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MERCY CORPS/MONGOLIA
GOBI REGIONAL ECONOMIC GROWTH INITIATIVE
Cooperative Agreement
#438-A-00-04-00002-00

Report on the Opportunities and Constraints for Vegetable Cultivation in the Gobi Region of Mongolia

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August, 2005

EXECUTIVE SUMMARY

This consultancy was performed over a six-week period in July and August 2005 to (a) assist Gobi Initiative (GI) staff in developing a policy related to support for vegetable production in the Gobi and hangai regions, and (b) document findings and provide recommendations related to current production efforts. The GI aimags visited included Bayanhongor, Uvurhangai, Dundgovi and Umnugovi. A formal training workshop was also conducted in Uvurhangai.

Based upon a field survey of twenty GI-supported vegetable sites currently under cultivation in the four aimags, it is possible to conclude that vegetable production in the Gobi and hangai regions of Mongolia is economically viable under certain conditions. These conditions include an adequate water supply and at least average soil conditions. There are, however, a number of specific technical issues that, if successfully addressed, could also greatly improve both the quantity and quality of vegetable production. Of primary importance is that the growing of vegetables should be concentrated in smaller land areas, thus reducing labor requirements, the quantity of inputs needed for soil improvement, and problems related to weed and pest control, while at the same time improving water use efficiency. Of equal importance is that the GI project should continue the work of building the technical knowledge and skills of the local aimag-based consultants.

The field surveys and discussions with project staff, clients, and local consumers helped to confirm that the GI model for assisting herder families in increasing income through agricultural diversification is conceptually-sound. In addition to assisting the herders directly, vegetable production is also aiding consumers through increasing the availability of higher-quality local produce. The current production limitations noted in this report can all be resolved with relative ease. A good example concerns seed. A one-time importation of high quality, locally-adaptable, open-pollinated vegetable seed can significantly improve yields to profitable levels.

At most of the sites visited, adequate irrigation water was available in both quantity and quality. In situations of more limited water resources, simple drip irrigation systems are recommended. Drip tape, emitters, fittings and filters are already available in country, and are in fact already in use in certain regions. Continuing soil improvement programs will be critical to the longer-term sustainability of vegetable production efforts. Organic matter, nitrogen and other fertilizer levels can also be increased to improve yields and profit. The soil pH levels in most locations should be decreased and effective weed management instigated in all areas. To accomplish these improvements, continuing vegetable production training will be essential for both clients and training and technical assistance providers. Local consultants should receive additional technical, and scientifically-based, training. This training should start with basic plant biology and progress to advanced vegetable culture science. Finally, additional printed materials should be developed for farmers and regular training provided at demonstration centers.

This report outlines the conditions under which vegetable cultivation should take place. It also contains specific findings and recommendations related to vegetable cultivation in the Gobi and hangai regions. A "Vegetable Production Manual" is included with the report; this Manual provides greater detail and specific technical information that can be used to address the findings and recommendations contained in this report.

VIABLE VEGETABLE PRODUCTION IN THE GOBI AND HANGAI REGIONS

As noted in the Executive Summary, vegetable production in the Gobi and hangai regions of Mongolia is economically viable under certain conditions. Such production should only be supported when the following is in place:

1. An adequate water supply, defined as (a) minimum availability, during the growing season, of 250 tons per week per hectare, (b) a proper distribution system, including gasoline or electric pump capability and a gravity-fed irrigation network, and (c) sufficient water quality with a maximum pH of 8.3.

2. At least average soil conditions, defined as (a) soil pH values ranging between 6.0 and 7.5, (b) the presence of some organic matter, and (c) the absence of toxic sodium, chloride and boron (to be determined by laboratory analysis).
3. A "frost free" growing season of at least 90 days.

FINDINGS RELATED TO VEGETABLE CULTIVATION

An analysis of current vegetable production practices revealed a determined effort by herders to produce for domestic consumption but also for sale at local markets. Eleven production limiting factors were noted based on field observation and discussion. If these factors are addressed through the work and activities of GI, production yields could be maximized.

1) Fertilizer is not always applied appropriately or in adequate amounts; especially lacking is adequate nitrogen application.
   - In many crops observed, including potatoes, cabbage, and melons, nitrogen deficiency symptoms were noted. Current farm fertilization practices range from no fertilizer/ manure addition to 40 tons of manure (collected during the socialist period) per hectare.
   - Currently, no commercial fertilizer is apparently available in the country.
   - Many current supplies of manure are stockpiles from former state farms and are non-renewable. Sheep manure, the most commonly available, is slow to break down and release nutrients. It also contains high numbers of weed seeds, which is contributing to the considerable weed problem encountered at most vegetable sites.

2) Information on the physical characteristics of the vegetable seed used, including planting date, length of growing period, maturity date, open-pollinated or hybrid, and determinate or indeterminate variety are often not known. For example:
   - Vegetable seed that is available sometimes includes hybrid varieties that are not suitable for producing seed to be saved and used in following years.
   - In many cases, potato “seed” comes from general market potatoes and not selected seed potato stock.

3) Business and Marketing plans are often based on optimistically high yields. This distorts the true economic viability of the vegetable cultivation activities.
   - World Bank figures for potato yields in Mongolia are 7.6 T/ha. Many GI business plans contain yield calculations that were estimated at 10-12 T/ha.

4) Most vegetable sites are too large in size for the available labor force.
   - Because of a lack of committed labor, there is an inefficient use of the land that is currently in farm production. There are often large sections that are empty, have poor plant density, and have yield- reducing levels of unmanaged weeds. As a result inefficiencies exist in water application, manure utilization (when used), and labor allocation.

5) The organic matter levels in most site soils are below adequate for optimum vegetable production
   - Higher levels of organic matter are needed for soil structural factors as well as improving nutrient availability for the crops.

6) Current weed management practices are ineffective.
   - On many farms, weeds are not removed until after competing with crops for water and nutrients, and often not until the weed seeds have matured. Also, at several sites, weeds known to be toxic to livestock are being fed to livestock. Observed toxic weeds include pigweed-*Amaranthus* species, lambs quarter–*Chenopodium* species, nightshade-*Solanum* species, and dock–*Rumex* species.

7) The insecticide currently in use for cabbage pests is largely ineffective.
   - Decis (deltamethrin) use is currently ineffective due to improper mixing rates and application, incorrect timing, and high water pH.

8) The level of technical training of local consultants in some cases is inadequate.
   - Several farmers were told by local consultants to remove the flowers from potato plants in order to increase tuber size. There is no reason to remove the flowers from potatoes as there is no improvement in tuber yields when this is done. Removing flowers actually reduces yields by taking labor away from such important tasks as removing weeds when immature.
   - Some farmers were removing leaves from the potato plant in an effort to "grow larger potatoes". The only way a potato tuber can get photosynthate (sugars) is from the leaves. Any leaf removed will only serve to reduce yields.

9) Relatively high soil and water pH values are found in many areas.
   - Based on project-completed soil tests and on-site tests by the consultant, pH values are generally above 8.0. This limits the nutrient absorption ability of plants. These high pH values can particularly limit the yield of potato crops, with optimal pH values around 5.2.

10) Although most sites are still relatively new, the concept of crop rotation is not yet being considered.
   - Growing potatoes in the same part of the field year after year can result in serious disease problems as well as specific soil nutrient depletion.

11) In a few cases, farmers were attempting to irrigate fields by hand from wells.
   - A mid-season vegetable crop requires 250 tons of water per hectare per week, making it impractical to adequately irrigate any but very small fields by hand.

RECOMMENDATIONS FOR IMPROVED VEGETABLE PRODUCTION SYSTEMS

The following are sixteen recommendations for improving vegetable production in the Gobi and hangai regions of Mongolia. Additional detail can be found in the "Vegetable Production Manual" attached to this report.

1. Fertilizer Use and Improvement of Soil Fertility

Fertilizers other than manure should be considered. This could include one or more of the following: bone meal, blood meal, hoof and horn meal, cover crops and chemical fertilizers.

Commercial chemical fertilizer could be used, perhaps in conjunction with manure, and application rates should be based on commercial laboratory analysis of the soil. Another option for increasing plant nutrient concentrations in the soil is the use of cover crops. These are generally leguminous plants, such as alfalfa, clover, medic, field peas, cowpeas, soybeans and other types of beans. These crops should be grown in rotating sections of the farm on an annual basis. Thus, if the farm is divided into 4 sections, one section each year will have a cover crop, the other three used for vegetable production. The cover crops are grown each summer up to the period when they are in full-flower stage. They are then cut and incorporated into the soil directly. At seeding rates of 20 kg/ha for clover, approximately 100 kg/ha of nitrogen is produced in the plants and becomes available in the soil. Half of the nitrogen produced by the cover crop is useable by vegetable crops planted the first year, and the remaining nitrogen is useable in the second year.

2. Vegetable Seeds

Vegetable varieties should be adapted to local conditions. This includes climate, length of growing season, and desire to save some seed from the crop for the next year's cultivation. Thus, cold-adapted, short season, open-pollinated vegetable varieties should be tested under local conditions. For potato seed, efforts should be make to experiment with different varieties from certified stock and suited for the area.

Specifically, Russet Burbank types, with good storage qualities, should be tested under Mongolian conditions.

3. Business and Marketing Plan Yield Estimates
Program officers and technical consultants should work with the herder clients to help them with the development of business plans and marketing plans for vegetable production ensuring that they have realistic production yields for the vegetables. Production yield figures under Mongolian conditions for onion, potato, carrot, cabbage and melon can be found in the "Vegetable Production Manual". Examples of known yield figures can be found from various organizations such as the Ministry of Agriculture, World Bank, and Asian Development Bank.

4. Farm Size
For perhaps several reasons, including the historical 'kolkhoz" model, many herders seem to want large parcels of land for farming use. In many cases, there is an inadequate labor commitment to the farm, and production per area is relatively low. Plant spacing is often less than efficient. Manure or any other fertilizer or organic matter application is definitely inadequate in most situations. All these factors lead to low yields per area, and per unit labor time.

In order to promote a more efficient use of land, manure, seed, water and labor, the program should look to encourage smaller, high intensity growing practices. High yield per square meter should be the goal, not how many hectares of land one has under cultivation.

5. Organic Matter
Organic matter in soil is important for vegetable production for many reasons. One role of such organic matter is to improve soil structure – aeration, drainage, rooting, etc. Another role is to increase the cation exchange capacity of the soil, i.e. the ability of the soil to hold plant nutrients for use by crop plants. If the amount of organic matter is too low, applied fertilizers will not be held in the soil and are quickly leached out of the root zone. Based on 34 soil tests from GI-supported sites, the present organic matter ranged from 0.1% to 8.6%. Optimal organic matter levels should be around 2.0% to 5.0%. More than one-half of the sites tested have organic matter levels below 2%. Although application of manure can increase the presence of organic matter, as discussed earlier, this is probably not a sustainable prospect.

The best option is to encourage the rotational planting of cover crops. In addition to providing nitrogen to soil, cover crops also add organic matter. Legume cover crops, such as those listed in the fertilization section, produce the equivalent organic matter of 10 tons / ha of manure.

6. Weed Management
Another benefit of cover crops is in weed management. Sites planted with cover crops will have substantially fewer weed problems because the densely planted legumes out-compete the weeds for water, fertilizer and sunlight. Major weeds noted at the sites included: pigweed-*Amaranthus* sp., lambs quarter-*Chenopodium* sp., morning glory-*Ipomea* sp., nightshade-*Solanum* sp., ragweed-*Ambrosia* sp., dock–*Rumex* sp., Russian thistle–*Salsola* sp. and puncture vine-*Tribulus* sp.

Chemical herbicides can be used in some situations for effective weed control. However, no single herbicide can control all weeds be safely used around all vegetable crops. Also, there appears to be little understanding of the proper use of pesticides among the new herder/farmers. Field observations made on the current use of the insecticide "Decis" (deltamethrin) show untrained people applying the chemical in a largely ineffective manner. Therefore, the widespread use of herbicides is not recommended until a system of training in the safe use and application of herbicides is developed. The availability of suitable herbicides in Mongolia is another issue that would have to be addressed.

7. Cabbage Insect Management
As noted, the use of "Decis" is not necessarily the best option for pest control. A safer alternative for dealing with many caterpillars is a biological insecticide, Bacillus thuringiensis. It is sold as Dipel, Thuricide, and other names. It is legal to use in Mongolia according to the Ministry of Agriculture. It is

recommended that insect control trials be done to determine the effectiveness on cabbage pests under local conditions.

In at least one aimag – Uvurhangai - serious grasshopper populations were noted. With proper timing, this pest can also be managed with a safe biological insecticide - Nosema locustae.

8. Local Consultant Training

Local consultants should receive regular technical training in vegetable crop production. This would include extension methodology as well as current scientific vegetable culture topics.

During the consultancy period, two technical training workshops were conducted for local consultants and GI Aimag-based agriculture officers. This provided an opportunity to provide a good overview of some of the findings and recommendations contained in this report. Follow up training is recommended.

9. High pH

The optimal soil pH value for most vegetables, including onion, carrot, cabbage and melon is about 6.5 (slightly acidic). An acceptable range is 6.0 – 7.5. The exception is potato which should have an optimal soil pH of about 5.2. Of the 34 soil tests done by GI on soil samples from clients, 32 had pH values greater than 8.0. These high pH (basic or alkaline) conditions are significantly reducing nutrient availability and therefore vegetable yields. In the case of potatoes, the potential yield reduction is even greater. In addition to potato yield reduction, susceptibility to diseases such as scab is greatly enhanced by high soil pH.

A common method of acidifying soil is with the application of sulfur (S). In order to lower farm soil pH to more acceptable levels, this method is recommended for most vegetable sites. It should be noted that the bio-chemical process of lowering soil pH is slow, requiring more than one year to complete. The sulfur should be applied partially over an extended period of time. Sulfur is currently not commercially available in Mongolia.

10. Crop Rotation

(See recommendations for fertilization, organic matter and weed management)

11. Irrigation Parameter for Support

At most sites, irrigation water is gravity fed to the crop fields from nearby springs or rivers. In some cases, well water is used with small gasoline-powered pumps. At a few sites, there was an attempt to irrigate from a water well, lifting and applying water by hand. It is recommended that if well hand-lifting is the only option for a particular site, it should not be supported. One hectare of vegetables under local climate conditions will require 250,000 liters of water per week. The amount of extra labor required for hand lifting of water vs. gravity-feed or pump would make the operation inefficient and probably not economically feasible.

The best irrigation option for small-scale vegetable cultivation in the Gobi region would be gravity-fed systems from natural springs or rivers. The use of gravity-fed drip irrigation systems is an option that could be explored further. The necessary materials to build drip irrigation systems are available in Mongolia and the systems would increase the efficiency and effectiveness of water use.

12. Demonstration / Training Site Recommendations

Although local consultants are available in many areas to work with farmers, good, efficient demonstration farms are fewer in number. Extension Demonstration Farms are a proven method for effective farmer education world-wide. One site observed in Mongolia is operated by Mr. Baraaduuz in Hanhongor soum, Umnugovi. It is an especially harsh site, but he has managed to improve soil conditions for good crop and tree production. An excellent tomato crop was observed, as well as good cabbage and several other vegetables. He has incorporated innovative ideas for irrigation and micro-climate manipulation. In addition, the site currently has the brick framing for a training building, three cement ger sites and a pit toilet. With support, this would be a good site for a regional demonstration/ training center. Well trained field consultants are also important in this process.

13. Support for Tractors

Although they are commonly requested in business plans, tractors should only be obtained and used under certain conditions. If the number of actual average daily workers is less than 6-10, then smaller-sized plots should be encouraged that would not require a tractor. If more than 6-10 workers are available and the total productive, planted area is relatively large, then a tractor is likely to be cost-effective.

14. Soil Testing Equipment

As discussed in the production manual, soil pH values are generally too high for optimum vegetable production. If chemicals are used to change the soil pH, there will be a need to measure the soil acidity on a regular basis. Each GI agricultural officer and all agricultural consultants should be equipped with pHydrion, pH testing paper. With these very inexpensive kits, less than $5.00 each, the field offices and consultants could quickly and easily test soils in their regions and provide advice to the herders.

15. Tunnels – 'Greenhouses'

With market prices high in winter months for short-storage vegetables such as tomatoes and cucumbers, small commercial greenhouses are recommended. In addition to better prices, an efficient, 0.5 ha greenhouse can easily produce more vegetables than 20 hectares of field grown vegetables. In many parts of the world, for example, greenhouse tomato and cucumber yields average 14 kg per plant, 20 – 40 kg per sq meter. Current field tomato yields in Mongolia are 2 – 3 kg per sq meter. These greenhouse yields are possible in Mongolia, even in winter months, if adequate heating can be provided. Entrepreneurial growers, with sufficient loans, could construct these greenhouses in several areas of the country and have the potential of significant profit. These greenhouses should be double layer, air separated polyethylene or polycarbonate structures. Winter heating could be supplied by coal, dried manure, wood, electric heaters, gas, or recycled waste heat from power plants. Ventilation could be passively designed and air circulation fans could be electric or solar electric powered. A “bag-culture” growing system, easily adapted for supplies available in Mongolia, is recommended. Complete detailed plans, material lists, construction guidelines, and operational instructions are available from numerous sources. These details would be customized for Mongolian conditions and materials available.

16. Training Workshop

A one-day training workshop was conducted in Uvurhangai for the GI agriculture officers and the local aimag-based consultants. For the workshop, a detailed, locally-adapted training manual was prepared that included a seminar outline, basic vegetable production manual, specific leaflets on growing irrigated potatoes and cabbage, and a leaflet on underground vegetable storage cellars. During the workshop, the technical information presented to the participants coincided with the findings and recommendations contained in this report.

It is recommended that a standard adult-education methodology be followed for future workshops. This includes adequate instructor preparation time, adaptation time for printed materials and interpretation, and availability of an LCD computer projector in the field.

Recommended Reference Book

Maynard and Hochmuth, 1997, fourth ed., Knott’s Handbook for Vegetable Growers. J.D. Wiley and Sons, NY. ISBN 0-471-13151-2

Attachments to this Report include:

Appendix A - List of GI Herder Cooperatives Engaged In Vegetable Production
Appendix B - Scope of Work - Vegetable Cultivation Consultant
Appendix C - Vegetable Production Manual

Acknowledgements
I would like to thank Mr. Tornon for his facilitation during my assignment. He arranged for my logistical support and provided overall explanations that were most useful to me in understanding specific vegetable production problems in Mongolia. Thanks also to Ms. Bayarmaa for interpreting during my field visits and especially during the seminars, which were especially challenging.

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Appendix A

LIST OF GI HERDER COOPERATIVES ENGAGED IN VEGETABLE PRODUCTION

Bayanhongor

1. Vant Hairhan cooperative in Erdenetsogt soum
2. Ulziit Noyon Orgil cooperative in Ulziit soum
3. Tovgoriin Dalan cooperative in Baatsagaan soum
4. Baidragiin Hishigt cooperative in Bombogor soum
5. Baruun Nuur cooperative in Buutsagaan soum.
6. Gurvan Tsahir cooperative
7. Asgamba cooperatives in Bayan-Ovoo soum
8. Hoolt Ehlel cooperative in Bayan-Ovoo soum

Uvurhangai

1. Munhgurvan hairhan cooperative in Nariinteel
2. Uguujteel cooperative to Nariinteel soum-15km
3. Barchiinzalaa herder group in Hairhandulaan soum
4. Mazarbayanhangai and Ugalzbuman sureg cooperatives in Tugrug soum Mazar bagh. – 75km
5. Zuunbogdiin Uguuj partnership in Bogd soum
6. Aviatamanbulag cooperative in Baaranbuyan Ulan soum

Dundgovi

1. Har Hairhan partnership in Saihan Ovoo soum.
2. Arvindalai herder group in Saihan Ovoo soum
3. Shar Ereg herder group in Saihan Ovoo soum

Umnugovi

1. Ankh San Cooperative in Bulgan soum
2. Altan gobiin shiree cooperative in Bulgan soum
3. Visited Mr. Baraaduuz, local consultant in Hanhongor soum

Appendix B

SCOPE OF WORK
VEGETABLE CULTIVATION CONSULTANT
USAID "GOBI REGIONAL ECONOMIC GROWTH INITIATIVE"

Requirements:

The consultant will have significant prior experience with the development of small scale vegetable production in arid/dry regions, including (a) undertaking feasibility assessments with regard to the cultivation of vegetables in arid/dry regions, (b) evaluating client and potential client capability, and (c) providing training and technical assistance on vegetable cultivation and operations. Such experience should include work in countries that are transitioning from large-scale centralized planning and operations, and in areas within countries in which vegetable production, due to climate, limited population, and other considerations, will never be a large-scale operation.

The consultant will undertake this work in up to six (6) rural *aimags* (provinces) in southern Mongolia (Gobi desert region) and potentially in an additional three target *aimags* in western central Mongolia. In the *aimags*, program clients are already engaged in small scale vegetable production with varying degrees of success and the consultant will work primarily with these clients.

Objectives:

The consultant will, in collaboration with MC/Mongolia staff, (a) conduct a brief survey of current vegetable cultivation conditions in the target *aimags* and identify the major problems and constraints encountered by the Mongolian herders cultivating vegetables, (b) conduct a brief assessment of the market situation (current situation and market opportunities) and identify potential opportunities for new products (raw vegetables and processed), and (c) provide training materials and information of appropriate technologies in vegetable cultivation for arid/dry regions.

The consultant will:

1. Conduct a brief assessment of the market situation (current situation and market opportunities) and identify potential opportunities for new products (raw vegetables and processed). This will enable the consultant to 'balance' his/her recommendations based on market demand and the production environment. The market analysis will provide a basis for the consultant to assess the economic viability of vegetable production in the region.

2. Undertake an assessment of current vegetable cultivation operations in the target *aimags* and identify the main constraints and problems encountered by the herders.

3. Provide detailed recommendations on potential solutions to the identified constraints and problems. This might include, but not be limited to, suggestions on alternative vegetable crops that would be suited to the climate and conditions, water harvesting techniques and irrigation systems appropriate to arid/dry conditions, appropriate pest control measures that may include integrated cropping systems and environmental preservation, the appropriateness of using greenhouses to prolong the growing season and for the production of higher value crops or vegetable seedlings in the Gobi region considering the conditions.

4. Provide information and advice with regard to the following:
    - Specific cultivation dates and production periods for vegetable crops grown in the various eco-zones of the Gobi region. This will include appropriate planting dates, harvesting dates, expected average yield considering the conditions and circumstances, etc.
    - Standard water requirements for vegetables cultivated in the various eco-zones of the Gobi. This will include advice on suitable irrigation equipment and systems, operating costs for these systems and potential suppliers.

- Appropriate methods to improve the fertility of the soil in the target regions, to include, but not be limited to, the use of manure (from livestock) and composting systems and the use of artificial fertilizers, taking into consideration the economics of the vegetable production systems and suppliers in country.
- Appropriate pest and weed control measures. This may include integrated cropping systems and alternative production and cultivation systems that will ensure that there are no long-term environmental or health-related effects from the control of weeds and pests.
- Provide advice on appropriate cultivation equipment and machinery for the size of cultivation that program clients are engaged in, such as small scale tractors, hand operated rota-tillers etc.
- Potential greenhouse design and construction materials that would be appropriate in the Gobi eco-zones and economically viable for program clients.

5. Provide detailed design information and construction of appropriate underground cellars for vegetables and on the best ways to harvest and store vegetables and how to manage the cellars during the winter so that vegetables do not go bad or rot.

6. Analyze the economics of vegetable production in the Gobi region by comparing the costs of production (taking into consideration the conditions) and the estimated revenue from sales (considering the market analysis), to provide guidance and suggestions to clients on the optimal vegetable crops to cultivate, the selling season and the actual product (i.e. 'raw' or 'processed') to be sold.

7. Design a four-day training course for *aimag*-based consultants and GI program officers to build their skills and technical knowledge in vegetable and fodder crop cultivation. This will include providing some training materials (the format of these materials and most appropriate dissemination methods will be discussed and developed in collaboration with Mercy Corps staff), and providing advice on where additional information could be sourced.

8. Work closely with MC/Mongolia program staff and will liaise as necessary with *aimag* government officials and other interested/involved parties.

Deliverables:

The consultant will provide:

1. A brief weekly written report on status against scope of work objectives,
2. A comprehensive report detailing the main constraints and problems encountered by the herders and Provide detailed recommendations on potential solutions to the identified constraints and problems. The report will include a brief analysis on the economics of vegetable production in the target regions and suggestions on optimal vegetable crops to cultivate.
3. Provide detailed written recommendations on potential solutions to the identified constraints and problems as detailed in #2. Especially those related to, "water sourcing and weed/pest control".
4. Provide detailed design information and construction methods of appropriate underground cellars for vegetables. Provide advice on the best ways to harvest and store vegetables in underground cellars and advice on how to manage the vegetable cellars during the winter so that vegetables do not rot.
5. Develop some basic training manuals that compliment the recommendations and advice provided (the format of these materials and most appropriate dissemination methods will be discussed and developed in collaboration with Mercy Corps staff), and advise on additional sources of information relevant to vegetable production in dry/arid regions.

The consultant will work closely with the Gobi II Rural Economic Development Adviser, the MC/Mongolia Program Director and the MC/Mongolia Country Director, and any other consultants employed for the implementation of this work.

Reporting:

The consultant will report to the Gobi Initiative Rural Economic Development Adviser

Timeline:

The consultancy will be for an initial 30 - day period, beginning on or about 25th July 2005 and ending on or about 26th August 2005. The days will be normal working days (Monday through Friday) unless approved in advance by the Gobi Initiative Rural Economic Development Adviser or MC/Mongolia Country Director.

Vegetable Production Manual for Mongolia

Prepared for the Gobi Regional Economic Growth Initiative

By: Gary W. Hickman, Consultant
August, 2005

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Background

During July and August, 2005, an extensive field survey of over 50 current vegetable production sites in Mongolia was conducted. Visits and discussions with farmers and local consultants were made in the following aimags: Bayanhongor, Uvurhangai, Dundgovi, Umnugovi, and Zavkhan. Formal educational seminars were conducted in two locations – Zavkhan and Uvurhangai. Based on these visits and discussions, specific observations, limitations noted and recommendations for vegetable crop production are given.

1) General Recommendations

Factors	Onion	Potato	Carrot	Cabbage	Melons
Minimum Soil Temperature For Germination (^{0}C)	0	(plant one week before last frost)	4.5	4.5	16
Optimum Soil Temperature For Germination (^{0}C)	27		27	27	35
Planting Distance between Plants	5-7.5 cm	30 cm	2.5-5 cm	30-50 cm	30-75 cm
Distance between Rows	30-60 cm	60-90 cm	35-60 cm	60-75 cm	120-180 cm
Number of days to Germination	7-12	8-16	10-17	4-10	3-12
Weeks to Transplant Size	8			5-7	3-4
Days to Maturity	95-120	90-105	60-80	65-95	75-100
Yields (T/ha) Mongolia (est.)	10	10	9	12	8
Yields (T /ha) USA (actual)	44	38	34	36	20
Storage Temperature (^{0}C)	0	4-10	0	0	10
Storage Humidity (%)	70	90	95	98	90
Approximate Storage Period (Months)	1-8	4-9	7-9	5-6	0.5

2) Seeding, Transplanting and Harvest Dates

Seeding Dates

The date to plant seeds is dependent on the last frost date in the area. Three estimated last frost dates selected for examples are: April 7, April 14, and May 1

Transplant Production Seeding Dates

To gain earlier field plant production for onion and cabbage, transplants can be started in small tunnel "greenhouses", 3-8 weeks prior to field planting.

The estimated time to start transplant seeds is:

Crop	Last Frost Date April 7	April 14	May 1
Onion	Feb 10	Feb 18	March 4
Cabbage	March 4	March 11	March 27

Direct, field, seeding dates

crop	Last Frost Date April 7	April 14	May 1
Onion	April 7	April 14	May 1
Cabbage	May 8	May 15	Jun 1
Melon	(when soil temperatures are above 16 ^{0}C)		
Carrot	May 8	May 15	Jun 1
Potato	April 1	April 8	April 24

Average Expected Harvest Dates
(from direct field seeding)

Last frost date	Onion	Potato	Carrot	Cabbage
April 7	July 26	July 10	July 17	July 27
April 14	Aug 3	July 17	July 24	Aug 3
May 1	Aug 19	Aug 3	Aug 9	Aug 19

3) Fertilization

For good plant growth and yield, significant amounts of fertilizer are required. Whether from natural soil components, chemical fertilizer or manures, the needs of the plant are the same.

Available Soil Nutrient Requirements

Crop	Fertilizer (Kg / Ha)		
	nitrogen	phosphorus	potassium
Onion	160	130	90
Potato	200	130	150
Carrot	160	110	160
Cabbage	160	90	130
Melons	130	110	110

The level of each nutrient in the soil should be determined prior to planting. If additions are needed, they can be met by chemical fertilizer or in some cases with organic materials such as manure and additional plant and animal by-products.

Current farm fertilization practices range from no fertilizer/manure addition to 40 tons of “socialist” period collections of manure per hectare. Currently, no commercial fertilizer is apparently available in the country. Many current supplies of manure are stockpiles from former state farms and are non-renewable. Sheep manure, the most commonly available, is slow to breakdown and release nutrients. It should be applied annually at rates of 10 tons/ha. Higher annual rates of manure application, especially non-aged product, can result in salt accumulations damaging to crops. Sheep manure also contains high numbers of weed seeds, which is contributing to the considerable weed problem on most farms. Commercial fertilizer, when available, should be applied at rates of 130-200 kg/ha of nitrogen (N), 90-130 kg/ha, phosphorus (P), and 90-160 kg/ha potassium (K), and should be based on commercial laboratory analysis.

Another option for increasing plant nutrient concentrations in the soil is the use of cover crops. These are generally leguminous plants, such as alfalfa, clover, medic, field peas, cowpeas, soybeans and other types of beans. These crops should be grown in rotating sections of the farm on an annual basis. Thus, if the farm is divided into 4 sections, one section each year will have a cover crop, the other three used for vegetable production. The cover crops are grown each summer up to the period when they are in full-flower stage. They are then cut and incorporated into the soil directly. At seeding rates of 20 kg/ha for clover, approximately 100 kg/ha of nitrogen is produced in the plants. One – half of this nitrogen is useable by vegetable crop plants the first year, and the remaining half the second year. Other benefits of cover crops are discussed in following recommendations.

Manure – Average Fertilizer Composition (% dry weight)

Animal	nitrogen	phosphorus	potassium
Cow	1.3	0.9	0.8
Horse	2.0	1.0	1.7
Sheep	2.0	1.4	3.5
Poultry	3.0	5.0	1.8
Swine	3.5	0.5	0.7

If using animal manures to obtain at least some of the needed soil nutrients, the process should be started several years before planting a field and should continue. This is important because of the decomposition and nutrient release rates of manures, as well as the relatively large amounts needed to provide adequate crop nutrients. This is especially true if using fresh manures. At least one growing season should be allowed after application and before planting. The total potential n-p-k from the manure is not available immediately. In cold climates, such as Mongolia, the decomposition and nutrient release process can take 2-3 years.
Example – Sheep manure (content- 2.0 % N, 1.4 % P, 3.5% K), to be used on a potato crop (fertilizer needs, Kg/Ha- 200 N, 130 P, 150 K)

Necessary Application Rate of sheep manure to supply adequate fertilizer nutrients for potatoes: 10 Tons / Ha/ year. (Assumes manure application process to the field was started several years before first crop).

One major problem with using cover crops in Mongolian vegetable farms is that herders will probably want to divert this plant material for animal fodder and not reincorporate for the benefit of the vegetable farms. A choice must be made as to providing adequate vegetable crop nutrition or simply supplementing animal ventures by basically inefficient means.

Currently unused animal by-products may be a more practical fertilizer source for some elements on the vegetable farms. The vegetable farms are currently deficient in several fertilizer nutrients and this is severely limiting yields. Relatively low cost, readily available animal by-products such as bone meal, blood meal, hoof and horn meal, may be a more practical fertilizer source for the vegetable farms. For example:

Bone meal – 2% nitrogen, 22 % phosphorus
Dried blood meal – 13% nitrogen, 1.5% phosphorus and 0.8% potassium
Hoof and horn meal – 12% nitrogen, 2% phosphorus
Bird feathers – 15% nitrogen, 30 % phosphorus

Wood Ash
Although wood ash contains phosphorus (P) and potassium (K), its use is not recommended at most Mongolian vegetable farm sites. The reason is that wood ash has a very high pH. This should not be added to the already existing high soil pH fields.

4) Vegetable seed varieties

Vegetable "Seed" – Potato
Potato plants are started from 30-70 gram small potatoes or pieces of tuber. These "seed" potatoes should be from firm, disease-free stock. Ideally, only improved varieties should be used. In several locations farmers mentioned the lack of storage quality of some varieties currently used in Mongolia. Efforts should be made to experiment with different varieties more suited for this area. Trial varieties should include russet Burbank types, which have good storage qualities. (see table 1 below)

Table 1. Potato yields of commonly grown varieties in irrigated trials from North Dakota , USA. – Recommended for trials in Mongolia

Variety Color	Color	Yield T/ha
Goldrush	Russet	36 - 45
Russet Norkotah	Russet	38 - 41
Russet Burbank	Russet	40 – 40
Shepody	White[1]	34 - 40
Atlantic	White	41 - 44
Norchip	White	35 - 40
NorValley	White	36 - 47
Snowden	White	34 - 47
Nordonna	Red	36 - 40
Red Norland	Red	36 - 45
Red Pontiac	Red	37 - 50

Vegetable seed – cabbage, tomato, onion, carrot, others
Vegetable varieties should be adapted to local conditions. This includes climate and length of growing season. For example, some onion varieties mature in 90 days, some in 120 days. Considering the relatively short growing seasons, shorter maturity varieties should be selected. Farmers in several locations mentioned the progressive reduction in fruit size and quality from saved seed. In some cases, the seed used was hybrid seed. Seed saved from a hybrid tomato, for example, will generally not produce the same quality of plants in subsequent years. Since the

practice of saving seed is important to farmers, “open-pollinated” varieties should be used. These types of seeds will generally reproduce plants very similar year to year.
Some recommended vegetable varieties for testing in Mongolia:

Cabbage- Head Start, Copenhagen Market, Drumhead, Early Jersey Wakefield, Dynamo, Parel, Primax, Arrowhead, Capricorn, Farao

Tomato- Siberian Red, New Yorker, Early Swedish, Oregon Spring, Stupice.

Onion – New York Early, Copra, Prince, Frontier, White Sweet Spanish, Blanco Duro, Superstar, Ringmaster.

Carrot – Dominator, Nantes, Chantenay, Danvers

5) Soil Conditioning

Soil and Water pH (acidity/alkalinity)

The optimal soil pH value for most vegetables, including onion, carrot, cabbage and melons is about 6.5 (slightly acidic). An acceptable range is 6.0 – 7.5. The exception is potato. The optimal soil pH is about 5.2 32 of the 34 soil tests done on Gobi-Initiative - supported farms had pH values greater than 8.0. These high pH (basic or alkaline) conditions are significantly reducing nutrient availability and therefore vegetable yields. In the case of potatoes, the potential yield reduction is even greater. In addition to potato yield reduction, susceptibility to diseases such as scab is greatly enhanced by high soil pH.

Optimum Soil pH
Tomato, Onion, Carrot, Cabbage, Melon – 6.5
Potato – 5.2

A common method of acidifying soil is with the application of sulfur (S). In order to lower farm soil pH to more acceptable levels, this method is recommended for most Mongolian herder farms. Sulfur is an eye and skin irritant, but is relatively safe to trained applicators and the environment.

Application rates necessary to correct soil pH depend on the starting alkalinity and the desired end value. Also, specific soil buffering capacities will require testing to determine exact application amounts needed. The general range necessary to change soil with a current pH of 8.0 to a pH of 6.5 is approximately 0.7 to 3 tons / ha.

It should be noted that the bio-chemical process of lowering soil pH is slow, requiring more than one year to complete. The needed sulfur should be applied partially, over an extended period of time

If chemical fertilizers are used, ammonium sulfate not only adds nitrogen to the soil but also lowers soil pH.

Gypsum, calcium sulfate, can improve soil structure and water penetration on sodic soils, i.e. soils high in sodium salts. In areas where laboratory tests have confirmed high sodium, applications of approximately 10 tons per hectare are recommended. Even when tests indicate gypsum application is needed, increasing organic matter levels will enhance the benefit obtained from gypsum application. The fall season is generally the best time for application.

Soil Organic Matter

Organic matter (o.m.) in soil is important for vegetable production for many reasons. One is to improve soil structure – aeration, drainage, rooting, etc. Another factor in o.m. is to increase cation exchange capacity. This is the ability of the soil to hold plant nutrients for use by crop plants. If o.m. is too low, applied fertilizers will not be held in the soil and are quickly leached out of the root zone. Based on 34 soil tests from G.I.-supported farms, organic matter % ranged from 0.1 to 8.6. Optimal o.m. levels are around 2% to 5%. More than one-half of the farms tested have o.m. levels below 2%. Although application of manure can increase o.m., as discussed earlier, this is probably not a sustainable prospect. The other preferred option is rotational planting of cover crops.

Crop Rotational Plan – One field divided into 6 sections. Move each crop planting location one place, in a clockwise direction, each year.

Year one

```
------------------------------------:
 :  cabbage     ?    potato     :
 :              :          ?     :
:               :                :
:_______________:_______________:
:       ?       :               :
        cover   :   cover       :
:   crop        :        crop   :
:_______________:__________?____
:       ?       :               :
 : tomato       :       onion/  :
:               :       melon/  :
:            ?          cuc     :
:_______________:_______________:
```

Year two

```
------------------------------------
:               :               :
:  cover     ?    cabbage       ?
:      crop     :       :       :
________________:_______________
:               :               :
?  tomato       :   potato      ?
:    :          :
:_______________:_______________
:               :               :
:        onion/ :       cover   :
?        melon/ :       crop    :
:        cuc    :               :
______________?  ___________
```

Cover Crops for Organic Matter

In addition to providing nitrogen to soil, cover crops also add organic matter. Legume cover crops, such as those listed in the fertilization section, produce the equivalent organic matter of 10 tons / ha of manure.

6) Irrigation

Vegetable crops in Mongolia have the same biological evapo-transpirations rates as any other area with equivalent temperatures and wind. Depending on size of crop, amount of ground cover, wind, temperature and species, vegetable corps in Mongolia need approximately 250,000 liters of water per hectare per week. That is equivalent to 2.5 cm, or 250 tons of water. While plants are small and temperatures are cool, the water use will be approximately 100 tons, and large mature plants in hot, windy areas may need 350 tons of water per week for peak production. An alternative to furrow or flood irrigation, called drip irrigation, is discussed in appendix 2.

7) Weed Management

A major yield-limiting factor on herder farms is poor weed management. On most farms observed, weeds were significantly in competition with crops for nutrients, water and even sunlight. Although some efforts were being made to remove weeds by hand, the timing of this substantial labor input made it ineffective. By waiting to remove weeds until after they had absorbed scarce fertilizer and water away from vegetable crops and had produced seeds, another large weed problem next year is all but assured. By simply hand-pulling weeds earlier in the season and before seed production, weed populations will gradually be reduced in subsequent years and their competitive effect on current seasons crops will be minimized. This change in timing would also not require any additional labor.

One more benefit of cover crops, (see fertilizer and soil organic matter sections) is in weed management. Sections of farms planted to cover crops will have substantially fewer weed problems simply because of the densely planted legumes' ability to out-compete weeds for water, fertilizer and sunlight. Major weeds noted on farms included – Pigweed- *Amaranthus* sp., lambsquarter- *Chenopodium* sp., morning glory- *Ipomea* sp., nightshade- *Solanum* sp., ragweed- *Ambrosia* sp., dock – *Rumex* sp., Russian thistle – *Salsola* sp. and puncture vine- *Tribulus* sp.

Chemical herbicides can be used in some situations for effective weed control. However, there is no one herbicide that will control all weeds and can safely be used around all crops. Also, there appears to be little training in the proper use of pesticides in general. Observations made on the current use of the insecticide Decis show untrained people applying the chemical in an unsafe and usually ineffective manner. Therefore, the use of herbicides is not recommended until a system of training is developed. Availability of herbicides is another issue that would have to be addressed.

8) Insect Pest Management

The most serious insect pests observed were various species of lepidopterous larvae (butterfly and moth) feeding on cabbage. On some farms, Decis (deltamethrin) was being used. As the product label was not in the Mongolian language, or English, recommended application rates were apparently not known. Also, several incidents of very unsafe application practices were observed with this product. Without full label information in the Mongolian language and complete training on use, it is recommended to discontinue use of this material. Also, in almost all cases, for a variety of reasons including high water pH inactivating the insecticide, effective insect control on cabbage was not being achieved.

A safer alternative for control of many caterpillars is a biological insecticide, Bacillus thuringiensis. It is sold as Dipel, Thuricide, and other names. It is legal to use in Mongolia according to the Department of Agriculture. It is recommended that insect control trials be done to determine the effectiveness on cabbage pests under local conditions. In at least one aimag – Uvurhangai- serious grasshopper populations were noted. With proper timing, this pest can also be managed with a safe biological insecticide- Nosema locustae.

9) Farm Size

For perhaps several reasons, including a colhoz model, there seems to be an encouragement of herder farmers to want large parcels of land in their farms. In many cases, there is an inadequate labor commitment to the farm, and production per area is relatively low. Large areas of current farms are often improperly weeded or not planted. Plant spacing is often less than efficient. Manure or any other fertilizer or organic matter application is definitely inadequate in most situations. All these factors lead to low yields per area, and per unit labor time.

A more efficient use of land, manure, seed, water and labor would be to encourage smaller, high intensity growing practices. High yield per meter square should be the goal, not how many hectares one has in a farm.

10) Tunnels

Existing plastic-covered vegetable "greenhouses" range in size from a few square meters to over 100 meters square. In most cases, these are low, 1.0 – 1.5 m high, wood or metal frames with a single layer of polyethylene covering. The internationally-used term for these structures is "tunnels". No daytime ventilation is provided. As a result, carbon dioxide depletion is the limiting factor in production. Recommended tunnel side and roof vents should total 20% of floor area. A tunnel with dimensions of 6 meters by 12 meters, 72 meters square, should have 14 meters square of vents. This relatively inexpensive addition to current tunnels alone will dramatically increase yields. As no heating systems are installed, these structure can only be used from late spring to early fall.

With expected market prices very high in winter months for such short-storage vegetables as tomatoes and cucumbers, a pilot commercial quality greenhouse is recommended. This should be a double layer, air separated polyethylene or polycarbonate structure. Winter heating could be supplied by coal, dried manure, wood, electric heaters, natural gas, or recycled waste heat from power plants. Ventilation could be passively designed and air circulation fans could be electric or solar electric powered. In addition to the higher winter vegetable prices available, an efficient, 0.5 ha greenhouse can produce more vegetables than 2 hectares of field grown vegetables. As an example, in many parts of the world, including Central Asia, greenhouse tomato and cucumber yields can average 14 kg per plant. These yields are possible in Mongolia, even in winter months, if adequate heating can be provided.

SUMMARY

The current production limitations on Mongolia vegetable farms are all resolvable. Most are, in fact, easily solved. For example, the one-time importation of high quality, locally adaptable, open-pollinated vegetable seed will do much to improve yields to profitable levels. A few low-toxicity, relatively low cost chemicals will also dramatically change production prospects. These include pH reducing sulfur, biological cabbage “worm” and grasshopper control products and nitrogen fertilizer.

On most farms observed, adequate irrigation water was available in both quantity and quality. In situations of more limited water resources, simple drip irrigation systems are recommended. Drip tape, emitters, fittings and filters are already available in Ulaan Bataar, and are in fact being used in Khovd aimag.(personal communication with farmers and University specialists in the region) .

Continuing soil improvement programs will be critical to the longer term sustainability of these farms. Organic matter, nitrogen and other fertilizer levels must be increased to improve yields and profit. The soil pH levels in most locations should be decreased and effective weed management instigated in all areas. To accomplish these improvements, vegetable production training will be essential for the longer term economic success of this project.

Appendix 1
Limitations to Vegetable Production based on Field Observations and Discussions

1. Commercial fertilizer availability in country.

2. Information on characteristics of seed used, including length of growing period. e.g. Planting 120 day maturity melon seed in mid-July (not harvestable until mid-November, well past first frost date)

3. Vegetable seed most suitable for the area
    - Vegetable seed that is available sometimes includes hybrid varieties, which are not suitable for producing seed to be saved and used in following years.
    - In many cases, potato "seed" comes from general market potatoes and not selected seed potato stock.

4. Most vegetable farms are too large in size for available labor force.
    - Inefficient use of land currently in farm production. Large sections are empty, many 'skips' in rows.

5. Organic matter levels in soils

6. Effective weed management
    - On most farms, weed removal is not done until after the weeds have already released their seeds and, the pulled weeds were not promptly removed from the field. Also, on several farms, weeds known to be toxic to livestock are being removed from the farm and fed to livestock. Observed toxic weeds include- pigweed- *Amaranthus* sp. , lambsquarter – *Chenopodium* sp. , nightshade- *Solanum* sp. , and dock – *Rumex* sp. .

7. Effective insect pest management, especially on cabbage

8. Relatively high soil and water pH values in most areas

9. Crop rotation – e.g. potatoes planted in same plot year after year.

10. In a few cases, farmers were attempting to irrigate fields by hand from wells.

11. Marketing plans based on optimistically high yields and process to be paid by consumers. World Bank 2003 figures for potato yields in Mongolia = 7.6 T / ha. Marketing plan yield estimates – 10 to 14 T / ha.

APPENDIX 2

DRIP IRRIGATION MANUAL FOR VEGETABLE CROPS IN MONGOLIA

The primary advantages of drip irrigation for vegetables include:

1. Relatively constant soil moisture content
2. Ability to irrigate only rooting area, resulting in water conservation and reduced weed populations.
3. Reduced evaporation, ability to match application rates to infiltration rates, reduction of run off.
4. Reduction of disease problems versus overhead sprinklers

Typical vegetable spacing for emitters is 30 cm. apart along the line. For tomatoes, a single emitter is placed near each plant. For root crops such as carrots, onions, etc, two plants per emitter are planted. In intensive growing systems, parallel emitter lines are 40 cm apart. Conventional line spacing would be 60 cm. The line pipe diameter is 1.25 cm.

Planning

The available water supply will determine the number of plants that can be watered at any one time. The flow rate of the water supply should be determined by collecting the maximum output per minute. Usable water is 75% of maximum and determines liters per minute.

Emitter Placement

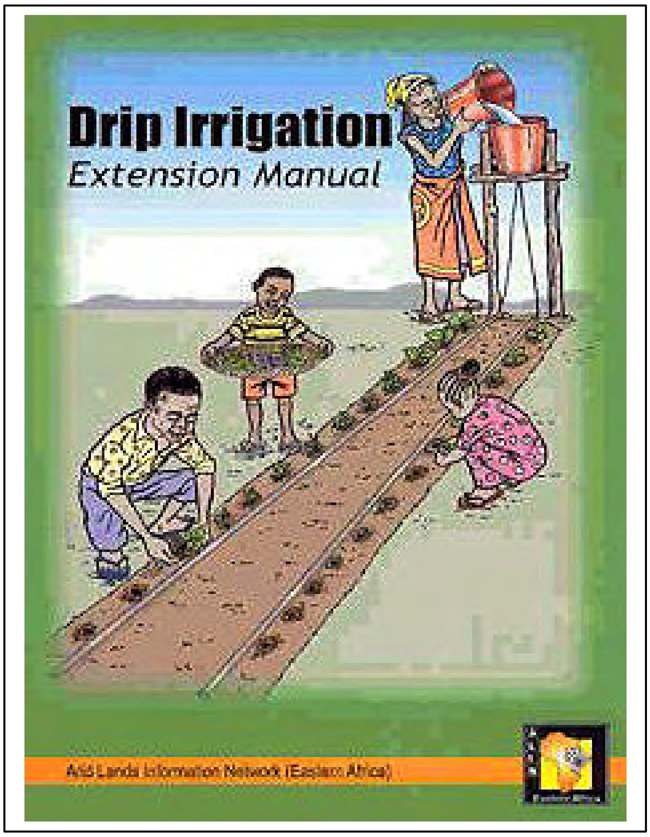
The most important factors in emitter placement are the crop rooting depth and soil type. Shallow roots – carrots, onions- require closer emitter placement than deeper rooted crops such as tomato and melon. In coarse soil- gravel, sand – water moves downward readily and requires closer spacing than fine – clay- soil. Typical emitter flow rates are 1.9 liter, 3.8 liter, and 7.6 liter per hour. Shallow rooted vegetables should have 1.9 – 3.8 liters per hour emitters, while deep rooted crops should use 3.8 – 7.6 lph emitters.

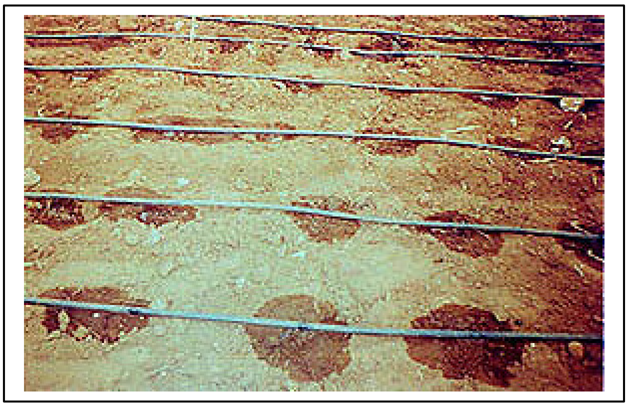
Tubing

The tubing size is 1.25 cm diameter and can be used for flow rates up to 1200 liters per hour. Downhill flows add 0.4 psi per vertical foot. For gravity feed drip systems more than 3 meters in elevation, pressure regulators may be needed. Polyethylene tubing is the least expensive and has a life of approximately 20 years. PVC can be used as an alternative. Filters should be used at the water source and before entering drip lines.

Watering Schedules

Typical vegetable water schedules are 0.5 – 1.5 hours, every 2 days. Peak water use for vegetables in warm climates is 2.5 – 5.0 cm per week. 2.5 cm of water is equal to 250 liters / 10 m^2 (250,000 liters per hectare). Rainfall amounts should be subtracted from drip water applications.


Drip Irrigation
Extension Manual
Arid Lands Information Network (Eastern Africa)



GROWING CABBAGE MANUAL - BRASSICA OLERACEA

Adapted from Oregon State University , "Cabbage", Aug. 2004 - Gary W. Hickman, Consultant

VARIETIES (approximately 75 days for early varieties, 90 days for mid-season, to over 120 days for late large-headed varieties).

Excellent cabbage varieties are available that are resistant to heat, cold, and a number of important diseases and physiological disorders. Choose test varieties carefully. The following is only a representative listing.

Fresh Market

Green Early - Heads Up, Stonehead. For Trial: Charmant, Cheers, Dynamo, Earliana, Golden Acre, Green Cup, Grenadier, Rocket.

Mid-season - Bravo, Market Prize, Market Topper, Protector, Quisto, Tastie. For trial: Blue Pack, Jump Start; K-K cross and O-S Cross (heat tolerant, large).

Late - Bartolo, Danish Ballhead strains. For trial: Excel, S-D Cross, Winter Star, Zerlina

Other green cabbage for trial: Columbia, Delos, Farao, Gideon, Izako, Pennant, Parel, Supreme Vantage, Rocket, Royal.

Savoy Cabbage: Savoy Ace. For trial: Clarissa, Wirosa.

Red: Red Head, Ruby, Ruby Ball, Ruby Perfection. For Trial: Cardinal, Primero, Red Jewel, Red Rookie, Rona, Super Red 80.

Processing Cabbage

The following have been grown successfully:

Green: Bravo, Carlton, Danish Ballhead. For trial: King Kole, Late Flat Dutch, Roundup, Superette, Titan 90, Atria (very late), Ergon (very late), Krautking (late, large), Krautman, Krautpacker (mid-season), Marvellon (early), Orbit (late), Rodolfo (mid-season), Sagitta (late).

Red: Ruby, Ruby Ball, Ruby Perfection. For Trial: Cardinal, Red Head.

Important Considerations for Field Selection

Before planting this Crucifer crop, consider the following important factors which affect a number of diseases such as club root and *Sclerotinia*:

1. No crucifer crop, or related weed has been present in the field for at least 2 years, 4 years preferable. Crucifer crops include cabbage, cauliflower, broccoli, kale, kohlrabi, Brussels sprouts, Chinese cabbage, all mustards, turnips, rutabagas, radishes etc. Cruciferous weeds include wild radish, shepherdspurse, wild mustards etc. Also, crucifer plant waste should not have been dumped on these fields.

SEED AND SEED-BED TREATMENTS

Use treated seed to protect against several serious seed-borne diseases. Hot water seed treatment is used under certain conditions (especially for transplant production). This treatment is very specific (50 C exactly, for 25 to 30 minutes; the wet seed must then be quickly cooled and dried).

TRANSPLANT PRODUCTION

Seedbeds for Transplants:

When seedlings are to be grown in a seed-bed for production of transplants, choose a site where cole crops have not been grown before.

Always use certified or hot water treated seed for transplant production. Seed in a greenhouse for an early crop, in a cold frame for a less early crop, and in outdoor seedbeds when the weather is warm enough for germination and growth (above 10 C). In each case seed 5-6 weeks ahead of when the plants are wanted for transplanting.

200 – 350 gm of high quality, sized and density graded seed will provide enough transplants to plant 1 hectare.

SOIL

Cabbage may be grown on a variety of soils but it does best on a well- drained, loam soil well supplied with organic matter. Sandy loams are preferred for early crops. Adjust soil pH to 6.5 - 7.0 for maximum yields.

Cabbage is often referred to as a cole crop. Cabbage will tolerate a wide range of environmental conditions but thrives in cooler temperatures. Cabbage can tolerate hard frosts, but severe freezes can be damaging. Cabbage flavor improves with cooler temperatures because plant cells are working to convert starches to sugars to protect the plant against the cold. The result is a sweet, fresh taste that surpasses that of store-bought greens. Cabbage planting dates should be planned so that harvest dates occur in cool weather.

Spacing

Cabbages produce large leafy plants. Space cabbage plants at 30 – 45 cm within the row and space rows between 45 cm and 85 cm apart.

Direct Seeding

A well-prepared seedbed with adequate moisture is a must for direct seeded cabbage. Sow cabbage seeds 1.25 cm deep. Gently press the soil after planting to ensure the seed is in contact with it. Thin to one seedling within each 30 cm.

Germination

These seeds germinate best in soils around 24°C. Germination will take 4-14 days.

Transplanting Into the Garden

Transplant cabbage seedlings at 4-6 weeks.

Watering

An even moisture supply is needed for transplants to become established and to produce good yields. Do not over-watering transplants after setting them out.

Harvesting

Heads should be harvested when firm and before they split or burst.

Post-Harvest Handling

Cabbage should be handled carefully from field to storage, and only solid heads with no yellowing, decay, or mechanical injuries should be stored. Before the heads are stored, all loose leaves should be trimmed away; only three to six tight wrapper leaves should be left on the head. left on the head. Loose leaves interfere with ventilation between heads, and ventilation is essential for successful storage.

Storage

Store cabbage at 0°C and a relative humidity of 98% to 100%. A large percentage of the late crop of cabbage is stored and sold during the winter and early spring, or until the new crop from the southern states appears on the market. If stored under proper conditions late cabbage should keep for 5 to 6 months. The longest keeping cultivars belong to the Danish class. Root cellars or other limited control storage should be insulated sufficiently to prevent freezing of the cabbage. Heaters are sometimes needed to prevent freezing of cabbage in common storage during severe cold weather. Cabbage wilts quickly if held under too dry storage conditions. Cabbage should not be stored with fruits emitting ethylene. The most common decays found in stored cabbage are watery soft rot, bacterial soft rot, gray mold rot, alternaria leaf spot, and black leaf speck.

Growing Irrigated Potatoes Manual

(adapted for Mongolia from - North Dakota State University, AE-1040, March 1999) Gary W. Hickman, Consultant

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Planting Season

The planting season for potatoes generally extends from about April 1 to June 1. In general, late varieties used for processing and early maturing varieties for the fresh market should be planted first. Early maturing table varieties destined for storage may be planted in late May or early June.

Varieties

Potato yield response to irrigation will vary depending on whether short season or long season varieties are wanted. In general, the full season varieties will show the greatest response to irrigation. Most varieties that have performed well under dryland conditions also perform well under irrigation. Market demand will generally dictate the selection of a variety or varieties to grow.

There are three types of potatoes grown under irrigation: smooth red skinned varieties (used primarily for the fresh market), smooth white skinned varieties (used in processing; chips and dehydrated products), and russet skinned varieties (used for the fresh market, french fries and dehydrated products). Within each of these types there are early and late maturing varieties.

A desirable characteristic for potatoes used in processing is the percentage of total solids (mostly starch). This trait is variety-dependent and typically ranges from 17% to 23%. The most important varieties for production of french fries are Russet Burbank, which has good yields, high solids, and stores well, and Shepody, which can be harvested earlier with acceptable yield and solids content. Another important processing trait is the percentage of reducing sugars that influence browning during the fry process. NorValley and Snowden are somewhat resistant to the increase in reducing sugars that comes with storage at colder temperatures.

Table 1. Potato yields of commonly grown varieties in irrigated trials from North Dakota , USA.

Variety Color	Color	Yield T/ha
Goldrush	Russet	36 - 45
Russet Norkotah	Russet	38 - 41
Russet Burbank	Russet	40 – 40
Shepody	White[1]	34 - 40
Atlantic	White	41 - 44
Norchip	White	35 - 40
NorValley	White	36 - 47
Snowden	White	34 - 47
Nordonna	Red	36 - 40
Red Norland	Red	36 - 45
Red Pontiac	Red	37 - 50

With a high percentage of total solids, good storage characteristics, and appropriate shape, the Russet Burbank variety is the most popular variety grown under irrigation. Currently, it is the industry standard for french fry potatoes. However, other varieties were higher yielding on irrigated potato trials.

Production and Cultivation Practices

Seed bed preparation before planting will be determined by the previous crop. The soil should be loose at planting with a minimum of preplant tillage.

Seeding Rate and Depth

The amount of seed needed for planting depends on variety, distance between rows, the spacing within rows and the size of the seed pieces (Table 2). Seed pieces should be cut from tubers no larger than 280 grams for round varieties and 340 grams for Russet Burbank. Seed pieces cut from smaller tubers are more uniform in size, give better plant stands and usually more tubers per hill. Seed pieces should be between 42 gm. and 70 gm.

A healthy 30 - 57 gram seed piece is considered best to establish a vigorous plant. Plants from seed pieces smaller than 30 grams are generally slower to emerge and have less vigor. Small seed pieces are also more likely to decay before the plant becomes established. Seed pieces cut larger than 57 grams result in higher seed costs with little potential benefit.

Generally the center of the seed piece should be planted 5 – 10 cm below field level and covered with 5 – 8 cm of soil. Shallow covering usually results in quicker emergence, less seed decay, less blackleg and less rhizoctonia attacking the sprouts. However, the best seed depth will vary somewhat with soil moisture and temperature. Moist soil with temperatures averaging from 50 to 60 °F favor wound healing in the soil with minimum seed decay. Very deep planting may result in poor wound healing and lead to seed decay, particularly if heavy rains follow planting.

Growth Stages

The growth, development and **water requirements** of the potato plant can be divided into the following four stages:

VEGETATIVE. After planting, this stage of growth begins when the eyes break dormancy and produce sprouts. This stage has duration of 15 to 30 days and ends with tuber initiation. Stored soil moisture and spring rains are usually sufficient during this period to provide adequate moisture for proper development. However, soil moisture monitoring should be started soon after emergence. For disease control, irrigation should be avoided between planting and emergence. If the soil is dry prior to planting, irrigate before planting rather than after.

TUBER INITIATION. This stage of growth begins when tubers develop at the stolon tips. Approximate duration of this stage is 10 to 14 days. Stored soil and spring moisture supplies are usually adequate during this period however; soil moisture levels should be watched closely because water stress during this period can reduce the number of tubers produced per plant.

TUBER BULKING. A constant rate of increase in tuber size and weight occurs during this stage, unless a growth limiting factor is present. This stage can last from 60 to over 90 days, depending on the length of the growing season and presence of pathogens. **Tuber size and quality is closely related to moisture supply in this period.** Research has shown that the total yield of potatoes is most sensitive to water stress during mid-bulking. Mid-bulking occurs three to six weeks after tuber initiation, however, water stress any time during this period will have an effect on the total yield. Tuber growth is retarded by moisture stress and does not resume uniformly when moisture again becomes available. New growth and enlargement will take place at the top end while the other portions of the tuber remain stunted. Thus, especially in some long tuber varieties, constricted areas develop that are related to the stage of tuber growth at the time the moisture stress occurred. Other deficiencies in quality such as growth cracks and knobbiness are also related to moisture stress followed by periods of adequate or surplus moisture.

MATURATION. This stage of growth begins with canopy senescence. Older leaves gradually turn brown and die. This condition spreads throughout the vines and leaves eventually resulting in canopy loss. Tuber growth rates are lower than during tuber bulking. Potato plants require less water for tuber bulking during this stage because of reduced transpiration from the dying leaves.

Weed Control

Weeds reduce potato yields by competing for water, nutrients and light. Also, certain weed species can cause difficulty in harvesting, release toxins that inhibit crop growth, and harbor insects, diseases or nematodes that may attack potatoes.

An effective weed control program includes environmentally sound cultural, mechanical and chemical weed control methods. Crop rotations, cultivation and the use of different herbicides help avoid the buildup of resistant weed species. Certain herbicide residues from previous years can damage potatoes. Use a planned weed control program and avoid herbicides that will injure or reduce growth of subsequent crops. Always read the pesticide label for information on crop rotations and intervals.

Tillage and herbicides are the two primary means of controlling weeds in potatoes. Cultivators, harrows and rotary hoes are commonly used. The first tillage operation after planting is usually a "blind" cultivation or harrowing before the crop emerges. The number of tillage operations will vary, but three cultivations and two harrowing operations are common.

After emergence, inter-row cultivation is used to control weeds and to form a ridge or hill over the seed-piece and developing tubers. Besides controlling weeds, the ridge or hill helps protect tubers from sunburn (tuber greening), late season frosts, excessive rainfall or irrigation, and reduces the amount of soil to be moved at harvest. One danger of excessive cultivation and deep cultivation of potatoes is root pruning. Potatoes are a shallow rooted crop, with roots growing laterally 25 – 45 cm and downward to a maximum depth of one meter. Root pruning may be a problem with late cultivations, reducing the overall growth potential of the potato plant.

Fertilization

A potato crop makes a large demand on the soil for nutrients. The amount a 30 T / ha crop of potatoes will utilize depends on potato variety, climate, soils, and irrigation system management. The average nutrient content is:

Nitrogen – 90 kg.

Phosphorus (P_20_5) – 27 kg

Potassium (K_20) -- 136 kg.

One-third to one-half of these nutrients are found in the vines and returned to the soil. The remainder is removed with the harvested tubers and must be replaced.

Soil Testing

The best way to determine the amount of fertilizer to apply is by a soil test. Fields should be tested every year for nitrate-nitrogen and every two to four years for phosphorus and potassium.

With a good crop rotation, a certain amount of residual nitrogen will be carried over for use by potatoes. Potatoes following any legume such as soybeans, alfalfa, dry beans, or clover will benefit. Also, if sugarbeet leaves are green at harvest, some N would also be expected to be released the following year. Potatoes following corn or small grains may not inherit much residual nitrogen. Soil sampling before planting will indicate how much residual nitrogen is left in the soil but may not reflect mineralization of residues during the year.

Fertilizer Application

Fertilizer applied at planting should not come in direct contact with the seed pieces. The recommended method is to place fertilizer in two bands, each band one cm. to the side and one cm. below the seed pieces. Broadcasting is also acceptable. Application of all the required nitrogen in a single preplant operation is not a recommended practice. Fertilizing to achieve maximum utilization of nitrogen in potatoes on irrigated sandy ground requires split applications. A rule of thumb on medium to heavy soils would be one-half the needed nitrogen applied preplant and the remaining nitrogen needs applied as urea or 28% liquid solution at hilling. On sandy soils consider applying one-third to one-half at planting followed by one-fourth to one-third at emergence and the remainder at hilling.

Studies on irrigated potatoes show little to no advantage to applying more than 200 kg /ha of total nitrogen to reach optimum yields. The quality of the potato for storage also declines if excessive nitrogen is used.

All fertilizer products can be used in potato production. Dry product blends that match soil test needs and are broadcast applied prior to seedbed preparation offer management and application convenience. Also, during the hilling operation, the fertilizer is moved to the row with the soil, which concentrates nutrients in the active root growth zone. Equal management convenience can be obtained with a variety of fertilizer products that are sidedress applied in bands that the root system intercepts early in the vegetative growth stage.

Disease

High quality, healthy seed is essential to production of a good potato crop. Use only certified seed. Sanitize knives between seed lots and prior to cutting. Plant seed immediately after cutting. If possible, avoid irrigation to obtain crop emergence. Early irrigation can lead to early infection from Verticillium and to problems with soft rot and blackleg.

Potatoes should not be grown more often than every three years on the same piece of land. This reduces carryover of diseases such as early blight, silver scurf, late blight, and Verticillium wilt. Potatoes should be monitored beginning in late June for both early blight and late blight. Early blight is common on irrigated potatoes. Fungicide applications should begin when early blight is beginning to show up on the lower leaves of the plants.

Notes relative to observed practices on some Mongolian farms:

Removal of potato flowers – There is no reason to remove the flowers from potatoes. There is no improvement in tuber yields with this practice. Removing flowers actually reduces yields by taking labor away from such important tasks as removing weeds.

Removal of green potato leaves – The only way a potato tuber can get photosynthate (sugars and starches) is from the leaves. Any leaf removed will only serve to reduce yields.

APPENDIX 5

UNDERGROUND CELLAR MANUAL FOR VEGETABLE STORAGE IN MONGOLIA
GARY W. HICKMAN, CONSULTANT

This report is based on field observations of vegetable farms in Mongolia in July and August of 2005.

New vegetable production ventures by herder families in Mongolia have resulted in the production of surplus product. The primary crops grown, that need storage cellars, are potato and cabbage. Other crops include onions and carrots. Good cellar designs satisfy three conditions: coolness, darkness and proper humidity.

Optimum storage temperatures and humidity levels for specific crops are given in the general recommendations section of this manual. In summary, most potatoes are best stored at temperatures of 4 to 10 C. with a humidity level of 90%. This is especially true for the long-storing varieties such as russet Burbank. Optimal cabbage and carrot temperatures are 0 C and 96% humidity. Onions are best stored at temperatures of 0 C and 70% humidity.

Given the local conditions in Mongolia during winter months, the challenge will be to keep storage conditions from going below freezing.

Based on interviews with farmers and local consultants, the soil freezes down to depths of 0.5 – 2.5 meters during the winter. The maximum expected soil freeze depth will determine the cellar parameters at each specific location. The top of the actual vegetable storage should be below the expected soil freeze depth.

Several good cellar designs have already been constructed at various farms in Mongolia.
These are basically pit rooms dug into the ground, covered with a wooden roof, and the removed soil placed on top of the roof. Exact dimensions are not important, other than depth.
For a 20 ton storage structure, the following dimensions have been used in Mongolia:
Depth- 4 meters, width- 5 meters. Top soil over wooden roof – 2 meters deep.

Wooden shelves should be provided to keep stored crops off the ground. If soil water tables are high, drainage out from the cellar should be provided. This can be accomplished by installing perforated pipe around the inside of the cellar and sloping is away from the inside.

For humidity control, closable vents should be installed from the cellar ceiling to the outside. These vents should also be screened to prevent rodent entry.

To help reduce disease incidence in the cellar, air movement should be considered. Small solar electric powered fans could be used. Also, even a small amount of heat supplied to well-insulated cellars during very cold periods may help keep temperatures above freezing. This could be accomplished with solar electric (or wind electric) infra-red heat lamps. Ordinary white light bulbs should not be used with stored potatoes as this would promote “greening”.

Cellar doors and roof should be insulated to restrict cold entry. Simple styrofoam sheets can be used.

An excellent leaflet from Alaska, with winter conditions similar to Mongolia, is below.

UNIVERSITY OF ALASKA, FAIRBANKS, COOPERATIVE EXTENSION SERVICE
VEGETABLE STORAGE IN ROOT CELLARS

by Michele Hébert
Land Resources Agent
HGA-00331

In Alaska, cold winter temperatures and cold soils all year long, make root cellars a good method for storing vegetables. Root cellars offer gardeners a method for storing produce through the winter or for holding produce until there is time for canning and freezing. Consumers can also use root cellars to store produce bought in bulk from the farmers market or grocery. High quality, locally-grown vegetables can be available from the root cellar throughout the winter.
Stored fruits and vegetables are living organisms and to keep the quality and nutritional value high, certain storage conditions should be met. The best conditions for each crop will vary, but the important requirements include temperature, moisture, and ventilation. To have the best success using cold storage, select late-maturing varieties of vegetables that have been allowed to grow late into the fall and fully mature.

Temperature
During the day, plants make food through photosynthesis. At night or during storage, plants respire or use the stored food to survive and keep alive. To keep produce at the highest quality, it is important to slow down the growth and respiration with cool temperatures. Respiration reduces quality and speeds up with warmer temperatures. The optimum storage temperature for most vegetables is between 0° and 4.4°C. This temperature can be maintained by a combination of utilizing insulation on walls and ceilings, thermostats, and a heat source when needed. An adequate heat source can sometimes be a little as a 100 watt light bulb placed near the floor. Keep in mind that heat rises and warmer temperature will be found at the top of the root cellar. Thermometers can be positioned throughout the cellar to monitor temperatures.

Humidity
High humidity (between 80 to 95 percent relative humidity) keeps vegetables from drying out. The exception to this rule is with cucurbits (squash family) and onions—vegetables that produce a thick wall. These vegetables prefer dry storage conditions and tend to mold when the moisture is high. The easiest way to keep the moisture high is to have a dirt floor which helps the root cellar keep constant moisture during the winter. If the floor is concrete or wood it may be necessary to place several pans of water on the floor. Vegetables are 90% water. The fuller the root cellar the higher the humidity. That is why a small, full root cellar will work better than a larger one.

Ventilation
Ventilation is used to help control the temperature and humidity. Excess moisture that encourages mold can be exhausted and the room aired out when not in use. Be sure the ventilation system is screened to keep rodents out.

Harvest and storage
Choose to grow vegetable varieties that are late maturing or have good storing qualities.
Harvest as late in the season as possible before a killing or damaging frost. Vegetables should be harvested in the morning after the dew has time to dry but before the afternoon heats up the vegetables. Remove the field heat by cooling in a cold place. Produce can be grouped according to storage requirements into four groups; cold and very moist, cold and moist, cool and dry, and warm and dry. Most vegetables need a cold and very moist
storage condition because of thin skin or leaves. Thin-skin produce including beets, kohlrabi, turnips, carrots, parsnips, radishes, and cucumbers are harvested leaving a 1/2 inch stem and stored to retain moisture. This can be done with packing material or perforated plastic bags. Layer vegetables in packing materials such as moist sawdust, sand, and peat moss. Leafy vegetables such as celery, Chinese cabbage, endive, kale, and cauliflower should be lifted out of the garden with roots attached and replanted in moist

packing material. Vegetables with strong odors such as cabbage and turnips are best when individually wrapped in newspaper to prevent drying out and reducing smells.

Potatoes and tomatoes need a cold, moist storage condition. Potatoes need to be cured in a warm environment before cold storage. Harvest potatoes late in the season and store in the dark at a warm temperature for 7 to 10 days to allow the potato to dry and develop a thick skin. Then potatoes should be moved to a cold, dark area. If potatoes are stored in crates or boxes together they will share moisture and keep each other from shriveling. Do not store potatoes above 4.4°C or they will begin to sprout. Tomatoes are harvested leaving a short stem attached. Place tomatoes one layer deep in a shallow box and cover with newspaper to keep them from drying out.

Onions, like potatoes, are cured for several weeks after harvest. This allows the skin to become papery and roots to shrivel. Onions are best stored in a cool dry location with good air circulation. Onions are often braided or put in a mesh bag and hung from the ceiling of the root cellar. Winter squash and pumpkins are best stored in a dry warm spot such as the corner of a room indoors. Cut as late as possible before a frost, leaving a 5 cm long stem. The more mature, the thicker the skin and more resistant to decay and drying out the vegetables will be. If stored in a moist location, squash will quickly mold.

Building a root cellar

A root cellar should be cold, dark, and damp and be in a convenient location. It is easier to control temperature and humidity in a small cellar. Most families can get by with an area 1.2 m x 1.8 meter in size. The most convenient locations may be a walled off part of a basement or garage area containing a window for ventilation. A common location in rural Alaska is in the floor of the kitchen. With an inside installation be sure to put a vapor barrier towards the inside of the root cellar protecting the rest of the house from excess moisture and rot. In both attached and separate structures select wood designed for direct burial for the walls and floor. Check with supplier to be sure that the wood treatment is not toxic in this application. Uninsulated masonry walls will conduct the cool ground temperature into your root cellar and are very durable. Water drainage is important for keeping out surface water in the spring and during summer rains. Insulate above-ground walls to protect from cold temperatures in winter and warm temperatures in summer. Be aware that seasonal frost can extend over 1.2 meters deep seasonally into the soil. Keep this in mind being sure to have the insulation extend below the frost line.