan with celebrity guest chef Graham Elliot at the Shamrock Food Service VIP event. 2014, Albuquerque, NM.

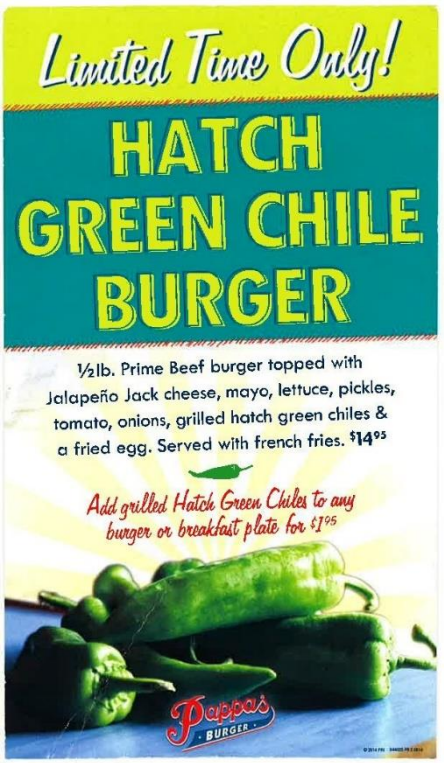
Shamrock Food Service Event promoting New Mexico Wines. Summer 2015, Albuquerque, NM.



HOME GROWN
A New Mexico Food Store & Gift Market

November 22-23

Food grown in New Mexico is showcased at this first-time event as vendors from around the state will sell their products as the gift-giving season approaches. The Museum is partnering with the New Mexico Department of Agriculture and the state's growers to offer great products to buy, sample, as well as cooking demonstrations book signing and much more.



New Mexcio-Produced Food Featured This Weekend

Lamb from Talus Wind Ranch, Galisteo

Bison from Taos Pueblo

Green chile, Hatch

Red chile, Chimayo

Pecans from NM Pecan Company, Las Cruces

Goat cheese from Old Windmill Dairy, Estancia

Asadero cheese from F & A Dairy, Las Cruces

Goat cheese/feta from Tucumcari Cheese

Corn from Schwebach Farm, Moriarty

Raspberries from Heidi's Raspberries, Corrales

Assorted greens and garlic from El Bosque Garlic Farm, Dixon

Tomatoes from Valentina's farm, Fairview

Various fruits and vegetables from the Santa Fe Farmers Market

Potatoes, beans and flour from Navajo Pride, Farmington

Wines from St. Clair, Gruet, Vivac

WELCOME TO THE TABLE!

New Mexico is blessed with an abundance of resources — mostly of the sort not measured by the national "surveys" reported in the press. Truly, few states are on a par in cultural diversity and offerings (notably preserved by our own Department of Cultural Affairs). On all things food, the absolute best experts in their field reside within our state, and are joined by several from without, be prepared for more than the occasional "ah-hah!" moment.

This year helping stir the pot and giving lie to the "too many cooks in the kitchen" adage is MIAC / LOA director Della Warrior, whose invaluable insight provided focus on Native life / foodways. The museum's curators and Carnell Chosa from the Santa Fe Indian School helped us establish connections with many Pueblos, among them, Tesuque, Jemez, Santa Clara, Santo Domingo, Laguna, and Cochiti. Additionally lending their important voices are a noted Apache chef from Arizona, a Kiowa chef, and a Navajo [Diné] chef from New Mexico.

The heat in the kitchen was not too hot to deter MCIFA director Marsha Bol, big-thinker marketing director Shelley Thompson, and our very own culinary legend Cheryl Alters Jamison, from adding their ingredients to the stew. And while not new to FUZE.SW, Deborah Madison contributed greatly of her time, expertise, and shared her immense and inspiring passion.

This year's FUZE.SW established a deep and valuable partnership with Dennis Hogan from the New Mexico Department of Agriculture and continued to strengthen DCA's bond with the New Mexico Department of Tourism. In keeping with the conference's spirit, Dennis locally sourced all the foods served this weekend.

Graphic design whiz — and sharing our passion for all things food and culture — is Monica Meehan. She deserves special appreciation; in what deep *cazuela* resides her incredible patience? I am also in near-speechless awe of my sous-chef Calliope Shank, a creative force in her own right, a multi-tasker extraordinaire.

Everyone involved, speakers, sponsors, and especially our new mayor, Javier Gonzales, from the outset grasped the significance of this year's theme, "sitting at the same table" — where New Mexico's diverse cultures join to find the common ground sustaining us.

Acknowledgements cannot be complete without calling out Charlene Cerny and Charmay Allred and the work of their tireless volunteer committee.

Cocked up last year to complement the *New World Cuisine* exhibition, FUZE.SW adds an extra dimension to our state museums' outreach with another view of our shared culture through food. Thank you for attending, be inspired, and let's hear it for FUZE.SW 2015!

Steve Cantrell
FUZE.SW Curator

EVENT PARTNERS

HOTEL SANTA FE THE HACIENDA AND SPA
HotelSantaFe.com

NMDA
NMDA.NMSU.edu

NEW MEXICO Taste the Tradition
NewMexicoTradition.com

NEW MEXICO true
NewMexico.org

Museum of Indian Arts and Culture
IndianArtsAndCulture.org

Museum of International Folk Art
InternationalFolkArt.org

New Mexico Department of Cultural Affairs
NewMexicoCulture.org

El Palacio
ElPalacio.org

Museum Hill Café
MuseumHillCafe.net

MNMF
MuseumFoundation.org

Delicious New Mexico
DeliciousNM.com

edible Santa Fe
EdibleSantaFe.com

Eloisa
Drury Plaza Hotel in Santa Fe
DruryPlazaSantaFe.com

Street Food Institute
SimonCF.org/site/SFI

Cooking with Kids
— for a healthy future —
CookingWithKids.org

Georgia O'Keeffe Museum
OKeeffeMuseum.org

Native Seeds/SEARCH
NativeSeeds.org

Santa Fe Botanical Garden
SantaFeBotanicalGarden.org

café FINA
CafeFinaSantaFe.com

CCA
CCASantaFe.org

dulce
DulceBakery.com

Ohori's Coffee
OhorisCoffee.com

VARA
VaraWines.com

vivác Winery
VivacWinery.com

Anasazi Restaurants
RosewoodHotels.com

la boca / Taberna
LaBocaSF.com

restaurant martin
RestaurantMartin.com

TERRA
FourSeasons.com

SUNDAY, SEPTEMBER 14

TIME	EVENT	LOCATION
10:00 AM – 4:00 PM	Delicious New Mexico MARKETPLACE FUZE.SW MarketPlace	Museum Hill

This free-to-the-public, day-long family food event is brought to you by FUZE.SW and Delicious New Mexico. Vendors will offer tastes of and sell New Mexico-grown, produced, and prepared foods, from jams to empanadas. Enjoy Native American dance performances, cooking demonstrations, cookbook signings, a green chile roast, tours of the Santa Fe Botanical Garden, food trucks, and more activities that everyone will relish.
Other partners include Cooking with Kids, The Food Depot, Georgia O'Keeffe Museum, and Native Seeds/SEARCH

SPECIAL THANKS

A BIG NEW MEXICO-SIZED THANK YOU TO DENNIS HOGAN AND THE NEW MEXICO DEPARTMENT OF AGRICULTURE

Chef Juan José Bochenski
Stephanie Cameron
Chef James Campbell Caruso
Lynn Cline
Chef Andrew Cooper
RoseMary Diaz
Anna Ferrier
Corey Fidler
Damien Flores
Chef Lois Ellen Frank
Jennifer Fresquez
Dody Fugate
Weldon Fulton
Honey Harris
International Folk Art Foundation
Irrational Pie
Tom Ireland
Cheryl Alters Jamison
Max Lahman
Shirley Lujan
Deborah Madison
Paul Margetson
Marja Martin
Candace Tangorra Matelic
Maxine McBrinn
Doug Patinka
Earl Potter
Vicki Pozzebon
Bob Ross
Daniel Cuat
Santa Fe Art Institute
Santa Fe Indian School
Jason Silverman
Simon Charitable Foundation, Steven H. Simon and Bear Nash
John Stafford
Luci Tapahonso
Doris Valdez
Jodi Vevoda
Candace Walsh
Chef Walter Whitewater
Janey Zimmer

FUZE-SW 2014
Food+Folklore Festival · September 12–14

REPORT ON FUZE.SW 2014

The inaugural FUZE.SW, held in late fall 2013, was conceived to enhance the visibility of MOIFA's *New World Cuisine* exhibition. It accomplished this objective and was in itself an event as smashing success. The inaugural FUZE parlayed Santa Feans fascination with food into new audiences for the museum. This dovetails nicely with that has been called "the American food revolution" where beginning the in 19902 affluent consumers developed a serious interest in food and became more discriminating in their tastes. ("The Shake Shack Economy," Jan 26, *The New Yorker*, James Surowiecki).

FUZE.SW built astounding "mutually beneficial relationships" between MOIFA and MIAC, with new publics, and with a growing list of other institutions and organizations (see below). FUZE.SW created high-level, museum related content and engaged a passionate and supportive audience.

Important support came this year from the New Mexico Department of Agriculture providing New Mexico grown and sourced food and beverage for FUZE.SW 2014 – greatly elevating the event and assuring significant national media exposure for FUZE.SW 2015. Amazingly for those of us who love our chile, the leading national media food writers attending this year had never tasted "true" New Mexico food – an excellent reason for continuing our partnership with NMDA. *Food & Wine* food editor Tina Ujlaki said, "We've not covered New Mexico food and culture since the 80s. There's a lot happening here and it's time we turn our attention to New Mexico." Margo True, senior ecitor of *Sunset Magazine*, was equally astounded at the interrelation between culture and food in New Mexico. This year some national media was received (see asterisked list below) and many others on the list assured us of both their attendance in 2015 and with promised articles. Two things: Media attending in 2014 were attracted more by the "buzz" generated by the first FUZE.SW 2013.

Three other small but telling developments from FUZE.SW 2014; attending were Dr. Sarah Wider, a professor at Colgate University whose concentration is on Native American literature will bring a class of 12 students next year; renown food historian Penelope Bingham, an Illinois Humanities Council Road Scholar, will bring a group from Chicago, and event panelist Dr. Thomas Antonio, an IAIA professor, said that the school will send students in their Native agriculture program. Other participants have committed to expanding their partnership in 2015; Cooking with Kids by involving the students and chefs in their program, and the Santa Fe Community College Culinary Program by opening their four kitchens to FUZE.SW chefs for hands-on cooking classes and demos.

Summary

The long-term plan for FUZE.SW is not the event itself, in isolation from its connection with DCA divisions – which has the ingredients to remain a success (given the resources) – but its ability to favorably feature our multiple divisions and to use foods of New Mexico as the gateway to understanding and appreciating our state's diverse cultures.

"Sitting at the Same Table" was the FUZE.SW 2014 theme – through our foods we can learn and appreciate our shared cultures.

Media attending FUZE.SW 2014

American Way Magazine
Cowboys & Indians
Dallas Morning News
Food & Wine
Hemisphere's Magazine*
LA Times
Native Foodways
Native Peoples Magazine
New Mexico Magazine*
New York Times*
Outside Magazine*
Sunset Magazine
Texas Monthly
SF New Mexican* / ABQ Journal* / SF Reporter* / Local Flavor* / Edible Santa Fe* / Edible Santa Barbara

Select FUZE.SW 2014 Media Coverage

The ABQ Journal
http://www.abqjournal.com/457027/entertainment/fuze-sw-returns-sept-12-14-offering-presentations-tastings-and-more.html

Santa Fe New Mexican
http://www.santafenewmexican.com/life/taste/fuze-sw-conference-spotlights-fusion-between-native-american-and-mexican/article_6adfe574-81ad-50ce-9ba9-27a091805d8a.html

United Hemispheres Magazine
http://www.hemispheresmagazine.com/2014/12/01/farming-goes-underground/

Outside Magazine
http://www.outsideonline.com/outdoor-adventure/the-current/eat-and-drink/Making-And-Eating-The-Worlds-Greatest-Green-Chile-Cheeseburger.html

Green Fire Times
http://greenfiretimes.com/2014/10/fuze-sw-2014-food-folklore-festival/#.VJBu18t0z5o

New York Times
http://intransit.blogs.nytimes.com/2014/08/01/santa-fe-food-festival-revels-in-the-regional/?_r=0

New Mexico Magazine
http://newmexico.travel/tasting_nm_blog/wordpress/?p=1126

USA Today 10 Best Things To Do In September
http://www.10best.com/destinations/new-mexico/santa-fe/all/attractions/fuze-sw/

Santa Fe Travelers

http://www.santafetravelers.com/food-thoughts/fuze-sw-food-folklore-festival-back/

UNM Program on Sustainability Studies
http://sust.unm.edu/events/2014/09/fuze-sw.html

The Literary Gardner
http://www.theliterarygardener.com/food/fuze-sw-food-folklore-in-santa-fe-chocolate-in-chaco-sunshine-and-what-we-ate/

I Am New Mexico
http://iamnm.com/?p=245

The Christensen Fund
http://newmexico.travel/tasting_nm_blog/wordpress/?p=1126

Eastern New Mexico State University
http://www.enmu.edu/current-students/orgs/multicultural/native-american/events.shtml

Albuquerque Business Journal
http://www.bizjournals.com/albuquerque/blog/morning-edition/2014/08/new-cookbook-features-nm-restaurants-food.html

Santa Fe Radio Café
http://www.santaferadiocafe.org/sfradiocafe/2014/09/01/deborah-madison-carmella-padilla/

Yahoo News
http://news.yahoo.com/fall-previews-fall-2014-food-161526941.html

FUZE.SW 2014 PARTNERSHIPS

State Departments
New Mexico Department of Agriculture
New Mexico Department of Tourism
New Mexico Department of Economic Development – Main Street Program

Department of Cultural Affairs – Divisions
Jemez Historic Site
Museum of Indian Arts and Culture
Museum of International Folk Art
Office of Archaeological Studies
Office of Historic Preservation

Native Americans (Pueblos and Tribes)
Acoma, Cochiti, Laguna, Jemez, Pojoaque, Santa Clara, Santo Domingo, Tesuque; AND one Apache chef from Arizona, one Kiowa from New Mexico, two Navajo (Diné) chefs from New Mexico, and a Potawatomi Nation from Oklahoma.

Community
Center for Contemporary Arts
Cooking with Kids
Flowering Tree Permaculture Institute
The Food Depot, Georgia O'Keeffe Museum
IAIA
Indian Pueblo Cultural Center
La Montanita/The Co-Op
Museum of Indian Arts and Culture (DCA)
Museum of International Folk Art (DCA)
National Hispanic Cultural Center 's Voces
Program
Native American Culinary Association
Native Seeds/SEARCH
New Mexico State University
Northern Arizona State University
Office of the Mayor, City of Santa Fe
Santa Fe Convention and Visitors Bureau
Santa Fe Farmer's Market
Santa Fe Art Institute
Santa Fe Botanical Garden
Santa Fe Community College
Santa Fe Convention and Visitors Bureau
Santa Fe Indian School
Simon Charitable Foundation / Street Food
Institute
Southwest Grassfed Lifestock Alliance
T'Ohono O'dham Action Committee
University of New Mexico

Post event praise for FUZE.SW 2014

Steve: That was awesome of you to allow us to participate in FUZE. I hope we can keep building this opportunity with FUZE. I think if we collectively pool our talents, connections, vision culture and spirits, we will do some incredible things for New Mexico! I look forward to working with you guys. Thanks again Steve and Carnell. ***Rich Luarke, Governor of Laguna Pueblo***

> Dear, Dear Calliope!!!! And Steve!!! What fantastic organizers you are. WORLD CLASS!!!! It was all amazing!....If you have worries about any hiccups...do not!!!!! No one, I mean, NO ONE noticed anything but how wonderful it all was. I'm just back at the hotel after a glass of wine at Tracey Ryder's beautiful house with Betty Fussell and Beverly Cox....they, too, sing the praises of your and Steve's work on this event. Keep it happenin'. It was a fabulous event. Kudos to you and to Steve and all that made it so. Thank you to all for the great job and wonderful experience! Sending smiles! ***Loretta Barret Oden, Chef, Author***Hi Steve- We had an amazing time this weekend! Home run out of the park! Thanks for including us. Got some great fodder for posts. ***Best, Billie Frank, Santa Fe Travelers***

Hi Steve, Congratulations to you and all the members of the FUZE committee. I continue to hear very positive feedback from the weekend events. The momentum is building for 2015.
Best, Jamie Clements, President/CEO – MNM Foundation

Hello Steve, I thought it a great conference, and it was especially interesting to see in terms of those who don't know the Southwest and who were eating their first breakfast burrito ever, (like the editor of Food and Wine.) They were really impressed and inspired, as was I and others who have lived here a while. Fine tuning is always possible - but my goodness - it was really quite good!
Best, Deborah Madison, James Beard Award winning chef, author

> Dear Steve, What a wonderful conference, thank you so much for including us! We met terrific new people, reconnected with old friends and colleagues, ate well and gathered much food for thought! Congratulations on a terrific event!
> ***Mary Paganelli, Editor & Publisher, Native Foodways Magazine***

Hi Steve, Thank you for making it so easy to be part of the FUZE Festival. I had a blast and felt well taken care of the entire time.
Take care, Pat Sharpe, EXECUTIVE EDITOR / FOOD WRITER – Texas Monthly

> Hi Steve, It was such a pleasure meeting you and I just can't thank you enough for inviting me to participate at Fuze this year. The whole conference was so rich, so interesting, so diverse, so thought-provoking, so compelling! It was by far the most interesting conference I've been to in a long long time. I learned so much, and It was an honor to be a part of it. I wish you a super good rest and post-Fuze recovery.
> ***All best, Tina Ujlaki, Executive Food Editor | Food & Wine***

Dear Steve and Calliope, On behalf of all of us at Cooking with Kids- congratulations! WHAT an incredible weekend! Thank you for your grace, hospitality, good humor--we all had such a good time. If you're not tired of hearing this---FUZE.SW was a HUGE success! Thank you for allowing CWK to be part of it. Hope you both are getting some well-deserved R and R!
With great admiration, Anna Farrier, Community Liaison, Cooking with Kids, Inc.

> Dear Steve, It was a pleasure and an honor to be included in the FUZE event this year. Wonderful and inspiring presentations and a great group of participants, and very well run. Thank you so very much for your support and also for being so responsive about including Laurie on the Native Livestock panel; she added much knowledge and a sense of humor! We were both pleased with how it went, I hope you had good feedback.
> ***Nancy Ranney, Ranney Ranch, Corona, New Mexico***

Hi Steve, I just wanted to thank you for the chance to participate in FUZE last Friday. I enjoyed myself immensely. If you do it again next year I would love to come... Maybe on something like the soup plate and its integration into Pueblo pottery manufacture or the copying of Spanish decorative patterns on Pueblo Pottery.... or something else. It is a year off... I had never been to a food conference before. You really hit the nail on the head with that event. With the foodie movement right now, you are capturing something impressive. All the feedback I heard was great. In any event, thank you... thank you... thank you! ***Matt Barbour, Site Manager, Jemez Historic Site***

> Steve, As usual, you sir, you scaled new heights in the Santa Fe food –sphere with the 2014 FUZE event! Can't wait see the line-up for 2015!
> ***John Sedlar, Chef, Eloise at the Drury Plaza, Santa Fe and Rivera in Los Angeles***

Steve, I thoroughly enjoyed FUZE.SW 2014 and you are to be congratulated for all your hard work in making it a success. I made some great connections and found inspiration from many of the presentations.
Regards, Tom
Thomas M. Antonio, Ph.D., Associate Professor and Science Coordinator, IAIA

> Hi Steve - It was my pleasure to participate this year and hope to be asked back again. I'm sure you will need time to catch up after all you and your team did to make the event a huge success, so enjoy taking deeper breaths (at least for a little while)!
> ***Cheers and thanks, Tracey Ryder, Co-founder, Edible Communities***

Hello Steve, Thank you! It was a lot of fun to participate, interesting discussions, wide range of presentations, great food! I have to admit that I have done a lot of professional conferences, but this was the first time I've ever participated in something so different and creative. You all did such an incredible job of pulling together a diverse assemblage of people, kinds of presentations, and foodways. It was very impressive. I hope that you and your team have some time to relax, catch your breath, and unwind... When you start gearing up for next year, just let me know what I can do to help out. It was a pleasure to play a small role in contributing to something so well-organized and orchestrated.

Take a break.... Thanks again,
Lois Stanford, Professor of Anthropology, NMSU

> Hi Steve, Thanks for all your hard work and careful maneuvering. It certainly paid off.
> I too hope there will be a FUZE 2015
> ***Very best to you all, xxBetty Fussell***

Steve, Thank you for the opportunity to participate in FUZE.SW 2014. I thoroughly enjoyed myself and certainly was happy to renew old acquaintances and to meet new scholars and chefs. I found the organization of FUZE was great and your staff was super. All in all I was very pleased to have been invited.
Dick Ford, Professor Emeritus (Anthropology), University of Michigan

> Thank you, Steve. I would be excited to hear about planning for a 2015 FUZE SW event. I had a wonderful, delicious, and very thought provoking, experience.
> ***Best regards, Lynda Prim, Conservation Farm Manager, Native Seeds/SEARCH***

Hi Steve, I thought that this years FUZE was interesting, and very well organized. I had a great time, and very much appreciated being included. Hope that our paths will cross again sometime soon. If you get up our way, please let us know and plan to pay us a visit at the ranch.
Very best wishes, Beverly Cox, Native Times Magazine

END

-1477 Project 4: Promoting Jujubes in New Mexico with Cultivar Demonstrations, Research and Extension

ALBUQUERQUE JOURNAL

Jujubes, or Chinese dates, add zip to New Mexican plates

By Donna Olmstead / Journal Staff Writer

Wednesday, November 11th, 2015 at 12:02am

ADOLPHE PIERRE-LOUIS/JOURNAL
Dried jujubes, also known as Chinese dates, taste a little like apples.

Someday asking for more jujubes – the fruit, not the candy – may be as common in New Mexico as requesting red or green chile.

Like chile, jujubes are packed with vitamin C and other nutrients.

The plum-sized coppery fruit, also known as a Chinese date, loves the high desert climate. Hot days and cool nights make it sweet. Jujubes come in many subtle flavor variations depending on whether it's fresh or dried,

Jujubes ripen in September and October and can be dried.

but it's sweet like apples or sometimes like raisins.

"It kind of absorbs and enhances the flavors of whatever you cook it with," explains Laura Bittner, a home economist.

Rich aromas filled a kitchen one recent, overcast morning, as she experimented with jujubes as a tangy addition to dressing, the center of bacon-wrapped appetizers and as a warm dessert sauce, like a chutney, with vanilla ice cream.

Bittner, program director of the Valencia County Extension Service, says the nutrient-packed fruit is a great way to increase vitamin C and fiber in a variety of dishes. "It's healthy."

Jane Moorman, a spokeswoman for NMSU, has jujube trees in her West Mesa backyard. She says likes them fresh off the tree when they taste more like apples.

Jujube trees bloom in the summer, so unlike apples or peaches and apricots that flower earlier and then can get hit with a frost, jujube trees make fruit every year, she says.

Although it grows well from Las Cruces to Alcalde, SunStar Herbs, a farm near Madrid, produces most of the commercially available fruit and sells jujubes at the Santa Fe Farmers Market.

Becky Thorp, who owns the orchard with her husband, Dave, says the jujube grows prolifically on the mountain farm at an elevation of 6,000 feet. The couple have about 128 trees and none of them died in the bitter frost several years ago. "It's a very hardy tree. The cold or the heat doesn't bother it," she says. She says the Lee and Lang varieties are her best producers.

She usually has dried jujubes available through April from their harvest that is most abundant in September and October.

"They're really an amazing fruit. If you are hiking or traveling and get hungry, three jujubes will give you enough energy to make it until you can sit down and eat," she says. She often mixes them in her stir-fries, fruit smoothies or granola.

Along with her farm stand at the Santa Fe Farmers Market, she also sells jujubes to herbalists and doctors of

Oriental medicine who buy the fruit to make medicine. She says the root and the seed are often used: "Jujube aids in digestion."

"The seed crushed up is a traditional Chinese herb," says fruit scientist Shengrui Yao, a NMSU specialist, who began her research in China.

Jujubes are native to China, where they have grown for the past 4,000 years. It first came to the United States in the mid-1800s and likely came to New Mexico in the 1900s with Chinese immigrants, she says.

Using natural methods, she is experimenting with different varieties to see which ones are most productive in NMSU orchards in Alcalde and Los Lunas.

According to Yao's report, jujubes have as much as 200 to 500 milligrams of vitamin C in two or three fruits, some 10 times more than citrus. They also have fiber, minerals, bioflavonoids and are rich in cyclic adenosine monophosphate, a protective nutrient that assists many bodily processes.

"Through the years there has been a natural selection of the cultivars. Growers select trees for the quality of the fruit, such as size or taste. There are no hybrids," she says.

JUJUBE STUFFING WITH SAUSAGE AND HERBS

Serves 8-10

2 cups chopped onion

COURTESY of JANE MOORMAN, NMSU
Jujubes in dressing add a tangy sweetness.

2 tablespoons butter, melted

1½ pounds spicy sausage

6 pieces of bacon, pork or turkey

½ teaspoon cinnamon

¼ teaspoon allspice

Salt and pepper to taste

4 cups roughly chopped stale bread pieces or the same amount of grain, like a mix of quinoa and wild rice, cooked according to the box directions

½ cup chopped and pitted dried jujubes

¾ cup walnuts

¼ cup sliced green olives

4 tablespoons capers

¼-½ cup sherry or brandy

Cook onion in butter until soft. Add sausage without casings and bacon. Stir and crumble the sausage until browned. Remove from heat and add spices. Stir in bread crumbs or cooked grain, chopped jujubes, and half of the walnuts and olives. Mix in food processor until blended and place in large bowl, adding the rest of the walnuts and olives and the capers. Add brandy until mixture holds together. Serve warm.

BACON-WRAPPED JUJUBE APPETIZERS

Serves 24

Bacon-wrapped jujube appetizers cook in about 30 minutes.

12 jujubes, pitted and halved

12 pieces of bacon, turkey or pork

2 tablespoons maple syrup

Red chile powder

12-ounce container crumbled cheese, gorgonzola, feta or goat

Toothpicks

Preheat oven to 350 degrees. Line a cookie sheet with parchment paper.

Fill jujube halves with crumbled cheese, dollop with a drop of maple syrup, sprinkle with red chile. Wrap each jujube with a half strip of uncooked bacon. Secure with a toothpick.

Arrange on cookie sheet. Bake 25-30 minutes, bacon should be crisp.

SAVORY JUJUBE DESSERT TOPPING

30 jujubes

¼ cup brandy

COURTESY of JANE MOORMAN, NMSU
A warm dessert sauce with jujubes and spices dresses up vanilla ice cream.

1/3 cup raw sugar

¼ cup wildflower honey

1 tablespoon flour or quick-cooking tapioca

Zest of one lemon and juice of ½ lemon

1 tablespoon finely grated fresh ginger

½ teaspoon cinnamon

½ teaspoon vanilla extract

Pinch of salt

Seed and chop jujubes.

Put all ingredients in a pot and cook on medium heat, stirring every few minutes.

When jujubes soften, take off heat and cool. Mix or chop in food processer.

Serve on ice cream or yogurt.

– Courtesy Laura Bittner, home economist and program director of the Valencia County Extension Service, NMSU.

BECKY'S FAVORITE JUJUBE RECIPE

Serves 2-4

6-12 jujube fruits, sliced and pitted

1 onion, chopped

¼ pound mushrooms, sliced

¼ pound butter

½ pound meat, cubed and cooked — goat, lamb or chicken, optional

Saute onions with butter until they begin to soften, add sliced jujubes. Cook until jujubes begin to crisp on medium to low heat stirring often. Be careful not to overcook as jujubes are delicate and burn easily. Add mushrooms, cook until soft.

Add precooked meat. Cook on low flame, stirring occasionally for 5 minutes.

Serve over rice or quinoa.

– Courtesy Becky Thorp, SunStar Herbs

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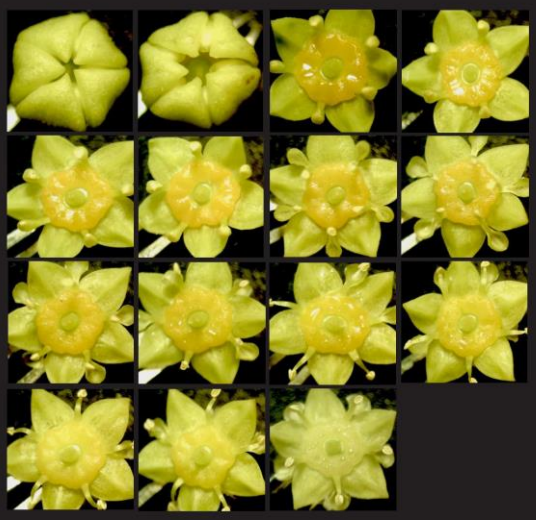

JUJUBE (ZIZIPHUS JUJUBA MILL.)

HortScience 50(6):839–846. 2015.

Jujube (*Ziziphus jujuba* Mill.) Flowering and Fruiting in the Southwestern United States

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Additional index words. blooming type, blooming process, self-pollination, self-fertility, seed development

Abstract. **Fifty-six jujube cultivars were observed for their flowering habits and fruiting characteristics at Alcalde, New Mexico. Jujube cultivars were classified as morning blooming type or afternoon blooming type. Among the 56 cultivars observed, 24 belonged to the morning type and 32 belonged to the afternoon type. Eighteen out of the 56 cultivars had their blooming type reported for the first time. The sepal splitting for morning type occurred from sunrise to 1000 MDT, whereas it occurred between 1300 and 1600 MDT for the afternoon type. Even though their opening time differed, pollen release happened during daytime for both—morning type released pollen in the afternoon and afternoon type released pollen in the late afternoon and the next morning. Rainy and cloudy weather delayed blooming for several hours. Each flower experienced the following stages during blooming: sepal splitting, sepal flat, petal standing, petal and anther separation, petal flat and anther standing, anther flat, and stigma browning; the time and duration of each stage varied with cultivar and blooming type. Flower size varied by cultivar and helps with cultivar identification. Cultivars Li, Li-2, Redland, Qiyuexian, Xiangzao, Teapot, and Daguazao were self-pollinating/self-fruitful in New Mexico. For open pollination, fruit set varied greatly by cultivar. 'Abbeville' had the best fruit set each year. Most cultivars had better fruit set from open pollination than self-pollination; however, self-fruitful cultivars Li, Li-2, and Redland had better fruit set with self-pollination than open pollination in some years. Open pollination increased fruit size for all cultivars. 'Zhongning', 'Abbeville', 'Jinsi-2', and 'Globe' had high seed percentage from open-pollinated fruit, whereas 'Lang', 'Don Polenski', 'Junzao', and 'Xingguang' did not produce fully developed seed in any years but some dark brown empty seedcoat sacs. Seed development was also affected by weather and pollination conditions. Fruit blooming type, pollen release, self-pollination, self-fruitfulness, self-fertility, and seed development are all critical information for jujube breeders, researchers, extension personnel, and growers.**

Jujubes (*Ziziphus jujuba* Mill.), also called chinese dates, belong to the Rhamnaceae family. Jujube cultivars were first imported into the United States by U.S. Department of Agriculture (USDA) agricultural explorer Frank N. Meyer from 1908 to 1918 (Meyer, 1911; Thomas, 1924; Yao, 2013). In the past hundred years, jujubes were cultivated mainly in the southwest, southern, and southeastern states from North Carolina, South Carolina to Florida, and from Florida and Georgia all the way to California; but they had been reportedly grown as far north as Pennsylvania (Ashton, 2006, 2008; Atkins, 1987; Locke, 1948, 1955; Lyrene, 1979, 1983; Yao, 2013). Recently, we noticed some jujube trees along the historic Chinese railroads or mine worker campsites in the southwest (Yao, 2015). Dry jujubes were part of those Chinese workers' diet and the littered seeds left behind grew voluntarily. Local people did not know much about jujubes but kept the trees that produced large and good-tasting fruit. These volunteer seedling plants belong to *Z. jujuba* and could be good germplasm for new cultivar selections.

Early researchers had identified that jujube grew and produced well and had great potential in the southwestern United States (Fairchild, 1918; Hager and Edward, 1989; Lanham, 1926; Locke, 1948, 1955; Meyer, 1916; Sweet, 1985). Because of various reasons, however, jujube production is still limited. Recently, interest in jujubes from growers and consumers is surging, and nurseries have had a hard time meeting the market demand (Ron Ludeke ns, personal communication). The challenges now are very limited commercially available cultivars and research support. Growers are frustrated due to insufficient information on cultivars, cultural management, processing, and marketing.

There are over 800 jujube cultivars known in China (Guo and Shan, 2010; Liu, 2008) while there are only a few cultivars commercially available in the United States with 'Li' and 'Lang' as the two most dominant. All jujube growers request more cultivars to extend the fruit supply season and to be used for different purposes to meet the consumers' demand (Yao, 2013).

Unlike apple or peach, jujube flowers are not initiated the previous year but the same year as they bloom. As the flexible deciduous fruiting structure—branchlets grow, they initiate flowers (Yao, 2012a). Jujubes have tiny flowers of ≈6 mm in diameter and have many more flowers than most fruit crops (Guo and Shan, 2010; Liu, 2006; Yao, 2012a). Each branchlet can have from 20 to over 100 flowers depending on the cultivar. Branchlet growth, flower initiation, blooming, fruit setting, and fruitlet growth occur simultaneously. Because of the high nutrient competition, jujubes, in general, have low fruit set (Guo and Shan, 2010).

In the 1950s, the USDA Chico Plant Introduction Station had a jujube breeding program for some years; unfortunately, the Chico Station was closed in the late 1950s. During their jujube breeding/cultivar selection process, they mentioned the need for a complete understanding of flowering, pollination, self-sterility, and seed development and conducted some preliminary research on these topics (Ackerman, 1961). Yan et al. (2009, 2010) reported the fruiting characteristics of more than 100 Chinese cultivars. In the United States, the flowering and fruiting habits of existing cultivars and new importations are largely unknown, and this fundamental knowledge would be critical for jujube breeders and researchers. Extension personnel and growers also need this information for cultivar recommendations or cultivar selections.

The New Mexico State University (NMSU) Sustainable Agriculture Science Center at Alcalde, New Mexico, has imported 30+ jujube cultivars from China and collected a number of cultivars in the United States for a total of over 50 cultivars. The objective of this study is to examine the blooming types, flowering characteristics, self-pollination/self-fertility, and seed development of these cultivars.

Materials and Methods

This experiment was conducted at the NMSU Sustainable Agriculture Science Center at Alcalde, New Mexico (lat. 36°05′27.94″ N, long. 106°03′24.56″ W, and 1737 m elevation) and all cultivars used are listed in Table 1. Since trees were planted or grafted in different years, not all cultivars were used for every test in this study (cultivars used are clearly listed for each experiment). Among those cultivars, Abbeville, Lang, Li, Sihong, Shuimen, Shanxi Li, Globe, Redland, Don Polenski, Fitzgerald, and So were planted in 2006, whereas 'Jin', 'Sui', and 'Topeka' were planted in 2011. Also in 2011, another 30 cultivars were imported from China as scionwood and grafted to wild jujube sucker rootstocks that had been planted in 2010. Because of the needs from researchers and growers and limited adult trees at Alcalde, New Mexico, we used young trees for part of the experiment. Another reason for using young trees is jujube's precocity—they can bear fruit during grafting year or planting year.

The planting density for the 2006 planting was 1.8 × 3.6 m, whereas the imported cultivars were grafted in the nursery area with spacing of 1.2 × 1.8 m. From 2012 to 2014, trees from both locations were used for the flowering habits and self-pollination/self-fertility studies. Trees from a 2011 replicated planting with 'Li', 'Lang', 'Sugarcane', 'Honeyjar', 'So', 'Shanxi Li', 'Li-2', 'September Late', and 'GA-866' at 1.8 × 3.6 m spacing were also used for the self-pollination/self-fertility experiment. Trees were fertilized two to three times in late May to June each year at a rate of 33–45 kg N/ha and irrigated weekly depending on season and precipitation.

Jujube flower number and blooming type. In 2012, 10 jujube branchlets (flexible deciduous fruiting branches) (Yao, 2012a) were sampled for 25 cultivars on 15 June. Total nodes and flower number at each node were counted and averaged for each cultivar. Flower diameter of 15 flowers for 46 cultivars was measured in 2012 and 2014. Jujube blooming times were observed at 3–4 dates in late June to early July each year for all cultivars from 2012 to 2014. At each date, the flower-blooming process was monitored hourly from 0600 to 1700 MDT and at 2200, 0300, and 0500 MDT. Four or five flowers per cultivar were harvested, stored in 1.5-mL tubes and brought back to the laboratory for pictures. The flower-blooming sequence was photographed hourly from 0600 to 1700 MDT for 'Li', 'Lang', 'Sugarcane', 'Sihong', and 'Abbeville' in July 2013 with a Cole Parmer digital microscope (Vernon Hills, IL). Their pollen release, stigma changes, and nectar exudation were monitored during this process.

Cultivar self-pollination/self-fertility study—bagging experiment. Four to ten 1- to 3-year-old secondary branches of 40–45 cultivars were selected and half of them were randomly chosen for bagging on 6–7 June 2012, 8–10 June 2013, and 22–25 June 2014, whereas the other half were left for open pollination without bagging. For those bagged branches, cultivar was self-pollinated naturally without any further hand pollination. Spatially, secondary branches from southeast, south, and southwest aspects of trees were chosen instead of those on the north side to avoid shading. In 2012, red nylon seed bags of 30 × 50 cm or 40 × 60 cm were used for bagging with mesh size of 1.5–2 mm. Since 2013, pollination bags of 45 × 50 cm with opening of 0.5–0.8 mm in length replaced the seed bags in the bagging experiments because they could block all insects (Middletown, DE). All opened flowers were removed from selected branches for either bagging or open pollination, and bags were twist-tied at the end. Branchlet number for each secondary branch was counted at treatment time. Bags were kept in place for 6 weeks and removed in late July (early Aug. in 2014). Some cultivars still had a few flowers or flower buds remaining at the end of 6 weeks, and they were removed during the unbagging process. Fruit sets were counted in August, late September, and at harvest. Total fruit weight and fruit number were recorded per treatment per cultivar at harvest.

Cultivar seed development. Harvested fruit from bagged or open-pollinated branches from 2012 to 2014 were air-dried, and the pits (stones) were cracked and their seed conditions were evaluated as fully developed seed, aborted seed, or no seed. Fully developed seeds are filled seeds; aborted seeds are dried, dark brown seedcoat sacs only; and no seed means no visible seed or seedcoat inside the stone.

Jujube flower diameters were averaged by cultivar and standard errors were calculated. Cultivar fruit set was calculated as fruit number per 100 branchlets. Seed development was calculated as filled seed or aborted seed percentage. Average among years and standard error were calculated for cultivar fruit set and seed percentage.

Results

Flower number and flower size. Flower number at each node varied greatly by cultivar (Fig. 1), but was relatively stable for each cultivar from year to year. 'Zhongning', 'Li', 'Li-2', 'Shanxi Li', 'Redland', 'Daguazao', 'Shuimen', 'Globe', and 'Abbeville' had fewer flowers than others with only one to three flowers per node. 'Liuyuexian', 'Sihong', 'Jinsi-2', 'Miyun', 'Sugarcane', and 'Jinsi-3', on the other hand, had more than seven flowers in the middle section of the branchlets (Fig. 1). 'Fitzgerald' had the highest number of flowers with 13 per node in the middle section of the branchlet. The branchlet length and number of nodes varied with cultivar, weather, and nutritional levels.

Jujube flowers are small without showy petals. Its flower diameters ranged from 5 to 7 mm (Table 2). 'GA-866', 'Chaoyang', 'Sui', 'Zaofengsui', 'Globe', 'Maya', and 'Honeyjar' had small flowers with diameters <6 mm, whereas 'Lang', 'Jing-39', and 'Dragon' had big flowers with diameters >7 mm. Most cultivars had flower diameters between 6 and 7 mm. Flower size for each cultivar is relatively constant and can be used as a supplemental trait for cultivar identification.

Flower blooming type. Jujube cultivars can be classified as two blooming types—morning blooming or afternoon blooming—based on their sepal splitting/opening time (Table 1). For the morning type, their sepals split from sunrise to 1000 MDT, whereas for the afternoon type it is usually from 1300 to 1600 MDT. Among the 56 cultivars observed, 24 were morning blooming type and 32 were afternoon type (Table 1). Most cultivars, except 'Mopanzao' and 'Teapot', had all sepals opened/split at the same time with even recess; 'Mopanzao' and 'Teapot' normally had partial opening with two to three sepals opened earlier than others.

Flower blooming time for each cultivar was relatively consistent from day to day and from year to year at one location. Rain and cloudy weather delayed the blooming process, but cultivars with the same blooming

Table 1. Jujube cultivars used in this study and their blooming types at New Mexico State University's Sustainable Agriculture Science Center at Alcalde, New Mexico.

Cultivar	Blooming type	Source	Cultivar	Blooming type	Source
Abbeville	AM	Louisiana	Li-2	PM	California
Ant Admiral	PM	China	Liuyuexian	PM	China
Banzao	PM	China	Maya	PM	China
Chaoyang	PM	China	Miyun	PM	China
Chico	AM	California	Mu	AM	California
Dabuding	PM	China	Mopanzao	AM	China
Daguazao	PM	China	Pitless	PM	China
Don Polenski	AM	California	Qiyuexian	PM	China
Dragon	PM	China	Redland	PM	California
Edhegard	AM	Alabama	Russia-2	AM	California/Russia
Fitzgerald	AM	Georgia	September Late	PM	California/China
Fuping	AM	China	Shanxi Li/Linyi Li	PM	China
GA-866	PM	California	Sherwood	PM	Louisiana
GI-1183	AM	California	Shuimen	AM	California/China
Globe	AM	China	Sihong	PM	California/China
Honeyjar	PM	China	So	AM	California
Huipingzao	AM	China	Sugarcane	AM	California
Jin	PM	China	Sui	AM	California
Jinkuiwang	PM	China	Teapot	PM	China
Jing-39	AM	China	Topeka	PM	Kansas
Jinsi-2	PM	China	Tsao	PM	Pennsylvania
Jinsi-3	PM	China	Thornless	AM	California
Jinsi-4	PM	China	Xiangzao	AM	China
Jixin	AM	China	Xingguang	AM	China
Junzao	AM	China	Youzao	PM	China
Kongfucui	PM	China	Yuanling	PM	China
Lang	AM	California	Zaocuiwang	AM	China
Li	PM	California	Zhongning	PM	China

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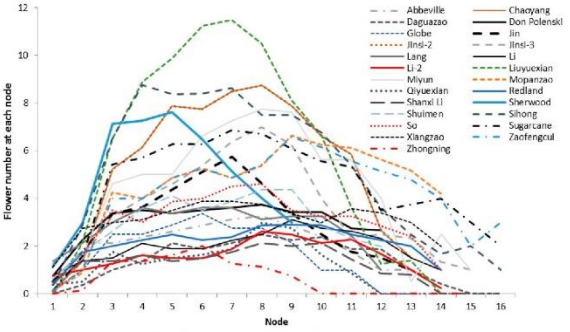

Fig. 1. Flower numbers at each node for different jujube cultivars in June 2012 at Alcalde, New Mexico.

Table 2. Jujube flower diameter of different cultivars at New Mexico State University's Sustainable Agriculture Science Center at Alcalde, New Mexico.

Cultivar	mm ± SE	Cultivar	mm ± SE
GA-866	5.0 ± 0.10	Daguazao	6.3 ± 0.08
Mopanzao	5.1 ± 0.05	Shanxi Li	6.3 ± 0.08
Chaoyang	5.5 ± 0.06	Jinsi-2	6.3 ± 0.09
Globe	5.8 ± 0.06	Redland	6.3 ± 0.11
Zaofengcui	5.8 ± 0.06	Yunling	6.3 ± 0.11
Sui	5.8 ± 0.07	Liuyuexian	6.4 ± 0.05
Banzao	5.9 ± 0.04	Dabailing	6.4 ± 0.07
Maya	5.9 ± 0.06	Don Polenski	6.4 ± 0.14
Honeyjar	5.9 ± 0.08	Sihong	6.5 ± 0.07
So	6.0 ± 0.05	Zaocuiwang	6.5 ± 0.07
September Late	6.0 ± 0.07	Hupingzao	6.5 ± 0.08
Sherwood	6.0 ± 0.07	Youzao	6.5 ± 0.08
Abbeville	6.0 ± 0.08	Sugarcane	6.5 ± 0.11
Xiangzao	6.0 ± 0.11	Jinsi-4	6.5 ± 0.14
Li	6.1 ± 0.03	Gaga	6.6 ± 0.04
Li-2	6.1 ± 0.09	Mu	6.6 ± 0.15
Qiyuexian	6.1 ± 0.10	Zhongning	6.7 ± 0.06
Fuping	6.2 ± 0.06	Miyun	6.7 ± 0.08
Kongfucui	6.2 ± 0.05	Jixin	6.8 ± 0.07
Jin	6.2 ± 0.07	Xingguang	6.9 ± 0.07
Pitless	6.2 ± 0.10	Junzao	6.9 ± 0.11
Shuimen	6.2 ± 0.11	Lang	7.0 ± 0.04
Jinsi-3	6.2 ± 0.12	Jing-39	7.0 ± 0.11
Jinkuiwang	6.3 ± 0.05	Dragon	7.0 ± 0.18
Average	—	—	6.26

type still bloomed at a similar time after delay. In New Mexico where it is mostly sunny weather, delayed blooming was not common. Even within the same blooming type, some cultivars always bloomed early, whereas others always bloomed late. For the morning type, 'Sugarcane' always bloomed earlier, whereas 'Mu' and 'Jing-39' bloomed later than others.

Flower blooming process. When jujube flower buds were close to bloom, their flower buds turned yellowish in color. The blooming process included the following stages: sepal splitting, sepal flat, petal standing, petal and anther separation, petal flat and anther standing, anther flat, and stigma browning, but the time and duration for each stage varied with cultivar and blooming type (Fig. 2). As sepals split, flowers opened up, and the nectar disk started to exude nectar with morning type peaking in the afternoon and afternoon type peaking the next morning (Fig. 2). The fragrance from the nectar disk attracted insect visitors to the flowers. The color of nectar disk varied with cultivar from light yellow to orange–yellow for 'Li' and orange for 'Lang'. As anthesis progressed, the nectar disk color became lighter and lighter until the same color as the sepals after bloom.

Even though there were two blooming types, both released pollen during daytime—the morning type flower released pollen mainly in the afternoon and the afternoon type released pollen from 1600 to 1700 HR and again the next morning. The blooming process lasted for 24 h. For the morning type, the blooming process finished within the same day with no pollen and nectar the next morning, whereas the afternoon type bloomed until noon the next day without much nectar and pollen left. Each flower only bloomed for one day but for each branchlet blooming lasted 4–6 weeks or longer. For trees at Alcalde, New Mexico, blooming continued for up to 2 or 3 months from June to mid-August depending on cultivars, tree age, vigor, and management.

When flowers first opened up, anthers already carried pollen in chunks outside their sacs but the two stigmas were still together and not ready to accept pollen yet. After a few hours (time varied with cultivar), the two stigmas grew, separated, and were ready for pollen (Fig. 3). The two stigmas clearly separated in the late afternoon for the morning type and the next morning for the afternoon type.

Self-pollination/self-fruitfulness. 'Li', 'Li-2', 'Redland', 'Daguazao', 'Qiyuexian', 'Teapot', and 'Xiangzao' were self-fruitful (Table 3). 'Li', 'Li-2', and 'Redland' had higher fruit set with

Fig. 2. Jujube flower blooming process for both morning type and afternoon type at Alcalde, New Mexico. (**A**) Li: Afternoon blooming type, 12 July to 13 July 2013. Row 1: 1300, 1400, 1500, 1600, and 1700 HR; Row 2: 0600, 0700, 0800, 0900, and 1000 HR; Row 3: 1100, 1200, 1300, 1400, and 1700 HR. (**B**) Lang: Morning blooming type, 12 July to 13 July 2013. Row 1: 0600, 0700, 0800, 0900, and 1000 HR; Row 2: 1100, 1200, 1300, 1400, and 1500 HR; Row 3: 1600, 1700, 0600, 0700, and 0800 HR.

self-pollination than open pollination in 2014. For the remaining cultivars, bagged branchlets had lower fruit set than those with open pollination. Nineteen cultivars had no fruit set after bagging in both 2013 and 2014. Although 'Abbeville', 'Chaoyang', 'Dragon', 'Mopanzao', 'Shanxi Li', 'Sugarcane', 'Youzao', and 'Jinkuiwang' had a low percentage of fruit set from self-pollination in one year, there was no fruit set from self-pollination the next year; further study is needed to confirm or disprove their self-fruitfulness. 'Dabailing' could be

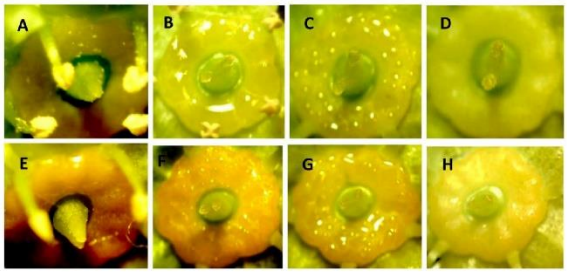

Fig. 3. Stigma changes during flower blooming process for afternoon type 'Honeyjar' and morning type 'Lang'. 'Honeyjar': (**A**) two stigmas together at 1700 HR; (**B**) two stigmas separated and disk with plenty of nectar at 0600 HR the next day; (**C**) stigmas started to turn color at 1200 HR; (**D**) brown stigmas and dry nectar disk at 1700 HR, the next day. 'Lang': (**E**) two stigmas together at 1300 HR; (**F**) two stigmas separated with some nectar at 1500 HR; (**G**) two separated stigmas with plenty of nectar at 1700 HR; (**H**) stigma changing color and no nectar at 0600 HR the next morning.

self-fertile and the zero fruit set in 2013 was due to low and oversha ded branches. Commercially popular cultivar 'Lang' was not self-fruitful.

Cultivars had varied fruit set from open pollination (Table 3). 'Abbeville' had the best fruit set at Alcalde among all the cultivars tested (Table 3). Its small fruit is not the most desirable, but it may be used to improve other cultivars' fruit set through breeding. On average, cultivars set better in 2014 than in 2013.

Seed development. Because of the large mesh size of the bags in 2012, insects could touch some flowers from the outside, especially flowers close to the bag. As a result, the fruit set and seed development for bagged branches are not reported. No fruit from bagged branches of any cultivar in both 2013 and 2014 had filled seed, so self-pollinating/self-fruitful cultivars were not self-fertile in this study at Alcalde, New Mexico.

For open pollination, cultivars were classified into two groups: <10% filled seed on average or >30% on average. Cultivar seed percentage varied among years (Table 4). Among the cultivars tested, 20 of them were evaluated each year from 2012 to 2014. Averaging those 20 cultivars, the filled seed percentage was 39.1% for 2012, 32.5% for 2013, and 26.3% for 2014; the variation could be related to weather and pollination environment differences. Cultivar Zhongning had the best seed percentage each year, followed by 'Abbeville', 'Jinsi-2', 'Globe', and 'Chaoyang' (Table 4). Fruit of 'Li', 'Li-2', 'Redland', 'Shanxi Li', 'Dabailing', 'Daguazao', and 'Qiyuexian' had very low seed percentage and varied with years. Fruit of 'Lang', 'Don Polenski', 'Junzao', and 'Xingguang' had no fully developed seed during any year (Table 4)—seeds stopped their development at an early stage with a dark brown sac residue inside the stone.

Discussion

Flower number, fruit set, and fruit size. In general, large-fruited cultivars such as 'Li', 'Li-2', and 'Redland' had fewer flowers at each node and lower fruit set per branchlet compared with small-fruited cultivars like 'Fitzgerald'. But 'Abbeville' had very small fruit with only two to three flowers per node, and medium fruit-sized 'Zhongning' also had few flowers. Both 'Abbeville' and 'Zhongning' had good fruit set each year. Flower number is relatively constant for each cultivar and can be used as a supplemental trait for cultivar identification.

Jujube blooming types. Cultivars were classified as morning blooming type or afternoon blooming type in New Mexico (Table 1). In China, they are called day blooming type and night blooming type (Guo and Shan, 2010; Qu et al., 1989). A recent publication also mentioned that in China, the "sepal flat" stage occurred between 0800 TO 1130 HR and 1400 to 1600 HR for night blooming type and day blooming type, respectively (Han et al., 2008). Our results are similar to observations in Florida (Lyrene, 1983). There was a 6-h shift between the reported splitting time from China and the United States, which may be related to location and weather conditions (Lyrene, 1983). The morning type in the United States would be equivalent to the night blooming type and the afternoon type is equivalent to the day blooming type in China.

Among the 56 cultivars, 'Chico', 'Edhegard', 'Fitzgerald', 'GI-1183', 'Shuimen'/'Sui', 'So', 'Thornless', 'GA-866', 'Li', and 'Tsao' were the same blooming type as Lyrene (1983) had reported. In New Mexico, 'Lang' was morning type, different from what Lyrene (1983) had reported. 'Lang', 'Don Polenski', and 'Thornless' have similar fruit shape and all were morning blooming type at Alcalde, New Mexico (Table 3). 'Globe', 'Hupingzao', 'Junzao', 'Xiangzao', 'Banzao', 'Chaoyang', 'Dabailing', 'Daguazao', 'Dragon', 'Honeyjar', 'Jin', 'Jinsi-2', 'Jinsi-3', 'Jinsi-4', 'Liuyuexian', 'Qiyuexian', 'Shanxi Li'/'Linyi Li', 'September Late', 'Youzao', 'Yuanling', and 'Zaofengcui' were the same as reported in China with a 6-h shift (Guo and Shan, 2010; Qu and Wang, 1993; Wang et al., 2007). 'Jixin' and 'Mopanzao' were different from reports from China, which could be due to homonym or location differences, and the partial opening of 'Mopanzao' may also lead to misidentification. 'Abbeville', 'Ant Admiral', 'Gaga', 'Jinkuiwang', 'Jing-39', 'Kongfucui', 'Li-2', 'Maya', 'Mu', 'Redland', 'Russia-2', 'Sherwood', 'Sihong', 'Sugarcane', 'Topeka', 'Xingguang', 'Zaocuiwang', and 'Zhongning' are 18 cultivars whose blooming type is being reported for the first time.

Self-pollination, self-fruitfulness, and self-fertility. 'Li', 'Li-2', 'Redland', 'Daguazao', 'Qiyuexian', 'Teapot', and 'Xiangzao' were self-fruitful in this study and 'Daguazao' and 'Teapot' were also reported self-fruitful in China (Yan et al., 2010). Our cultivars' self-fruitful percentage was much lower than what Yan et al. (2009, 2010) and Liu et al. (2009) reported. This could be due to location, cultivar differences, or tree age. In this study, young trees could underestimate the fruit set percentages, but the bagging material used could also make a significant difference. In our preliminary study in 2012, nylon seed bags with 1- to 2-mm holes were used, and the

Table 3. Jujube cultivar fruit sets from open pollination and self-pollination with bagging at New Mexico State University's Sustainable Agriculture Science Center at Alcalde, New Mexico, in 2013 and 2014.

	Branchlets		Fruit/100 branchlets			Branchlets		Fruit/100 branchlets		
Cultivar	2013-B	2014-B	2013-B	2014-B	Avg ± SE	2013-O	2014-O	2013-O	2014-O	Avg ± SE
Redland	76	59	51.3	52.5	51.9 ± 0.8	79	55	36.7	20.0	28.4 ± 11.8
Li-2	59	36	22.0	55.6	38.8 ± 23.8	57	32	49.1	25.0	37.1 ± 17.0
Qiyuexian	27	32	37.0	37.5	37.3 ± 0.4	35	34	97.1	185.3	141.2 ± 62.4
Dabailing	45	49	0.0	67.3	33.7 ± 47.6	46	58	8.7	127.6	68.2 ± 84.1
Li	102	120	7.8	54.2	31.0 ± 32.8	91	137	16.5	30.7	23.6 ± 10.0
Xiangzao	77	52	7.8	21.2	14.5 ± 9.5	92	55	45.7	154.5	100.1 ± 76.9
Daguazao	48	63	4.2	23.8	14.0 ± 13.9	54	60	46.3	73.3	59.8 ± 19.1
Teapot	30	31	6.7	16.1	11.4 ± 6.6	30	32	46.7	118.8	82.8 ± 51.0
Mopanzao	33	23	18.2	0.0	9.1 ± 12.9	40	29	72.5	103.4	88.0 ± 21.8
Dragon	33	53	6.1	1.9	4.0 ± 3.0	40	38	2.5	34.2	18.4 ± 22.4
Abbeville	77	108	1.3	3.7	2.5 ± 1.7	105	115	208.6	134.8	171.7 ± 52.2
Youzao	43	26	4.7	0.0	2.4 ± 3.3	36	30	36.1	106.7	71.4 ± 49.9
Sugarcane	92	82	2.2	0.0	1.1 ± 1.6	101	75	27.4	93.3	75.4 ± 25.4
Chaoyang	51	96	2.0	0.0	1.0 ± 1.4	40	105	92.5	100.0	96.3 ± 5.3
Shanxi Li	103	66	0.0	1.5	0.8 ± 1.1	95	74	37.9	48.6	43.3 ± 7.6
Don Polenski	73	52	0.0	0.0	0.0	75	47	65.3	93.6	79.5 ± 20.0
GA-866	12	68	0.0	0.0	0.0	54	49	20.4	14.3	17.4 ± 4.3
Gaga	31	56	0.0	0.0	0.0	25	58	116	143.1	129.6 ± 19.2
GI-1183	34	59	0.0	0.0	0.0	34	56	32.4	37.5	35.0 ± 3.6
Globe	81	57	0.0	0.0	0.0	82	55	47.6	21.8	34.7 ± 18.2
Honeyjar	26	48	0.0	0.0	0.0	37	48	102.7	147.9	125.3 ± 32.0
Hupingzao	19	55	0.0	0.0	0.0	19	45	63.2	11.1	37.2 ± 36.8
Jin	96	27	0.0	0.0	0.0	94	29	78.7	93.1	85.9 ± 10.2
Jinsi-2	53	22	0.0	0.0	0.0	54	30	63.0	103.3	83.2 ± 28.5
Jixin	60	91	0.0	0.0	0.0	50	85	28.0	49.4	38.7 ± 15.1
Junzao	85	23	0.0	0.0	0.0	81	26	39.5	107.7	73.6 ± 48.2
Kongfucui	34	60	0.0	0.0	0.0	30	74	56.7	106.8	81.8 ± 35.4
Lang	79	76	0.0	0.0	0.0	92	83	14.1	47.0	30.6 ± 23.3
Maya	50	90	0.0	0.0	0.0	46	99	171.7	116.2	144.0 ± 39.2
Sihong	34	30	0.0	0.0	0.0	35	27	8.6	7.4	8.0 ± 0.8
So	43	119	0.0	0.0	0.0	40	113	15.0	36.3	25.7 ± 15.1
Sui	49	67	0.0	0.0	0.0	48	57	22.9	64.9	43.9 ± 29.7
Xingguang	49	44	0.0	0.0	0.0	52	50	32.7	114.0	73.4 ± 57.5
Zhongning	62	34	0.0	0.0	0.0	61	46	145.9	47.8	96.9 ± 69.4
Jinkuiwang	41	—	7.3	—	—	40	—	127.5	—	—
September Late	—	28	—	0.0	—	—	31	—	174.2	—
Jinsi-3	40	—	0.0	—	—	38	—	139.5	—	—
Jinsi-4	33	—	0.0	—	—	23	—	147.8	—	—
Liuyuexian	23	—	0.0	—	—	20	—	130	—	—
Pitless	34	—	0.0	—	—	46	—	163	—	—
Sherwood	74	—	0.0	—	—	63	—	23.8	—	—
Shuimen	56	—	0.0	—	—	65	—	58.5	—	—
Zaocuiwang	27	—	0.0	—	—	37	—	13.5	—	—
Zaofengcui	48	—	0.0	—	—	53	—	35.8	—	—

B = Bagged; O = Open pollination.
The fruit number per 100 branchlets was the fruit count at harvest.
Cultivars with only 1 year's data are listed at the end of table for reference only.

cultivars' "self-fruitful" percentage was much higher (72%) than in 2013 (33%) and 2014 (30%) when bags with smaller-sized holes were used. Because of jujube's unique shoot structure and flower development in an inflorescence (Liu, 2006; Yao, 2012a, 2013), it is almost impossible to bag a single flower cluster, a branchlet or the whole secondary branch needs to be bagged. With large holes on the bags and jujube's tiny flowers (Liu, 2006; Yao, 2012a), flowers touching the bags could be pollinated by insects from outside the bag. We observed a wide range of jujube flower insect visitors in New Mexico (Grasswitz and Yao, 2014). Yan et al. (2009, 2010) and Liu et al. (2009) reported that 87.8% of the 179 cultivars were observed to be self-fruitful. Considering the bags they used had 27.5 holes/cm^2 (1.5–1.8 mm in length), those cultivars that set a few fruit per 100 branchlets from bagged branches may or may not be from true self-pollination. In this study, with small-holed bags in 2013 and 2014, the self-fruitful cultivar numbers dropped and cultivars performed consistently in both years (Table 3). Guo and Shan (2010) mentioned a high percentage of cultivar self-fruitfulness in commercial production in China. The commercial production in China is different from the case in the United States. Those solid plantings of 'Jinsi' series in Hebei and Shandong provinces in China could be a complex of many strains after thousands of years of production. Their fruit set could be from self-pollination or cross-pollination from different strains. Asatryan and Tel-Zur (2013) reported that four *Z. jujuba* cultivars could set small seedless fruit through controlled self-pollination with 27.8% fruit set for 'Li' and only 2.2% for 'Lang', and cultivar Tamar was parthenocarpic (fruit set without fertilization of ovules). Lyrene (1983) reported 'Silverhill' and 'Leon Burk' were parthenocarpic (isolated trees set full crop of fully developed fruit whether or not there are viable seeds in the fruit). Different authors classified parthenocarpy differently. From our study without further investigation, we only can conclude 'Li', 'Li-2', 'Redland', 'Daguazao', 'Qiyuexian', 'Teapot', and 'Xiangzao' were self-pollinating and self-fruitful. More detailed research is needed to find whether they were strictly parthenocarpic (without fertilization process). Most jujube cultivars had viable pollen grains with varying germination rates (Yao, 2012b).

Self-pollinating cultivars 'Li', 'Li-2', and 'Redland' were considered U.S. cultivars. 'Li' was imported 100 years ago and it is hard to find its equivalent in China now. Ackerman (1961) reported that with hand self-pollination, 'Li' had normal fruit set, whereas 'So' and 'Shuimen' had only a few fruit. Our results confirmed that 'Li' was self-fruitful in accordance with Ackerman (1961). In Ackerman's experiment, hand self-pollination was conducted while the branches were bagged, whereas our study did not use hand

Table 4. Percentage of fruit with filled seeds of different cultivars with open pollination at Alcalde, New Mexico, from 2012 to 14.

	Fruit number			Filled seed (%)			
	2012	2013	2014	2012	2013	2014	Avg ± SE
Don Polenski	11	47	44	0.0	0.0	0.0	0.0 ± 0.0
Junzao	32	31	28	0.0	0.0	0.0	0.0 ± 0.0
Lang	12	14	38	0.0	0.0	0.0	0.0 ± 0.0
Xingguang	8	19	57	0.0	0.0	0.0	0.0 ± 0.0
Jin	13	54	27	0.0	3.7	0.0	1.2 ± 1.2
Li-2	16	27	8	2.4	6.3	0.0	2.9 ± 1.8
Teapot	20	12	38	0.0	0.0	10.5	3.5 ± 3.5
Qiyuexian	8	34	63	0.0	2.9	7.9	3.6 ± 2.3
Li	26	11	42	0.0	9.1	2.4	3.8 ± 2.7
Daguazao	16	16	44	0.0	18.8	0.0	6.3 ± 6.3
Redland	13	21	11	7.7	19.0	0.0	8.9 ± 5.5
Shanxi Li	25	26	36	24.0	3.8	0.0	9.3 ± 7.4
Mopanzao	12	23	30	100.0	34.8	10.0	48.3 ± 26.8
So	14	5	41	86.0	60.0	56.1	67.3 ± 9.3
Sugarcane	25	59	71	84.0	74.6	43.7	67.4 ± 12.2
Chaoyang	21	39	107	100.0	71.8	63.6	78.5 ± 11.0
Globe	21	11	12	100.0	72.7	66.7	79.8 ± 10.2
Jinsi-2	31	10	34	90.0	88.2	74.2	84.1 ± 5.0
Abbeville	79	209	155	87.0	84.2	90.3	87.3 ± 1.8
Zhongring	30	87	22	100.0	100.0	100.0	100.0 ± 0.0
Average	—	—	—	39.0	32.5	26.3	—
Liuyuexian	11	25	—	100	72	—	86.0
Jinsi-3	14	53	—	42.9	50.9	—	46.9
Shuimen	22	41	—	45.5	39	—	42.3
Dabailing	19	—	74	0	—	1.4	0.7
September Late	—	—	54	—	—	96.3	96.3
Honeyjar	—	38	71	—	100	88.7	94.4
G1183	—	8	21	—	100	28.6	64.3
Jinsi-4	—	34	14	—	97.1	50	73.6
Jixin	—	14	42	—	85.7	33.3	59.5
Kongfucui	—	17	67	—	70.6	40.3	55.5
Shi	—	7	37	—	42.9	18.9	30.9
Maya	—	78	115	—	82.1	29.6	55.9
Hupingzao	—	12	5	—	8.3	0	4.2
Xiangzao	—	28	85	—	67.9	12.9	40.4
Youzao	—	13	30	—	84.6	53.3	69.0

Cultivars on the lower part of table with 1 or 2 years' data are for reference only.

self-pollination. This plus smaller sample sizes and young trees could have contributed to the difference in results for 'So' and 'Shuimen'. Ackerman (1961) also reported that clones 'G158' and 'G159' sealed in a tent with beehives set normal fruit. 'G158' and 'G159' could be seedlings of the same plant but they cross-pollinated each other, and the solid 'Jinsi' series commercial planting in China could be similar with self-pollination ability or different strains pollinating each other. Like 'Shanxi Li' and 'Abbeville', cultivars with 1–5 fruit/100 branchlets after bagging were below acceptable yield. If they were planted as a solitary tree in the field or backyard without bagging and with enough insect visitors, the fruit set might improve.

Ackerman (1961), Yan et al. (2009, 2010), Liu et al. (2009), and Asatryan and Tel-Zur (2013) all reported self-pollinated fruit were smaller and cross-pollination always increased fruit set and fruit size. The results from this study are similar (data not shown). As a result, commercially, we recommend growers to plant at least two cultivars. Our self-pollination study is useful for researchers and breeders and for guiding home gardeners who may just have room for one tree. Self-fruitful 'Li' would work as a single tree planting, whereas 'Lang' will not.

Seed development. Among the 46 cultivars tested, only a small number of cultivars set fruit by self-pollination and none of the fruit had seed inside the stone from any of the cultivars, which indicates that although some cultivars were self-fruitful, no cultivar was self-fertile in this study at Alcalde, New Mexico (Tables 3 and 4). Asatryan and Tel-Zur (2013) also reported four *Z. jujuba* species were self-fruitful with varied fruit set but seedless, not self-fertile. Ackerman (1961) reported no fully developed kernels after self-pollination for 'Li', 'Shuimen', 'So', 'Yu', 'G11', and '21996' and 1% filled seeds for 'G144'. Yan et al. (2009, 2010) and Liu et al. (2009) indicated that fruit of 99 cultivars (84.5%) had no seeds from self-pollination but the other 17 cultivars had 1% to 9.9% seed percentage and 1 cultivar had over 10% filled seeds from self-pollination. Cultivar differences, favorable weather conditions, and mature trees could be reasons for these higher numbers, and cross-pollination by insects could have occurred through the bags with 1.5- to 1.8-mm holes. Further experimentation with insect-proof bags is needed to confirm those jujube cultivars' self-fertility. The high seed percentage of 'Li' from open pollination in California (Ackerman, 1961) could be due to its large sample size and favorable weather conditions, especially during the fruit set period.

Seed percentage from open pollination varied by cultivar and year (Table 4). Cultivar seed development and percentage would be critical information for parent selection in a jujube breeding program (Yan et al., 2009). 'Lang', 'Don Polenski', 'Junzao', and 'Xingguang' had no fully developed seed from open pollination in any years (Table 4). Interestingly, those four cultivars had similar fruit shape. 'Xingguang' is a witches-broom resistant strain from 'Junzao' (Liu et al., 2006), whereas 'Lang' in the United States may not be the same cultivar as 'Lang' in China now. 'Don Polenski' had smaller flowers than 'Lang', whereas 'Lang', 'Xingguang', and 'Junzao' had similar flower diameters. The relationship among 'Lang', 'Junzao', and 'Don Polenski' is not clear. Fruit in 2014 had lower seed percentage than other years in this study. A late frost on 15 May 2014 (–5.6 °C) could have contributed to the lowest seed percentage in 2014 because frost killed the early growth. The plants regenerated themselves, but the season was delayed. To promote early fruit set after the mid-May frost, water was sprayed over the whole tree twice per week for 2 weeks for all treatments to boost fruit set during the full bloom period, but it did not improve seed development. Cultivars with less than 10% filled seed would not be suitable as female parents in breeding. We also noticed that early-set and larger fruit had good seed development, whereas some small late-set fruit had only a partially developed stone or was near pitless, especially in 'Lang'.

As a warning, jujubes do have suckers and can become a serious weed if abandoned in hot areas especially in the southeastern United States. In humid and rainy areas, especially with rains around fruit maturation season, fruit cracking/splitting can make the fruit unmarketable. Cracking in most years is not a problem in the semiarid southwest United States.

In summary, this study covers the flowering and fruiting characteristics of the majority of U.S. jujube cultivars. This information would be useful for future jujube-related research, breeding programs, and guiding growers in cultivar selections.

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Jujube: Chinese Date in New Mexico

Guide H-330

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ORIGIN

Jujube (*Ziziphus jujuba* Mill), also called Chinese date, red date, or Tsao, is native to China. It originated in the middle and lower reaches of the Yellow River, and has been cultivated in China for more than 4,000 years. Botanically, it is derived from its wild relative sour jujube or wild jujube (*Z. spinosa* Hu). In ancient times, people selected and cultivated sour jujubes with bigger fruit, and it gradually became the cultivated modern jujube species (*Z. jujuba*). There are still semi-cultivated sour jujubes like 'Tiger Eye'-big round sour jujube and Yanjishan big sour jujube, which are popular in Beijing and Shandong Province, China, respectively.

Jujubes belong to the Rhamnaceae (Buckthorn) family. The jujube can be easily confused with the Indian jujube (*Z. mauritiana* Lam), which is a tropical plant of the same genus, whereas the Chinese jujube is a cold-hardy deciduous plant. Although it varies with location, jujube usually starts to leaf out in April or May, blooms in June to July, and matures in late August to October. The dried fruit of the date palm (*Phoenix dactylifera*) looks similar to that of jujube, but botanically they are not related to each other.

HISTORY

Jujubes were first introduced to the U.S. from Europe by Robert Chisholm and planted in Beaufort, NC, in 1837. In 1876, G.P. Rixford brought jujubes from France and introduced them to California and nearby states. Most of the early imports were from seedlings. USDA Agricultural Explorer Frank N. Meyer introduced the first group of commercial cultivars to the Plant Introduction Field Station at Chico, CA, in 1908. Later, they were distributed to other USDA stations in Texas, New Mexico, Oklahoma, Georgia, and Florida. Scientists evaluated those jujube introductions until the 1960s, and a few selections were developed at Chico, CA. Shortly after the importation, Meyer and other scientists realized the potential of jujubes in the U.S., especially in the Southwest where sunshine is plentiful, summers are hot, and the climate is arid. In 1947, L.F. Locke from the Southern Great Plains Field Station at Woodward, OK, wrote, "This jujube is little known, but is highly dependable fruit of high food value."

In New Mexico, jujube trees can be found growing in diverse locales around the state. There are 50-year-old sour jujube and regular jujube trees (cultivars unknown) on the NMSU Las Cruces campus (Doña Ana County, elevation 4,000 ft). There are jujube trees in the South Valley area outside Albuquerque that were planted in 1928. A homeowner in Cliff, NM (Grant County, elevation 4,500 ft), has jujubes near his house, and they have been producing a prolific crop every year for the past 30 years. Other scattered trees in Las Cruces, Los Lunas (Valencia County, elevation 4,856 ft), Albuquerque (Bernalillo County, elevation 5,312 ft), Tucumcari (Quay County, elevation 4,816 ft), and Alcalde (Rio Arriba County, elevation 5,700 ft) are all growing and producing well.

DESCRIPTION

Tree

Jujube is a deciduous ornamental fruit tree 15 to 30 ft in height with very hard, strong wood. Branches are zigzagged with paired spines in young trees. Depending on the cultivar, tree growth habit varies from broad spreading canopies to very narrow and upright.

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Leaves

Leaves are shiny, ovate or oval in shape, and not branched, and grow on alternating sides of branches. Leaves are 1 to 2 inches (2.5-5.5 cm) long and 0.75 to 1.5 inches (2-4 cm) wide.

Buds and shoots

Jujube shoots are different from other fruit species. Vigorous new shoots of peach, apple, and grape can have branches in the same growing season, and the branches have structure similar to the primary shoot. Jujube has four types of shoots: primary (extension) shoot, secondary shoot (side branches), mother bearing shoot (fruiting spur), and fruit-bearing shoot (branchlet) (Figure 1). There are three kinds of buds for jujubes: main buds, secondary buds, and dormant buds.

There are two buds, one main bud and one secondary bud, at each node of both primary and secondary shoots and at the apex of mother bearing shoots. The terminal main bud of the primary shoot will keep growing each season to expand the tree canopy, and the lateral main buds (at the base of each secondary shoot) normally do not sprout and instead become dormant except with strong stimulation. The secondary buds on each node of primary and secondary shoots are early-maturing buds, which produce secondary shoots or fruit-bearing shoots.

The jujube primary shoot is always accompanied by secondary shoots (side branches), or the secondary shoots are part of the primary shoot and later diverge in function. The primary shoot elongates every year to expand the tree canopy. The secondary shoot acts as a base for the fruiting structure, does not extend in length, and withers back after two or three years. At each node of the secondary shoot is a mother bearing shoot (fruiting spur), which is a compact spur that grows approximately 0.04 inch (1 mm) and produces 2 to 5 fruit-bearing shoots each year. The fruit-bearing shoot (branchlet) is thin, flexible, deciduous, and 4 to 8 inches (10-20 cm) long; it bears flowers and fruits at its axils. The primary shoot, secondary shoot, and branchlet are zigzagged and spiny.

Flowers and fruits

Unlike apples or peaches, jujubes do not have big, showy flowers. The flowers are fragrant, pale greenish-yellow in color, and small, with diameters ranging from 0.15 to 0.30 inch (4-8 mm) (Figure 2). Flowers can appear singly or in a cluster at each leaf axil. Jujube's flower cluster (inflorescence) is a cyme (Figure 2) with up to 13 flowers depending on the cultivar and its position on the branchlet. Jujube flower buds initiate, bloom, and develop to mature fruit within one growing season, which is unique and different from other tree fruit crops. Jujube bloom lasts for several weeks, making jujubes good nectar plants.

Jujube fruit is a drupe with one pit (stone) in the middle containing up to two seeds. Its fruit derives from its ovary and the nectar disk. Fruit size varies from thumb-size to golf ball-size depending on the cultivar. The fruit shape can be round, oblong, oval, ovate, obovate, oblate, apple–like, or abnormal shapes.

CULTIVARS

Currently, there are 700 to 800 jujube cultivars in China, including fresh eating, drying, multipurpose (good for both drying and fresh eating), candied, and ornamental. Cultivars for drying, including multipurpose cultivars, formerly dominated and accounted for 90% of the jujube production in China. Now, with the selection and introduction of new fresh eating cultivars, plus the abundance of cold storage facilities, fresh eating cultivars are gaining popularity in China.

In the U.S., jujube cultivars are very limited. They include Frank Meyer's cultivars, cultivars recently imported from China or other jujube-growing countries, those released from the USDA Chico breeding program, and a few selections from seedlings across the country. Research from China indicated that quite a few regional dominant cultivars are self–fertile with no need for additional pollination; some cultivars can self-pollinate and set fruit, but cross pollination will improve the fruit set and fruit yield. A few cultivars are sterile without pollen, and a pollinizer cultivar and pollinating insect activity are required for these. Common pollinating insects include honeybees, houseflies, and ladybugs. As for the cultivars in the U.S., their self-compatibilities are not clear yet. For that reason, it is best to plant two or more cultivars instead of a single cultivar.

Figure 1. **Jujube shoot structures: A. primary shoot, B. secondary shoot, C. mother bearing shoot (young fruiting spur), D. old fruiting spur, E. fruit-bearing shoot (branchlet). (Photos by Shengrui Yao).**

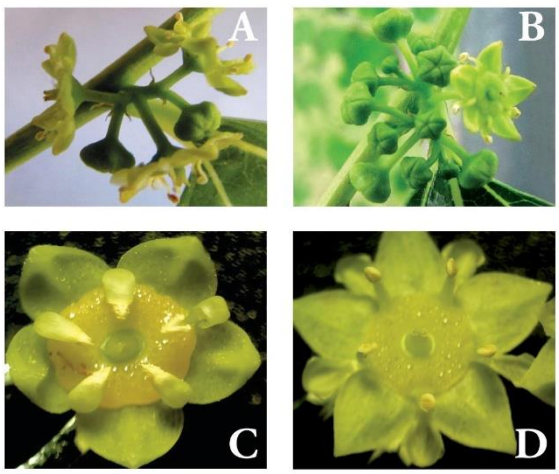

Figure 2. **Jujube flowers: A. a simple cyme, B. a large cyme, C. a half-opened flower, D. a fully opened flower. (Photos by Shengrui Yao).**

'Li': Popular commercial cultivar imported directly from China by Frank Meyer. Large, round fruit up to 3 ounces, mid-season, fresh eating cultivar. Good quality.

'Lang': Popular commercial cultivar imported directly from China by Frank Meyer. Fruit is big and pear-shaped and good for drying. Some fruit may split if it rains at mature season.

'So': Frank Meyer's cultivar. Beautiful ornamental tree with zigzagged branches. Medium-sized, round fruit with balanced sweet/tart flavor. Good for fresh eating and drying. Suitable for landscaping and home gardeners.

'Shuimen': Frank Meyer's cultivar. Medium-sized, elongated fruit with big pit, good for fresh eating and drying.

'Sugarcane': Small- to medium-sized, round to elongated fruit with excellent quality. Fruit is extremely sweet and crunchy on a spiny tree. Good for fresh eating and drying. It could be the offspring of Chin zse tsao. This cultivar has low fruit set at Alcalde, NM. Pollinizing cultivars and bee activity are necessary to ensure good fruit set.

'GA866': From USDA Chico Plant Introduction Station's jujube breeding program in California. Excellent large fruit with very high sugar content. Fruit is elongated and pointed at the far end.

'Sherwood': A seedling from Louisiana. Firm fruit with excellent quality. Trees are upright and narrow. Late-maturing cultivar. Good for long growing season areas.

'Honey Jar': A recent importation from China by Roger Meyer (no relation to Frank Meyer). Round, small fruit with excellent quality. Very sweet and crispy. Excellent for fresh eating. Tree is precocious and fruits during planting year or grafting year.

'Shanxi Li': Became popular in the late 1980s and early 1990s in China. Now one of the major fresh eating cultivars in China. Medium- to large-sized fruit with good eating quality. Mid-season maturity. Tree is precocious and productive.

'Sihong': A new importation from China by Roger Meyer. Good for fresh eating and excellent for drying. When dried, fruit has fine wrinkles on its surface. Mid-season maturity.

'Abberville': Tree is prolific and loaded with small fruit. Fruit quality is mediocre. Branchlets and fruits remain on tree for 1 to 3 weeks after defoliation, making it a good ornamental tree.

NMSU's Alcalde Science Center imported over 30 cultivars directly from China in 2011, including famous traditional cultivars, recently selected fresh eating and drying cultivars, and several early season and ornamental cultivars. As of 2012, they are still under USDA quarantine, but the best-performing cultivars will be released to the public after several years of evaluation under New Mexico conditions.

CULTURE

Propagation

Most commercial jujube trees are grafted on sour jujube (*Z. spinosa*) because of its seed availability and stress tolerance. Tongue–whip grafting and bark grafting are popular methods of jujube propagation. Jujubes can also be propagated through root suckers if the mother plants are from root suckers. If the mother plants are grafted trees, the suckers are only good as rootstocks. Softwood cutting is also possible for jujubes in a moist environment.

Precocity and tree life span

Jujube trees are very precocious. They bear flowers the same year as planting or grafting, and some cultivars can even bear some fruit. Most cultivars will produce a few fruits in the second year. After 4 to 5 years, jujubes will have a reasonable yield. A mature jujube tree can have 40 to 100 lb or more of fruit depending on tree size and culture management. Jujube trees can keep producing in commercial orchards for 50 years or more. The 'Jujube King' is over 1,000 years old and is still producing fruit annually in Shandong Province, China.

Soil requirements

Jujubes can grow and set fruit well in a wide range of soil conditions, from sandy to loam to clay, and from acidic to alkaline (pH 5.0-8.5). Jujubes can survive in barren soils. Most New Mexico soils should be suitable for jujube production.

Irrigation and fertilization

Jujube plants are quite tolerant to drought. For a premium fruit set and yield, though, jujube trees need to be irrigated in New Mexico's arid weather conditions.

There is limited research on jujube fertilization. Trees will survive with little or no fertilizer, but for commercial production, fertilizer applications are usually necessary. Do not fertilize newly planted trees until they are well-established.

Pruning

In general, jujube's training and pruning are simple, but there are some basic rules to follow. "One cut stops, two cuts sprouts" is a saying unique to jujubes. Unlike apple and peach, if you give a one-year-old jujube shoot just one cut in the middle, no

bud will grow under that cut. To force a main bud to sprout below a cut, the secondary shoot must be removed below the cut. Jujubes are light-demanding (full sunshine) plants. Pruning them annually will benefit the tree and improve the fruit set and fruit quality.

Harvest

As the fruit begins to mature, fruit color changes from dark green to yellow-green, known as the creamy, white mature stage. As maturation continues, brown/red spots develop at the petiole end (where the fruit joins the stem) or randomly in the middle of the fruit. The color further changes to half red/half creamy, and eventually becomes fully red/brown, known as the fully mature stage. People often compare firm jujube fruit texture to that of a crispy apple. Several days after fully red, fruit texture starts to soften and wrinkles appear on the surface.

Fruit maturity is not uniform. Fresh eating cultivars can be marketed from the white mature stage until they are fully red but still firm. Fresh fruit harvested when first ripe can be stored at 40°F (5°C) for two weeks or more without losing quality. The best time to harvest drying cultivars is when they are fully red. In New Mexico's arid climate, fruits can be harvested when they start to wrinkle or can be left hanging on the trees for a while after wrinkling. In humid areas, fruits must be harvested when they are fully red in color and dried as soon as possible to avoid yeast or mold infection. Manual harvest is preferable for fresh eating cultivars. For drying cultivars, growers in China lay tarps below trees and then shake the trees or use long poles to dislodge fruits. Mechanical harvest using trunk shakers may be applicable for production of large acreage of drying cultivars.

Pests, diseases, and disorders

In China, the dominant diseases for jujube are witch's broom and fruit splitting. Witch's broom is caused by a type of phytoplasma bacteria (*Candidatus Phytoplasma ziziphi*) and can destroy an entire orchard. The worst fruit splitting, resulting from heavy rainfall near harvest time, can ruin the entire season's crop. Peach fruit moth (*Carposina niponensis*) is the number one pest for jujubes in China.

It is easy to produce jujubes organically in New Mexico because, so far, jujubes are disease- and pest-free in the state. Fruit cracking is sometimes observed in the 'Lang' cultivar at Alcalde if it rains in early September. Most of the time in this climate, though, cracks will remain dry without developing yeast or fungal infection, and thus will not really affect fruit quality.

FRUIT NUTRITION AND USES

Jujube fruit is recognized as a nutritious food and important traditional medicine in China, Korea, Japan, and Southeast Asia. Jujubes are richer in vitamin C, sugar, bioflavonoids, edible cellulose, and minerals than other fruit species. Soluble solids content ranges from 20 to 40% in fresh mature fruit. Carbohydrate content in dried jujubes can reach as high as 70 to 85%. Fresh jujube fruit contains 200 to 500 mg of vitamin C per 100 g fresh weight, while apple, pear, and peach have 1 to 8 mg/100 g fresh weight. Jujubes are also rich in cyclic adenosine monophosphate (cAMP), which is an important "second messenger" in many biological processes in the human body.

Thus far in the U.S., jujubes have been considered more of a novelty than a specialty crop, with fresh and dried production mainly for home and local markets. However, the fruit can be used in many different ways. Dried jujubes are a nutritious snack and can replace raisins and dates in baking. Recipes have been created for jujube cake, jujube butter, candied jujubes, and jujube syrup. In China and Southeast Asia, besides being eaten fresh and dried, jujubes are also processed as candied fruit, smoked fruit, juice, jam, wine, mixed beverages, powders, and tea. Dried fruits are also cooked in porridge or broth, and are further processed into a paste for moon cake filling. As jujubes become more familiar and popular in the U.S., many value-added products with jujubes will be created.

Recipes

Jujube Butter

6 pints jujube pulp
1 teaspoon nutmeg
1/2 teaspoon cloves
2 teaspoons cinnamon
10 cups sugar
1/4 pint vinegar
1 lemon

Boil fruit until tender in sufficient water to cover. Drain, then run cooked fruit through a sieve or colander to remove the skin and seeds. Add remaining ingredients and cook slowly until thick. If you want to can the mixture, please follow safe canning procedures (see the *USDA Complete Guide to Home Canning*, available from http://nchfp.uga.edu/publications/publications_usda.html).

Jujube Cake

1 cup sugar
1/2 cup butter
2 cups dried, minced jujube
1 cup water
Bring these to a boil, then set aside to cool.

2 cups wheat flour
1 teaspoon soda
1/2 teaspoon salt

Sift these together, then add to the wet ingredient mixture and combine. Bake in your favorite cake pan at 325°F for around 20 minutes until a toothpick stuck into the center comes out clean.

Jujube Paste

Cook desired amount of dried jujubes in water for 10 minutes or until soft. Make sure to not overcook the fruit, which might turn sour if overcooked.

Puree in a food processor, then sweeten with sugar to taste. Work the puree into smooth paste. The paste can be used as a spread or as filling for confections such as cookies, desserts, and steamed buns.

CONCLUSION

Late-season startup, precocity, cropping reliability, nutritional benefits, and mild flavors make jujube an excellent edible ornamental and backyard tree. It also has great potential for commercial production in New Mexico. The large American-Asian food market and the medicinal food market are familiar with jujubes and are ready to consume them; however, it may take some time for Americans to become familiar with this exotic fruit. Growers can start with small acreage, and expand their operation to a bigger acreage with more diversified cultivars as the market grows.

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Past, Present, and Future of Jujubes—Chinese Dates in the United States

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Additional index words. *Ziziphus jujuba*, cultivar, biology, flowering, pests and diseases, nutrition, propagation, fruit use, processing

Abstract. **This article summarizes jujube importation and culture history and current jujube cultivars in the United States. Described within are jujube taxonomy, biology, adaptation, fruit nutrition, pests and diseases, propagation, and research conducted in the United States. It also discusses the current issues with jujubes in the United States and possible solutions to them. Jujube adapted and grew well in the southern and southwestern United States, and it could become a valuable industry in the United States within 15 to 20 years.**

Jujube (*Ziziphus jujuba* Mill), also called chinese date, red date, or tsao (zao), is native to China (Liu, 2006; Qu, 1963). It originated in the middle and lower reaches of the Yellow River and has been cultivated in China for more than 4000 years (Guo and Shan, 2010; Liu, 2006). Botanically, it is derived from its wild relative sour jujube or wild jujube (*Z spinosa* Hu). In ancient times, people selected and cultivated sour jujubes with big fruit and good flavor, and it gradually became the cultivated modern jujube species (*Z jujuba*). There are still semicultivated sour jujubes like 'Tiger Eye', big round, sour jujube, and Yanjishan big sour jujube, which are popular in Beijing and Shandong Province, China, respectively (Guo and Shan, 2010).

Jujube was first dispersed within China from its original center and then to countries bordering China. It was through the famous "Silk Road" that jujubes were introduced to Europe at the beginning of the Christian era (Liu, 2006; Lyrene, 1979). It is widely distributed in Persia, Armenia, Syria, Spain, and France (Locke, 1948; Lyrene, 1979). Most early jujube imported to Europe were seedlings (Locke, 1955; Lyrene, 1979) and were used as a table dessert or winter sweetmeat.

Liu (2006) reviewed the jujube basics and research in China and worldwide. Lyrene (1979) briefly summarized the jujube tree situation in the United States. This review focuses on the cultivar history, biology, adaptation, and production challenges in the United States and makes a comparison with the jujube situation in China whenever necessary.

Jujube History in the United States

Robert Chisholm first brought jujube seedlings to the United States and planted them in Beaufort, NC, in 1837 (Rehder and Rixford, 1929). In 1876, G.P. Rixford brought jujubes from southern France to California's Sonoma Valley and neighboring states (Rehder and Rixford, 1929). By 1901, jujube had escaped from cultivation and naturalized along the Gulf Coast from Alabama to Louisiana (Bonner and Rudolf, 1974; Lyrene, 1979). All of those early imports were seedling plants from Europe, not vegetatively propagated cultivars. It was not until 1908 that USDA agricultural explorer Frank N. Meyer introduced the first group of commercial jujube cultivars directly from China (Meyer, 1911). Meyer mentioned that one of the most promising tree crops of China was the chinese jujube, and he predicted jujube would be of great value in the semiarid south and southwest United States (Meyer, 1916). Jujube was one of two plants sculpted on the Frank N. Meyer Memorial Medal from the American Genetic Association in recognition of his contribution to plant germplasm collection and use (Fairchild, 1920).

Jujube Cultivars in the United States

The jujube cultivars in the United States now include several groups: Frank Meyer's direct imports from China, U.S. cultivars from the USDA Chico jujube program, selections from across the United States, and recent imports from China or other jujube-growing countries (Table 1). Those in Table 1 were listed as cultivars, but only a few of them were formally named, released, and went through cultivar trials.

Cultivars imported through Frank Meyer and the remaining cultivars currently in the United States. Frank N. Meyer reportedly made four trips to China (1905–08, 1909–11, 1912–15, and 1916–18) (Plantexplorers.com, 2012). Locke (1948) mentioned that 83 of 2500 of Meyer's PIs to the United States were jujubes. The author went through all the 1905–18 PI records (online now) and found that 67 jujube accessions were directly imported by Meyer from China (Table 2) (Galloway, USDA, 1907, 1908, 1909a, 1909b, 1912; Taylor, USDA, 1916a, 1916b, 1917a, 1917b, 1917c, 1922a, 1922b). Besides Frank Meyer's collection, others also collected 20 jujube accessions from 1905 to 1918 with 14 from China, four from the United States, one from Paris, and one from Asia (Table 3) (Galloway, USDA, 1909c, 1910, 1911a, 1911b, 1911c, 1911d; Taylor, USDA, 1914a, 1914b, 1915, 1917a, 1917c, 1919). Later, those accessions were rarely mentioned in literatures.

Table 2 indicates that Meyer visited the five major jujube-producing provinces in China: Hebei (formerly Chihli), Shandong, Shanxi, Shaanxi, and Henan Provinces as well as the Beijing and Tianjin areas. Frank Meyer collected roots or budwood of an unknown big-fruited cultivar during his first trip in 1905, which possibly did not survive because this was his first jujube import without any rootstock preparation, and the shipment itself may have been problematic. He sent back 12 batches of jujube seeds from jujube cultivars and sour jujube (*Z. spinosa*) from 1905 to 1907. Some of those seeds were collected in Sept. 1907 from famous cultivars like 'Chin sze tsao' (Jinsi zao in Chinese), 'Yuen ling tsao' (Yuanling zao), and two rare flat cultivars like mini apples in Shandong Province. In Mar. 1908, Meyer collected budwood for the famous 'Lang' and 'Mu shing hong tsao' together with 'Hu ping tsao' (Huping zao) and 'Tsui ling tsao' (Cuiling zao) from Shanxi Province. The USDA Chico Station received them in 20 Apr. 1908, which opened a new era for jujubes in the United States with big-fruited cultivars.

Meyer collected the major cultivars in each region, like 'Chin sze tsao', 'Yuen ling tsao', 'Lang tsao', 'Hu ping tsao', and 'Ta tsao' (big-fruited tsao) and 'Hsiao tsao' (small-fruited tsao). However, 'Ta tsao' and 'Hsiao tsao' are different from region to region, which usually refer to the two local dominant cultivars, but they are different in size. He also collected some rare cultivars—a flat one resembling a mini apple, a seedless (pitless) one named 'Wu hu tsao' (Meyer, 1911), 'Yu tsao' (Ya zao, tooth-shaped), a contoured one with gnarled and zigzagged branches, 'So' (PI 37484), and another one with crooked and twisted branches called 'Dragon' or 'Dragon's-claw' (Meyer, 1911). He also intentionally collected wild jujube seeds as rootstocks (Meyer, 1911) and seeds from trees with good fruit flavor for cultivar breeding purposes (Table 2). Meyer mentioned several times the hen egg-sized jujube fruit, and 'Li' was one of them. Of the 67 accessions imported, the very first one (PI 17752) was an unknown cultivar, 35 were vegetative parts from 34 cultivars (two 'Wu hu tsao' from different locations), one accession was a rooted plant from one of those 34 cultivars, and another one was a sample of dried fruit; the other 29 accessions were seeds from either *Z. spinosa* (three accessions) or *Z. jujuba* cultivars (26 accessions). All of Frank Meyer's introductions were first planted at the USDA Plant Introduction Station at Chico and were later distributed to other USDA stations, especially in Dalhart, Big Spring, and Lubbock, TX; Woodard and Lawton, OK; Garden City, KS; and Tucumcari, NM (Locke, 1948). In the mid-1930s, J.L. Collins of the Tennessee Valley Authority tested 40 cultivars near Norris, TN, and 'R3T1' (Row 3, Tree 1) was a selection from that planting (Osborn and Miller, 2009).

In the 1920s, the USDA Chico Station recommended four cultivars—'Mu shing hong' (PI 22684), 'Lang' (PI 22686), 'Shui men' (PI 38245), and 'Li' (PI 38249) (Thomas, 1927). 'Mu shing hong' was described as "one of the best varieties"; 'Lang' was "the best variety for general purposes"; 'Shui men' was "of average size and useful for many purposes"; and 'Li' had "the largest fruit and is one of the best to eat fresh and ripened one to two weeks later." Coincidently, all four cultivars were originally imported from Shanxi Province. Locke (1948) mentioned three of the four cultivars without 'Mu shing hong'. The observation and research work on jujubes at the USDA Chico Station continued until the end of the 1950s (Ackerman, 1961).

Now 'Li' and 'Lang' are the two most available cultivars in the United States. 'So', 'Yu', 'Mu' (Mu shing hong), and 'Shui men' of Frank Meyer's importation are also available in small quantities at Fountain Valley, CA, a private collection of Roger Meyer (not directly related to Frank Meyer), who is a jujube enthusiast and vice-president of California Rare Fruit Growers [Xotcfruit (R. Meyer), 2013].

Cultivars from the USDA Chico breeding program. There were several cultivars bred at the USDA Chico Station by Dr. Ackerman and his colleagues, although most of them were not officially released.

'Chico', also called 'GI-7-62', bred at the USDA Chico Station, is a seedling of PI 37484 ('So') with round but flattened fruit. Paul H. Thomson, who is one of two founders of California Rare Fruit Growers, named it 'Chico' to remember the Chico Station in California (Thomson, 1971). 'GI-1183' is another cultivar from the USDA Chico Station bred by Ackerman from unknown sources (Ashton, 2006). 'GA866' is a cultivar bred and selected at the USDA Chico Station by Ackerman with unknown sources (Ashton, 2006; California Rare Fruit Growers, 1996). 'Thornless' is a cultivar bred/selected at the USDA Chico Station by Ackerman and Smith; the fruit shape is similar to 'Lang' and the source is unknown (Ashton, 2006).

Cultivar/selections from across the United States. The United States does not have large germplasm resources (gene pool) for cultivar selection like China does, but after more than 175 years of jujube cultivation in the United States, there are some jujube plants with great fruit quality scattered in people's backyards without names. Locke (1948) mentioned that the patent office distributed jujube seeds to interested people in 1854. This is why there are many cultivars from different states named after people or towns, which are the result of long-term selections from seedlings or survivors of Frank Meyer's imports. Some of them could be the same cultivar but were found and renamed at other locations. Genetic analyses are needed to clarify their relationships. To date, there has not been much genetic or molecular work on jujubes for cultivar classification and grouping in the United States.

Some cultivars from this group are of sufficiently high quality to be officially named, but most of them lack regional tests. For example, 'Sherwood' (Atkins, 1987) was an excellent cultivar for California, Texas, and Louisiana, but it has poor fruit set and does not ripen before first frost in northern New Mexico. The author noticed several jujube trees 30 to 50 years old or older across New Mexico with good quality for both fresh eating and drying that would be worth further attention and testing.

Recent imports from China and other jujube-growing areas. In California, Roger Meyer imported several cultivars from China's Nanjing Botanical Garden in the 1990s [Xotcfruit (R. Meyer), 2013]. Jim Gilbert of One Green World Nursery in Oregon, introduced 'Autumn Beauty' and 'Winter Delight'[TM] from China (Ashton, 2006) and several cultivars from the Ukraine (personal communication) and the New Mexico State University Sustainable Agriculture Science Center at Alcalde, NM, directly imported over 30 cultivars from China in 2011. Cultivar evaluation trials are greatly needed across the United States to move jujube production forward. Growers need more cultivars for different purposes and to extend their harvest seasons.

The jujube cultivars in China have changed and increased rapidly after 1980 and especially since the 1990s. Researchers have done significant work on jujube germplasm collection and selections. An increasing number of new selections were named after 1990, but hybridization breeding is still problematic as a result of jujube's tiny flower and the multiple flowers in a florescence (Liu, 2006). There are over 800 jujube cultivars in China now (Guo and Shan, 2010). There are total of 60 to 70 "cultivars" in the United States, but only a few of them are commercially available. Hopefully, after several years of research and evaluation, we will be able to recommend 10 to 20 cultivars for different purposes to growers.

Taxonomy and Biology

Jujube belongs to the Rhamnaceae (Buckthorn) family. Its close relative is the sour jujube, from which cultivated jujubes were selected (Liu, 2006). Sour jujube grows in the wild in the mountainous areas of northern China. It is sometimes used as hedgerows,

Table 1. Current jujube cultivars in the United States.

Sources	Cultivars
F.N. Meyer's collection	Li, Lang, Shui men (Shuimen, Sui men or Sui), Mu'Mu shing hong, So, Yu
Chico breeding program[z]	GA866, GI-7-62/Chico, GI-1183, Thornless
Cultivars from across the United States	
Alabama	Silverhill,[a] Ed Hegard,[a] Swobada[a]
California	Don Polenski,[a] Jin,[a] Porterville,[a] Redland #4,[a] Sugarcane[a]
Georgia	Fitzgerald,[a] Leon Burk,[a] Prine[a]
Florida	Geant[a]
Kansas	Topeka[a]
Kentucky	Priest[a]
Louisiana	Abbeville,[a] Sherwood[a]
Pennsylvania	Tsao[a]
Tennessee	R3T1[a]
Texas	Texas Tart[a]
Washington, DC	Admiral Wilkes[a]
Imports after the 1990s	
R. Meyer's import[c,z]	Shanxi Li, Honeyjar, Globe, September Late, Ant Admire, and Sihong
J. Gilbert's import	Qiyuexian/Autumn Beauty,[c] Mango Dong Zhao/Winter Delight[TM],[c] Black Sea[TM], Coco[TM], etc.
NMSU Alcalde's import	Jinsi #2, Jinsi #3, Pitless, Jinzao, Taipot, etc., with total of 30 cultivars

[a]Atkins, 1987.
[b]Ashton, 2006.
[c]California Rare Fruit Growers, 1996.
[d]Lyrene, 1983.
[e]Osborn and Miller, 2009.
[z]Xotcfruit (R. Meyer), 2013.

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Table 2. Jujube accessions imported from China by agricultural explorer Frank N. Meyer during 1905–18.

PI no.	Collecting date	Plant part	Name	Chinese name	Collecting location	Province/area (now)
17752	20 Mar. 1905	Roots or bud sticks of a large- fruited cultivar	N/A		Chang-li, Chihli	Hebei[z]
17892	20 Mar. 1905	Seeds of sour jujube	Suan tsao			Hebei
18565	20 Mar. 1905	Seeds	N/A		Peking	Beijing
19394	5 Oct. 1905	Seeds from market of a large- fruited cultivar	N/A		Peking	Beijing
19397	26 Oct. 1905	Seeds	N/A		Pee-san	Hebei (?)
20092	26 Sept. 1906	Seeds of a large-fruited cultivar	N/A		Vladivostok, Siberia	Siberia
21618	30 Sept. 1907	Seeds	Chin sze tsao	金丝枣	Laoling, Shandong	Shandong
21619	7 Sept. 1907	Seeds	Yuen ling tsao	圆铃枣	Shantung	Shandong
21993	Aug.–Sept. 1907	Seeds mixture from different locations	N/A		Shantung	Shandong
21994	22 Aug. 1907	Seeds	Twen ku lu tsao	磴砧矿枣	Chingcklowfu, Shandong	Shandong
21995	19. Sept. 1907	Sour jujube seeds	Suan tsao	酸枣	Boihan, Shantung	Shandong
21996	22 Sept. 1907	Seeds	Tun ku yu tsao		Chinanfu, Shantung	Shandong
22606	9 Dec. 1907	Seeds	N/A		Jehol, Chihli	Hebei
22683	1 Mar. 1908	Budwood	Hu ping tsao	壶瓶枣	Tsintse, Shanxi	Shanxi
22684	10 Mar. 1908	Budwood	Mu shing hong tsao	木型红枣	Tsintse, Shanxi	Shanxi
22685	10 Mar. 1908	Budwood	Tsai ling tsao	鹅铃枣	Tsintse, Shanxi	Shanxi
22686	10 Mar. 1908	Budwood	Lang tsao	船枣	Tsintse, Shanxi	Shanxi
22914	1 Apr. 1908	Budwood	Lung tsao tsao shu	龙枣	Tientsin, Chihli	Tianjin
30411	10 Nov. 1912	Seeds	N/A		Chinese Turkestan	Xinjiang (?)
31737	4 May 1911	Dried fruits, tree originally from Honan	N/A		Chugutchak, Mongolia	Mongolia
35253	30 Mar. 1913	Cuttings	Wu hu tsao	无核枣	Laoling, Shantung	Shandong
35254	30 Mar. 1913	Cuttings	Wu hu tsao	无核枣	Laoling, Shantung	Shandong
35255	30 Mar. 1913	Cuttings	Tze lin tsao	大铃枣	Laoling, Shantung	Shandong
35256	30 Mar. 1913	Cuttings	Tang tsao	罐枣	Laoling, Shantung	Shandong
35257	30 Mar. 1913	Cuttings	Hsiao tsao	小枣	Laoling, Shantung	Shandong
35260	30 Mar. 1913	Rooted plants of 35253			Laoling, Shantung	Shandong
35287	18 Mar. 1913	Sour jujube seeds	Suan tsao	酸枣	Peking	Beijing
35601	1 Apr. 1913	Seeds (scion is 35255)			Tsinan, Shantung	Shandong
35602	1 Apr. 1913	Seeds	Pou hong ta tsao	泡红大枣	Peking	Beijing
35603	1 Apr. 1913	Seeds	Yuan ling tsao	圆铃枣	Tsinan, Shantung	Shandong
35604	1 Apr. 1913	Seeds	Ta hong tsao	大红枣	Tientsin	Tianjin
35605	1 Apr. 1913	Seeds	Ta hsiao hong tsao	大小红枣	Peking	Beijing
35606	1 Apr. 1913	Seeds	Hsiao tsao	小枣	Tsinan, Shantung	Shandong
35607	1 Apr. 1913	Seeds	Hsiao tsao	小枣	Tientsin	Tianjin
35608	1 Apr. 1913	Seeds	Rho hsiao tsao	壳小枣	Tientsin	Tianjin
35609	1 Apr. 1913	Seeds	Pou hong hsiao tsao	泡红小枣	Peking	Beijing
36852	7 Nov. 1913	Budwood	Ta tsao	大枣	Peking	Beijing
36853	8 Nov. 1913	Budwood	Hsiao tsao	小枣	Peking	Beijing
36854	9 Nov. 1913	Budwood	Yu tsao	牙枣	Peking	Beijing
37475	23 Dec. 1913	Budwood	Ta tsao	大枣	Lingpao, Honan	Henan
37476	24 Dec. 1913	Budwood	Ta kungTsao	大红枣	Lingpao, Honan	Henan
37484	6 Jan. 1914	Budwood	So Tsao	酸枣?	Sianfu, Shensi	Shaanxi
37489	8 Jan. 1914	Budwood	Lung chao tz'u shu	龙爪刺树	Sianfu, Shensi	Shaanxi
37659	4 Feb. 1914	Budwood	Ma lieu tsao	马连枣	Sianfu, Shensi	Shaanxi
37668	10 Feb. 1914	Budwood	Ta tsao	大枣	Shansi	Shanxi
38187	14 Mar. 1914	Budwood	Ta tsao	大枣	Kuyehsien, Shantung	Shandong
38243	14 Feb. 1914	Budwood	Ta Yuan tsao	大园枣	Paihsiangchen, Shanxi	Shanxi
38244	14 Feb. 1914	Budwood	Tuo tsao	垛枣	Paihsiangchen, Shanxi	Shanxi
38245	14 Feb. 1914	Budwood	Shui men tsao	水门枣	Paihsiangchen, Shanxi	Shanxi
38246	14 Feb. 1914	Budwood	Chi hsin tsao	瘠心枣	Paihsiangchen, Shanxi	Shanxi
38247	14 Feb. 1914	Budwood	Yuan ts'ui tsao	圆脆枣	Paihsiangchen, Shanxi	Shanxi
38249	14 Feb. 1914	Budwood	Li tsao	梨枣	Anyihsien, Shanxi	Shanxi
38250	14 Feb. 1914	Budwood	P'o p'o tsao	婆婆枣	Anyihsien, Shanxi	Shanxi
38251	14 Feb. 1914	Budwood	Ken tsao	硬枣 (?)	Anyihsien, Shanxi	Shanxi
38252	14 Feb. 1914	Budwood	Kuai tsao	筷枣	Anyihsien, Shanxi	Shanxi
38253	14 Feb. 1914	Budwood, less twisted than 38252			Anyihsien, Shanxi	Shanxi
38258	27 Feb. 1914	Budwood	Hui tsao	灰枣	Wulipu, Honan	Henan
38260	27 Feb. 1914	Budwood	Chiu yueh ch'ing tsao	九月青枣	Honan	Henan
38261	27 Feb. 1914	Budwood	Ma ya t'ou tsao	马牙头枣	Honan	Henan
38359	27 Feb. 1914	Budwood	Su tsao	酥枣	Honan	Henan
39194	20 Jun. 1914	Seeds	Hsiang tsao	葙枣	Peking	Beijing
40506	20 Jan. 1915	Budwood	Chin tsao or Fei tsao	金枣或肥枣	Pinchow, Shensi	Shaanxi
40877	20 Jan. 1915	Seeds of 40506	Chin tsao or Fei tsao	金枣或肥枣	Pinchow, Shensi	Shaanxi
40878	31 Jan. 1915	Seeds of 37476	N/A		Lingpao, Honan	Henan
40899	5 May 1915	Seeds for rootstocks	N/A		Peking	Beijing
44203	16 Dec. 1916	Seeds from big fruits for new selection	N/A		Peking	Beijing
44687	16 Dec. 1916	Small fruits used for seeds as rootstocks	N/A		Peking	Beijing

[z]Chihli was the old name for Hebei Province, China.
N/A = not available in the original reference.

and local people also collect the fruits for its seeds, which is a traditional Chinese herb "suanzaoren," or use the fruits for soft drinks or further processing. It is also sold as snacks directly when freshly picked during harvest time in small quantities (Guo and Shan, 2010). The fruits of sour jujube are small and puffy without much flesh between the skin and the seed; however, it has higher vitamin C and titratable acid contents than jujube cultivars (Wang et al., 1956). Indian jujube, or ber, is also from the same genus (*Ziziphus mauritiana*) and is widely planted in India and nearby countries (Baloda et al., 2012). Jujubes are also known as chinese dates as a result of the similarity in appearance of dried jujube fruit and dried date (date palm, *Phoenix dactylifera*). Interestingly, the Chinese word for date palm ("zongzao") literally means palm jujube as a result of its similarity to jujube.

Jujube is a small tree of 20 to 30 feet depending on location with strong and hard wood. Its leaves are shiny, ovate or oval in shape, not branched, and alternate. Leaves are 2.5 to 5.5 cm long and 2 to 4 cm wide.

Buds and shoots. Jujube shoots are different from other fruit species. Vigorous new shoots of peach, apple, and grape can have branches in the same growing season, and the branches have similar structure to the primary shoot. Jujube has four types of shoots: primary (extension) shoot, secondary shoot (side branches), mother-bearing shoot (fruiting spur), and fruit-bearing shoot (branchlet) (Fig. 1). There are three kinds of jujube buds: main buds, secondary buds, and dormant buds (Liu, 2006; Yao, 2012a).

There are two buds, one main bud and one secondary bud, at each node of both the primary and secondary shoots and at the apex of the mother-bearing shoots. The terminal main bud of the primary shoot will keep growing each season to expand the tree canopy, and the lateral main buds (at the base of each secondary shoot) normally do not sprout and become dormant except with strong stimulation. The secondary buds on each node of the primary and secondary shoots are early-maturing buds, which produce secondary shoots or fruit-bearing shoots (Yao, 2012a).

The jujube primary shoot is always accompanied by secondary shoots (side branches), or the secondary shoots are part of the primary shoot and later diverge in function. The primary shoot elongates every year to expand the tree canopy. The secondary shoot acts as a base for the fruiting structure, does not extend in length, and withers back after 2 or 3 years. At each node of the secondary shoot is a mother-bearing shoot (fruiting spur), which is a compact spur that grows ≈1 mm and produces two to five fruit-bearing shoots each year. The fruit-bearing shoot (branchlet) is thin, flexible, deciduous, and 10 to 20 cm long; it bears flowers and fruits at its axils. The primary shoot, secondary shoot, and branchlet are zigzagged and spiny (Yao, 2012a).

Flowers and fruit. Unlike apples or peaches, jujubes do not have big, showy flowers. Its flowers are fragrant, pale greenish yellow in color, and small with diameters ranging from 4 to 8 mm (Fig. 2). A jujube flower has five sepals, five petals, five anthers, and one ovary with two ovules (Yao, 2013). The five sepals are connected and sealed before anthesis. The anther and petal are isometric between sepals, and the petals are spoon- or cup-like and hold the anthers until pollen-dispensing. The nectary disk around the ovary is full of nectar during bloom and attracts insect visitors. Flower buds initiate as the branchlets grow. Flowers can appear singly or in a cluster at each leaf axil. Jujube's flower cluster (inflorescence) is a cyme (Fig. 2) with up to 13 flowers depending on the cultivar and its position on the branchlet. Jujube flower buds initiate, bloom, and develop to mature fruit within one growing season, which is unique and different from most tree fruit crops. Jujubes bloom for several weeks, making jujubes good nectar plants for the Asian honeybee (*Apis cerena*) in China. However, in the United States, the western honeybees (*Apis mellifera*) rarely visit the jujube flowers in New Mexico, and a jujube grower in California has made a similar observation (Roger Meyer, personal communication).

Jujube fruit is a drupe with one pit (stone) in the middle containing up to two seeds. Its fruit derives from its ovary and the nectary disk (Liu, 2006; Yao, 2013). Fruit size varies from thumb-sized to golfball-sized depending on the cultivar. The fruit shape can be round, oblong, oval, ovate, obovate, oblate, apple-like, or abnormally shaped (Liu, 2006) (Fig. 3). Jujubes are very precocious: they

Table 3. Jujube accessions collected from 1905–18 by others excluding Frank N. Meyer.

PI no.	Location	Presenter	Cultivar	Plant part
23455	Beaufort, SC	F. Chisolm	N/A	Stock
24573	Kutais Province, Transcaucasia	N.E. Hansen	N/A	Fruit
25777	Paris, France	N/A	N/A	Stock
26109	Hangchow, China	J.H. Judson	N/A	Plant
28764	Las Cruces, NM	David Griffiths	N/A	Seeds
28926	Shandong, China	T.J. League	Chang hung tsao	Cuttings
28927	Shandong, China	T.J. League	Yuan ling tsao	Cuttings
29356	Shandong, China	J.S. Whitewright	N/A	Roots
34054	Tientsin, China	Yamei Kin	N/A	Seeds
34162	Washington, DC	L. Reynolds	N/A	Plant
34874	Peking, China	N.S. Hopkins	N/A	N/A
37069	Tientsin, China	Yamei Kin	Ya hu tsao	Budwood
37070	Tientsin, China	Yamei Kin	Kang tsao	Budwood
39477	China	Paula Ritter	N/A	N/A
42046	Shorter, AL	C.G. Howard	N/A	Cuttings
42305	Damingfu, Chihli	J.G. Cole	Pu tao tsao	Cuttings
42306	Damingfu, Chihli	J.G. Cole	Tan tsao	Cuttings
42307	Damingfu, Chihli	J.G. Cole	Pu tao tsao	Cuttings
42308	Damingfu, Chihli	J.G. Cole	Pu tao tsao	Cuttings
42309	Damingfu, Chihli	J.G. Cole	Mu yu tsao	Cuttings

N/A = not available in the original reference.

Fig. 1. Jujube shoot structures: (**A**) primary shoot, (**B**) secondary shoot, (**C**) mother-bearing shoot (young fruiting spur), (**D**) old fruiting spur, (**E**) fruit-bearing shoot (branchlet) (Adapted from Yao, 2012a).

Fig. 2. Jujube flowers: (**A**) a simple cyme, (**B**) a large cyme, (**C**) a half-opened flower, (**D**) a fully opened flower (Adapted from Yao, 2012a).

normally set some fruit the second year after planting and even sometimes set fruit during the year of planting or grafting.

Jujubes have morning blooming type and afternoon blooming type (Lyrene, 1983; Yao, 2012b). In China, a lot of dominant cultivars were self-fruiting, some cultivars performed better with cross-pollination, and a few of them were self-fruitless or self-sterile without pollen (Guo and Shan, 2010; Wang et al., 2006; Yan et al., 2010). However, cross-pollination always increases fruit set and improves fruit size, quality, and seed development. Some home gardeners have pollination problems in the United States. Until a thoroughly jujube fruit pollination and fruit set study has been completed, it is recommended to plant two cultivars for cross-pollination. There were a few reports about parthenocarpic cultivars, but more research is needed on this as a result of the tiny jujube flower and replication issues (Guo and Shan, 2010; Lyrene, 1983).

Jujube's Adaptation and Culture

Jujubes adapt well to a wide range of soil and weather conditions. They grow across China except in Heilongjiang and Jilin Provinces and the Tibet region. Jujubes grow from 0 to 2000 m elevation, between lat. 18°14′ to 45° and long. 76° to 124°, and in soil pH 5.5 to 8.5 (Guo and Shan, 2010; Liu, 2006). In the United States, they grow from Pennsylvania, Washington, DC, North Carolina, South Carolina, to Florida, then from Florida, Georgia, Tennessee, Louisiana, Mississippi, Oklahoma, Texas, Kansas, New Mexico, Arizona, to California (Ashton, 2008; Brubaker, 1977; Locke, 1948; Lyrene and Crocker, 1994). Fairchild (1918) reported that jujubes could tolerate 48.9 °C in the summer in northern California and withstood –30 °C in the winter. Jujubes have been shown to grow and fruit well in the hot and arid southwestern United States (Locke, 1955; Meyer, 1911; Thomas, 1927; Yao, 2012a). In China, the story is similar: Hebei, Henan, Shandong, Shanxi, and Shaanxi are traditionally the five dominant jujube-producing provinces, but during the last 20 years, jujube plantings in the Xinjiang region, where the climate is hot and arid, have produced the best fruits in China with prices two to three times higher than others (Liu, 2008). Because jujubes like full sunshine and tolerate hot weather, the southwestern United States is an ideal location for jujubes where the arid climate also restricts many disease problems.

Numerous authors have mentioned the reliability of jujubes as a crop (Fairchild, 1918; Hager and Edward, 1989; Lanham, 1926; Locke, 1948; Lyrene, 1979; Meyer, 1916; Thomas, 1927; Yao, 2012a). With its late-season start-up, it avoids much of the late frost threat and, as a result, jujube trees rarely miss a crop. Jujube normally leafs out 4 to 6 weeks later than most temperate tree fruit crops and it blooms even later and continues blooming for 2 months or longer. Because it finishes flower bud initiation, blooming, fruit setting, and maturing within one growing season, it is not directly affected by the previous year's weather or pest problems that, for other fruit, may have a carryover effect on return bloom.

Jujubes are drought-tolerant (Hager and Edward, 1989). The tree can survive with an annual rainfall of only 200 mm, but for better fruit set and fruit quality, more precipitation or supplemental irrigation is needed. In Tucumcari, NM, there are several untended jujube patches that were planted in the 1930s (Fig. 4). They spread by seeds or by root suckers on dryland sites without any irrigation or care and have survived for 80 years. The trees can survive extremely dry weather and will set fruit in wet years, which makes them good backyard or landscape trees.

Nutrient Contents

Jujubes have been used in China as fruit and a traditional Chinese herb for a long time because of their beneficial health effects, although their nutrient composition was not clear at that time. The sour jujube seeds were used to treat insomnia, which could be related to the jujuboside A and B in the seeds and their sedative effect (Fang et al., 2010). Jujuboside A and B are also found in the seeds of *Z. jujuba* (Otsuka et al., 1978). As a result of its ability to inhibit platelet aggregation, jujuboside B could also be used in preventive or therapeutic herbal medicine for cardiovascular disease (Seo et al., 2012).

Jujube fruit is high in sugar, vitamins, edible cellulose, minerals, cyclic adenosine monophosphate (cAMP), and cyclic guanosine monophosphate (cGMP) (Church, 1924; Guo and Shan, 2010; Liu, 2006; Liu and Wang, 1991). Jujube fruit has much higher sugar concentration than most temperate fruits like apples, peaches, and grapes. The soluble solids content of grapes can reach 22% to 25%, but for jujubes, 30% soluble solids content is not rare and some cultivars can reach 40% (Meyer, 1991b). Wang et al. (1956) reported the ascorbic acid (vitamin C) content of jujube fruit to be 300 to 500 mg/100 g fresh weight and 800 to 1000 mg/100 g fresh weight for *Z. spinosa*. Bi et al. (1990) tested the vitamin C content of 121 jujube cultivars and found an average of 412 mg/100 g and a range from 166 to 808 mg/100 g with fresh-eating cultivars containing less vitamin C than drying cultivars. However, most of the vitamin C gets lost during the sun-drying process, and on average only 10% remains. So, for the benefit of vitamin C, eating fresh jujube fruit is much better than eating dried fruit. The USDA recommended daily vitamin C

Fig. 3. Jujube cultivars with different sizes and shapes grown at Alcalde, NM, in 2012 (Photo by S. Yao).

Fig. 4. Eighty-year-old, naturally spreading jujube patch at Tucumcari, NM, 2012. There were several patches there ranging from 0.2 to 0.5 ha each. The few old original plantings could still be seen in the middle and they spread out naturally by seeds or by root suckers. They might have set fruit during years with heavy rainfall, but during most years, they likely set few fruit and struggled to obtain enough water without irrigation. The average annual precipitation at Tucumcari is 409 mm. The species is *Z. jujuba* with small fruit (Photo by S. Yao).

requirements are 90 mg for men and 75 mg for women, and based on the average vitamin C content, 20 to 30 g of fresh jujube/day (one to three fruit depending on the fruit size) would meet this requirement.

Cyclic adenosine monophosphate was first isolated from jujube fruit in 1980 (Cyong and Hanabusa, 1980) and cGMP in 1982 (Cyong and Takahashi, 1982). It was found that cAMP and cGMP from jujube fruits had the same physicochemical properties as pure cAMP and cGMP. The cAMP content of jujube fruits ranged from 100 to 150 nmol·g^{-1} of fresh fruit and from 100 to 600 nmol·g^{-1} of dried jujube fruit, and the cGMP content was 30 to 60 nmol·g^{-1} dried fruit and it increased 90 times as the fruit ripened (Cyong and Takahashi, 1982; Qu et al., 1987). Liu and Wang (1991) reported the highest cAMP in jujube cultivar Muzao at 303 nmol·g^{-1} fresh weight (756 nmol·g^{-1} dry weight), which is the highest known in higher plants. Cyong and Hanabusa (1980) found jujube cAMP content 10 times higher than all other fruit tested. Zhao et al. (2009) studied the cAMP and cGMP contents in different jujube cultivars, development stages, and organs. The cAMP is a second messenger in our body, and the jujube fruit could be used as a natural source of cAMP (Li, 2012). (As for cAMP's medical effects, please refer to Serezani et al., 2008.)

Jujube fruit also have high total phenol contents and total antioxidant activity (Kamiloglu et al., 2009; Li et al., 2005). In the 1920s, people paid attention to sugar and protein content and compared jujubes with dried palm date and figs (Church, 1924). Currently, with higher health awareness, people pay more attention to the benefits fruit provides, like ascorbic acid, phenols, antioxidants, and medicinal effects. Consumers would accept jujube fruit much easier than in the 1920s. It is expected that the jujube commercial production era could be imminent in the United States.

Jujube Propagation

Jujube grafting has been recorded in the oldest Chinese farming book, "Qi Min Yao Shu" (Essential farming skills for the common people), which was published 1400 years ago (Guo and Shan, 2010). However, in practice, the most widely used method of jujube propagation was by root suckers in China until the 1960s. After the 1980s, as more new cultivars were selected and released, jujube grafting with sour jujube rootstocks became increasingly popular. In traditional jujube-growing regions, people still used root suckers to propagate because their trees were from root suckers and their new suckers still produced fruit identical to the mother plants. In new production areas, plants were grafted and the suckers only used as rootstocks for grafting, not directly for planting. Researchers also tried softwood cuttings (Sheng et al., 2008) and tissue culture propagation of jujubes (Wang et al., 2009), but grafting is still the most popular propagation method. T-budding, which is popularly used in pome and stone fruit propagation, does not work well for jujubes as a result of their shoot and bud structure and their thin bark. Whip tongue grafting, bark grafting, and cleft grafting are the most popular and successful grafting methods (Guo et al., 1994). Whip grafting requires that the diameters of the scionwood and rootstock are similar. This grafting method is the most difficult to perform, but it can use the small rootstocks, and windbreak is rare after grafting. Bark grafting needs to be done in the growing season when the cambium layer is active, and its operation is easier than whip grafting. Cleft grafting and side grafting can also be used in addition to bark and whip grafting; cleft grafting is used with big rootstocks, and side grafting can be used in warmer areas. With jujube's hard wood and lack of T-budding, jujube grafting is more challenging than other fruit tree species. However, with a combination of whip grafting and bark grafting around tree budding time and several weeks after that, the author achieved 95% grafting success in northern New Mexico.

The majority of jujube plants sold from nurseries now are grafted plants on sour jujube rootstocks. However, for those scattered old plantings in people's backyards, some are on their own roots and their suckers are identical with the mother plants, which can be used directly for planting. This is especially useful for home gardeners who want to get a jujube plant from friends or neighbors.

Pests and Diseases

The dominant jujube diseases in China are witches-broom and fruit splitting/cracking. Witches-broom is widespread in jujube-producing areas in China, Korea, and Japan (Guo and Shan, 2010; Jung et al., 2003; Zhou et al., 1998). It can wipe out a whole orchard, and there is no cure except for preventive management. Witches-broom is caused by a phytoplasm, '*Candidatus* Phytoplasma ziziphi' (Jung et al., 2003). The leafhopper species *Hishimonus sellatus* Uhler (Rl.H) (Doi et al., 1967), *Hishimonoides chinensis* (Wang et al., 1984), *Hishimonodies aurifoviales*, and *Typhlocyba* sp. (Chen et al., 1984) were reported as vector insects for jujube witches-broom disease.

Fruit splitting/cracking is a water-related physiological disorder that can ruin the whole crop in some extreme years. The severity of the problem depends on water management during the growing season, precipitation around the fruit maturation season, and cultivar resistance to splitting. Guo and Shan (2010) mentioned that serious splitting and fruit rot happened once every 5 years with 40% fruit loss in Laoling County, Shandong Province. Maintaining a stable water supply during the growing season will ease splitting, but the cultivar is what makes the ultimate difference.

The most important insect problem on jujubes in China is peach moth (*Carposina nipponensis*) damage to fruit. There are also other insects that damage leaves. In the United States, the pest and disease pressure for jujubes is low at this time. Most researchers in the United States mentioned that there were no pests and diseases for jujubes thus far (Ashton, 2006; Locke, 1955; Lyrene, 1979). We have yet to see disease problems in New Mexico, but we occasionally noticed peach moth damage to the sour jujube fruit that was collected in Las Cruces, NM, for seeds that will be used for rootstocks. In California, growers have complained about bird damage to fruit (Roger Meyer, personal communication).

Jujube-related Research in the United States

Formal jujube research started when the big-fruited cultivars were imported to the USDA Plant Introduction Station at Chico, CA, in 1908. Scientists evaluated the imported cultivars, propagated them at Chico, dispersed them to other USDA stations for evaluation (Locke, 1948), recommended cultivars, tested their nutrient value, researched their pollination and fruit set (Ackerman, 1961), and conducted jujube cultivar breeding/selection. Bonner and Rudolf (1974) tested jujube and sour jujube seed germination and found that jujube and sour jujube seeds could germinate directly, but stratification for 2 to 3 months increased the germination rate; water soaking at 21 to 37.8 °C for 2 d also prompted *Z. spina-christi* seed germination. Outlaw et al. (2001) studied the jujube nectar composition and found it was dominated by sucrose with 40% total sugar content. Jujube flowers attracted 18 species of insects, including bees, flies, and beetles, but honeybee numbers were not high in the netted insects. Kader et al. (1982) studied the postharvest storage of jujubes at the University of California–Davis and found that jujubes were high in sugar and total phenols but low in titratable acid. They also indicated that jujube's high ascorbic acid puts it near the top of the list of fruits for vitamin C sources. The jujube fruits were stored at 0 °C for 26 d and exhibited chilling injury of pitting (Kader et al., 1982). Lyrene (1983) observed 18 jujube cultivars flowering and fruiting in Florida and noticed two blooming types with varied fruit set. He concluded the heavily fruited cultivars were parthenocarpic such as 'Silverhill' and 'Leon Buck', which were recommended for the southeast United States. Sweet (1985) discussed jujube cultivars, propagation, and production in his article and predicted a large market potential for Chinese jujubes in the United States. There were quite a few people across the country from the North American Fruit Explorers group who tested jujubes in their own yards or orchards. In general, jujube research is very limited in the United States, and there are almost no research publications after 2001.

Jujube Uses/Processing Products

When jujube fruits are close to maturity, their skin color turns from dark green to light green/creamy with high vitamin C content (white mature stage). The soluble solid content measures ≈20% for most cultivars. The fruit then change color and become half cream/half red and eventually turn fully red/brown (crisp mature stage). At this stage, the fruit becomes crispy, sweet, and juicy with high sugar and acid content. The fruit skin gets thicker, harder, and easier to separate from the flesh after boiling. Fruit have the best fresh-eating quality at this point, but the vitamin C content starts to decrease. After that, the skin of the fruit will wrinkle and start to dehydrate and the flesh color near the kernel changes from greenish white to yellow/light brown and turns soft. Sugar and acid contents continue to increase, and vitamin C content continues to decrease (fully mature stage). Depending on the purpose, jujube fruit can be picked from the white mature stage, to the crisp mature stage, or the fully mature stage. Fresh-eating cultivars can be picked from the white mature stage until the crisp mature stage when the fruit texture is still firm.

Red date (dry date). Red date is the dominant jujube product for the domestic and export markets in China. Fruits are picked when they are fully red or the fully mature stage because the more mature they are, the higher their sugar content and drying quality. After picking, fruits can be air-, sun-, or heat-dried. Hear drying is the optimal method because it retains more vitamin C, leads to better fruit quality, and avoids disease-related fruit losses. Red date can be consumed directly as snacks; used in porridge, stew, soup, or tea; or processed further as jujube paste or other products. "Zongzi" is a traditional Chinese food that is consumed near the Dragon Boat Festival to remember the patriotic poet, Qu Yuan. Red dates are placed in the middle of sweet rice, which is then wrapped by bamboo or reed leaves and cooked for 2 to 3 h. After the cooking process, the red date is sweet, tasty, and gives the surrounding glutinous sweet rice great flavor. The red dates of small-sized cultivars like 'Jin sze tsao' and 'Wu hu tsao' (pitless) are excellent when cooked with rice or millet in porridge (Meyer, 1911).

Candied jujube (honey jujube). Frank Meyer (1911) mentioned the cooking process of honey jujubes, which have been popular in China for ≈200 years. Fruits are picked at white mature stage and 60% to 80% of vitamin C content can be kept, which is much higher than the sun-dried jujube. Fruit surfaces are sliced with rows of blades or needles to enhance sugar-soaking and product appearance (Gao and Shan, 2010).

Spirited jujube ('drunk' jujube). Fruits are picked during the fully red stage and 60% to 70% of the vitamin C content is preserved. Spirits of 130 to 140 proof or good-quality hard liquor is used for this product. The jujube fruits are poured into the liquor and fully covered with liquor. They are then sealed in jars or zip bags and can be stored for 6 months to 1 year. They can also be sealed in small packages and sold directly in those packages several months later (Guo and Shan, 2010).

Smoked jujube. This product is mainly produced from the cultivar Yuan ling tsao in Shandong Province. Fruits are picked at the fully red stage, precooked in boiling water, and then smoked. The product can be eaten directly or used in cooking.

Roasted jujube. Red dates are used for this purpose. The fruit are first pitted and then sliced vertically to pieces ≈3 mm wide before roasting. Fully mature fresh fruit of drying cultivars can also be used but require a longer roasting time than using dried fruit.

Jujube jam. Full red fruits are also used for jam, which can preserve 65% to 80% of the vitamin C content. The fruit needs to be skinned and pitted for this purpose.

Jujube paste/filling. Jujube filling is widely used in the pastry industry in China; it is one of the traditional fillings of mooncakes (Guo and Shan, 2010; Yao, 2012a). It can also be directly spread over bread.

Jujubes can also be used to make juice, wine, and vinegar, whereas the red date is also widely used in the culinary world.

The Chinese and Southeast Asian populations in the United States are used to having jujubes in their diets, consuming them fresh, dried, or processed. If we promote jujubes and want the rest of Americans to consume them, American-style jujube products are needed. There are a few recipes listed at Ashton (2006), California Rare Fruit Growers (1996), and Guggenheim (1994).

Eating fresh would be the easiest way for Americans to accept the fruit. The author conducted some jujube fruit-tasting workshops, including the New Mexico State Fair, and with school kids through the Cooking with Kids program in Santa Fe, NM. Most people who tasted the fruit liked them. Fresh jujubes have an apple-like texture without any strong flavor and are sweet and nutritious. With a good promotion program, it would not be difficult for the public to accept this nutritious fruit. Fresh fruit can also be used solely in pie or together with apples. It seems the ascorbic acid preserved well for products cooked with fresh fruit (S. Yao, unpublished data), which would be beneficial because people have more concern about health than before. Fresh fruit can also be used in ice cream or fruit salad or processed into jam.

Dried jujubes can be directly used in fruit and nut mixes or used to replace raisins or palm dates in baking for cakes, tarts, or other pastry products or baked goods. Jujube paste can be used directly as a spread or used as filling for other pastries. A popular product is needed to promote the jujube and to develop a viable market.

Jujube is also a multipurpose plant (Outlaw et al., 2002). Except for its fruit, jujube is a nice nectar plant with a long blooming period and jujube honey is popular in China. Its seeds, especially the seeds from *Z. spinosa*, are a famous traditional Chinese herb, "Suanzaoren" (Qu et al., 1987). Its wood is very hard and good for instruments or utensils.

Challenges and Opportunities: Why Not an Industry Yet?

When jujubes entered the United States, Frank Meyer and other researchers who worked with jujube were impressed with jujube's fruit quality and nutrient content, wide adaptability, reliability, lack of frost damage, drought tolerance, and easy care (Lanham, 1926; Meyer, 1911). They predicted a bright future in the United States, especially in the Southwest (Lanham, 1926). There was another round of interest in jujubes beginning in the 1980s, especially among the members of the California Rare Fruit Growers and the North American Fruit Explorers. Growers and home gardeners had big interests in jujubes and wanted to promote jujubes in the United States. Roger Meyer wrote a series of papers about jujube culture, propagation, fruit use, and cultivar collection (Meyer, 1988, 1989, 1991a, 1991b, 1994; Meyer and Meyer, 1994a, 1994b). Jujube was the "Fruit of the Year" for the California Rare Fruit Growers in 1994 (Guggenheim, 1994). However, lack of research support, propagation hurdles, limited cultivars, and lack of marketing, promotion, and American-style products all restrict jujube's adoption in the United States.

After hosting a "jujube-growing habits and pruning workshop" in the spring and "jujube flowering, fruiting, and fruit-tasting workshop" in the fall for 3 years, more and more people are interested in jujubes in New Mexico and the nearby states. Currently, nurseries have a hard time meeting the jujube plant demands. Realizing the challenges for commercial jujube production, these areas are what scientists should focus on; pomologists should conduct research on pollen germination, fruit set, cultivar regional trials, and culture practices with the goal of recommending more cultivars to the growers. Extension specialists should write more jujube publications, educate the public, and guide the commercial jujube production. Food scientists should experiment with American-style jujube products while agricultural marketing specialists work on jujube promotion and marketing. Growers can start small and expand gradually. With big cities like San Francisco and New York, it would be an easy start through targeting the Asian population and Asian markets with fresh fruit or dried fruit (red date). As more and more people come to know this exotic fruit, free sampling at local markets would enhance customers' acceptance. The basic foundation is solid: with jujube's wide adaptation to soil and weather conditions, it does grow and produce well in the southern and southwestern United States with excellent fruit quality. Jujube is an excellent backyard tree for home gardeners, serving dual purposes for its fruit

and tree. With continuous research and extension input plus good promotion strategies, after 15 to 20 years, jujube production could become a valuable industry in the United States.

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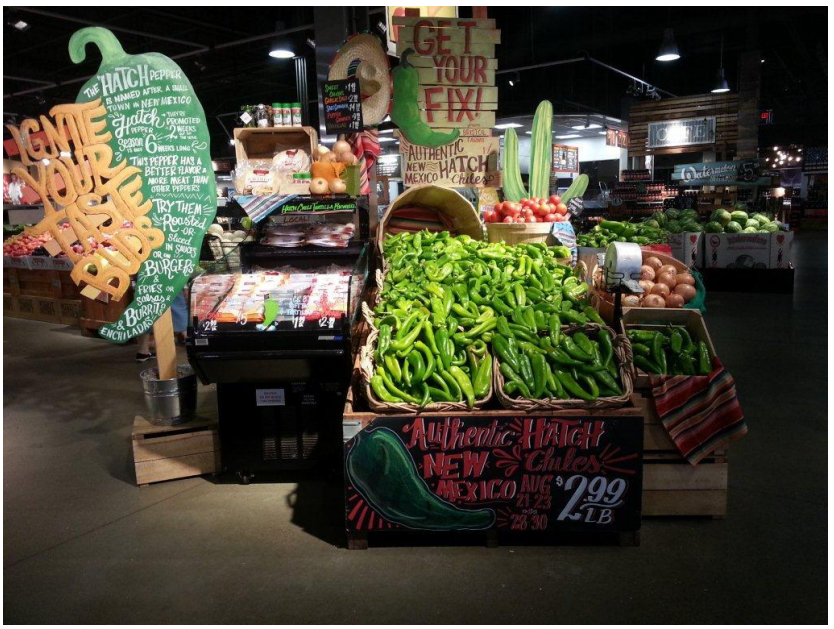
Green chile display at a Giant Eagle Store. Summer 2015



Instagram post by Frieda's Produce promoting the Get Your Fix program and Hatch Green Chile. Summer 2015

Chile roasting lessons in Cleveland. Summer 2015

Chile roaster mechanics in Pittsburg. Summer 2015

Chile roasting in Cleveland and Pittsburg.
Summer 2015