# Developing an organic commercial production system for the Goji berry
# Year 2
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# Report received 1/11/11

**Introduction**

The 2010 growing season provided some challenges as well as new insight into goji berry production. The objective of this second season of goji propagation was to field test the 2009 cuttings. Cuttings taken in June, August and September were last evaluated on October 13th, 2009. The plants went dormant in early November and so it was no longer possible to evaluate them until bud break the following spring. The rooting success of cuttings taken from different times during 2009 is shown in Table 1.

**Table 1:** Comparison of cutting mortality, rooting success, and cutting length and root number as indicators of transplant success.

| | June Cuttings | | August Cuttings | | September Cuttings | |
|---|---|---|---|---|---|---|
| Cuttings that survived the rooting process and were planted to the GH | 32/43 total | 74.4% | 31/40 total | 77.5% | 54/150 total | 36% |
| Mean length (cm) of cuttings that survived to be field planted | 14.8 cm | | 6.2 cm | | 9.4 cm | |
| Mean length (cm) of cuttings that died before field transplant | 12.8 cm | | 6.8 cm | | 9.4 cm | |
| Mean root # of cuttings that survived to be field planted | 7.4 | | 3.7 | | 4.3 | |
| Mean root # of cuttings that died before field transplant | 9.0 | | 2.5 | | 2.6 | |

**Materials and Methods**

The winter of 2009-2010 was exceptionally cold and snowy. The National Oceanic and Atmospheric Administration (NOAA) reported that Dulles International Airport located on the eastern edge of Loudoun County recorded 5 days in February with subfreezing highs. The weather station located at Dulles received 73.2 inches of snow during the winter, well above the average for Virginia. Cuttings that were rooted during the 2009 growing season were transplanted into 4" plastic pots and placed in an unheated glass greenhouse. Once the plants lost their leaves and were dormant for the winter, they were left unattended until the spring. Considering the frigid conditions and a more severe winter than usual for our region, the evaluation of the overwintering ability of the transplanted cuttings promised to yield some useful information regarding cold hardiness of goji plants.

The goji plants in the greenhouse began to break bud around mid March 2010. By March 25th, the rooted cuttings had fully extended leaves and were actively growing. Assessing which plants had died during the winter was then possible. Plants were moved in April to 1 gallon pots containing the same mixture of worm castings, woodchips and native loam to accommodate the large amount of new growth.

The 2010 spring was difficult for most of the Mid-Atlantic region. Loudoun County experienced the warmest March on record. Spring bud break was very early because of the exceptionally warm weather.

Warm and wet weather continued through most of the spring and included several severe thunderstorms, wind and hail damage as well as flooding. Field preparation was difficult due to the rain as soil remained too wet. Although mid May was originally the time frame selected for moving the rooted cuttings to the field, the decision was made to hold off until June because of the wet conditions and unpredictable weather. This proved to be a good move since Loudoun experienced a severe frost event on May 11$^{th}$ and 12$^{th}$ which damaged many small fruit and tree fruit crops. This may have killed the newly transplanted, tender goji plants and would definitely have stunted their growth and affected their ability to fruit.

On June 8$^{th}$, 2010, 51 goji plants derived from the June (19 plants), August (6 plants) and September (26 plants) cuttings of 2009 were field planted. Plants were randomly placed in two rows 100 ft in length and 4 ft wide. These rows were separated by 6 ft wide strips of turf. Drip irrigation was installed and bamboo stakes were used to secure the plants. A fence was built around the field test plot to prevent damage from deer, rabbits and groundhogs. Flower buds had begun to form on plants during field planting. The number of flower buds on each plant was counted. The first crop was very light compared to the second crop in the fall. In addition to the number of flower buds, the diameter of the largest stem, the height of the plant as well as the number of shoots were all measured and recorded in order to compare overall cutting performance during the course of this project.

Summer conditions were equally as difficult as the winter and spring. Western Loudoun, especially the Lovettsville area, experienced a drought. Temperatures were well above average in June, July and August. The NOAA weather station at Dulles International Airport recorded 20 days in July and 12 days in August with temperatures at or above 90$^{o}$F. The summer of 2010 was the warmest on record for the DC metro region. The 51 newly established goji plants survived the extremely hot and dry summer months with drip irrigation.

Plants did go into a dormant state during the peak temperatures in July and August. Once night temperatures decreased at the end of August, the plants put on a new flush of growth. Flowering and fruiting began again in September and continued through November until the first hard frost killed the flowers. Fruit production in the fall was much heavier than in June. This may be because of the late field planting date as well as the early start to the extremely hot weather. The fruiting evaluation was completed on November 5th, 2010. Observations of whether plants did not produce fruit, produced an average number of fruit or plants that were "super" fruit producers were recorded. All 51 plants that were placed in the field survived through the final evaluation in November despite severe weather conditions.

## Results and Discussion

One of the goals of this project was to determine how to best propagate goji berry plants. In total, 243 cuttings were taken in June, August and September of 2009. Data taken on the cutting length, root number, and mortality were compiled and compared (see Table 1). In Table 2, the survival rate of the different cuttings is compiled and compared to best outline which group of cuttings was most successful in making it to field establishment.

Overall, 44% of the 43 cuttings taken in June survived to be planted in the field while only 15% of August cuttings and 18% of the September cuttings survived rooting and transplant to the greenhouse to make it to field establishment. September cuttings had the smallest percent that survived rooting in the aeroponics chamber. August cuttings survived poorly when transplanted to the greenhouse with only 17.5% of the cuttings still alive after being transplanted to pots for less than two months.

**Table 2**: Comparison of the survival rate of cuttings taken in June, August and September during transplant to the greenhouse. Survival rates of transplants are compared between observations dates. ("T" indicates the date the cuttings were removed from the aeroponics chamber and transplanted to the greenhouse.)

| *Date cuttings taken:* | Cuttings survived – rooting in aeroponic chamber | | Transplants alive evaluated 8-28-09 | | Transplants alive evaluated 10-13-09 | | Transplants alive evaluated 3-25-10 | |
|---|---|---|---|---|---|---|---|---|
| | Total | % | Total | % | Total | % | Total | % |
| June *6-17-09* | **32**/ 43 | 74.4% | 25/32 | 78.1% | 23/**32** | 71.9% | 19/**32** | 59.4% |
| August *8-1-09* | **31**/ 40 | 77.5% | T | T | 7/**31** | 22.6% | 6/**31** | 19.4% |
| September *9-8-09* | **54**/ 150 | 36.0% | | | T | T | 26/**54** | 48.1% |

What does this mean for a grower determining when cuttings should be taken? A high rooting rate and high transplant survival would be ideal. Looking at Table 2 suggests that June cuttings were the most successful. Although June cuttings had a slightly lower rate of rooting at 74.4% than August cuttings with 77.5%, June cuttings survived better after they were transplanted to the greenhouse. 32 of the 43 June cuttings were transplanted to the greenhouse initially. June cuttings had the highest transplant rate with 59.4%. 19 of 32 June cuttings survived the winter and were transplanted to the field.

The total survival rate of June cuttings from rooting to field planting was 44%, the highest between the 3 different groups (data not shown). September cuttings had the second highest total survival rate with just 18% of the original 150 cuttings surviving to be field planted. It is clear that cuttings taken in August did not fare well with only 15% or 6 out of 40 total cuttings surviving. Propagation of goji is not recommended during the peak of the summer especially when the plants are not actively growing.

Goji plants go dormant during the summer when temperatures peak and water stress occurs. When the plants are stressed, they shed their leaves and remain in an inactive stage. This also occurs when the plants are overwatered. So this stress response is not limited to the summer. We observed some seed-derived plants dropping leaves when they were waterlogged during the wet spring. Once the plants experienced better growing conditions, such as moving the plants to a drier location or a break in the summer heat and drought, they began sending out new shoots and leaves.

Cuttings taken from plants during the summer stress fared poorly. Cuttings were taken from plants in the greenhouse where they were adequately watered. However, the extreme dryness and the heat of the summer still affected the parent plants. August cuttings rooted well, 77.5% of the 40 cuttings formed roots. This was the highest rate of rooting between the three different time frames (Table 2). However, the August cuttings did not survive transplantation to the greenhouse and had the lowest overall rate of transplant survival. Only 6 (15%) of the August cuttings were planted for the field evaluation.

**Table 3:** The percent of rooted cuttings transplanted to the greenhouse that successfully overwintered

| | Cuttings alive 10-13-09 | Overwintered cuttings alive 3-25-10 | % Cuttings overwintered successfully |
|---|---|---|---|
| June Cuttings | 23 | 19 | 82.6% |
| August Cuttings | 7 | 6 | 85.7% |
| September Cuttings | 54 | 26 | 48.0% |

Table 3 compares the rate the cuttings overwintered successfully. June and August had very high rates of survival at 82.6% and 85.7% respectively. These cuttings would have had the most time to develop an adequate root system. Only 48% of the September cuttings survived over the winter. The bulk of the successfully rooted cuttings that will not survive being transplanted to the greenhouse die within the first 2 months. It is hard to determine if the September cuttings died because they were not able to deal with the colder weather, or if the cuttings died simply because they were not viable. Because plant material was scarcer than anticipated in September, cuttings were taken from woodier, older tissue. This could have adversely affected the viability of the cuttings. June cuttings were taken from the tips of the shoots which is ideal for propagating. June cuttings certainly had a good deal more time to grow and form roots before going dormant and dealing with cold weather.

Did the September cuttings not survive the winter as well because they were not as developed? A combination of poor quality rooting material and reduced rooting time before the plants entered dormancy may have negatively impacted the survival of the September cuttings.

When the plants were evaluated in March of 2010 to determine which cuttings had overwintered successfully, the size difference between the cuttings was noticeable. Cuttings taken and rooted in June were much larger with more new growth than those taken in August. Cuttings taken and rooted in September were the smallest. June cuttings had the longest period of time during the 2009 growing season to develop roots as well as woody stems. September cuttings were likely still very small because they had the least amount of time, only a matter of a couple of months before the winter, to grow. Figure 1 shows the size difference between the cuttings taken in June, August and September.

June August September

**Figure 1:** Rooted cuttings from June, August and September on March 25, 2010. Size difference between the three different rooted cuttings is apparent.

Harvesting fruit is the goal of any farmer interested in goji berry production. Cutting-derived plants flowered and fruited within the first month of field establishment. This is much more quickly than seed-derived plants which flower and fruit two years after germination. Propagating goji plants from cuttings will allow growers to begin harvesting much more quickly than if they were to germinate seeds. In addition, seedlings had widely varying characteristics. Growth habit, fruit quality and even leaf characteristics differed between the seedlings. Consistency in fruit production of the rooted cuttings appears to be another benefit of asexual propagation.

The field transplanted goji plants were evaluated for fruiting ability on November 5th, 2010. All 51 of the plants established in the field on June 8th, 2010, survived. Most of the plants put on extensive growth and flourished. Each plant was examined and the quantity of fruit on the plant at that time was recorded. Each plant was placed in one of three categories: no fruit production, average fruit production, and super fruit production. If the plant had ½ or less of its branches bearing fruit, it was placed in the average fruit production category. If more than ½ of the branches of a goji plant were bearing fruit, it was categorized as a super fruit

**Figure 2**: Norma and an attendee of the 2010 Goji Berry Open House at Butterfly Hill Organics examine seed-derived plants for differences in growth habits and other characteristics.

producer. By comparing measurements taken on cuttings and transplants, light may be shed on what may impact the fruiting ability of goji plants. Table 4 compares how many of the goji plants in the field planting did not produce fruit versus how many were average or above average producers. The fruiting production ability of the plants is then broken into the subcategories of when the cuttings were taken.

**Table 4:** Comparison of fruiting ability between the the cuttings groups, derived in June, August, and September. Field established plants were categorized as not producing any fruit, producing an average number of fruit, or producing a large, above average amount of fruit (super fruit production).

| | Total Cuttings | | June Cuttings | | August Cuttings | | September Cuttings | |
|---|---|---|---|---|---|---|---|---|
| Total # in field test | 51 | | 19 | | 6 | | 26 | |
| No fruit production | 3 | 6% | 2 | 11% | 0 | 0% | 1 | 4% |
| Average Fruit Production | 34 | 67% | 16 | 84% | 5 | 83% | 13 | 50% |
| Super Fruit Production | 14 | 27% | 1 | 5% | 1 | 17% | 12 | 46% |

The three plants that failed to produce fruit appeared unlucky in their field position. One plant had been accidentally weeded and was in the process of regrowing. The other two plants that failed to produce fruit were stunted and damaged by insects. One plant had been heavily damaged by gall mites before transplanting. Once in the field it was also heavily fed on by grasshoppers. The third plant was also damaged by intense grasshopper feeding, indicating that insects can be very detrimental to goji fruit production.

Table 4 shows that the bulk of the 51 plants, 67%, was comprised of average fruit producers. 27% of the field-established goji cuttings were super fruit producers. All of the super fruit producers were noted to be highly branched. Encouraging lateral production seems to be helpful in increasing fruit production and may be a clue to developing the best pruning methods. Most of the super fruit producers were from the September cuttings. This may be because most of the cuttings in general were from September. There were simply more cuttings made at that time. However, if we compare the ratios of average to super fruit producers between June, August and September, September still has the highest rate with 46% of the 26 cuttings exhibiting a higher quantity of fruit production. September cuttings had the least amount of time to develop before field planting. Figure 1 shows the size difference between the three groups. September cuttings were much smaller than either June or August cuttings. What about the cuttings taken in September was indicative of their potential for higher fruit production?

Table 5 compares the measurements taken of the cuttings shortly before they were planted in the field on June 8$^{th}$, 2010. The stem diameter, number of stems, height (length of the longest shoot) and number of flower buds on each of the plants was recorded. At the very beginning of the season, the September cuttings had a significantly larger number of flower buds (21.1) per plant than the other cuttings. In addition, September cuttings had already outgrown their counterparts and were significantly taller at 101.9 cm. June cuttings were on average shorter (77.7 cm) than the other two cuttings. August cuttings were difficult to compare because only 6 cuttings survived to be planted in the field. Even with a longer period in the greenhouse to produce roots and a higher rate of survival from rooting onwards, June cuttings appeared to be significantly behind September cuttings in both flower bud production as well as shoot growth. This may have contributed to the mostly average fruit production of June cutting-derived field plants.

**Table 5:** Comparison of the mean measurements between June, August and September cuttings on June 8$^{th}$, 2010, before transplant to the field. Letters denote significant differences between means.

| | Mean Stem Diameter (cm) | Mean# of stems | Mean height (cm) | Mean # of flower buds |
|---|---|---|---|---|
| June Cuttings | 0.37$^a$ | 2.4$^a$ | 77.7$^a$ | 14.3$^a$ |
| August Cuttings | 0.43$^a$ | 3.5$^a$ | 91.2$^b$ | 13.5$^a$ |
| September Cuttings | 0.43$^a$ | 2.4$^a$ | 101.9$^c$ | 21.1$^b$ |

Which characteristics overall lead to super fruit producing plants? In Table 6, all of the data from cuttings as well as that taken from the plants shortly before field establishment were combined and broken into the fruiting categories to compare if overall characteristics of the cuttings regardless of the time they were rooted were important. The cutting length of the super fruit producers, 9.4 cm, was significantly less than that of the average fruit producers, 11.4 cm. The mean number of roots the cuttings produced was also significantly less in the super fruit producers at 4.6 compared to the average fruit producers who had a mean root number of 5.3. Selecting the appropriate cutting length is important to the success of propagation. A

**Table 6:** Comparison of mean measurements collected from cuttings and from plants before field establishment compiled in fruit production categories.

| | Cutting Data (2009) | | Field Transplant Data (June 2010) | | | |
|---|---|---|---|---|---|---|
| | Mean cutting length (cm) | Mean Root # | Mean stem diameter (cm) | Mean stem # | Mean height (cm) | Mean # of flower buds |
| Total | 10.9 | 5.3 | 0.4 | 2.5 | 92 | 17.6 |
| No Fruit | 12.7 | 8.0 | 0.3 | 2.3 | 66 | 4.3 |
| Average Fruit | 11.4[a] | 5.3[a] | 0.4[a] | 2.7[a] | 90[a] | 16.9[a] |
| Super Fruit | 9.4[b] | 4.6[b] | 0.5[a] | 2.1[b] | 104[a] | 22.1[a] |

(F-test, $\alpha = 0.10$)

longer cutting is not necessarily more likely to survive. Shorter cuttings rooted well, as Table 1 shows. The mean cutting length for August was half that of the other plants. August cuttings had the best rate of rooting, but the poorest rate of survival post-greenhouse transplanting. So cutting length may or may not play a role in the success of a plant. The data are not complete enough to make an argument for either.

Once the cuttings were transplanted to the greenhouse and were ready for field establishment, they were already ahead in the growth department. Super fruit producers had a significantly larger mean stem number, 2.7, and were already taller at 104 cm mean height. No surprise though, the super fruit producers also had a significantly higher mean number of flower buds at 22.1 per plant compared to average fruit producers which only had 16.9. Even though those plants that failed to produce fruit in November were observed with insect damage and survived human error, before field transplant they were lagging in all of the metrics. They were on average shorter at 66 cm in height, with fewer stems, mean 2.3, in addition to having a reduced stem diameter of 0.3 cm. At a mean of 4.3 flower buds per plant, the plants that failed to produce any fruit in November were likely to have had issues prior to field establishment. The insects may have selected weaker plants to feed on. The plant that was weeded by mistake may have been smaller and less obvious than its neighbors.

Is it more important that cuttings survive the rooting and field establishment process? Or does it make more economic sense to have a higher mortality rate of cuttings balanced by less time spent in the greenhouse and the potential to produce more fruit the first year in the field? This is a hard question. It is likely that the June cuttings will become excellent fruit producers this upcoming growing season. After a year in the field, all of the plants will probably grow and fruit equally as well. Cuttings taken in the spring require more care and upkeep in the greenhouse, but ultimately a larger number of plants will make it to field establishment. Making a decision to take cuttings in June or September may boil down to specific conditions faced by individual farmers. Adequate plant material for propagation, accessible greenhouse space, the time availability of the farmer could all change propagation recommendations. Ultimately, it is feasible for a small farmer to successfully propagate and establish a goji planting using organic methods.

## Updates on 2009 Report

The galls that were observed on cuttings in 2009 were caused by gall mites. A sample was sent to the Virginia Tech Insect Identification Lab in the spring after the cuttings emerged from dormancy and symptoms developed. The exact species of mite has not yet been identified. So far the damage has been minimal. A dormant oil application during the winter and insecticidal soap as the buds open are the management tools recommended by Eric Day at the Virginia Tech Insect Identification Lab.

The number of plants that had galls and distorted growth was recorded before they were transplanted to the field. Once the plants were established in the field, the gall mite damage did not progress and the plants eventually outgrew the symptoms. The cuttings rooted in June and placed in the greenhouse for the longest period of time had the highest rate of infestation, with 8 out of the 19 plants showing the curled leaves and galls. 1 of the 6 rooted cuttings from August had symptoms while none of the September cuttings were observed to have any damage. The gall mites were definitely a greenhouse-related problem during the course of this project. Once the plants began to grow a significant amount outside, the damage was not an issue. This applied to flea beetle damage as well.

One of the impressive things about the field establishment of the goji berry plants was their fruiting ability in the fall. It was assumed that the spring crop would be heavy and that a fall crop would be fairly light and not have much impact on the overall harvest. However, the goji plants in the field began to flower and fruit at the beginning of September and continued until the first hard frost in November. This frost killed the flowers, but left the already developed fruit intact. High tunnels may provide a substantial season extension to goji production by protecting the plants in the spring to encourage earlier fruit production. More importantly, a high tunnel would likely extend the fall fruiting season well past November. High tunnels would also help deter birds from feeding and damaging the crops. High tunnels will be an interesting topic of study in the future.

The brown marmorated stink bug (BMSB) is a newly problematic, invasive species in Virginia. Populations of the BMSB have been enormous for the past two years. Small fruit production has been severely impacted. Growers in Loudoun experienced high levels of damage on their raspberries and blackberries with some production fields showing 100% fruit damage. Tomatoes and peppers, close relatives of the goji, were also severely damaged by the stink bug. We were very concerned that the goji fruit would be a BMSB favorite; however, no damage from this insect was observed on any of the asexually propagated or seed-derived plants. Grasshoppers were another issue. They did damage some plants extensively.

Ripe goji fruit on a greenhouse plant

Norma taking measurements in the GH

Tomato hornworm on goji parasitized by beneficial wasp

**Outreach and Extension**

On the weekend of September 11th and 12th, 2010, Butterfly Hill Organics held a Goji Berry Production Open House. Growers from Virginia, Maryland, and West Virginia were invited to see the field planting of goji berries and to learn more about the OFRF-sponsored research project. In addition, samples of fresh and dried goji berries were provided to allow those not familiar with the fruit to try a taste. Norma's oatmeal goji berry cookies were a hit as were the goji berry juice spritzers.  A total of 10 potential growers attended the open house. Four growers signed up to receive plants in the spring of 2011 to begin their own propagation and production. Multiple requests for more information on goji berries by those that were unable to attend the open house program were received. To aid potential growers, an informational write-up was developed. This was handed out at the open house as well as emailed to those who have requested information.

On February 11th, 2011 Norma Wilson and Leslie Blischak presented on the OFRF-funded goji berry project to the Virginia Association of Biological Farmers at their annual conference in Danville, VA. This is especially exciting as Eliot Coleman is the keynote speaker this year and high attendance numbers are expected. Developing alternative crops that can be grown organically is generating excitement in Virginia.

Norma preparing the rows for field planting

Attendees of the Goji Berry Production Open House touring the planting and discussing the OFRF-funded project