Online course

POTATO SEED PRODUCTION IN GEORGIA

JUNE
JULY
2022

Online Course on Potato Production for Georgia: Final Technical Report (FTR)

Jeffery W. Bentley, Jorge L. Andrade-Piedra

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Acronyms

ARC	Apical rooted cuttings
CIP	International Potato Center
FTA	Flinders Technology Associates
FTR	Final technical report
IT	Irrigation time
NPK	Nitrogen, phosphorous, potassium
PLRV	Potato leafroll virus
PVM	Potato virus M
PVX	Potato virus X
PVY	Potato virus Y
Q&A	Question and answer
RIL	Required irrigation lamina
RTB	CGIAR Research Program on Roots, Tubers and Bananas
USAID	United States Agency for International Development

Summary

The Online Course on Potato Production for Georgia was held to strengthen the potato seed production capacities of local and national technicians in the USAID Potato Program in Georgia. The virtual course was funded by USAID and organized by the International Potato Center (CIP) covering the following topics: pest and disease management, seed production, and fertilizer and water management.

The course was organized around six online webinars and six discussion sessions using CIP's Talent MS platform. Each webinar and discussion session took between 60 and 90 minutes. The online webinars included a pre-recorded presentation and a Q&A session led by the course instructors. The webinars were prepared in English by the course instructors (with input from the course organizers) and were translated (text and voice over) into the Georgian language. The discussion sessions mainly included panels, with the instructors asking questions to stimulate discussion, and responses from the participants or students (farmers, business people, extensionists and researchers). There was simultaneous English-Georgian translation for all Q&A and discussion sessions.

About half of the course participants were women.

The online webinars were held over six consecutive weeks (1 June—7 July), usually on Tuesdays (two webinars were held on Wednesdays). The discussion sessions took place that same week on Thursday.

A 10-question, multiple-choice test was given at the start of each webinar and near the end of each discussion session (one unique test each week) to judge how well the participants mastered the course material.

Students who attended at least five webinars and five discussion sessions received a certificate of participation.

The six units were:

Unit 1: Integrated management of late blight - Wilmer Pérez

Unit 2: Integrated management of viral diseases - Segundo Fuentes

Unit 3: Plant nutrition and fertilizer management – Elke Vandamme

Unit 4: Postharvest and seed potato storage – André Devaux

Unit 5: Production of seed potato - Jorge Andrade-Piedra

Unit 6: Irrigation and water management – David Ramírez and Javier Rinza

At the end of week 6, the participants evaluated the course, suggesting that they thought that the content, instructors and format were of high quality.

Acknowledgments

This course was conducted by the International Potato Center (CIP) and supported by USAID. Thanks to all of the instructors, Viviana Infantas and the IT staff at CIP/Lima, and to Rusudan Mdivani, Ia Mdzeluri, Ana Doijashvili, and the rest of the CIP staff in Georgia, to Alexandre Chkheidze (interpreter), and all those who took part in this course.

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The 6 webinars for this 2022 *Virtual Course on Potato Production* are available on CGSpace, at the links shown in Table 1.

Table 1. Links to presentations for the Virtual Course on Potato Production

Unit	Author	Title and link, English	Title and link, Georgian
1	Perez, W.	Integrated management of late blight	ფიტოფტორული ინფექციის ინტეგრირებული მართვა
2	Fuentes, S.	Integrated management of viral diseases	ვირუსული დაავადებების ინტეგრირებული მართვა
3	Vandamme, E.	Plant nutrition and fertilizer management	მცენარის კვებისა და სასუქის მართვა
4	Devaux, A.	Postharvest and seed potato storage	მოსავლის აღების შემდგომი პროცესები და შენახვა
5	Andrade-Piedra, J.L.	Production of Seed Potato	სათესლე კარტოფილის წარმოება
6	Ramírez, D. & Rinza, J.	Potato water requirements, partial root-zone drying irrigation and effective use of water	კარტოფილის მოთხოვნა წყალზე, ფესვთა ზონის ნაწილობრივი გაშრობის ირიგაცია, წყლის ეფექტური გამოყენება

The presentations and other details are also available at the course website:

Potato Production Course - International Potato Center (cipotato.org).

UNIT 1. Late blight management

Instructor: Willmer Pérez, CIP

1.1 Late blight webinar

1 June 2022

Summary. Late blight is a devastating disease, but farmers can manage it with resistant potato varieties. The pathogen is an oomycete, not a fungus, and it can evolve resistance to fungicides if they are used improperly. Cultural measures also help to manage late blight, including good soil preparation, high hilling, adequate distance between potato plants, positive selection, negative selection and crop rotation.

Learning objectives. At the end of the unit, participants will:

1. Understand the plant health risk of imported potato seed.
2. Know the difference between an oomycete and a fungus.
3. Integrate basic epidemiological knowledge to manage potato late blight.
4. Know how to select fungicides with low environmental impact.

Question and answer (Q&A) session, late blight

Question from Mirian Chokheli. Are there any diseases that cause similar symptoms in plants that might be indistinguishable in the field?

Reply from Jorge Andrade-Piedra (CIP). There are several diseases that have similar symptoms. Early blight caused by Alternaria is a bit similar, also Septoria can be a little bit similar. In general, to distinguish late blight you need to see the mycelia on the underside of the leaves.

Reply from Wilmer Pérez. Another difference is how fast the spots grow. Late blight progresses quicker that Alternaria or Septoria. The most important symptom is to see the mycelia under the leaves.

Question from Mirian Chokheli. Are there any ways to increase immunity of potato to late blight?

Reply from Jorge Andrade-Piedra. We can use phosphite to increase the response of the potato a little bit. Phosphite can be applied, as Willmer mentioned in his presentation. This works with varieties that have some level of resistance.

Reply from Wilmer Pérez. Late blight lesions are also fast growing. Other potato diseases progress slowly. The most important thing is to see the mycelia under the leaves. In the USA and in Argentina, phosphite has been used for Fusarium, but this work is in an early stage. So far only two or three experiments have been done.

Question from participant. Is it possible to use systemic fungicides after flowering?

Reply from Wilmer Pérez. Yes, you can. The use of systemic fungicides after flowering is common. It is cheap and it is recommended, especially as a preventative application for late blight, especially when you grow susceptible varieties.

Question from participant. Some people are interested in how Phytophthora diseases are tested in the lab. Can we talk about this in more detail? Can you please elaborate more on lab techniques to identify late blight?

Reply from Jorge Andrade-Piedra. There are several techniques to identify Phytophthora. CIP has a manual for lab tests, so we can provide you with protocols for collecting samples using FTA cards and getting the genotype of the pathogen. And there are simpler techniques to grow the pathogen and to see the mating type of Phytophthora and the resistance to metalaxyl, a fungicide. We have a lot of experience on this. So, we can provide the lab manual, which has that information.

Reply from Wilmer Pérez. There are some protocols. CIP has published a manual for late blight protocols to characterize phenotypic tests and we can share those. The most important thing is the budget; you can collect, isolate and maintain the pathogen, but it is very costly. We are using FTA cards because they are simple, and they give confident results. They can be used in laboratories. Using the protocols depends on the agreements with the institutes or the national government programs.

1.2 Late blight discussion session

2 June 2022

Late blight discussion session, Willmer Pérez

Q&A Session

Comment from participant. Many farmers do not use resistant varieties of potato, and they do not use protocols of fungicides, and this has a negative effect on increasing resistance on strains of late blight.

Reply from Willmer Pérez. This is similar to other parts of the world. If you plant susceptible varieties you need to be careful with late blight infection. If you see that there are rainy days, and you are planting a potato variety that is susceptible to late blight, you need to take more care of your potato crop. If you can pant before the rains start, that may help.

Question from participant. How many important strains are there of late blight, and can we use the same fungicide against them all?

Reply from Willmer Pérez. All fungicides are effective against each strain of late blight. The exception is if the Phytophthora is resistant to metalaxyl, then that fungicide is not effective. That is why it is important to know which pathogen strain you have in each region.

Question from Giorgi. What are the main reasons for the establishment of late blight?

Reply from Willmer Pérez. Late blight requires high humidity, and cool temperatures between 15 and 21 degrees centigrade. If the potato variety is susceptible, that weather combination is even more dangerous. Phytophthora requires high humidity, in contrast to Alternaria, which requires a higher temperature and less humidity. If you use irrigation in your region, it is possible to get late blight.

Question from participant. If farmers follow organic production, are fungicides allowed?

Reply from Willmer Pérez. Yes, copper fungicide, but only 5 times, no more. It depends on the strategy of organic production. In some organic production strategies you can use resistance inducers like potassium phosphate. Or other fungicides may be permitted; Bordeaux mix is a fungicide that is often allowed in organic agriculture.

Question from participant. When is late blight expected the most?

Reply from Willmer Pérez. All the time, but if it is resistant, it depends on the temperature. In my presentation, I showed you a slide with the disease triangle. All plant diseases require the host (the potato, in this case), the pathogen (Phytophthora), and the environment. If all the conditions are optimal, the disease appears. You need to apply fungicide before the symptoms appear. If symptoms appear, it is possible for your whole potato plot to

be destroyed in a few days. It is different if you grow a resistant or moderately-resistant potato variety. If you see necrotic spots, it is possible to apply a fungicide, but if it is susceptible, the application will be less effective.

Question from Tekle. Thanks again, inducers sounds interesting. Can we say that if we have good aeration, it can prevent late blight a bit more? Because humidity will be lowered due to the air?

Reply from Willmer Pérez. It is important to know the characteristics of each variety. With more space between rows or between plants, you have better aeration, and you can avoid creating the microclimate that induces late blight infection, because the air dries the sporangia on the leaves and this is a good cultural practice to avoid late blight. Use adequate spacing between rows and between plants.

Question from Tekle. Can we use thinning of green leaves as is done in perennial plants? Or is just managing space enough?

Reply from Willmer Pérez. Managed space between rows is a good practice, but if you use moderate or resistant varieties, it is an even better option. If you use a lot of nitrogen fertilizer it is possible to have a greener plant, but potato plants with a lot of nitrogen fertilizer will be more susceptible to late blight. The fertilizer needs to be balanced.

Question from Tocha. Are there alternatives (other chemicals) to regular fungicides that can stop late blight, when you do not have any such regular fungicide at hand but need to act immediately?

Reply from Willmer Pérez. Late blight is very dangerous. If you grow susceptible varieties and the environment is optimal, this disease is dangerous. The best option is to use moderate or resistant varieties. If you grow a susceptible variety you need to apply a fungicide. Some countries apply plant extracts (of onion, garlic, or different plants) to the potato crop. There are moderate options, but if there is a lot of rain, you won't have the best results, because the rain washes off all the product from the leaves. The best option is to plant a resistant variety. Another issue is to plant before the start of rainy season. In other cases you can plant in places where there is a low incidence of late blight.

Question from Gocha Sirbiladze. Normally, at what stage of plant development is late blight to be expected most?

Reply from Willmer Pérez. Late blight usually appears at first development, or at the end of the growing stage of the potato, so all the stages are important. This is why if you are planting a susceptible variety, you need take care of it, and use fungicides preventively.

Question from participant. If we are using an irrigation system, what would be a preferable time to water the plants in order to avoid the establishment of late blight?

Reply from Willmer Pérez. It is best to spray in the afternoon, not at night, because the cool night temperatures are optimal for late blight development. So try to keep the plant leaves dry and avoid moisture.

Question from participant. About irrigation system, what is more efficient regarding fungi control, drip irrigation or sprinklers?

Reply from Willmer Pérez. Drip irrigation is better, if farmers can afford it.

Question from Tekle. What are the main problems when fighting against phytophthora? Are prevention and protection enough or there are other crucial factors to consider?

Reply from Willmer Pérez. It is difficult, especially if you grow a susceptible variety, and if you don't have enough money to buy fungicide or protective clothes. In your region if there are conditions conducive to late blight, it is dangerous to grow a susceptible variety. You need to know your varieties. That is why you need to know if your

region is conducive to late blight, and if your varieties are susceptible. Then you can grow potatoes in a season when late blight does not appear. Or apply fungicide when necrotic symptoms appear. It is necessary to use protective clothing.

Question from participant. Will drying the leaves protect the tubers from late blight? Can you remove those leaves to protect the plant?

Reply from Willmer Pérez. Yes, it is a good practice when the plot is small, or in a garden. But if you have more than two hectares it is difficult. A desiccant can help to avoid introducing soil spores to the tuber.

Discussion activity

The instructor, Willmer Pérez asks the participants to fill out four tables, to analyze late blight in Georgia (see Tables A.1 through A.4 in Annex 1).

Table A.1. Participants are asked to fill out a table to show the incidence of late blight per region (see Annex 1).

Comment from Amiran Jvaridze. Adjara is a seaside region, so it is more humid, and may be more conducive to late blight. But in reality, all regions are susceptible to late blight.

Another comment. Samtshke Javakheti is dry, so late blight is less common there, but the disease is still common for some people who do not follow cultural practices.

Willmer Pérez. Remember the disease triangle. That is why you need to know your region. Late blight requires a temperature between 18 and 21 degrees, but sometimes it appears at 10 degrees, and at other times at 25 degrees, if the humidity is high. Alternaria requires high temperatures and less humidity.

Comment from a participant. Many people are not following the proper protocols to manage late blight.

Willmer Pérez. Remember the disease triangle. This is why it is important to have resistant varieties. If you plant susceptible varieties, you need to be careful. You need to apply a systemic fungicide before late blight symptoms appear. If there is a rainy day, and humidity is high, you need to apply fungicides before you see late blight symptoms.

***Table A.2*.** This table asks if each potato variety has high, moderate or low resistance to late blight, and the country of origin of the variety (e.g., Netherlands or Georgia). The purpose is to find out if participants are aware of any resistant varieties in Georgia.

This sparks a warm debate, with participants speaking rapidly, and overlapping each other, so it is not always possible to know who is speaking. Mr. Khafi says that there is a “red variety” or Meskhetian Red, which is the most resistant variety.

A second person (possibly Rusudan Mdivani) adds that this is the local name given to the Unica variety, from CIP. This variety was released in Georgia and it was given the name Meskhetian Red .

Question from a participant. Do you have experience with other varieties that are highly resistant to late blight?

Another participant comments. Since we received some seeds two years ago in Kazbegi, they appear to have high resistance. In that region, with that variety, there have been no cases of late blight. I think those were CIP clones.

Ramaz Gogoladze comments. The most common variety is Jelly, from Germany.

Another person (possibly Diana Antonova). Jelly is quite susceptible to the disease, but CIP clones are more resistant. Most varieties are of moderate resistance, because farmers try to avoid the ones that have no

resistance. In some years Jelly had no tubers growing and the entire yield was lost. So one has to ask why Jelly is a popular variety. This has to do with its taste, but in Akhalkalaki no one is planting Jelly anymore. In Georgia we use a lot of different varieties.

Comment from Zura. Of those that are imported, most are Jelly.

Another person. I agree that Jelly is susceptible, but 90% is too much. The loss may be 40 or 50%.

I disagree, 90% is too much. There are more resistant varieties, such as Agria.

I agree, it is more resistant, but it does not sell as well.

We're not talking about how commercially viable it is. The question here is the resistance.

Jelly is moderately resistant, and another variety, Keli, is highly resistant. In Kazbegi late blight does not appear any more, and they are not even using fungicides. But in other places late blight is destroying vast amounts of potato.

Unica is the resistant variety.

Yes, of course, all of CIP clones are resistant, and Jelly should be avoided. So what are the seeds that we used two years ago?

Kriala is the name. It was very resistant. And another registered variety is Meskhetian Red which is also very resistant.

Comment from Willmer Pérez. That is important to know what are the different criteria to distinguish a variety. It is interesting to know that Jelly is the most popular variety in Georgia, and that CIP varieties are resistant. It is important to do a small experiment. Plant Jelly, and plant the variety from CIP, Unica (Meskhetian Red), and other varieties in a small plot, and don't apply fungicide. Then, plant the same varieties in another small plot, and do control disease with fungicide. Then when late blight appears you will know which varieties are resistant. And then you can know what is the best variety for each region. In a small test you can find the different treatments you need to control late blight, and you can do this experiment yourselves, in your own region.

UNIT 2. Managing virus diseases

Instructor: Segundo Fuentes, CIP

2.1 Virus webinar

7 June 2022

Summary. Viruses are microscopic pathogens that can infect living things to cause disease. Potato seed degenerates because viruses accumulate in the plants, as infected materials are planted over many seasons. Viruses can be transmitted in seed potato and by insect vectors e.g., aphids. Viruses reduce the size of individual tubers, and lower the overall yield. These diseases can be managed by using healthy seed, by removing diseased plants in the field, by planting resistant varieties and by controlling insect vectors.

Learning objectives. At the end of the unit, participants will:

By the end of this unit, the participants will:

1. Understand the principles to control viruses in potatoes
2. Describe how to integrate different components to manage viruses

Question and answer (Q&A) session Managing virus diseases

Comment from Segundo Fuentes (instructor). Remember that there are also some links at the end of the presentation, that you can click on to find more information on virus diseases.

Question from Mirian Chokheli. What is the percentage of infected plants that may not be showing symptoms?

Reply from Segundo Fuentes. It depends on the potato variety and on the viruses in the plants around your field. It could be low or high. If you have insects moving around, you probably have all of your plants infected, showing symptoms, but if you are protecting your plants, some plants start to show symptoms. You need to eliminate infected plants, by rogueing, to keep them from spreading to other plants in your field. Different contexts have different percentages of plants that are infected with viruses. Whether a plant has symptoms or not depends on the variety. Some varieties are resistant or tolerant and do not show symptoms. It also depends on temperature. For example, mosaic virus symptoms can only be observed between 12 and 24 degrees Celsius. Outside of those temperatures there are not symptoms, even though the plant may have the virus.

Question from participant. In the field, the seed is infected. This can be deduced by the LAMP method. In the case of Georgian technicians, is LAMP is a common method, and if not, should it be recommended, while examining the suspicious plant material to tell if it is in infected or not?

Reply from Segundo Fuentes. We use it in the seed production sector, because they can use it in the field and take decisions there. The machine that I showed in my presentation can run 8 samples at one time. You can do it in the field with a few samples, to take decisions in place. If you want to do it for routine testing, if you have one real time PCR machine in Georgia, you can set it to run a LAMP test on a large number of samples. Another advantage of LAMP is that the enzyme we use in the reaction tolerates inhibitors that can influence the common PCR test. In LAMP we can do almost crude extractions and put them directly in the reactor so we can get results. In PCR you have inhibitors in that sample, so LAMP is simpler to do in the field.

Comment from Mirian Chokheli. What is the distance that insect vectors can transmit viruses? The maximum distance that flying insect vectors can transmit a virus?

Reply from Segundo Fuentes. Insects fly up and then the wind moves the insect. Depending on the speed of the wind it can go far, almost 100 km. PVY is transmitted in a non-persistent manner, in two hours, if it is moving from one site to another, it can still infect plants. But PLRV, which infects the insect for its whole life, they can move a large distance and the insect can infect new plants. When you produce seed, you have to isolate the seed field, in a place where there is no commercial potato seed around, to prevent the movement of the insects. If the insect can move 100 km you have to think which is the best place to put your seed field.

Comment from participant. Could we receive these materials in the form of booklets?

Reply from Ia. The material has all be translated into Georgian, but it might be more feasible to print it in booklet format, to distribute it to farmers and communities, This can help the participants to become more familiar with LAMP, PCR and other techniques.

Reply from Segundo Fuentes. You need to know the principles behind the control measures. We will share a spreadsheet with participants on how to control viruses. If you understand the principles, you will understand how to control the diseases.

2.2 Virus discussion session

9 June 2022

Segundo Fuentes, instructor, reviewed how viruses are transmitted.

Like other plants, potatoes can be affected by many viruses; 35 have been reported for potato. They cause different kind of symptoms, and there are no chemicals to eliminate viruses from the plants. There is no cure, except eliminating the plant. So when you plant potatoes every season, viruses accumulate, causing disease. Only a few viruses are important because they affect yield. The most important ones are PLRV, PVY and PVX, which have all been reported in Georgia. You may also have PVM. To control them you have to know how they are transmitted. PLRV is transmitted by aphids in a persistent way, for the rest of the life of the insect, but PVY is transmitted by aphids in a non-persistent way. PVX is transmitted by contact. PVM is also transmitted by insects in a non-persistent way.

PLRV has a low virus load, so it cannot be transmitted by contact. PVY and PVX and PVM have higher concentrations in the plant, so they can be transmitted by contact, or mechanically. These viruses are replicated in the plant's cells. If we want to infect a plant with PLRV, we have to put the virus in the phloem. The other viruses infect the epidermal cells.

The spreadsheet discusses disease control per each type of virus (see Figure 1). Control of viruses is based on preventing the establishment, development and the dispersal of the viruses, mainly by using certified seed and resistant varieties. You can also reduce the virus source, or inoculum, because insects can move the viruses. You can also eliminate diseased or volunteer plants, and weeds which are also infected by viruses. Weeds also allow the aphids to develop there. You can also isolate potatoes in fields far from commercial ones.

Figure 1. Control measures and type of virus

	კონტაქტით Contact (PVX)	არამდგრადი გადაცემა Non-persistent (PVY)	მდგრადი გადაცემა Persistent (PLRV)
ინფექციის წყაროს ელიმინაცია Elimination of sources of infection			
(1) მასპინძელი მცენარეები / Host plants	x	x	x
(2) ინფიცირებული მცენარე(ურაყოფითი გადარჩევა) / Infected plants (rouging)	x	x	x
(3) სხვა მცენარეები (თვითმთესველი) / Volunteer plants	x	x	x
(4) სარეველები (ხელით ან ჰერბიციდით) / Weeds (manually or with herbicides)	x	x	x
(5) ნარჩენები / Stubble		x	x
თესვის და მოსავლის აღების პრაქტიკის მოდიფიცირება Modification of sowing and harvesting practices			
(1) თესვის დრო / Sowing time		x	x
(2) თესვის სიმჭიდროვე / Sowing density		x	x
(3) იზოლაცია (თესვა ინფიცირებული მინდვრებიდან მოშორებით) Isolation (sowing in areas far from infected fields)	x	x	x
(4) ფოთლეულის განადგურება / Foliage destruction		x	
(5) პირდაპირი თესვა / Direct sowing			
(6) ინფექციის ინჰიბიტორები / Infection inhibitors	x		
(7) თესლბრუნვა / Crop rotation	x	x	x
(8) მინდორში მიმოსვლის შემცირება / Traffic reduction in the field	x	x	
(9) კულტურების შეთავსება მცენარეებთან, რომლებიც არ არის ინფექციის მასპინძელი / Intercropping with non-susceptible crops		x	
გაუსნეველება / Decontamination			
(1) სასოფლო-სამეურნეო საქმეში / During cultural practices	x		
(2) ბოტანიკური თესლიდან სადეზინფექციო ხსნარებით/ მაღალ ტემპერატურაზე დამუშავებით/ ხანგრძლივი შენახვით From botanical seed with disinfectant solutions/ heat/ long-term storage			
(3) მანქანები (მოწყობილობები) და დანადგარები Machinery and cutting tools	x		
(4) პესტიციდის გამოსაყენებელი აღჭურვილობა (და სხვა) Pesticide application equipment, etc.	x		
(5) ჩითილის ნიადაგი/ მინდვრის ნიადაგი / Seedling soil/ Field soil			
(6) გორგლები / Tubers			
ვექტორის მართვა / Vector control			
(1) პირდაპირი ელიმინაცია ინსექტიციდებით Direct elimination with insecticides			x
(2) ინტერფერენცია გადაცემის მექანიზმში (მინერალური ზეთები) Interfering with the transmission mechanism		x	
(3) ვექტორების სიმრავლის შემცირება (ბარიერები, ხაფანგები, რეპელანტები) Reduction of the incidence of vectors (barriers of lived plants, repellents, attractants, yellow traps)		x	
მედეგი/ ტოლერანტული კულტურები / Resistant/tolerant cultivars	x	x	x
წინასწარი იმუნიზაცია / Cross protection			
ტრანსგენური მცენარეები / Transgenic plants			
ხარისხიანი/ სერტიფიცირებული ვეგეტატიური თესლი (კარტოფილის გორგლი) Quality/certified vegetative seed	x	x	x
ხარისხიანი/ სერტიფიცირებული ბოტანიკური თესლი (... გათვალისწინებით) Quality/certified botanical seed (considering...)			
(1) თესვა ნაკლები რაოდენობის ვექტორებით დასახლებულ ტერიტორიაზე Sowing in places with a low incidence of vectors	x	x	x
(2) ინფექციისადმი არამედეგი კომერციული სასოფლო-სამეურნეო კულტურებისგან დაშორება Away from susceptible commercial crops	x	x	x
(3) პრევენციული დამუშავება ინსექტიციდით (ვექტორები) Preventive application of insecticide (vectors)	x	x	
(4) მინდორში მიმოსვლის შემცირება Traffic reduction in the field	x	x	
(5) სიმპტომების მქონე მცენარეების ადრეული ელიმინაცია Early rouging (elimination) of plants with symptoms	x	x	x

PVX virus, is transmitted by contact, and can be managed by reducing traffic and decontaminating tools.

Non-persistent PVY is transmitted by tubers and aphids. It can be managed with natural barriers, by spraying mineral oils and by isolating your field.

Persistent PLRV is transmitted by insects can be managed by spraying insecticide and by isolation. Aphids are not the only insects that vector diseases. Beetles, thrips, whiteflies, and leafhoppers can transmit virus, but weevils don't.

PVX, PVY and PLRV are all transmitted over long distances by tubers.

PVY can be managed with certified seed and resistant varieties. PVY is the most difficult to control because many species of insects are vectors. PVY can be controlled by managing aphids.

Viruses infecting plants are in mixed infections. You may have two or four viruses together in the plant. You can control them all together. In commercial potatoes for consumption you apply insecticide when you see vectors, aphids, in the fields. For certified seed you have to use it as a preventative.

Use certified seed, resistant varieties, and eliminate virus sources, these are important control measures for all types of viruses. You can also eliminate weeds. After harvesting potatoes, the volunteer plants can produce infected plants. Eliminate volunteer plants and infected plants from the field. Viruses in stubble can move to healthy plants, especially if the stubble contains aphids. Aphids can move to healthy plants.

Different species of plants, besides weeds, can transmit virus to potatoes. Those host plants include Datura, Nicotiana and others. Some potato viruses can infect another solanaceous crops like tomatoes. If you have tomato fields close to your potato field the viruses can move between them. So, look for sources of contamination and eliminate them.

For PVX, if you use machinery, the equipment can be contaminated, and you need to clean equipment and tools after using them in the field.

For virus transmitted by aphids, like PVY, we can use vector control, like with mineral oil. Also use rogueing to eliminate all types of virus. You have to eliminate infected plants when they are young and more susceptible to viruses. Traffic reduction is especially for PVX.

Intercropping with non-susceptible plants can be used, especially to control viruses transmitted by insects, because the other plants act as a barrier, where the insects clean their mouthparts of virus. Crop rotation with non-susceptible crops can also be used for all types of potato virus.

Infection inhibitors can be used to control PVX.

Managing distance between plants is important, to prevent aphids from landing on the plants. Sowing time can also manage migration of insects that are vectors of viruses.

If you want to avoid chemical insecticides you can try natural extracts from capsicum, to keep the insects away from the plants. Some people are applying protein extracts from legumes or milk to the plant to increase the resistance of the plants to viruses.

Question from participant. Are there any biological ways of controlling weeds?

Reply from Segundo Fuentes. No.

Question from participant. What is the optimal isolation distance between plants and rows?

Reply from Segundo Fuentes. The distance is 25 or 30 cm between plants and 50 cm between rows.

Question from participant. And between fields for certified seed?

Reply from Segundo Fuentes. The farther the better. Also eliminate weeds around your field. Look for places where potatoes have not been grown before, because the viruses will survive in the weeds around the field. So do not grow potatoes where potatoes have been grown season after season.

Try to produce certified seed in the highlands, because there are fewer insect vectors there.

Rogueing has to be done at the start of the season, when plants are young and more susceptible to viruses.

Virus is eliminated with thermotherapy or meristem culture or by combining both. But when you use meristem culture, not all the plants are free of virus. Three of five may be free of virus.

For viruses transmitted by contact, it is not necessary to apply insecticide. Many species of aphids are able to transmit PVY. Several species of insects can transmit PVY, but PLRV is more specific to aphids.

Scab disease

At the end of the discussion session, Amiran Jvaridze asked if there was any way to manage scab disease if one planted potatoes and later discovered that the seed had the disease. The course organizers contacted Willmer Pérez, who provided the following answer, which was read at the start of Unit 3.

1. Use resistant varieties (if they are available in the growing area).
2. Use scab-free seed.
3. Seed treatments do not eliminate the pathogen but will provide some reduction on severity of disease.
4. Rotate infested fields small grains, corn, or alfalfa in rotations. Avoid red clover.
5. Maintain soil pH levels between 5.0 and 5.2 by using acid-producing fertilizers such as ammonium sulphate.
6. Avoid or limit the use of such alkaline-producing amendments as lime and manure.
7. Avoid moisture stress during tuberization. (Do not let the soil get very dry when tubers are growing)

UNIT 3. Plant nutrition, fertilizer management

Instructor: Elke Vandamme, CIP

3.1 Nutrition webinar

14 June 2022

Summary. Besides major nutrients (nitrogen, potassium, phosphorus), plants also need secondary nutrients: required in smaller amounts, but still important for growing a good potato crop. Organic matter improves the pH, structure and texture of the soil. Nutrients removed from the soil with the harvested potatoes must be replenished. Integrated nutrient management includes the use of manure, compost, green manures, inorganic fertilizer, crop rotation and intercropping. Nutritional needs can be measured by testing the soil, the plant or with predictive computer models.

Learning objectives. By the end of this unit, the participants will:

1. Understand the role of essential plant nutrients in potato crop nutrition and how to recognize deficiencies
2. Be able to explain how different soil properties affect soil fertility
3. Know the principles of integrated nutrient management and the practices that lead to improved nutrient cycling and management
4. Understand how fertilizer recommendations are generated and practices that improve fertilizer use efficiency

Question and answer (Q&A) session, Plant nutrition and fertilizer management

Question from facilitator (ice breaker). In many parts of the world, farmers hill up their potatoes. They take soil from the bottom of the furrow and place it loosely around the plants. This takes some time, but what are the advantages of doing this practice, of hilling up or cultivating potatoes?

Answer from the instructor, Elke Vandamme. Hilling up is widely practiced. It is a recommended practice, because it favors tuber development. It does loosen the soil, so it can contribute to erosion, but it is a good thing to do for the potatoes, because it facilitates nutrient uptake, and it help the tubers to grow properly.

Question from Amiran Jvaridze. You mentioned lime application, but not the time line, so how far ahead should we apply lime to raise the pH of the soil?

Answer from Elke Vandamme. You can apply lime during land preparation, or even at the time of planting.

Question from Mirian Chokheli. Can you recommend the right computer software to calculate nutrients during the process of fertigation? Is there any software that can help us to calculate the proper amount of nutrients that should be applied in fertigation?

Answer from Elke Vandamme. There is software, but it needs to be adapted and calibrated for Georgian conditions. Is that available for Georgia? It is available in general, but it would need to be adapted and calibrated for Georgia. We need data from the field and from trials and from soil samples to do that. I do not know if it is available. So I would like to learn that from this group.

Comment from Mirian Chokheli. It does not exist for Georgia. We have one called High Pass which is adapted to Israel. It is useful during fertigation to calculate nutrients, but we are not sure how different the results are for Georgia. It will probably require more research to establish the country specifics.

Comment from Elke Vandamme. On Thursday we want to discuss how to develop such tools.

Comment from Jorge Andrade-Piedra. We have at least two types of software. For the first type (to calculate the amount of commercial fertilizers needed for a solution for hydroponics) we really don't need a specialized software. But if we want a software to calculate the rate of solid fertilizer for soil, that is a different type of software. For the first type we don't need validation, but for the second type, for soil, I think we do need to adapt it.

Comment from Elke Vandamme. Yes, there are those two types. It is mainly the second type we have experience with in other countries and that needs to be validated for Georgia.

3.2 Nutrition discussion session

16 June 2022

Q&A Session

Question from Mirian Chokheli. Is it possible to recover nutrients that are lost from the soil?

Reply from Elke Vandamme. Yes. Even micronutrients can be applied. Toxicity is more difficult to manage, when nutrients are in excess.

Site specific recommendations are important, so that we can get good responses to fertilizer. Scientific nutrient recommendations are important, to make sure that nutrients are added efficiently, and that the inputs are tailored to the soil type and the location, and to the field's history, to make sure that we get good responses to these nutrients. To develop good fertilizer recommendations, the scientific challenge is complex. We talked about the methods. Recommendations can be based on soil testing, plant testing, or computer models that can predict the crop's needs, in areas where we don't have samples to test. Today we want to understand a bit better in the Georgian context what kind of information is available for potato farmers for fertilizer and nutrient recommendations. What kinds of information sources do you use, and what tools are available? Where are the gaps to start, or to think about new projects to improve information on fertilizer recommendations?

Discussion Question 1. Which information sources do you use for guidance on fertilizer use (rates, types, timing)?

Ramaz Gogoladze writes. I test fertilizers myself on my land. I choose fertilizers mainly for demonstration in my plots by examination.

Comment from Zurab Sadatierashvili. First of all, we find information about different needs of our soil for micro and macro elements. Mostly the fertilizer producers provide information based on standards of amount and rate to apply, whether it is potassium or nitrogen, and the farmers adapt it according to their own knowledge. It is always taking into account the recommendations and then adapting them.

Question from Elke Vandamme. Could Ramaz he be a bit more specific about what kind of fertilizer he tests and how he does it?

Elke Vandamme asks the group at large. Do you get information from the public sector, research centers or from NGOs that have a role in extension?

Ramaz Gogoladze writes. Mainly combined NPK with different percentage composition. Likewise for leaf feeding.

Comment from Mirian Chokheli. There is the Soil Examination Laboratory at the Agrarian University of Georgia, where farmers can bring in soil samples and get the results regarding the composition of the soil and also the recommendations for fertilizer use and based on that, it becomes easier to calculate the specific amounts of fertilizer to use. They have other methods also, such as calculating how much product to apply (in tons), and adjusting it, how much for specific needs. And for organic fertilizer, they deduce the specific coefficient for the soil where they work. They combine the data in order to deduce the nutrition requirements for different regions of Georgia.

Question from Elke Vandamme. Are these recommendations specific for potato or are they generic recommendations for all crops?

Comment from Zurab Sadatierashvili. Both. It can be specific to potatoes or other crops. We get specific information about what the soil has and what it needs, and the water content and other properties. Then later we also deduce the specific recommendations for potatoes, requiring less macro-nutrients and we try to adapt all the information we receive for specific varieties of potatoes.

Question from Elke Vandamme. Before we go to the next topic. I would like to turn around the question. Instead of ask what kind of information you are using, what are the gaps? Where do you need more support? What kind of information is missing for you to be able to apply the right types and rates of fertilizer in your fields?

Comment from Mirian Chokheli. We need computer modeling, to allow us to do site-specific modelling to determine the recommendations for different soils in different regions. We need computer software to help calculate these properties, instead of calculating it ourselves, based on our instincts.

And this doesn't concern specifically the potato crop, but all the crops. There are many nuances. Many times the companies give us basic information e.g., when pH is low or high, and how to adapt fertilizers, but it is mostly up to the calculations of each one. If software were available for each one, to allow calculations for each type of soil or variety, that would be fantastic, to simply getting these recommendations. If CIP could play a role in developing this software, that would be incredible to demonstrate to other farmers how software is used in other countries, with some training done.

Discussion Question 2. What kind of decision-support tools with fertilizer recommendation are available in (the area you work in) in Georgia? Are they based on soil testing, plant testing and/or predictive modelling? Which kind would be more useful to your work?

Comment from Elke Vandamme. So there is a system in place for soil testing. Is there a system in place for plant testing? Is there anyone who would like to add anything on this topic? There is a need for computerized models to help farmers get good, site-specific fertilizer recommendations. Are there any other tools available that we have not mentioned?

Comment from Zurab Sadatierashvili. Yes, there is plant analysis that is available in Georgia that helps them to determine if you need potassium or nitrogen, for example.

Question from Elke Vandamme. Do farmers use it? If not, what are the bottlenecks?

Comment from Zurab Sadatierashvili. It is rare, mostly larger farming industries use it, because of the high cost. It is difficult, because of the management required. The bigger farmers have representatives in the city who can manage the information. But in the villages farmers would need help managing it.

Question from Elke Vandamme. Is this the same for soil testing? What is the percentage of small farmers who can pay for soil testing costs?

Comment from Zurab Sadatierashvili or Mirian Chokheli. Two years ago the cost was around $120 (300 laris) and that is not affordable. Even for the main elements, in all these cases, it is very costly for farmers and not affordable.

Discussion Question 3. Which actors could be engaged to develop improved decision-support tools with fertilizer recommendation in Georgia? And to make them available to end-users (farmers)?

Comment from Elke Vandamme. How can we fill those gaps? There are two aspects. It would be great if an organization like CIP could help, but which other actors in Georgia could help to develop such models? And in

what form would you like such a tool to be available? As a website? As an app on your smartphone? A brochure? Which form of information would be most useful?

Comment from Nino Janukashvili. Websites could be useful and apps. Both could be feasible. Many parties are involved in this issue. The agrarian sector, the public sector and there are so many local farmers. It becomes difficult to involve them all and brochures could be of use too, especially for local farmers without internet. So there is a question as to who could help so many farmers manage all these processes and adapt it to specific contexts. The computer modelling could be helpful e.g., if it was a website with information on site-specific requirements, and farmers could log in and receive information specific for their regions, that could help to determine rates for specific sites. If you consider specific Georgian climate conditions and adapt them in the computer, it could be helpful and not as complicated as one might imagine. And that could really help us to get quick recommendations on fertilizer use.

Comment from Mirian Chokheli. I want to emphasize that brochures could be important, because not every farmer has access to internet.

Question from Elke Vandamme. I have not heard much about the actors. What type of partners could be engaged for developing and testing a method? When such a method is developed it requires a lot of testing before making it available to the wider public.

Comment from Mirian Chokheli. There are research agencies and consulting agencies that do help. Mainly they work under the Ministry of Agriculture of Georgia and it is easily accessible to most farmers. It would be helpful for local farmers to take part in developing the procedures, because they know the requirements of specific regions best, so that it will be open to the public.

Question from Elke Vandamme. You know that fertilizer prices are very high, as a result of various crises, including the Ukraine War. That has prompted many actors and governments to think about how we can improve nutrient recycling, and improve circular economies, so that nutrients that are lost through harvest are brought back in organic forms. I want to open the floor to discuss if you think this should be looked into in Georgia, and what are the restrictions to using organic nutrient sources, and how can we overcome these constraints to reduce the dependency on inorganic fertilizer.

Comment from Zurab Sadatierashvili. There are two problems. One is the need to have an animal farm on the property in order to have manure. And it requires processing and there is a huge problem of weeds. So a helpful thing would be bacteria-based nitrogenous fertilizer. We use nitrogen-fixing bacteria to promote soil nitrogen content when planting crops like potatoes and maize. So there are many issues associated with organic fertilizer. It takes a lot of time and energy to use.

Elke Vandamme. What would be needed if we wanted to move forward to increase the use of organic inputs. It is not always available and it requires a lot of energy. So what solutions are needed to overcome these constraints?

Question from Jeff Bentley (facilitator). Are there any other sources of organic fertilizer, besides manure?

Comment from Amiran Jvaridze. We use compost. Some farms use it based on the remains of plants.

Question from Diana Antonova. What is your advice to make it easier to improve the use of organic fertilizer? What recommendations can you make, besides manure and compost?

Reply Elke Vandamme. Try to close loops and look for more efficient ways to get access to organic nutrient inputs that may be available from other businesses or other locations. Look for supply chain efficiencies. And second, mechanization to reduce the burden of transporting and applying. Some small-sale mechanization would be make it useful to use these inputs and incorporate them into the soil, because there is some hard labor involved.

UNIT 4. Post-harvest

Instructor: André Devaux, CIP

4.1 Post-harvest webinar

21 June 2022

Summary. A potato store is not a hospital; quality is not improved in storage, but it can be lost. Avoid mechanical damage at harvest, and sort out the diseased tubers. A mature, healthy skin helps the potato to avoid weight loss in storage. Store ware potatoes at 3 to 5° centigrade, and 92% humidity. Potatoes need air, so the store should have ventilation. The building should be clean, dry and insulated. Potatoes for seed should have short, strong spouts. Exposing the tubers to light induces them to become green, which is good for seed potatoes.

Learning objectives. By the end of this unit, the participants will be able to:

1. Understand the concept of storing potato tubers in optimum conditions with a minimum of deterioration of quality and quantity between harvest and next planting
2. Describe the key phases during seed potato storage and actions required

Question and answer (Q&A) session, Plant nutrition and fertilizer management

Question from Amiran Jvaridze. What is the maximum length of time that you can store potatoes?

Reply from André Devaux. It depends on temperature. You can store during the winter time for six or seven months. In cold storage, as we have in Europe, people can store potatoes from October to April or May, for 8 or 9 months. It also depends on storage conditions. Some varieties have a longer dormancy and you can keep some longer than others. It depends on the quality of the potatoes you put into the store.

Question from Nino Janukashvili. I have a potato storage unit in Kazbegi. During the winter there is condensation and the roof is covered with water layers. What are the ways that I can overcome this? Can I implement improved ventilation? Or are there better ways to overcome this problem?

Reply from André Devaux. So the roof has some condensation. Is the water dripping on the potatoes?

Clarification from Nino Janukashvili. No, it isn't dripping. It is mostly in the corners between the roof and the walls and mold is forming.

Reply from André Devaux. The key element is ventilation. One way to improve storage is to have a false floor, which allows air to go below the potatoes, or you can have ducts below your potato bulk, so the air can circulate from below. It is good to have an exit hatch, an exit hole, so the store is ventilated and that will limit condensation and avoid rotten potatoes from high humidity. In the picture in my presentation, with the young woman in Peru, the potatoes were rotting, because the ventilation wasn't good and there was some accumulation of water, and it gets wet and that makes it easier to get disease.

Question from Zurab Sadatierashvili. There are several options. Some storage structures are state of the art and others are more limited and handmade. Are there any management methods that are accessible for Georgia? When should we turn ventilation on and off?

Reply from André Devaux. Potato storage depends on various factors. It is important to select your seed tubers well before you put them in the store. Remember that a potato store is not a hospital; if you have potatoes with disease they will not get better in the store. The potatoes must be dry, and ensure that if you are under rustic conditions, you should wait for two weeks before you start the ventilation, to allow the potatoes to be cured, so the skin will be stronger. Then start the ventilation. Ideally it is good to have ducts below the potatoes and

an exit hole on top to allow fresh air to circulate and to eliminate CO2. Cold temperature and good ventilation is the best advice to store potatoes. In Georgia for how long do you store the seed tubers? Is it more than 6 months?

Answer from Zurab Sadatierashvili. Mostly yes, because we start in October until May.

Comment from André Devaux. So it is long-term storage.

Comment from Zurab Sadatierashvili. It is not so much about the quality reduction, but the sprouting. As we use ventilation with ambient air, in April the air is warmer and so the potatoes sprout by May in the storage unit.

Comment from André Devaux. When you get sprouts in storage in May, it could be good to remove those sprouts and then they go through a re-spouting period. The potatoes sprout because it is dark in the store. Eliminate the long sprouts and find a place where you can expose your potatoes to diffused light. Remove the long sprouts and the tuber will get several short, strong sprouts, which is good for the potatoes that you will plant. So it is good to have a space where you can do re-sprouting, and get sprouts that are strong and ready to be planted.

Question from Mirian Chokheli. Does desiccation with chemicals have an effect on the quality and duration of potato storage?

Reply from André Devaux. You use chemicals to control diseases. You may have problems with soft rots; if potatoes have been infested by late blight or by certain bacteria, these potatoes should be eliminated before storing. It is not possible to control late blight or bacterial diseases in storage with chemicals. Silver scurf can be controlled with chemicals. You can see it on the skin, and if it develops in the store, and you lose more water, so you get some desiccation. That chemical may be applied when you store, and a second time before planting.

Clarification from Mirian Chokheli. I was talking about desiccation of the green mass of potatoes.

Reply from André Devaux. That is due to evaporation and transpiration. If you have unhealthy tubers, which were harvested too early and the skin is too soft, that contributes to more evaporation and the tubers lose more water, and that contributes to diseases like silver scurf. So chemicals cannot help against damaged or poorly cured potatoes. You need to have a good curing period. First, you need to harvest your potatoes when they are mature, and not too early or the skin will be very sensitive. Do not ventilate too fast. Keep the humidity relatively high at the beginning, so it will allow the potatoes to be cured and will strengthen the skin, and then you can start the ventilation.

Question from Mirian Chokheli. Does the storage duration and quality depend on the size of the tubers?

Reply from André Devaux. Not directly. If you store very small tubers they might dehydrate faster, but usually the size of the seed tubers do not affect the storage length. If they are very small and they start to sprout, they will lose all their energy, and their water, and they will get dehydrated faster than bigger tubers.

Question from André. The effect of variety can be important on tuber quality during storage. Have you seen difference between varieties? Some have a longer dormancy period, and it is easier to keep them than those that have a short dormancy.

Response from Zurab Sadatierashvili. Definitely. There are significant differences between varieties.

Remark from Dali. CIP varieties have a shorter dormancy period.

Comment from André Devaux. When you store potatoes for a long time they start to spout earlier and it is more difficult to keep them.

Question from André Devaux. What are the main potato diseases that you observe in storage?

Reply from Zurab Sadatierashvili. Mostly late blight, but also some silver scurf.

Comment from André Devaux. I have seen in the pictures that farmers are storing potatoes in cellars in the house. What is the most common practice for storing potatoes in Georgia, in bulk or in bags? Have you seen a difference between the two systems?

Reply from Ia Mdzeluri. Storing in bags is more effective, because ventilation is better. Storing in boxes is the most effective.

Comment from Andre. Yes, boxes allow more air to circulate. The air can circulate below the box and in the spaces between the boxes. So that is a good option. Is pre-spouting common in Georgia, before planting?

Reply from Ia Mdzeluri. We do use it, mainly ware potato, for earlier harvest.

4.2 Post-harvest discussion session

23 June 2022

Discussion activity

Question from Amiran Jvaridze. How should one manage dry and soft rot in the field, because we don't have access to Thiabendazole?

Reply from André Devaux. Eliminate these diseased potatoes before storing them. These are diseases that normally come from seed tubers. There are different types of soft rot, so during the growing season if you have soft rot from bacteria, it is important to do negative selection, to eliminate diseased plants during the growing season to reduce the propagation of the disease in the field, and to have fewer infected tubers at harvest. At harvest, you should avoid putting infected tubers into the store.

Question from André Devaux. What are the main causes of losses at post-harvest in Georgia? And what are the percentages of losses?

Question from Amiran Jvaridze. Farmers notice silver scurf, but do not pay it enough attention, and they store them with other potatoes, and this disseminates the disease.

Question from André Devaux. Do you have late blight, and potato contaminated by it, causing soft rot?

Reply from Amiran Jvaridze. I have observed that late blight is quite common and we try to take measures against it. It is widespread around Georgia.

Question from André Devaux. So silver scurf and late blight are major causes of loss at harvest time. Do you have an idea of the percentage of losses at harvest? Is loss from these two diseases a main cause of loss?

Reply from Amiran Jvaridze. On occasions the farmers lose more than half of their harvest, but it can range from 20 to 30%. These diseased potatoes are selected out and eliminated. With late blight the spread of the disease during storage leads to significant losses.

Question from André Devaux. So what do you normally recommend to farmers when they face these problems?

Reply from Amiran Jvaridze. Mainly to eliminate the diseased potatoes, and to do their best to provide hygienic measures in storage and provide positive selection to have healthier potatoes to store.

Comment from André Devaux. When you have rotten tubers, selection is very important, as is ventilation during storage, and having the temperature as low as possible.

Comment from Zurab Sadatierashvili. We do not have forced ventilation, so that is a problem.

Comment from André Devaux. If storing in boxes would improve ventilation, you have better air circulation between boxes. I also recommend that farmers who store in bulk should put ducts below the bulk. Farmers who store in bags should keep spaces between bags. Within stores, make sure you have an opening so air can get into the store, and keep an air outlet in the roof.

Question from André Devaux. What is the quantity of seed tubers that farmers usually store?

Reply from Zurab Sadatierashvili. It ranges from 1 ton to 100 tons. The average depends on region. In some places it is too warm. But others store three to ten tons, or up to 50 tons. It varies across the country.

Question from André Devaux. For those who store three to ten tons, how do they store them?

Reply from Zurab Sadatierashvili. They store them in the attic or in the cellar. The potatoes may be separated by wooden structures. Sometimes they try to provide ventilation, by keeping some distance between the bulks. I could try and provide some pictures later.

Comment from André Devaux. It's good to know that some use boxes.

Response from Zurab Sadatierashvili. Unfortunately we have a big problem with boxes. Transportation is related to mechanization, which is not accessible to most small producers. So, they store in bulk and in bags. So I only know of two storages that have box storage. This is a big issue that is inaccessible to most farmers.

Question from André Devaux. Are they inaccessible because of their cost?

Reply from Zurab Sadatierashvili. Yes. And it is related to mechanization, providing farmers with more opportunities to get these boxes.

Question from André Devaux. Farmers who store 50 tons or more, in which conditions are they storing?

Reply from Ramaz Gogolazde. We have non-standard stores that are mostly pits in the ground. And large amounts of potatoes are stored there.

Question from André Devaux. That is interesting that they keep large quantities in pits. And what are the losses like?

Clarification from Ramaz Gogoladze. They are not pits; the ground is dug out and it has roofing, and walls, but it is underground.

Question from André Devaux. So, it is like a cellar. In these bigger stores, what is the percentage of losses?

Reply from Ramaz Gogoladze. 10 to 15%.

Question from André Devaux. This is due to disease or sprouting or other problems?

Reply from Ramaz Gogoladze. Mainly the cause is that many farmers are unable to do positive selection and do not have enough resources, and do not select out the unfavorable tubers and only start sorting after storage.

Question from André Devaux. That is a recommendation, to improve the quality of potatoes moving into storage. Do you have an idea of the improvements that can be made to the storage system and practices in Georgia? What are the most important services that farmers require?

Reply from Zurab Sadatierashvili. It would be favorable to provide farmers with primitive schemes and diagrams of how they can provide their storage units with ventilation, any outlines or technical aspects of affordable ventilation ducts. Is there any information that can be provided?

Comment from Ramaz Gogoladze. I agree. Especially guidelines on regulating humidity levels, on how often farmers should open doors and window to provide ventilation.

Question from André Devaux. There is a project funded by USAID and implemented by CIP. Could this project help provide training for farmers?

Reply from Zurab Sadatierashvili. As of right now, there is no intervention of this sort, but maybe it should be implemented in the future.

Comment and question from André Devaux. This could be really helpful to reduce losses. Strengthening farmers' capacities can help them to reduce losses. You have varieties with short and long dormancy. Do farmers separate them in storage or keep them together?

Reply from Zurab Sadatierashvili. Mostly they are stored in the same space. They are sorted out and separated from each other, but they are stored together.

Comment and question from André Devaux. That is important because the ones with shorter dormancy start to sprout earlier and can be planted earlier. Do farmers store ware and seed potatoes together, or do they separate them before putting them in storage?

Reply from Amiran Jvaridze. It is rare that they are separated. They are usually stored together.

Question from André Devaux. At harvest farmers keep their potatoes together and at planting time they select the smaller tubers for seed, and the bigger ones for ware potatoes, correct?

Amiran Jvaridze: Yes.

Question from André Devaux. If you harvest in October, when do they start to sell ware potatoes?

Ramaz Gogoladze. We start storing in October and in mid-June we start to sell ware potatoes.

Question from André Devaux. And what about the seed, when do you take that out for planting?

Ramaz Gogoladze. The same as ware potato. If it is stored in September or October, it is planted in May.

Question from André Devaux. But people are also eating potatoes in the winter, so can you not sell them in the winter and take advantage of the price increase?

Response from Ramaz Gogoladze. There is a period when potato distribution is more of a problem, we try to export ware potato to neighboring countries, but we try to store them until the price starts to go up. In May or April until mid-July farmers are forced to increase prices. They might store more, but distribution is sometime around this period.

Comment from André Devaux. If you store in October, by May or June your tubers may be sprouted.

Response from Ramaz Gogoladze. It depends on the climate. In colder regions, if the store is kept at about 3 degrees, sprouting can start in later spring, in April.

Comment from André Devaux. Do you use sprout control products?

Response from Ramaz Gogoladze. We do not have resources for this, such as exposing potatoes to diffused light. If the storage starts to warm up, we just take out the sprouted potatoes and plant them immediately.

Question from André Devaux. You do not use chemicals to reduce sprouting?

Response from Ramaz Gogoladze. That is not common.

Comment from André Devaux. That is a problem if you are storing seed and ware potatoes together. In our conversation on Tuesday (Section 4.1) you mentioned that the clones that have been selected with CIP have a short dormancy?

Reply from Zurab Sadatierashvili. The main requirement is that farmers adapt to the needs of the market, while resistance to late blight is not much in focus.

Comment from André Devaux. That is a good strategy, because at the end you need to sell your potatoes. If you look at the market, varieties with a longer dormancy would be an advantage for the market.

Comment from Diana Antonova. I work at the research center. We brought in 3 varieties from CIP in 2009 and registered them. I am not certain what the ID numbers are, but I wanted to reply to your question. We selected the varieties with higher yield that were resistant to drought. We are trying to select late blight-resistant varieties. In Adjara we have a problem with potato cancer. And Meskhetian Red was the most resistant.

Jorge Andrade-Piedra writes in the chat. I think Diana is referring to "potato wart" caused by *Synchytrium endobioticum.*

Comment from André Devaux. These potatoes that are more successful, are they well received in the market?

Comment from Diana Antonova. Meskhetian Red is more accepted in Vaneti, and in some of the more mountainous regions. Meskhetian Red is like Unica. It is not so widespread at this stage.

Reply from Mirian Chokheli. The red ones are not so widely accepted yet. The Unica variety develops a huge green mass that is problematic to work on, and the tuber is tightly linked to the root system. On larger areas it is problematic, but on smaller farms it can be easier to control. Meskhetian Red is similar to Unica, and it has a long dormancy phase, making it difficult to grow in some areas.

Comment from Diana Antonova. Meskhetian Red has better results in some areas, because in some areas it cannot go through its dormancy period. In some regions we have flowering in September, but not in other regions.

Comment from André Devaux. Is the market requirement different from one area to the other?

Reply from Diana Antonova. Correct. We work on this process in collaboration with CIP. We have these clones being tested and tried.

Question from André Devaux. Apart from CIP clones, how many varieties are grown in Georgia?

Reply from Diana Antonova. Generally we have Dutch varieties, Agrian, Jelly, German varieties, around ten popular varieties.

Reply from Ramaz Gogoladze. We have 15 varieties in our municipality, German and Dutch and in the last few years French varieties are brought it.

Question from André Devaux. Georgia is importing seed from those countries?

Reply from Ramaz Gogoladze. Yes.

Question from André Devaux. Do you have an idea of what percentage of seed is imported and what percentage is locally produced?

Reply from Diana Antonova. I am not aware of the exact percentage, but about 80% is imported.

Reply from Ramaz Gogoladze. That may be too much. It is mostly commercial producers who acquire this seed. Smaller farms buy these varieties from larger commercial farmers.

Reply from Diana Antonova. Yes, I agree.

Comment and question from André Devaux. Most small-scale farmers use seed that has been multiplied once or twice. That is a big challenge for the seed growers, to get into the market. What characteristics should CIP clones have to be competitive in these markets dominated by the Dutch and German varieties?

Reply from Diana Antonova. Better taste. The taste of Dutch and German varieties is a little more accepted than CIP varieties, but CIP varieties are more resistant to pests, diseases and to heat.

Reply from Zurab Sadatierashvili. There used to be a bigger demand for oval potatoes, but now the demand is greater for round potatoes. The main demand is the slightly yellowish potato that is round. That is for 85% of the demand. And there is some demand for the Picasso type with red eyes, 10 to 15%. Visual qualities are important for demand, followed by resistance, yield and so on.

Reply from Ramaz Gogoladze. The highest demand is for yellowish potatoes. There are also French fry potatoes that have some demand and Agria is the most demanded for requirements in food production such as chips. So the Arizona variety is not ideal.

Comment and question from André Devaux. Many characteristics must be taken into account. Potatoes for processing are different than those for the fresh market. Do farmers manage their potato seed at the end of the storage period in preparation to planting the crop? Is pre-sprouting common?

Reply from Ramaz Gogoladze. Farmers do not allow enough time for pre-sprouting. They store them so that they grow big sprouts, and then plant them directly.

Reply from Diana Antonova. In Akhalkalaki there was a storage made which met all the requirements for ventilation. I am not sure if the cooling system meets the standards. Other people on the call know more about it, but these types of storage should be funded by the government. Otherwise it is a luxury for small-scale farmers.

Comment from André Devaux. The potato diseases are a major problem. You mentioned late blight and silver scurf and not enough selection before moving to storage. That is one recommendation, to improve the selection, because a store is not a hospital. If you put in a diseased potato, it will not be cured in storage. Guide farmers in the structure of store to be used, and how to implement a ventilation system. It does not need to be so sophisticated. You can use ducts below that pile, if you are not able to use boxes. You can store in bags and they can be separated. The store structure should allow cold air from the outside, and it will warm up a bit as it comes in so you need an opening at the top for the air to move out.

So, we have disease control during the growing season, besides selection, and improving storage structures in simple ways. The third recommendation is to store varieties so that the tubers are separated according to dormancy. And before storage, separate seed from ware potatoes. Keep your seed separate; farmers should have an idea of the quantity of seed they will need for the following year, and they can have a bulk of seed separated from the ware potato.

UNIT 5. Seed Management

Instructor: Jorge Andrade-Piedra, CIP

5.1 Seed Management webinar

29 June 2022

Summary. Around the world, most potato seed is uncertified, moving through informal systems. Seed degeneration can be managed by using certified seed, resistant varieties, and on-farm management (including positive and negative selection). Apical rooted cuttings (ARC) are a way to grow quality seed in part by on-farm nurseries. When the market demands better ware potatoes, farmers are able to buy better (e.g., certified) seed. The RTB toolbox is a set of tools, available online, for studying and intervening in seed systems.

Learning objectives. At the end of this unit participants will be able to:

- Explain key concepts about seed production: seed, seed system, seed quality, seed health, seed degeneration
- Explain the factors that contribute to seed quality
- Describe the main pests and pathogens that cause seed degeneration
- List the components of the integrated seed health strategy
- Explain the importance of using resistant varieties to control viruses
- Describe the main techniques for on-farm seed management
- Explain the process to produce certified seed.

Question and answer session, seed potato

Question from Mirian Chokheli. What is the genetic class in Peru in terms of regulations for potato varieties?

Reply from Jorge Andrade-Piedra. For seed classes we have genetic, pre-basic, basic, registered, certified. And we have certified and non-certified. But it depends on the countries. In general the regulations are similar, but the terminology may change from one country to another. It is up to the countries.

Question from Mirian Chokheli. Are there any chemicals not allowed for producing seed potatoes?

Reply from Jorge Andrade-Piedra. It depends on the production system. If you produce for a conventional seed system highly toxic pesticides are usually not allowed, but other than that, there are few prohibitions on chemicals. However, if you produce for an organic market, you have several products that cannot be used.

Question from Diana Antonova. At the end of the training will we have access to these materials? These presentations were very helpful for us.

Reply from Jorge Andrade-Piedra. You will have access to these presentations (see Table 1).

Question from Mirian Chokheli. What about the ambient temperature and climatic conditions for producing seed potato? What role does temperature play and what are the norms e.g., if we have hotter climates with droughts are there practices to produce potatoes there?

Reply from Jorge Andrade-Piedra. For commercial seed production, the recommendation is to produce seed potato as far as possible from commercial plots and during seasons when temperatures are not high. Because we want to avoid aphids which transmit viruses. In many countries, production areas are in the highlands, to take advantage of low temperatures. For commercial seed, try to find isolated areas with low temperatures. But if we produce seed for our own plots then we will try to produce during the coolest seasons, while avoiding frost.

5.2 Seed discussion session

30 June 2022

Questions and answers

Question from Mirian Chokheli. Is there a certification system that does not start from individual plants, but by selecting good seed from the field?

Reply from Jorge Andrade-Piedra. You can start the production of certified seed using positive selection. That is called clonal propagation or clonal selection; it is positive selection combined systematically with negative selection. Using these two techniques over two or three years you can get good seed, probably not as good as in vitro plants, but the quality is fine. This has been applied in Rwanda in the 1980s to start the formal system. Now the tendency is to use in vitro plants. If we have local varieties, and it is not possible to have in vitro plants, then we can apply clonal selection that combines positive and negative selection for several years and we can get very good quality seed.

Group discussion

- What are the three main factors that limit seed quality in Georgia?

Reply from Diana Antonova. First, temperature in the lowlands where the potato quality is affected by warmer temperatures, leading to degeneration, which is not conducive to seed production. Second, higher temperatures allow for more insects and vectors which can lead to poor quality. Third, the storage infrastructure does not always meet the standards, and the wrong temperature and poor ventilation are associated with poor quality and high losses. There are many more factors but these are the main ones. We have many regions where they can produce seed, especially in the highlands.

Question from Jorge Andrade-Piedra. What region can be a special place for producing seed potatoes?

Reply from Diana Antonova. Samtskhe Javakheti region. Akhaltsikhe and Tsalka have the best conditions.

- What experiences (good and bad) have you had when using apical rooted cuttings (ARCs)? Can ARCs be used by any farmer?

Reply from Diana Antonova. Your project resulted in significant positive results and farmers were very satisfied. Everyone was impressed by the results and today they are surprised and they did not expect this effect. Last year in these three regions Samtskhe Javakheti, Akhaltsikhe and Tsalka, all the farmers who took care of the seed had good results. Those farmers proceeded with ARC this year, and with the appropriate technologies they have had significant results. If this technique gains in popularity, it will be implemented on a larger scale in Georgia, as the farmers were satisfied. There were ten women who produced ARC and it is a successful technology, with a promising future.

Question from Jorge Andrade-Piedra. Can it be used by any farmer?

Reply from Diana Antonova. In our research center we had a training last year and drip irrigation is of utmost importance because rain is not reliable. It is not a problem for farmers to have a small plot producing seed with ARC and once they have the seeds they can expand to a larger area.

Comment from Jorge Andrade-Piedra. Yesterday we talked about seed plot technique. Farmers can buy high quality seed, for example ARC, and identify a good plot and produce seed there, and if they apply good management, they will have good seed for the next season. It seems that farmers must have irrigation to apply ARC.

Comment from Ia Imdzeluri. We were selling seed potatoes and promoting the market, in the Georgian highlands, where irrigation is not common. Dali demonstrated irrigation to them. Because the region is very high, they rely on the climate, not irrigation. So despite the region being humid, we did explain the importance of irrigation and the results that come from it.

Comment from Jorge Andrade-Piedra. With soil-borne diseases, it is also important to avoid planting potatoes in a plot which was recently planted to potatoes. We should try to use drip irrigation and plant apical rooted cuttings in good soil.

- What is your opinion of farmers using their own seed? Can this practice be improved and how?

Reply from Amiran Jvaridze. This has positive and negative sides. The advantage is that farmers if abide by all the standards, and manage plant health, then the seed is of good quality and it is important to store them in the right conditions and sell or plant them. If all standards are applied, then this can be a good technique. But some farmers store seed potatoes in poor conditions. The seed potatoes might be infected. This can be a dangerous process, because often farmers buy seed potatoes from different small producers which leads to a risky situation, if potatoes are not stored properly and given sufficient health care.

Question from Jorge Andrade-Piedra. There are positive and negative things about farmers' saved seed. What you mentioned about seed health is important. What techniques would you recommend?

Reply from Amiran Jvaridze. Many farmers who produce seed potatoes do not use negative or positive selection. They put healthy and unhealthy tubers together in the storage, which is the riskiest factor. We have to make sure that seed potatoes are not infected, and that they meet the standards. In Georgia we have a huge problem with potato storage, and before we store the potatoes, I recommend that some of the tubers are analyzed for the presence of diseases that do not manifest symptoms visibly. This could help us to avoid invisible disease factors. And we can ensure better planting material for next year. There are many more options, but I want to emphasize this approach.

Comment from Jorge Andrade-Piedra. Selecting seed from the best plants, with no symptoms, would help a lot. If you have enough resources, we can analyze the tubers or the plants for viruses, for example. But in reality, that is difficult, so just using the naked eye to identify healthy plants and harvesting tubers from them, making another selection for the tubers, and using that healthy seed will help a lot. There are experiences which show that negative and positive selection can increase yield by 30%. Our project is working with two partners, and they have the cold storage, large facilities with good equipment. That is excellent, but we also need to find a way for small-scale farmers to keep their seed through the winter. Some of the information that André Devaux provided in Unit 4 can be used by small-scale farmers: just keeping the seed well ventilated, not in contact with the soil, and selecting the tubers well before storing them could help a lot.

In some countries, even in Georgia, most seed is produced by non-specialized farmers, as informal seed. So improving this system is important. We can try to make it a formal system with ARC and in vitro, but this takes a lot of resources and time. Another way to improve seed quality is to train farmers on using simple techniques, like positive selection and negative selection, and helping farmers to store potatoes correctly. And to use varieties that degenerate slowly, like the two CIP varieties we have released in Georgia that are resistant to PVY and PLRV, the two main viruses for potato production.

- Is it possible to enforce the use of certified seed in Georgia? Are there any exceptions?

Reply from Zurab Sadatierashvili. In Georgia no farmer is obliged to use certified seed. It is an uncontrollable market.

Comment from Nino Janukashvili. I would like to add that certified seed has to be accessible to the farmers, and implementing regulations to enforce the use of certified seed could be good, but it has to be accessible and affordable for the farmers.

Question from Jorge Andrade-Piedra. Are there any exceptions where farmers should be allowed to use non-certified seed?

Reply from Mirian Chokheli. By 2024, according to Georgian legislation, it will be compulsory to use certified seed for a wider market, but for personal use one will be allowed to use one's own seed. Seed for market will have to be certified, and registered as seed for market. This obliges legislation to be adapted according to EU standards.

Comment from Jorge Andrade-Piedra. So if farmers want to use their own seed, it will be for their own plots. If they want to sell seed, then they will have to buy basic seed or ARC and produce certified seed according to standards.

Reply from Zurab Sadatierashvili. This regulation will be postponed, because it has been done many times before, when these sorts of regulations are proposed, it is impossible to certify this amount of seed. There is no government structure big enough to certify this amount of seed. Mirian, you will understand the area that we are talking about and the large scale it would require to certify this amount of seed.

Reply from Mirian Chokheli. This is possible, but I cannot say how events will transpire. However, it might be implemented. There might be some postponing, but it is a possibility.

Comment from Zurab Sadatierashvili. I think it will take a lot of preparation, but it is a possibility.

Comment from Irina Tvauri. At this stage it will not be possible to implement this regulation.

Comment from Jorge Andrade-Piedra. We see very similar situations in Asia, Africa, and South America. In South America we have had regulations for 30 years, but most seed is produced by farmers. In Georgia we should continue working on the formal seed system, producing in vitro plants, ARCs or mini-tubers, according to standards. But we also need to realize that producing certified seed for all farmers would be quite difficult. So, we should also strengthen the local, farmer-saved seed systems.

- How do ware markets affect the production and use of certified seed?

Reply from Diana Antonova. In the future we will have more use of certified seed. Farmers will be able to produce higher quality ware potatoes and this will tie into having high demand for consumption potatoes. This may take 10 years to take place in Georgia, considering the pitfalls that have to be overcome.

Comment from Jorge Andrade-Piedra. We have to work with the whole value chain, from seed potato, to ware potato, to the final consumer. That is the final goal of our project, but it will take several years.

If you want to buy certified seed, I was talking to a colleague in Chile who produces seed potato. If a farmer wants certified seed, they need to order it one year in advance. You sign a contract, and then you get your seed in one year. It is a well-structured system. Before buying seed you have to make a contract with the person who is selling it. That is the same in the US or in Europe. They produce seed on contract, based on demand.

UNIT 6. Irrigation and Water Management

Instructors: David Ramírez and Javier Rinza, CIP

6.1 Irrigation and Management webinar

5 July 2022

Summary. Fresh water is an increasingly scarce and costly resource, and agriculture uses about 70% of the world's supply. Potato plants are sensitive to drought, and require more water than many crops. Water demand is assessed by calculating evapotranspiration or by measuring soil moisture, to recommend the time of irrigation. Drip irrigation and partial root-zone drying reduce the need for water. Partial root-zone drying may only be used after the flower buds appear in the potato plants. Thresholds can help us to optimize irrigation schedules to save 450 to 600 cubic meters of irrigation water, without sacrificing yield (see Annex 2).

Learning objectives. At the end of this unit participants will be able to:

- Understand the importance of saving water in agriculture.
- Understand the methods used to optimize irrigation in potatoes through water demand assessment and the appropriate irrigation timing.
- Become familiar with some research experiences from CIP regarding water management in potato.

Question and answer session, seed potato

Question from Mirian Chokheli. Is it possible to implement these methods with other crops?

Reply from David Ramírez. Yes. The idea is to know more about the crop. If we want to estimate the water demand it is important to know about their root system. Different formulas are needed to calculate the water lamina, which is the quantity of water required for irrigation, depending on the root depth. We have shown the value for potato, but if we are working with other crops you need to know their root depth to calculate that. Stomatal conductance is related to whether the plants have water or not; you need to estimate the water stress index based on thermal imagery, with calibration for different crops. So the value that we have shown for crop water stress index is 0.4, which is the appropriate value for potato. But it can also be calculated for other crops. For that it is necessary to perform some research to do these calculations.

Question from Mirian Chokheli. Are there any computer programs that could help us avoid using these complex calculations? Is there any software that could calculate it?

Reply from David Ramírez. For software we have evapotranspiration which is very complex and it needs a lot of parameters: wind speed, temperature, humidity, and atmospheric pressure. There is some software to do that and we have a link where is possible to go to the FAO 66 manual to calculate it in an Excel file. Or sometimes the weather stations can calculate potential evapotranspiration, because they have software that can do that. We want to move to using soil moisture to calculate water demand. The formulas are easy. You can perform this in an Excel file. This is an exercise we want to work on in our discussion session. We have a manual and two exercises. So it is possible to put these in Excel.

Comment from Jeff Bentley. There are several innovations for reducing the use of irrigation water, such as drip irrigation and alternating every other row. These are ways to save water without sacrificing yield, right?

Reply from David Ramírez. We have worked on this innovation at CIP; it is called "partial root zone drying." When you irrigate alternate rows, you even see more marketable tubers, with more nutrients, and more oxidants. This is exciting research, about understanding the crop by saving water to help to adapt to climate change.

Question from Amiran Jvaridze. In the highlands, such as the Samtskhe Javakheti region, there are areas with no irrigation. What should we do to maximize potato quality and help the potato to adapt without irrigation?

Reply from David Ramírez. Yes, we have focused on irrigation, but we have shown that for situations where water is available. If irrigation water is not available, we need to move to other issues. First, is to move to water harvesting, one of the most important methods to guarantee water for the next season. Water harvesting in some cases demands some investments, but there are some easy ways to collect water to provide it in the development stage of the crop. I suggest moving to this research to guarantee that water is available. Water needs to be available at tuber initiation: the most important phenological stage for guaranteeing production. You can also use some mathematical models to predict when is the most important time to start the growing season. The main thing is to save water, using water harvesting.

Question from Amiran Jvaridze. What should we do if there is no water at all and we cannot provide water? Will the crop reach the production stage?

Reply from David Ramírez. If you cannot collect water, I recommend being able to save the water that the soil has. Mulching is one method to save water. We have an interesting experience in India, using rice straw mulching. We are using rice straw to cover the soil. This is one method. The idea is to reduce evaporation to increase the soil capacity to retain water.

6.2 Irrigation and Water Management discussion session

7 July 2022

Discussion activity

The aim of the unit is to apply only the amount of water needed by the crop, to avoid wasting water. For the discussion activity, David Ramírez reviewed key concepts from the manual that he and Javier Rinza prepared for this course (see Annex 2). These included water demand, and evapotranspiration. Bulk density is related to soil dry mass (the weight of the soil without water), the volume of soil and soil moisture (the amount of water in the soil). You need to calculate these for your area. Bulk density is also related to compaction, which increases density. It is the dry mass of the soil, divided by the volume of the soil (Section 1.1.1 in Annex 2).

To calculate soil moisture see Section 1.1.2, in Annex 2.

Field capacity is the ideal state of the soil following irrigation; all of the soil pores are filled with water, but the soil is not so saturated that water is running out of it. When all soil pores are full of air, the plants wilt, and when the soil is saturated, water is wasted and nutrients may leach out. If the root zone is not irrigated to field capacity, the potato tubers will only grow near the surface of the soil.

Field capacity depends on the soil type. Sandy soil has more pores than clayey soil and can hold more water at field capacity. Calculate soil moisture at field capacity, to be able to irrigate until the soil reaches field capacity.

Question from participant. Do these parameters change with fertigation?

Reply from David Ramírez. They do not change, but with fertigation it is even more important to perform these calculations, because if you saturate the soil, you will lose nutrients, which are expensive, and the nutrients can go deep into the soil, which can contribute to contamination.

It is also important to calculate soil moisture and the bulk density of the soil, so we know how to optimize the use of irrigation water. Course participants can learn more about calculating these parameters by watching this video on bulk density measurement.

The two main types of irrigation are 1) drip irrigation or 2) furrow or gravity irrigation. For furrow irrigation you need to take into account the required irrigation lamina (RIL), which is the liters of irrigation water needed by the crop, divided by the area in square meters. To calculate this, you also need to know how deep the roots are. You can calculate that by digging close to the plant so you can see the roots, and measuring the root depth of 10 plants chosen at random, and taking the average depth. For details on how to calculate RIL, see Section 2.1.1 of Annex 2.

The wetted area is the size of the wet area on the profile of the furrow (sides and bottom), multiplied by the length of the row. The total wetted area is important for calculating the RIL. For drip irrigation the wetted area is higher, in the row bed (not in the furrow). Less area is wetted than with furrow irrigation. However, the calculation of the RIL is the same for furrow and for drip irrigation.

Question from Zurab Sadatierashvili. Can we repeat these experiments in Georgia?

Reply from David Ramírez. Yes, you can. We have done these calculations in Lima, Peru, but they can be done anywhere. You can and should do them in Georgia. You need to read the manual and do these calculations.

To calculate RIL you need to know the soil depth, and the soil moisture (Exercise 1, Section 4, in Annex 2). You also need to know the flow rate of the water in the channel (the volume of water divided by time). For example, if it takes 3 minutes to fill a 200 liter drum, you can divide 200 liters by 3 minutes to obtain the flow (in liters per minute). We also need to know the time needed to open the flow of water into the furrow i.e., the irrigation time (IT), in order to know how much water to apply to a field to optimize the amount of irrigation water.

Question from Zurab Sadatierashvili. This was an important and useful course, and irrigation was the most difficult topic. Understanding irrigation requires a practical session, not just a presentation. The same is true of disease management. It would be useful to have a field practical on irrigation and disease management.

6.3 Close of the online course

At the end of the above discussion session, the course organizer, Jorge Andrade-Piedra, showed the course certificate that will be sent to participants who attended at least five webinars and five discussion sessions. Jorge introduced Konstantine “Kote” Kobakhidze, of USAID/Georgia. Kote said he hoped that the course was very interesting, and he hoped that producers and specialists gained an important experience. USAID in Georgia is glad to participate in this project and hopes that the knowledge and experience gained will help to improve potato production in Georgia. He expressed a readiness to continue with the collaboration, and thanked the International Potato Center (CIP) for the webinars.

Test and Evaluations

Test

The students were invited to take a test, with ten questions, at the start of each webinar, which they could repeat at the end of the discussion session for that unit. Students' test scores tended to improve after taking the unit (see Table 2).

Table 2. Participants' before and after test scores for the 6 units

	Unit 1, correct answers (of 10)			Unit 2, correct answers (of 10)			Unit 3, correct answers (of 10)			Unit 4, correct answers (of 10)			Unit 5, correct answers (of 10)			Unit 6, correct answers (of 10)			Average increase
User	Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif	
1	6	10	4	4			9	8	-1		10		9	10	1	6			1.3
2	7	9	2	3	8	5	6	7	1										2.6
3	6	8	2	5	7	2	9	10	1	7	8	1	9	9	0	6			1.2
4	5	9	4																
5	7	10	3	3	5	2	3	6	3		9		5	9	4	3	5	2	2.8
6					8		6	6	0		8		7	7	0	6			
7	8	9	1		9		3												
8	7	8	1	2	5	3	5									5	5	0	1.3
9	5	8	3																
10	9	9	0																
11	9	10	1	5			5	9	4		9		9	9	0	5	4	-1	1
12	6	8	2		8														
13	8	8	0																

Evaluations

At the end of the course, the participants evaluated the instructors, the content and the format. Only two students filled in the evaluation.

Q1. How helpful were the course contents for your work with potatoes?

On a five-point scale, the average answer was 4.5 (between "somewhat helpful" and "very helpful.")

Q2. How would you rate the quality of the instructors (e.g., their presentations, their answers to questions)?

On a five-point scale, the average answer was 4.5 (between "high" and "very high.")

Q3. How would you rate the quality of the on-line format (e.g., quality of the zoom meetings, ability to log in and participate in the course)?

On a five-point scale, the average answer was 4.5 (between "high" and "very high.")

Q4. Do you have any suggestions for improving a future version of this course? (Optional)

One person answered, writing in "In my opinion, online trainings should not be held in the future!" (ჩემი აზრით სამომავლოდ არა ონლაინ ტრენინგები, რომ ჩატარდეს!)"

The student would probably prefer in-person training, which would be helpful for practical demonstrations.

Conclusions

This course on potato production has now been prepared in English and Georgian. The material is now available online, so that the course participants, and other stakeholders in the Georgian potato sector, can share and review them (Table 1). Most of the material is applicable to other countries, besides Georgia. In the future, the course can be translated to Spanish and other languages, and used it can be replicated in Latin America and the Caribbean (LAC) and other regions.

Annex 1 status of Late blight in Georgia

Four Excel sheets prepared for unit 1 by one of the participants, Amiran Jvaridze, on late blight in Georgia.

Table A.1 Incidence of late blight per region of Georgia

	Late blight incidence		
Region	High	Moderate	Low
Adjara AR	x		
Kakheti	x		
Mtskheta-Mtianeti	x		
Samtskhe-Javakheti		x	
Kvemo Kartli	x		
Shida Kartli	x		
Other region	x		

Table A.2. Name of variety and level of resistance and country of origin

	Resistance to the disease			
Potato variety	High	Moderate	Low	Origin of the variety
Agriculture (აგრია)		x		Netherlands
Jelly (ჯელი)		x		Germany
Scarlet Red (წითელის სკარლეტი)		x		Netherlands
Sophia (სოფია)			x	Netherlands
Meskhuri Red (მესხური წითელი)		x		Georgia

Table A.3. Potato variety and losses to late blight

Potato variety	Losses due to late blight (%)
Picasso (პიკასო)	80%
Agriculture (აგრია)	85%
Jelly (ჯელი)	82%
Scarlet red (წითელი სკარლეტი)	87%
Sophia (სოფია)	90%

Table A.4. Names of fungicides

Fungicide		Action	
Commercial name	Active ingredient	Contact	Systemic
Anthrocol (ანტრაკოლი)	Propines (პროპინები) 700 g/kg	x	
Alieti (ალიეტი)	Aluminum Fosetil (ალუმინის ფოსეთილი) 800 g/kg		x
Sakozebi M-45 (საკოზები მ-45)	Mancozeb (მანკოცები) 800 g/kg	x	
Universal (უნივერსალი)	Kisses მანკოცები 640 g/kg + Metalaxil (მეტალაქსილი) 80 g/kg	x	x
Curzat R (კურზატი რ)	Cymoxanil (ციმოქსანილი) 42 g/kg + Copper chloride (სპილენძის ქლორჟანგი9 689,5 g/kg		x
Ridonet Mts 72 (რიდონეტი მც 72)	Mancozeb (მანკოცები) 640 g/kg + Metalaxil (მეტალაქსილი) 80 g/kg	x	x
Iron (აირონი)	Copper chloride (სპილენძის ქლორჟანგი) 140g/kg + copper hydroxide (სპილენძის ჰიდროქსიდი)	x	

Annex 2 Irrigation manual written for unit 6

Calculating Irrigation time and lamina based on water demand under furrow and drip irrigation in potato

DISCUSSION SESSION: UNIT 6 – IRRIGATION

David A. Ramírez & Javier Rinza

Table of contents

I. Bulk density and soil moisture at field capacity

1.1 Theoretical basis

1.1.1 Bulk density

From an agronomic point of view, it is necessary to obtain the moisture content as a volume of water in a unit volume (or surface area) of soil. The bulk density (ρ_b) **must be** defined as the mass of soil solids divided by the total volume per total soil volume.

$$\rho_b = \frac{Ms}{Vt} \qquad \textbf{(1.1)}$$

Ms is the soil dry mass, Vt is the volume of the soil sample. $\rho_b$is generally expressed in g cm^{-3}.

1.1.2 Soil moisture

Soil moisture is defined as the water content in a unit volume or mass of soil, called the volumetric water content (θ, cm^3 cm^{-3} or %) or gravimetric water content (w, g g^{-1} or %), respectively.

$$\theta = \frac{Mw-Md}{Vt} \qquad (1.2)$$

$$w = \frac{Mw-Md}{Md} \qquad (1.3)$$

Mw is wet soil mass (immediately weighted after sampling), Md is dry soil mass after oven drying (at 105°C) soil sample to get constant weight, and Vt is the volume of the container (soil sample rings, see 1.3) used for soil sampling. θ and w can be referred in percentage multiplying 1.2 and 1.3 by 100. When w and ρ_g **are available,** θ **can be calculated as follows:**

$$\theta = w.\rho_g \qquad (1.4)$$

The soil moisture measure when soil porous are saturated of water is called soil moisture at field capacity (FC). In condition where FC can't be measured, it is possible to use some empirical equations to estimate it using sand percentage (%), or organic carbon (OC, %) and clay percentage as follows[1]:

$$FC = 46.48 + 0.1228 * Sand - 0.0053 * Sand^2 \qquad (1.5)$$

$$FC = 2.432 + 1.393 * Clay - 0.01264 * Clay^2 + 6.03 * OC \qquad (1.6)$$

1.2 Materials and equipment

Aluminum foil, hoe, oven, permanent marker, plastic hammer, polyethylene plastic (black color, 2 m), polyethylene bags, precision scale, soil sample rings (six at least), tape measure and vernier caliper.

[1] Rab et al. 2011. Modelling and prediction of soil water contents at field capacity and permanent wilting point of dryland cropping soils. Soil Research 49: 389-407.

1.3 Procedure

- To dig a hole of approximately 2 m long x 1.5 m wide x 0.20 m depth. Fill the hole with water and avoid exceeding the pit edges (Fig 1.1 a). Cover the hole with the polyethylene plastic ensuring the edges are as hermetically sealed as possible (Fig. 1.1 b).

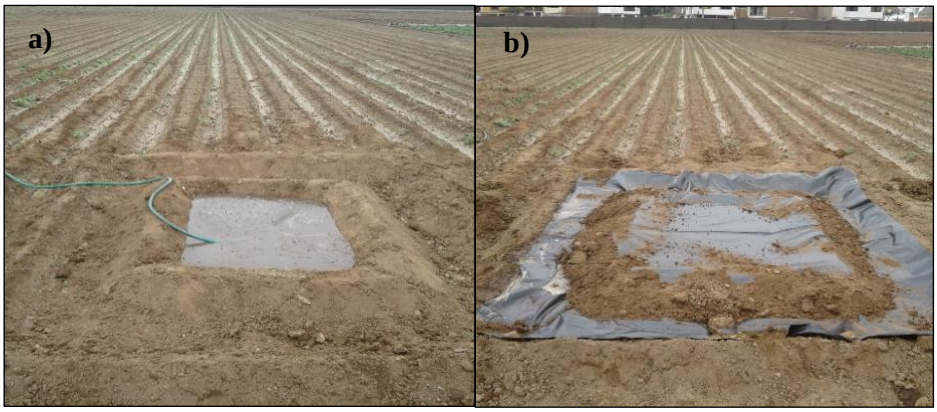

Figure 1.1. Hole to create conditions to achieve soil field capacity

- After 5 days dig a pit (approximately 0.8 m long x 0.7 m wide x 0.6 depth) into the hole area and tag 0, 10, 25 and 40 cm of depth levels on the soil profile (Fig. 1.2).

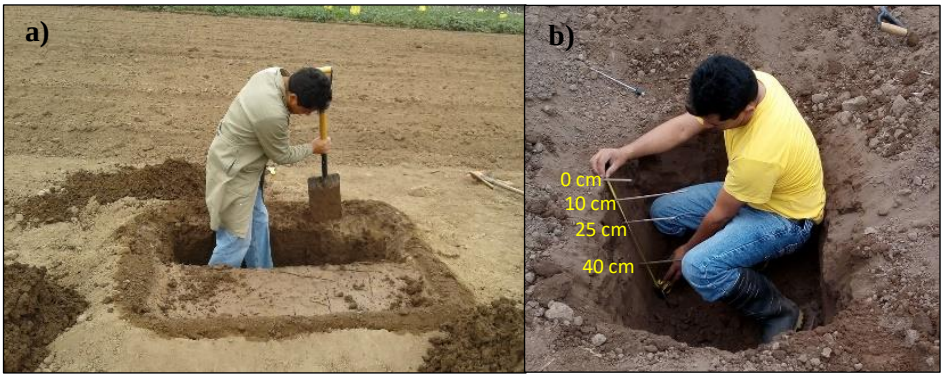

Figure 1.2. Pit in the hole area for the assessment of soil moisture at field capacity and bulk density

- Using a plastic hummer, introduce two soil sample rings for each marked depth level until they are flush with the profile (Fig 1.3. a). After that, carefully remove the rings with the soil sample, cover, and label them, and wrap them in aluminum foil to avoid any loss of the sampled soil (Fig. 1.3.b). More details in this video.

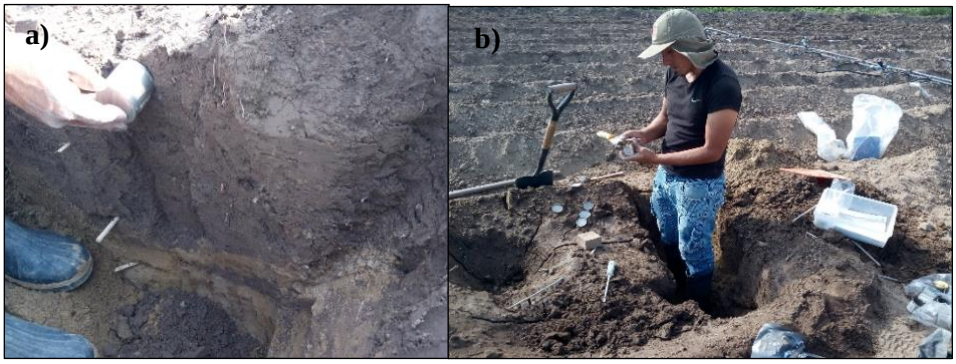

Figure 1.3. Soil sampling using soil rings at different depths on the soil profile in the excavation

- Using a precision scale, weigh the rings with sampled soil and dry them using an oven at 105°C until they reach a constant weight (assess them after 24, 36 and 72 h). Wet (Mw) and dry (Md) mass, and soil volume (Vt) are estimated as follows:

$$Mw = Mw_{R+S} - M_R \quad (1.7)$$
$$Md = Md_{R+S} - M_R \quad (1.8)$$
$$Vt = \pi * r^2 * h \quad (1.9)$$

Where Mw_{R+S} is the weight (g) of the ring with sampled soil immediately after soil sampling, Md_{R+S} is the weight (g) of the ring with sampled soil after drying process, M_R is the weigh (g) of the ring (without soil), r is the radius (cm) of the ring measured with the vernier caliper, h is the ring height (cm), π is 3.1416. ρ_b, θ and w for each assessed depth (0, 10, 25 and 40 cm) in the soil profile are estimated using formulas 1.1, 1.2 and 1.3, respectively.

2 Amount of irrigated water based on crop water demand under furrow irrigation

2.3 Theoretical basis

2.3.1 Determination of the required irrigation lamina (RIL) and irrigation time (IT)

RIL (mm or L m^{-2}) is the water quantity we must irrigate to supply the crop evapotranspiration and bring the soil to field capacity. We must know the soil moisture at field capacity, bulk density (ρ_b, **g cm^{-3}) (see Section I)**, and wetted side of the soil. This last variable is defined as the side over which flowing water is in actual contact with the channel walls and bottom (see Fig. 2.1). RIL is defined as:

$$RIL = 1000(w_{FC} * \rho_b - w_{act} * \rho_b) * Z \quad (2.1)$$
$$WA = ditch\ lenght\ (m) * wetted\ side\ (m) \quad (2.2)$$
$$IT = RIL * \frac{WA}{Q_s} \quad (2.3)$$

Where w_{FC} and w_{act} are gravimetric soil water content ($g^3\ g^{-3}$) at field soil capacity and the moment of the assessment (actual), Z is average root depth (m), WA is the wet area. Q_s is the flow rate of the channel in L min^{-1}.

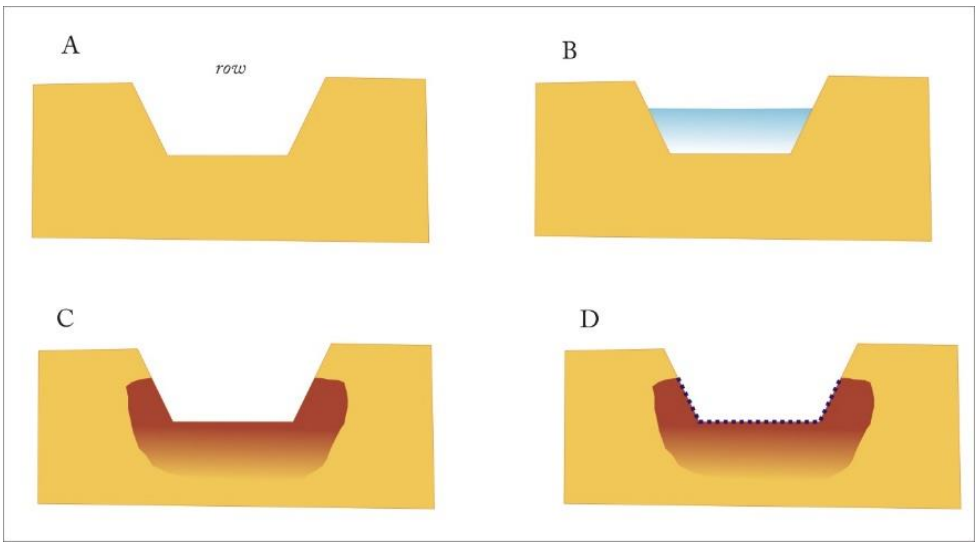

Figure 2.1. Schematic representation of the measurement of the average wetted perimeter. Transversal image of a row: A) before irrigation, B) during irrigation, C) immediately after the irrigation when it is possible to distinguish the wetted part of the row (dark color), and D) It is possible to measure the wetted perimeter using a tape measure in 20 points or rows (blue dotted line) in the plot; the average value can be used as the plot wetted side.

2.4 Procedure

The following steps allow establishing the time required for the irrigation lamina to supply the crop water demand:

- To measure soil bulk density and gravimetric soil moisture at field capacity in your soil (see Section I for details).
- To estimate crop evapotranspired water by assessing gravimetric soil moisture at root depth (see Section I).
- To define RIL using formula 2.1.
- To establish the irrigation time (IT) using formula 2.3 required to bring your soil at field capacity and supply the crop evapotranspired water or the crop water demand.

3 Irrigation time based on water demand under drip irrigation

3.3 Theoretical basis

The irrigation time based on crop water demand depends on the water quantity lost through the soil in the root zone and the water at field soil capacity. Under drip irrigation the irrigation run time (T_r, in minutes) and required irrigation lamina (RIL, in mm or L m^{-2}) are calculated as follows[2]:

$$RIL = 1000(\theta_{Fc} - \theta_{act}) * \mathrm{Z} \qquad (3.1)$$

[2] Yactayo, W., Ramírez, D. A., Gutiérrez, R., Mares, V., Posadas, A., & Quiroz, R. 2013. Effect of partial root-zone drying irrigation timing on potato tuber yield and water use efficiency. *Agricultural Water Management* 123, 65-70. https://doi.org/10.1016/j.agwat.2013.03.009

$$IT = \text{RIL} * \frac{A*L}{Q_s} \qquad (3.2)$$

Where, Z (m) is the depth of the root system[3] (Fig. 3.1), determined depending on the stage of development of the crop (0 - 0.35 m, for potato), θ_{FC} (see Section I) and θ_{act} is the field volumetric moisture and at plot capacity at the time of sampling (actual, see Section 3.3), respectively in cm^3cm^{-3}. A (m) is the row bed width (side to be wetted), L (m) is the length of the irrigation tape, and Q_s is the irrigation flow per furrow (in L min^{-1}), resulting from multiplying the dripper flow with the number of drippers per row.

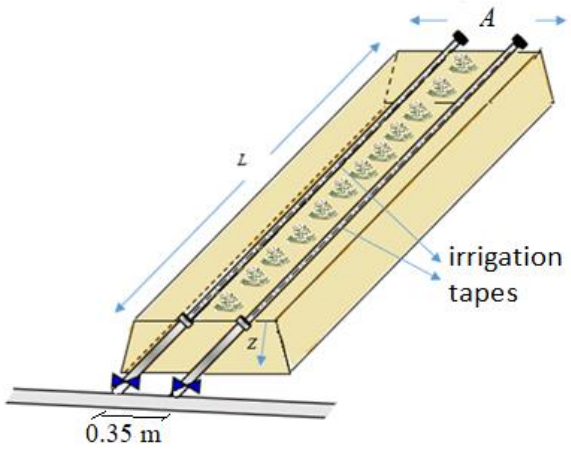

Figure 3.1. Dimensions of the volume of soil watered per row in the drip irrigation system, with A (0.45 m) x L (10 m) x Z (0 to 0.35m). Where A is the width of the furrow to be irrigated and L is the length of the furrow. Z is the depth of the root system of the crop.

3.4 Materials and equipment

Digital scale, oven, punch-type soil sampler (Fig. 3.2 a), plastic bags and petri dishes.

3.5 Procedure

- Extract 3 composite soil samples per plot with the punch-type soil sampler at the depth of the root zone of the crop (see Fig. 3.2 b).
- Place composite samples in previously labeled plastic bags.
- Take samples to laboratory to obtain determine fresh sample weight (see Fig. 3.3 a).
- Mix each sample in the plastic bag and separate about 200 g in previously labeled petri dishes (see Fig. 3.3 b).
- Weigh the wet sample from each petri dish (record the weight of the petri dish) and determine wet soil mass (Mw) by subtracting petri dish weight from sample weight.
- Dry in an oven per 24 h.
- Weigh the dry sample and determine wet dry mass (Md) by subtracting the weight of the petri dish from the weight of the entire sample.
- Use formula 1.3 to determine gravimetric soil water content (w) in cm^3cm^{-3}.

[3] It is recommended to assess the root length in 10 plants randomly chosen in the field.

- Determine the irrigation time (IT) and irrigation lamina (RIL) using formulas 3.1 and 3.2, and parameters shown in Table 3.1.

Figure 3.2: Punching soil sampler (a); obtaining the soil sample in the field (b).

Table 3.1.- Main important parameters for drip irrigationz

Bulk density (g/cm^3)	**1.6***
Volumetric humidity at field capacity (cm^3 cm^{-3})	0.32*
Dripper flow (L h^{-1})	1.56
Number of drippers per row (2 tapes with 0.2 m spacing between drippers)	104

*These values were determined for the soil of our experimental station in La Molina - Lima, Peru based on the collection of data in 2 pits established in experimental potato fields.

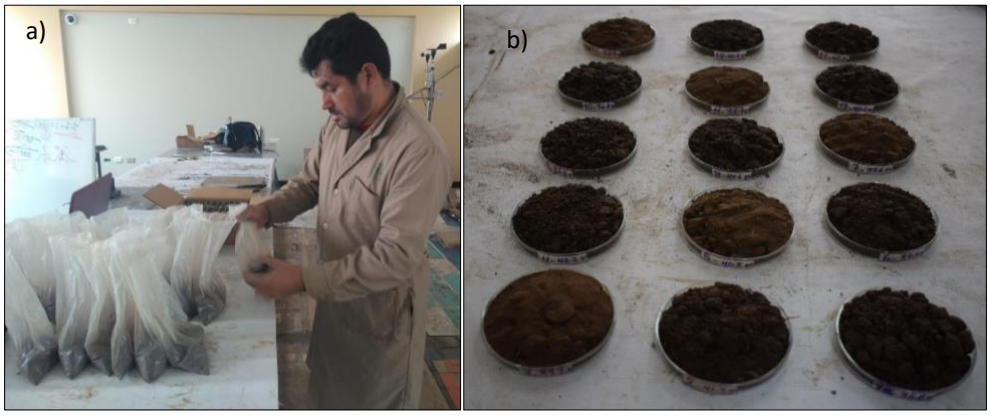

Figure 3.3: Soil samples labeled in plastic bags (a) and soils samples in Petri dish (b)

4 Exercises

4.3 Exercise 1.

The following information was obtained at the experimental station of La Molina, Lima-Peru. Considering that the crop is in full vegetative development with an average root depth of 25 cm (*Z*) and a gravimetric moisture (w) at *Z* of 13.23%, determine:

Z (cm)	ρ_b (g/cm^3)	θ_{Fc} (%)	w_{FC} (%)
0	1.56	34.49	
10	1.68	32.73	
25	1.66	31.12	
40	1.70	28.63	

a) Determine the volumetric moisture (θ) at the Z level

b) Determine the gravimetric moisture at field capacity (w_{FC}) in each level of the profile obtained

c) Determine the volume of water per plot in liters (4 row) needed to bring the soil at field capacity in the drip irrigation system. Knowing that the water flow rate applied per furrow was 3.55 L min^{-1} and an area to wet of 12.5 x 0.45 m^2

d) Determine the irrigation layer (RIL in mm) of the plot to be irrigated

4.4 Exercise 2

From the previous exercise in the same experimental station there is a field under gravity irrigation with the same soil and crop conditions. Considering a gravimetric moisture (w) at Z of 7.75%, a ditch length of 12.5m, wetted side of 0.51 m and water flow rate of 166 L min^{-1}. Determine:

a) The amount required irrigation lamina (RIL in mm)
b) Irrigation volume of water to be irrigated per ditch in liters
c) Irrigation time (IT) per ditch in minutes

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