Growing Vegetables Without Irrigation
More locally grown food in semi-arid regions is possible

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Author's Background

Robert M. Quinn: organic farmer, PhD in plant biochemistry from University of California at Davis, owns and operates 4th generation farm near Big Sandy, Montana, USA - has been 100% organic since 1988; president and founder of Kamut International.

Summary

There is a growing conflict between cities and agriculture for fresh water. To reduce this conflict and to learn what we can grow without irrigation in the vast semi-arid regions of the world as well as demonstrate the potential of a more local food production, I have been experimenting with growing dry land storage vegetables (potatoes, winter squash and onions) and some fresh vegetables on our organic farm in North-central Montana, USA located in the Northern Great Plains of North America. After 9 years of trials, I am confident that some vegetables can be consistently produced in dry land conditions having no more than 300-350 mm of annual precipitation. The main technique for successful production relates to plant spacing, although other water conserving techniques such as mulching have also been investigated. The storage vegetables can be eaten fresh or kept for 4 to 9 months for very little cost and thereby, in combination with fresh picked vegetables, can easily provide fresh and stored vegetables for the local population throughout the entire year even in harsh climates. This, of course, was done to some extent historically.

Background

Many years ago, I attended a local agriculture experiment station field day and saw a demonstration plot of dry land potatoes. We live in wheat, barley and cattle country in the dry prairie of North-central Montana in the US. No one on the tour was interested in the potatoes. As our tour wagon passed by the potatoes without stopping, an offhanded comment was made by our tour guide. "Well, at least you can grow dry land potatoes here," he said. The demonstration potato plot has long since disappeared but I thought about that demonstration from time to time over the years. "Why can't we grow potatoes on our farm without irrigation?" I wondered. With our annual precipitation averaging 300-350 mm, no one in our area seriously considers the possibility of growing much beside annual cereal crops such as wheat and barley. However, when the homesteaders first came to this land and started farming 100 years ago, many different crops were grown including some vegetables which were sold locally. Transportation was bad and it was difficult to ship in fresh produce even during the summer and impossible to ship it in during the winter. Since starting to convert our farm to organic production in 1983, I had experimented with many additional crops which would be necessary for rotations required to make an organic system viable. Finally, in 2005 I set aside about 1% of our crop land (16 out of 1600 hectors) strictly for experimental plots. Although most of my experiments were dealing with different grain and seed crops, one of the trials that year was potatoes because of the demonstration I had seen many years before. I was surprised how well the potatoes grew which led me to consider other storage vegetables such as winter squash and onions. I first considered crops that could be easily stored without processing as we had very few fresh market opportunities within 200 km of our farm and no processing facilities within 500 km. I was encouraged by initial successes and expanded my experiments to many fresh market vegetables. Of those, I had the greatest success with sweet corn and summer squash although I have seen potential with peas, green beans and root crops such as beets, garlic, carrots and some early leaf crops such as spinach and lettuce but some crops such are melons, broccoli and cauliflower have shown much less promise. Dry land production certainly changes the flavors. Most are improved by becoming stronger while some, such as broccoli became so strong that they were hardly fit to eat. Many believe dry land vegetables are more nutrient dense that those which are produced with irrigation, although we have done no research to substantiate this.

Our farm is located at longitude 110° 00' 53.0" W and latitude 48° 02' 15.4" N and at an altitude of 963 meters. Our USDA plant hardiness climatic zone is 3 although some recently revised maps have shown us now in zone 4 due to the effect of climate change. Zone 3 is characterized by low temperatures of -40 degrees C in the winter while Zone 4 has lows of only –34 degrees C. This past winter, which was colder and with more snow than we have experienced for many years, had a low of -36 degrees C in early December and –33 degrees C in mid-February. Forty per of our precipitation is concentrated in May and June (average of 64.5 mm/month) while the winter months of November through March are dry. We receive only 20% of our moisture during these 5 months (average 12.2 mm/month) while the other 40% of our precipitation is distributed quite evenly throughout the remaining 5 months of April and July through October (average

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30.2 mm/month). Over the past 30 years, our average precipitation has been 340 mm. Our average daily high and low temperatures in December and January are 0° C and -12° C and our average daily high and low temperatures in July and August are 30° C and 12° C. Our frost free days normally extend from May 15 to September 15 although in recent years we have seen that extended by several weeks.

Main chapter

When considering the organic production of vegetables in semi-arid regions, there are five main topics which must be addressed: soil building practices, conservation of water, varieties adaptable to dry land production, protecting the crops from insects and wildlife, and crop storage needs and possibilities.

SOIL BUILDING PRACTICES

Our soil building program begins with two years of soil building crops preceding our vegetable crops the third year. We would like to build up soil nitrogen and stored water as well as control weeds for the vegetables which are heavier feeders and need more water than cereal crops. Initially we were planting two years of peas in a row to produce two green manure crops. They produce a fair amount or nitrogen, about 110 kg/Ha in two years, without using an excessive amount of water as peas are shallow rooted. I was planting regular peas in mid-April of the first year and working them into the ground by late June as they were starting to bloom. I would then plant Austrian winter peas, which could survive the winter, in early September of that first year and work them into the soil about the 1st week of June the second year. This earlier termination the second year gives us more water for the next year's crop because water use is stopped about two weeks earlier with fall seeded peas than with spring seeded peas during our wet month of June. The best time to terminate a green manure crop for maximum nitrogen fixing is at blossom time. As the flowers develop, we have found the nodules producing the nitrogen begin to slough off the roots and the nitrogen stored throughout the plant begins to be translocated to the developing seeds. If you let those seeds mature and harvest them, you will use much of your stored soil moisture and you will be taking nearly 2/3 of the nitrogen off your field. This will not give you enough water or nitrogen for the vegetables planted the next year. My 2 year green manure program using peas worked well for about 3 or 4 years and then we discovered that we were losing huge areas of peas to fungal root diseases. Upon consultation with university plant pathologists and identification of the types of pathogens involved, we were advised to not have a pea crop more than once every 3 or 4 years in order to break up this soil born disease cycle. Now we have changed our strategy. The first year after our vegetable crop year we have started to plant buckwheat as a green manure plow down crop. Buckwheat will solubilize phosphorus which is normally tied up in insoluble salt compounds in our alkaline soil. It will also "scavenge for nitrogen" meaning that the deep rooted buckwheat can use nitrogen which is too deep for some of the shallow rooted vegetable plants to reach. Buckwheat is also a very good smoother crop, out competing the weeds, thus lowering the weed population and weed seed concentration in our soil. Even though buckwheat is not a legume which produces its own nitrogen, it has these other important advantages that make significant contributions to our system. The buckwheat is not planted until June and terminated about 6 weeks later in mid-July. We then plant Austrian winter peas in late August or early September. These are terminated early the following June allowing for both nitrogen production and water conservation the second year of our rotation. The soil is then in good shape for the vegetable crops which are planted the third year. For example, this spring the nitrate levels in the top 61 mm of our soil were 30 Kg/Ha for the plot with vegetables last year, 63 Kg/Ha for the plot with 1 year of plow down (buckwheat last year), and 91 for the plot with 2 years of plow down (peas and buckwheat).

WATER CONSERVATION

As explained above, the water conservation program really starts the year before the vegetables are planted by doing a green manure (green fallow) crop the previous year as explained above. Nothing is allowed to grow in the field from early-June until freeze up allowing the soil to accumulate and store most of the moisture falling during that period. Normally the peas are disked down and are thick enough to form a solid layer of mulch on top of the ground. This normally remains for the rest of the summer which further protects the ground by shading the soil and protecting it from drying winds. If there is no further significant rain during the summer, there will be no further weeds germinating and the field will not have to be worked again until spring. If there are summer rains which start a new crop of weeds, then the field will have to be disked again but it will also have extra moisture from the rains so we can afford the water loss that occurs when the ground is cultivated.

There are two important factors in water conservation for the year that vegetables are produced. They are having the correct plant spacing and making sure there is very good weed control. Our plant spacing is about 3.0 to 4.0 times greater than that normally used in irrigated systems. For example, potatoes are planted in hills which are about 1.0 meter apart in rows which are about 1.0 meter apart. The squash is planted in hills 2.0 meters apart in rows 3.0 meters apart. The sweet corn is planted 0.33 meters apart in rows 1 meter apart. The onions are planted 0.2 meters apart in rows 1 meter apart. We found when we did this the production per plant in a dry land field nearly matched the production per plant in irrigated fields. Of course, because of the reduced plant population, our yield per hector is only 1/3 to ¼ of that expected under irrigation. However, the value of these low vegetable yields far exceeds the value of the grain that could be produced on the same land.

We have found that weed control is critical. Weeds must be very close to 100% control as there is no extra water to spare and even a few weeds reduces yields of the cash crop significantly. We experimented with mulching for weed control in potatoes and squash but have had mixed results. For example, we saw almost no difference in the potatoes which were mulched with straw compared to those not mulched and mulch created more trouble at harvest. There was a little more yield with the squash that was mulched compared to that which was not. One challenge with early mulching is that it retards the warming of the soil in the early part of the summer which reduces plant growth for heat loving plants like squash and corn compared to plants grown on soil warmed by the sun. Of course mulching does conserve water and help with weed control which is important throughout the growing season but especially as the days grow hot. We continue to experiment with better mechanical weed control, such are flaming, to take the pressure off hand weeding. We have found that if we can eliminate the weeds by the end of June, almost none will regrow because low rainfall normally received in July and August prevents new weeds from germinating. So it is necessary to focus the weeding efforts intensely in June.

VARIETIES ADAPTABLE TO DRY LAND PRODUCTION

Different varieties also make a huge difference in production in dry land systems. Most breeding programs are focused on high input chemical systems. Plants are provided with all the water they need under high input irrigated systems which supplement rain fall. High levels of fertilizer must then be provided so that nutrients do not become limiting. Plants grown under these conditions of high input and high output are under a lot of stress. As a result, the faster growing, higher producing plants seem to be more susceptible to disease and attack by insects than their slowing growing counterparts. Stronger flavors, thought to be related to levels of anti-oxidants, are more common in dry land production than in irrigated production.

The few companies who are breeding plants better suited for organic production usually do not consider drought tolerance as a criteria for selection, as most vegetables are grown in areas of higher rain fall or are supplemented with irrigation in dry areas. Over the past nine years, we have compared nearly 50 different varieties of potatoes and 30 different varieties of summer and winter squash. We have grown fewer onions because of the lower demand and fewer choices available and therefore only looked at about 10 different varieties. We are still comparing different types of yellow and white onions as we found the red varieties did not perform or store well. We are focusing more on the yellow onions because they store longer than the white varieties. With the potatoes, squash and onions, we selected the best 1/3 each year until we have about 3 to 6 varieties of each vegetable that we plant each year. We chose those which were the most consistent in production, quality, taste and stored the longest and therefore were the best suited for our system. We are also limited in our range of varieties by our short growing season and our cool summer nights as mentioned above. This eliminated many varieties which required a longer, hotter season. We have noticed with squash and potatoes that the early maturing varieties do not store as long as the later maturing varieties. So in response to this observation, we normally grow a mixture of short season and mid-season vegetables. The longer growing mid-season varieties will out produce the short season varieties in a year with a long growing season. The short season crops will out produce the mid-season crops if we have a shorter growing season. Again the importance of diversity in the system is demonstrated.

We were surprised to find that the russet potato, which is very popular as a baking potato in America, did not do well at all in a dry land system. However, when we discovered that this potato was developed specifically for irrigated systems of Idaho, then our observation was more easily understood. The potatoes that we like the best are Yukon Gold, a medium season yellow potato; German Butterball, a smaller late season yellow roasting potato; Red Norland, an early red potato; Red LaSota, a late season red potato and Purple Viking, a purple and red skin white flesh mid-season potato with good flavor, good size and good keeping ability. Our favorite squash are Delacata and Carnival which are smaller earlier varieties and nearly as sweet as sweet potatoes which we cannot grow in our area. Other longer season squash we have had success with are: Lacota, Buttercup and Spaghetti squash although these are not as sweet as the first two mentioned. Our season is not long enough to produce good butternut which is the most popular winter squash in America. A neighbor of ours had experimented with many varieties of sweet corn so we just took their recommendation and did not do the testing ourselves. The sweet corn we are currently growing is Ambrosia. It is a super sweet hybrid and we are currently working on our own breeding program to turn it into an open pollinated variety. Since we are not in corn country, there is no corn grown in the neighborhood to interfere with our breeding program or to risk contamination with GMO corn. Our corn grows less than 2 meters high, much shorter than will be found in the corn belt of America. There are two ears per plant of normal size and they are very sweet and well loved by those who eat them. We continue to try new varieties of our vegetables, but normally try only a couple each year and compare them to what is now working best for us.

PROTECTING THE CROP FROM INSECTS AND WILDLIFE

We have seen no insect attacks on any of our vegetables except for Colorado potato beetle on potatoes. We control that with one or two applications of Bt spray once we have found newly hatched nymphs. This treatment is allowed in organic systems and seems to be quite successful. We also pick off any adult bugs that we find on the plants and destroy them. Hand picking is quite labor intensive, however, and is probably not a good option once we leave the experimental plot size of approximately 0.2 Ha and go to commercial production of several hectors. We have seen some stink bugs attack the nymph stage of the potato beetle but they are not in high enough concentration to keep the potato beetle population under control at this time. The only real animal pressure we have is in our sweet corn which during its peak, when it is ripe, is in high demand by both local markets and wildlife. We compete with deer, skunks and raccoons for this crop. This pressure has increased over the years after the animals discovered the corn patch. The first year of corn production had almost no loss to wildlife because it had not yet been found. We have tried surrounding the corn with safflower which has lots of stickers which most animals do not like to walk through. This gives good control if the safflower is thick and there are no trails or open spaces through it. We also put up high plastic fence which will keep out the deer if the fence is well maintained. We have also tried electric fence and some live traps for the smaller animals like skunks and raccoons with mixed results. We have almost no animal damage in our potatoes, squash and onions.

CROP STORAGE NEEDS AND POSSIBILITIES

We built a root cellar to store our potatoes which require cool, damp storage and have found that some varieties will keep until mid-July when the first new potatoes can be eaten fresh. This makes it possible to eat potatoes the year round. The temperature is about 11° C in mid-October when the potatoes are usually harvested and put in the cellar. The temperature declines slowly until the end of February when it reaches approximately 2° C. By the middle of July the temperature is back up to about 11° C when we clean out the root cellar. The temperature can reach a high of 16° C in late August. We normally have to take the sprouts off the potatoes twice, once near the end of May and then again the end of June when they are beginning to get a little soft but are still eatable. The relative humidity in the root cellar stays about 98% the year round. The cellar is built about 4 feet below the surface of the ground. It has cement walls and celling and a dirt floor covered with pea size gravel. It has 2 air vents placed at opposite corners. One reaches near the floor and one ends at the ceiling to promote circulation of fresh air. We also have a very small fan to help circulate the air and reduce condensation forming on the ceiling. There is a sump pump in the floor which can pump out excess water which is probably due to rain coming off the roof of nearby storage buildings. The cellar is about 4.2 X 3.8 meters with a ceiling 2.2 meters high. It has 4 sets of shelves that can hold a total of 2.7 MT of potatoes kept in plastic crates which can hold about 18 Kg each. The crates are steam cleaned and then wiped with a 10% solution of hydrogen peroxide to prevent the transfer of disease. We also plant certified disease free organic seed to prevent or reduce disease. We pull up diseased looking plants or removed diseased tubers from the cellar as we find them. We have found states and nurseries vary greatly in the amount of disease they have in their potatoes which are all supposed to be disease free. We now buy most of our potato seed from Montana although we have also had very good luck with certified seed from Maine and pretty good luck with potato seed coming from Washington State. The other seed for our vegetables is almost all organic. We have seen almost no disease in the other vegetables.

We can store the squash and onions in our basement or garage. They require dry conditions, rather than damp, and temperatures about 10° C. The squash will keep 3 to 8 months depending on the variety. Delecata has the shortest storage life while spaghetti squash has the longest. The white onions will keep about 2 months while the yellow varieties will keep about 3 to 4 months. These vegetables must be eaten or preserved by cooking and then freezing, canning or drying before they begin to go soft.

Core messages and conclusions

After nine years of experimenting I am convinced that dry land vegetables can be successfully grown in semi-arid regions of the world. Although I experimented with crops common to our region, the same principles could be used to study possibilities of growing additional crops common to other regions of the world better suited to the tastes and traditions of the people living in those areas. These principles could bring more diversity in farming and with local production and more food independence to any of these regions. This would also create more local jobs and reduce transportation costs of food to these regions. If processing facilities are lacking in these regions, storage vegetables like potatoes, winter squash, onions or others could be grown and stored for much of the winter or off season at a very low cost without processing. Production methods must be adapted to conserve water, build the soil and protect the plants from potential predators. Varieties must be found or selected which are best suited for drought tolerance. Cities which are starting to fight irrigators for the same water may be more willing to compromise if the water going to the local farmers was producing just their food instead of producing food to be sent all over the country. This would further increase development and dependence upon of local food production. As water becomes scarcer and transportation more costly, I believe that more regionally based dry land vegetable production holds great promise for the future in response to these challenges. Also there is a strong economic incentive for dry land vegetable production. When we compared grain to vegetable production, we found the vegetables we can grow are approximately 3 to 4 times the weight of grain we can grow on the same amount of land. Our normal production of cereal grain or oil seeds is about 1.0 to 2.5 Mt/Ha. Of course we are comparing wet verses dry weight. Another big advantage of vegetables is that the selling price per kg for vegetables which is 2.5 to 3 times the selling price for seeds or grain. When you combine those two advantages, your gross income for the vegetables is nearly 10 times the value of grain grown on the same amount of land. Of course there is more expense in labor which is required for weed control, planting, harvesting, handling and marketing than with grain and oil seeds. But the net result is that more people have more jobs on fewer acres. In our region of the world this means that farms do not have to continue to get bigger to support the farm family because of the income squeeze created by higher costs of inputs and machinery and lower value of the production. If these farms added a dry land vegetable enterprise, sons or daughters who wanted to come back to the farm would have an enterprise to sustain themselves and their families without having to buy more land. Beginning farmers could start out with a much smaller land base then is normally thought necessary to be successful in the grain belts of the semi-arid sections of the world. I will attempt to test this hypothesis on our farm. In the spring of 2014 I hired a young man to take our vegetable plot to a production level. His main markets will be local restaurants, grocery stores and schools. Our goal is to be profitable enough to support his family within three years. We have a web site for our farm (quinnorganic.com) so the success and progress of this enterprise might be shared with the world in hopes that successes and ideas from our farm might be used by others to help them achieve similar goals and desires.