Improving Potato Production in Kassala, Sudan

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Preface and Acknowledgement

This monitoring and knowledge transfer study on potato production in Kassala, Sudan, has been carried out during November 2016 – April 2017. The study has been initiated by the Netherlands Enterprise Agency (RVO) in order to facilitate the improvement of the total potato chain in Sudan, especially in Kassala region. This study/project strengthens the activities undertaken within the Netherlands – Sudan Agri Link (NSAL) programme, on improving the business climate for potato farmers in Kassala, Sudan.
From November 2016 – March 2017 Yusuf Abdirahman, a trainee of Wageningen University and Research, the Netherlands, and Ala Mohmed Nur and Mohammad Ismail, students of Kassala University New Halfa took care of daily monitoring of the potato fields, demos and field experiments of the NSAL programme. They did a great job in intensive communicating with all local stakeholders and the Dutch participants within NSAL. Without this project the NSAL potato programme would undoubtedly have been less successful.

The monitoring and baseline project would not have been possible without the help and support of the El-Acha Farmer's Association, the staff and researchers of the Agricultural Research Centre (ARC) in Kassala and the staff of the Royal Netherlands Embassy in Khartoum.
Yusuf, Ala and Mohammad had their office at the ARC, provided by Mr. Ibrahim director of the ARC in Kassala, and could make use of all facilities available of the ARC and its staff. We thank the board of El-Acha, the staff of the ARC and the Ministry of Agriculture and finally all farmers and other participants involved in the project for their inspiring and warm cooperation, help and support.

Summary

This project is part of the NSAL (Netherlands – Sudan Agri Link) program. Private companies from the Netherlands together with Wageningen Plant Research are working on re-introduction and improvement of potato production in Kassala, Sudan. The main focus is demonstrating the added value of seed potatoes and basic machinery from the Netherlands and providing training courses and practical field demonstrations on all aspects of potato production. To support this NSAL program, a monitoring and knowledge transfer project is carried out by Wageningen Plant Research. WPR trainees took care of day to day monitoring of the potato fields and direct communication between Sudanese and Netherlands partners on all aspects of potato production. Next to that the Universities from Khartoum and Kassala, the Ministry of Agriculture in Kassala and the Agricultural Research Corporation in Kassala were closely involved in the project, through direct communication and specific knowledge transfer activities.

1 Introduction

Background

Kassala is well known as a potato production region in Sudan from long time ago. According to Beukema, Van Ham and Meijer (1987)[1] small amounts of seed potatoes were imported from the Netherlands and distributed to Kassala. In the World Potato Atlas (2006 edition) the Gash Delta in Kassala is also mentioned as a zone of high potential for potato production. Yet most of the traditional Kassala potato growers have stopped their potato production gradually over the years and shifted to onions, tomatoes and other vegetables instead, because of lower risks and lower cost of production. Onions are an interesting cash crop for farmers. Onions are quite easy to grow and production cost per feddan are less than half compared to the production costs of potatoes.

In 2015 the Netherlands Enterprise Agency (RVO) launched the NSAL program: Netherlands – Sudan Agri Link. A comprehensive report of this project and the results of the first production season can be found in: S.J. de Vries, B.J.M. Meijer, ..., (2016) [2]. In the NSAL program, Dutch private companies and knowledge institutes aim at improving the potato chain in the Kassala region. One of the aims of the NSAL program is to revitalize the potato production sector in Kassala, by the following:

- Conducting training programs (theoretical and practical) in various potato production aspects, including post-harvest crop handling, marketing and sales, finance, entrepreneurship, etc.
- Setting up a demonstration farm for modern potato production, using new technologies, imported seed potatoes, basic machinery and storage, through intensive cooperation with the farmers' Cooperative.
- Establishing field experiments on testing new potato varieties and different irrigation techniques at the experimental farm of the Agricultural Research Corporation (ARC) in Kassala.
- Organizing field days, demonstration days, workshops, networking and other knowledge sharing events.

The NSAL program is a 3 year program (2015 – 2018) which has been committed by the Netherlands Enterprise Agency (RVO) and was financed by the Netherland Ministry of Economic Affairs, under the 2g@there OS Pilot Program, and the Dutch consortium partners: Teampro, Stet Holland BV, Bijlsma Hercules BV, Ostra International Projects, Wustman Potato Consultancy and Wageningen University and Research Centre.

In discussions with the consortium partners and the Netherlands Enterprise Agency it has been decided to broaden and strengthen the NSAL program by conducting a K2K project focused on monitoring and knowledge transfer of potato production in the Kassala region. The first year has been reported in 2016. Because of the success of this project, the Netherlands Enterprise Agency has decided to commit a new K2K project to support the second year of the NSAL program with less focus on baseline study and more focus on monitoring and knowledge transfer by two interns under the guidance of experts from Wageningen Plant Research. In doing so it would provide a solid base for a multi-year innovation program focused on innovation and development of the entire potato chain in Sudan and in the Kassala region in particular. This monitoring and knowledge transfer project contributes in the attempt of increasing the level of knowledge of the stakeholders on all aspects of potato production in Kassala region with increased interest in the introduction of technology from the Netherlands.

[1] H.P. Beukema, J.T.M van Ham, B.J.M. Meijer. Proposal potato development project in the Sudan, 1987. Government of the Netherlands Ministry of Economic Affairs; Directorate General of International Development Cooperation.

[2] S.J. de Vries, B.J.M. Meijer, R. Wustman, A.S. Jimale, Y. Abdirahman. Monitoring potato production in Kassala, Sudan. 2016. PPO report 701.

Objective and Approach of the K2K monitoring and knowledge transfer project

This second K2K project has been developed in consultation with NSAL to further strengthen its activities in Kassala / Sudan, by programming intensive observation, guidance and data collection and spread the knowledge gained, on:

- the cultivation and growth of various (Dutch) potato varieties
- the use of (Dutch) mechanization within Sudanese potato cultivation
- origin and treatment of the seed potatoes
- irrigation methodology and intensity
- data collection for research
- advice to growers, research and education.

This K2K project has been conducted by two experienced potato experts from Wageningen Plant Research (PPO) of Wageningen UR, with experience in Sudan and three trainees, one from the University of Applied Sciences - Hogeschool Van Hall Larenstein - VHL, and two from the Kassala University New Halfa – Sudan, in close collaboration with the other partners in the NSAL project. The three trainees have been staying in Kassala during the growing season, from planting until harvesting. Supervision of the trainees was done by Wageningen Plant Research, as well as analyzing all information and writing the project report.

The trainees have been monitoring the execution of the potato field experiments at the ARC Research Station, the potato demo fields of NSAL and the potato fields of farmers in Kassala.
Data collecting protocols have been discussed intensively with the trainees, leading to a basic questionnaire for the interviews and guidelines for data collection and analysis (Annex 1). A specific training sessions for the trainees on the most important aspects of potato production, including the occurrence and treatments of pests and diseases, have been provided by Wageningen Plant Research beforehand and during the growing season in Sudan.

The trainees were stationed at the ARC office, ensuring a good collaboration with the ARC researchers with direct access to the potato experimental fields at the ARC research station. The field experiments as well as the demo fields of NSAL and the commercial fields of the farmers were inspected intensively, several times a week or even on a daily base, by the trainees. In between they maintained contacts with the NSAL team on a daily / weekly base about growth and development of the potatoes and the occurrence of specific circumstances and cropping measures with respect to drought, diseases, pests and weeds, etc. Practical advices of the Dutch experts were passed through to the researchers of ARC, the extension service TTEA, the farmers of El-Acha and the “Omar” farmers group.

2 Results of potato production in Kassala, 2017

2.1 Introduction

This chapter describes the results of the potato fields within the NSAL/K2K project during the 2016-2017 production season. Two demonstration fields were planted under the auspices of the NSAL/K2K project, one large demo field of 6.7 feddan in total and a small demo field of 0.4 feddan close to the city for practical field training purposes. Potato fields of El-Acha farmers and farmers of Omar's group were also monitored by the NSAL/K2K project. Another new dimension within the project is the distinction between imported seed from the Netherlands and local seed form Khartoum North (multiplied once from imported seed from the Netherlands in the previous season). The project has been extended with local seed next to imported seed because the imported seed has the disadvantage of arriving rather late (sometimes too late) in Port Sudan, with seeds which is still (too) dormant. Healthy local seed, multiplied only once from imported high quality seed form the Netherlands and stored under good conditions can be planted earlier and should give better performance – a more rapid emergence, more growing days and thus higher yields – especially in the Kassala region. The following potato fields were monitored this season:

1. NSAL training field in Kassala, 0.4 feddan of imported and local seed
2. NSAL demo field at Ali Zain's farm, 5.7 feddan import and 1.0 feddan local seed
3. Hashim, 1.0 feddan of local seed
4. Hayder, 1.3 feddan of imported seed
5. Omar field I, 2.0 feddan of imported seed
6. Omar field II, 0.3 feddan of local and imported seed
7. Omar field III, 1.0 feddan of imported seed
8. Ali Ibrahim, 5.0 feddan of local seed
9. ARC experimental field with different Nitrogen applications with imported seed.

The demo fields were planted in the last week of November and harvested in the last week of February (local seed) and second week of March (import seed). Most of the other fields were planted and harvested in the same period, except for Omar field 3 where the imported seed potatoes have been planted in the first week of January because of problems with the availability of the planting machine. All of the imported seed potatoes were form the same batch, Bellini variety class E, delivered by Stet Holland. The local seed potatoes were of the varieties Bellini and Everest, delivered by Alanaam Trading Company, the representative of Stet Holland in Sudan.

This year we have been able to control the soil temperatures to (potato) acceptable levels via a strict and more frequent irrigation scheme. With this the growers have been able to avoid the black heart quality issues we faced at one of the demo fields of 2015-16. Also the soil properties where far better for a mechanized harvesting system, less clods and thus less defects / bruising of the potatoes. All in all a better product to the farmer. Potatoes grown out of local Sudanese seed potatoes where ready for harvesting as of calendar week 06-07 whereby potatoes grown out of Dutch import seed needed 3 to 4 weeks extra growth to come to a somewhat comparable yielding level. The rather later ripeness of the potato crop, grown out of imported seed, has a negative impact on the yield potential of the crop, because it simply is getting to hot as of mid-February. The earlier a heat occurs, the more negative its impact is on the growth and total yield of potatoes. The effect was stronger in cases of combined effects of high temperature and drought compared to high temperature under more favourable soil moisture conditions.

Drought & Heat-stress in potatoes at Hashim's farm

2.2 Results of NSAL potato fields

A short description and summary of the results of the potato fields which have been monitored within the K2K/ NSAL project is given below.

NSAL training field

This potato field has been established for having a good training and demonstration facility close to the city, as the big NSAL demo field is far away from the city of Kassala and therefore less suitable for training purposes. We are grateful to El-Acha for making this field available for us, the perfect place for organizing trainings and demonstrations, at the premise of Kassala University.

Import seed: Approximately 30% of the plants were affected by chafer grubs, just underneath the soil surface. Re-growth of the plants did occur, but it meant lagging in development of the crop. On average 2 stems per plant with 4-5 new tubers. It was a hollow crop with slight infestation of heat stress / Alternaria.

Local seed: This was a full covered field, with hardly no damage from chafer grubs. An average of 4-5 stems per plant with 6-8 new tubers. A slight infestation of heat stress / Alternaria and some Rhizoctonia, Fusarium, and bacterial wilt plants were observed.

The total impression of the NSAL training field was a healthy crop which could use some extra nitrogen by means of a top-dressing. Next to that it was advised to apply Amistar-Top (7-10 days) against Alternaria and to shorten the intervals between irrigation.

Harvesting of the potatoes was scheduled during the Potato Harvesting Demo Event on March 16th. The demo was opened by the Dutch ambassador, Mw. Karin Boven, by harvesting the potatoes she had been planting, at the beginning of the season, in December 2016. All the harvested potatoes have been shared with our audience, they were presented with a small bag of Dutch/Sudanese potatoes. The rest of the field was donated to the farmer and his work crew.

NSAL demo field at Ali Zain's farm

A plot of one feddan which has been planted earlier with local seeds under very dry circumstances, was considered lost (germination rate was less than 50%, severe heat stress / Alternaria / Fusarium symptoms). This field was not suitable for potato planting, causing uneven planting depths. Therefore the NSAL team decided to continue planting on a nearby field of 5.7 feddan where onions were grown as previous crop. 8 rows have been planted with local seeds, the rest of the field has been planted with imported seeds. This field (local and imported seed) was much better, due to better soil preparation and planting. The total impression was a healthy crop, comparable with the training filed, except the potato plants were dark green because of higher nitrogen application. Here too it was advised to treat Alternaria with Amistar Top (7-10 days) and to shorten the irrigation interval.

The demo field, with the size of 5.7 feddan, was harvested in the last week of February for the local seed potatoes (8 ridges) and on Monday March 13th with the potatoes from imported seed. It was decided only to harvest during the early morning hours and late afternoon due to daytime temperatures of +40 ºC, the potatoes to be picked directly behind the harvester and to have an intermediate storage in the corner of the field shaded from the sun. So harvesting activities where restricted to 6 hours and an average of 1½ feddan per day. For Ali Zain and his sons, the harvest was a steep learning curve to organise it all and to get a better understanding of the in-field logistics involved while harvesting potatoes. They managed it pretty good.

Potato harvest at Ali Zain's farm, Kassala

A sample, taken from behind the harvester, gave us an rough yield indication of 6 to 8 tons per feddan with some 75% of the tubers over 50 mm. The field was heavily invested by cypress grass and other weeds. Potatoes where sold to a local wholesaler in Kassala at the price of SDG 7,--/kg. Ali Zain was comfortable with this result and enthusiastic about the whole crop.

Hashim potato field

This field was lost; it had been planted with local seed under to dry circumstances – resulting in uneven planting depth. The soil structure was very poor, about 70% of the planted seed potatoes have languished away, rotten seed potatoes due to over- and irregular irrigation actions. The farmer had stopped irrigation totally by early January.

Hayder potato field

The field was irregular; by mid-January 70 % of the potatoes were germinated whereas 30% were still to come. There were hardly any new tubers over 5-10 mm at that time. The soil structure was poor. The crop looked healthy, some slight Alternaria lesions were noticed. This was a late crop.
We visited his field Monday morning March 13th. The crop was still very irregular, on average 2 stems per plant and 3 new tubers. The crop was suffering from Alternaria alternata and heat stress but it still had some 50 % green foliage; ridge temperature was around 26 ^{o}C. Based on sampling in the field a potential yield of 4-5 tons was estimated with rather small sized potatoes (80% < 50 mm). Mr. Hayder was advised to continue growing his crop as long it has green foliage as such might increase yield level. He was given a temperature meter to measure the ridge/potato temperature.

Omar potato field 1

This field was covered with weeds; re-ridging at an earlier state could have prevented this problem to a large extent. The crop looked healthy, irrigation intervals should be shortened.

Omar potato field 2

There were two small plots. The one with local seed, bought at the market, was fully affected with Y-virus or salinity stress due to high nutrient inputs. The other plot with imported seed showed some slightly Y-virus symptoms and high densities of aphids and trips. The overall impression was: poor / irregular germination, insufficient irrigation.

Omar potato field 3

This field has been planted early January because the planting machine was not to be available in time due to reasons unknown to us. This field too looked to dry and irrigation was insufficient. It was Omar's intention to use this field for the production of seed potatoes for the next season.

Ali Ibrahim's potato field

At the time of visit (mid-January) the total field seemed to consist of 2 plots, one half of the field with a germination rate of 40%, the other half 70%. The most important observations were: weed problems especially on parts of the 70% germination field, which seemed to be lost, the soil was to dry, heat stress / Alternaria symptoms. It was advised to the farmer to shorten the irrigation intervals and to apply a top-dressing with Nitrogen. The potatoes of this field have been harvested under too hot and dry circumstances and inadequate intermediate storage, with resulting quality problems (black hearts).

ARC Nitrogen experiment

Three levels of Nitrogen application were examined at the ARC Research Station in Kassala: respectively 24, 36 and 48 kg Nitrogen per feddan, compared with a control field on which no Nitrogen had been applied.

The fields looked fine and very regular in appearance, probably due to a smaller planting distance than the other fields. The number of new tubers per plant was lower compared to the NSAL training field end the NSAL demo field with imported. Details of the fertilizer experiment are given in Annex 2.

Table 1 *Summary of the potato fields in Kassala, 2016-2017 – yield figures based on yield samples end of February (fraction > 35mm).*

Potato field	Variety	Seed origin	Seed Kg	Planting date	Harvesting date	Growing days	Yield, Kg per feddan
NSAL training field, 1,083 m^2	Bellini	Import	238	29 Nov	16 March	108	4,150
NSAL training field, 228 m^2	Bellini	Local	50	29 Nov	16 March	88	7,370
NSAL training field, 228 m^2	Everest	Local	50	29 Nov	16 March	88	6,530
NSAL demo field, Al Zain, 5.7 feddan	Bellini	Import	5,700	26 Nov	13 March	113	8,310
NSAL demo field, Ali Zain, 1.0 feddan		Local	1,000	16 Nov	16 Febr	113	4,280
Hashim potato field, 1.0 feddan	Bellini	Local	1,000	18 Nov	Lost	---	-----
Hayder potato field, 1.3 feddan	Bellini	Import	1,450	28 Nov	28 Febr	121	3,700
Omar potato field 1, 2.0 feddan	Bellini	Import	2,450	9 Dec	2 April	114	3,030
Omar potato field 2, 0.3 feddan	Bellini	Imp / loc	300	5 Dec	2 April	118	1,500
Omar potato field 3, 1.0 feddan	Bellini	Import	1,000	4 Jan	2 April	90	1,500
Ali Ibrahim potato field, 5.0 feddan	Bellini	Local	5,000	20 Nov	5 March	105	3,890
ARC N-trial field, 0 kg N/feddan, 250 m^2	Bellini	Import	89	11 Dec	8 March	88	3,050
ARC N-trial field, 24 kg N/feddan, 250 m^2	Bellini	Import	89	11 Dec	8 March	88	9,300
ARC N-trial field, 36 kg N/feddan, 250 m^2	Bellini	Import	89	11 Dec	8 March	88	9,100
ARC N-trial field, 48 kg N/feddan, 250 m^2	Bellini	Import	89	11 Dec	8 March	88	8,760

2.3 Discussion

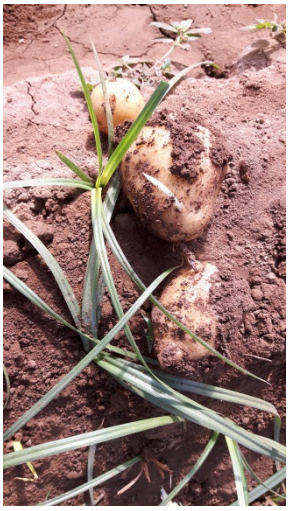
This year it was the intention to compare local seed with imported seed within the NSAL / K2K project. Therefore the local seed should have been planted by the end of October – beginning of November. Despite repeated efforts it did not work to have the local seed available in time, due to unknown reasons, and to be able to plant the local seeds several weeks prior to the planting of the imported seed. Both origins – imported and local seed – have been planted in the last week of November – first week of December. Nevertheless the fields with local seed gave higher yields than the fields with imported seed in a shorter period of time (less growing days). This finding confirms the meaning of the Netherlands potato experts that local healthy (!) seed, available in time, is better for potato farmers in Kassala – earlier on the market against higher prices and is better for the potato crop – less stress due to rise in temperatures as of February.

A good soil preparation before planting is very important for a successful start of the potato crop. In many cases the soil was too loose and too dry at planting time, causing problems with mechanical planting. The loose soil is pushed forward, potatoes are planted at irregular depth – causing an irregular crop / irregular ripening of the tubers / problems at harvesting time – adjustments of the harvesting machine

Seedbed preparation at the NSAL training field Kassala

Irrigation is another cultivation measure that requires full attention. Many farmers irrigate too much each time and wait too long before irrigating again, irrigation intervals should be shortened. The latter is also important to avoid heat stress of the potato plants and to keep the temperature in the potato ridge at an acceptable level.

Some potato fields were severely covered with weed, especially Sida / Cyprus grass. This weed can only be controlled properly in a multiyear farming system approach. Other important pests and diseases like chafer grubs, spider, white fly and Alternaria require a quick diagnose and proper chemical treatment.



Cyprus grass – "Sida"

Chafer Grub attack

Alternaria alternata infestation

2.4 NSAL Training, workshops and field demonstrations

During this second potato production season in Kassala several training activities have been carried out within the NSAL/K2K project.

Table 2 *NSAL training program 2016-2017*

Date	Trainer	Subject	Participants
29 Nov	Jacques Vergroessen	Soil preparation, seed quality, crop protection, irrigation	Farmers, students, researchers
29 Nov	Sicko de Vries	Fertilization; determination of fertilizer needs of a potato crop	Farmers, students, researchers
29 Nov	Sicko de Vries	Practical training & demonstration on the application of fertilizers in the potato field	60 Farmers, students, researchers
30 Nov	Doeke Oosterbaan	Practical training & demonstration on the use of different machines in potato cultivation	100 Farmers, students, researchers, councils of Ministry and Embassy
20 Jan	Sicko de Vries	Practical advice to potato farmers irrigation and on the application of fungicides, insecticides and nutrients based on field visits.	Farmers, researchers ARC
15 Feb	Doeke Oosterbaan	Practical advice to potato farmers on harvest preparations	Farmers, researchers ARC
10 March	Sicko de Vries	Practical advice to potato farmers on harvest preparations	Farmers, researchers ARC
15 March	Romke Wustman	Conservation of potatoes, handling at harvest / post-harvest, storage & storage management	50 Farmers, students, researchers
15 March	Thie Arend Brouwer	Entrepreneurship in potato farming	50 Farmers, students, researchers
16 March	Sicko de Vries	Harvest Demonstration NSAL training field Kassala	180 Farmers, students, researchers, representatives of Ministry and NL Embassy
16 March	NSAL team	Supply chain management	180 Farmers, students, researchers, representatives of Ministry and NL Embassy

Unlike in the previous project year, it was decided to pay extra attention to practical training and demonstrations in the field this year. Therefor a second, small demonstration field has been planted within the city of Kassala for practical training purposes and field demonstrations. During the November mission of NSAL / K2K, specific attention has been given to fertilization of the potato crop. The training started with a general presentation about fertilization and how to determine what kind of fertilizers should be applied to potatoes in a given situation. After this theoretical course the participants had to apply their knowledge in the field. Everyone was asked to “buy” fertilizers from the trainer for a specific field of a certain size. In this way farmers had to calculate how much fertilizers they would need. After that they were asked to apply the fertilizers by hand. A more efficient way of application by hand was demonstrated and trained. After practise the actual amounts given by the farmers were measured and compared. Needless to say that the differences were very big. This very practical training was highly appreciated by the farmers and other participants.

Agro-fertilizer-shop in the training field

Practical training in application & control of fertilizers

During the growing season field visits have been carried out to all potato fields mentioned in the previous chapter. Special attention has been given to recognize and discuss the diseases and other problems and specific conditions occurring in the potato crops. Practical advices have been given to the farmers how to treat the specific diseases and also how to prevent further damage in the crop. At the end of all the field visits a meeting has been organized to discuss all problems that have been recognized in the fields and practical advices to deal with them.

This type of knowledge transfer, a combination of theory and a lot of practice in the field, is highly appreciated by the farmers and other participants. To our opinion it is a most necessary and efficient way to support farmers in a sustainable potato production and to inspire farmers to continue and expand potato production in Kassala region. Potato will always be an expensive crop with a higher risk than other crops like cereals, onions and tomatoes. Therefore it is important for farmers in Kassala that the gap with Khartoum and other potato production regions will be caught up soon.

Practical training and knowledge transfer in the field – Potato planter

Entrepreneurship, marketing, post-harvest and supply chain management were also subjects of the training sessions. Especially storage of potatoes for several months is very important for potato production in Kassala in the near future, as the prices at harvest time will be low due to a peak in potato supply, also in other regions. The first steps in conduction a (small) potato store in Kassala have been taken by a private farmer. There are ongoing discussions to expand storage facilities for long term storage in Kassala.

2.5 Communication and Knowledge transfer within K2K

There have been many discussions with Agricultural Universities in the Netherlands (Dronten, Wageningen, Velp, Leeuwarden, Den Bosch), that were meant to recruit students for an internship in Kassala during the 2016-2017 potato season. Unfortunately they were not successful, despite of the many times of contacting students and teachers through different ways. We were told that these

students have the luxury to be able to choose form many interesting international projects in Asia, New Zealand, Australia, etc.. Sudan is definitely not on their priority list, compared to those countries. For this reason Yusuf Abdirahman, who was one of the two trainees in Kassala during the previous season, has been asked to go to Kassala again to guide the second potato season of the NSAL/K2K project.

Prior to the start of the second potato growing season, Kassala University New Halfa and The University in Khartoum, Shambat Research Station , have been visited. Meetings took place with the deans of the Agricultural Faculties of both Universities, Dr. Tag Elsir, (New Halfa) and Dr. Siefeldin Mudawi Gasim, Dean of the Agricultural Faculty of Khartoum University. Discussions were focussed on intensifying cooperation and information exchange. As a result two students from the University of New Halfa, Mrs. Ala Mohmed and Mr. Mohammed Ismael, were stationed at the ARC in Kassala to work within the NSAL / K2K potato project, under direct supervision of Yusuf Abdirahman.
Next to that the University received imported seed potatoes from the Netherlands to conduct their own potato experiments on nitrogen application and planting density and their effects on growth and yield.

Yusuf Abdirahman (trainee of Wageningen UR in Kassala) and Sicko de Vries (project manager of the K2K project) took care of most of the communication. There was almost day to day communication between Sicko and Yusuf via mail and WhatsApp. Next to that there was a regular information exchange (WhatsApp) between the K2K team in Sudan, via Yusuf, and the Netherlands' NSAL partners about the development of the potato fields in Kassala. Sicko provided for clear instructions on monitoring the potato fields and yield sampling at regular interval on the base of a pre-defined format and instructions. Yusuf took care of the communication in Kassala with the other students, Ala Mohmed and Mohammed Ismael, ARC and the farmers. On specific items like fertilization, pest and disease control, weed control, irrigation, harvesting & handling NSAL members were asked for advice via WhatsApp.

A Potato Knowledge Sharing Event has been organized at the University of New Halfa. The event was chaired by Dr. Tag Elsir, the dean of the Faculty, the meeting was attended by some 25 lecturers and students from the University. Presentations about the potato project in Kassala and the development of the potato demo fields and experiments were given by Yusuf, Ala and Mohammed and by ARC. Students and lecturers of the University gave presentations about the potato experiments at the University. Topics of discussion were: planting depth and delay of germination, irrigation frequencies and intervals, covering of potatoes to avoid damage from sunlight and hot temperature, effect of nitrogen fertilization and planting density on growth and yield. These discussions were very useful and also lead to practical recommendations for farmers. Furthermore it was a good opportunity to listen to the perception of scientists and students about current and future potato production perspectives in the region.

There were several meetings between the University and the K2K team on potato diseases (and how to prevent them). These meetings were organized by Dr. Mohammed Al-Wagi, a very motivated plant pathologist and lecturer of the Agricultural Faculty of the University of New Halfa. Moreover Dr. Al-Wagi joined several visits with the K2K monitoring team to the potato fields in the Kassala region. The contact with Dr. Al-Wagi has been very rewarding because of his expertise in Alternaria in the Sudan.

A delegation of two professors and students from Khartoum University visited the potato training field in Kassala. The trainees Yusuf, Ala and Mohammed have given presentations about potato production in general and about the potato project of NSAL and the cooperation between Sudanese and Netherlands partners. Many questions and subjects have been discussed and explained in the field. The visitors were very interested, for some of the students it was the first time to visit a potato farm.

Specific attention has been given to knowledge exchange on various aspects of potato production between the trainees and also between the trainees and the ARC staff. The trainees worked together very closely during the whole season. Intensive use was made of Potato diseases[3] and Potato Signals[4],

[3] A. Mulder and L.J. Turkensteen. Potato diseases. NIVAP, The Hague, 2005
[4] Kees van Loon and Han Hammink. Potato Signals, a practical guide to successful potato cultivation. Zutphen 2005

practical guides to successful potato cultivation. These books have been provided by WUR. Potato Signals has been translated in several languages, for instance: Russian, Myanmar, Spanish (Argentina). A translation in Arabic would be very beneficial for potato growers in Sudan and other countries.

The number of potato fields that have been monitored has increased significantly compared to the year before. The process of the monitoring started by a farm visit, explaining the K2K/NSAL project and sharing information on potato cultivation, challenges, possible profits and risks. Prior to the visits, the farmers were asked to invite other farmers in the region who were interested in growing potatoes in the near future. In this way potato cultivation aspects have been discussed with a larger group of farmers. Farmers' own ideas about growing potatoes on their farm could be discussed. It became clear that more farmers are interested in growing potatoes, but they still hesitate and want to see the results of the potato fields this year.

2.6 Lessons learned

As has been discussed before, many farmers in Kassala region are interested in growing potatoes, yet they have to be convinced by the successful results of the innovators, the farmers who have taken the risk and have started their potato production business as a serious new source of income and future development of their farm. Once the innovators are successful in potato production and marketing, the so called early adopters will shift to potatoes, gradually followed by other farmers. Because we are still at the very beginning of this Innovation Life Cycle, intensive communication with the farmers and practical guidance on potato cultivation remains utmost important. Potato cultivation is quite a challenge, perhaps even more in Kassala than in Khartoum, Shendi or Northern regions, because of the higher temperature and the lack of long-term experience and expertise. Farmers need to be supported intensively in the short term on all aspects of potato cultivation. A practical potato cultivation guide would be very beneficial to the farmers, ARC and others stakeholders in the potato cultivation chain.
The ARC in Kassala seems to be the most suitable organization to work on practical guidance of (potato) farmers, since they are the mandated institution for this task and they have their own facilities for practical research questions on specific cultivation aspects, like variety experiments, fertilization, crop protection, treatment and control of specific weeds, pests and diseases.

Mr. Hayder – thinking about lessons learned so far.

3 Knowledge need of potato growers

3.1 Introduction

As has been reported by Beukema, Van Ham and Meijer[5], Kassala used to be one of the important potato producing regions in Sudan, long time ago. Even small amounts of imported seed potatoes were transported to Kassala then. Due to several reasons, high cost and late availability of seed potatoes, high risk of potato cultivation itself, difficult climatic conditions and most probably lack of knowledge and knowledge support, famers gradually shifted from potato production to the cultivation of onions, tomatoes and other crops.

3.2 Knowledge transfer to small holder farmers in Sudan

The Agricultural Extension Service (TTEA) in Sudan has been established in 1958. Their main task is to translate the results of agricultural research of Universities and other sources to farmers' practice and to develop content for practical training of farmers.[6] The Extension Services are being organized by the State Ministries of Agricultural. Because of budget problems these organizations have insufficient capacity for adequate knowledge transfer to farmers, especially for small holder farmers producing vegetables and other minor crops.

From the Fact finding study to sustainable agro-inputs in Sudan we learned that more and more private organizations are taking care of knowledge transfer to farmers. They sell seeds, fertilizers and chemicals to farmers and provide them with practical advice and support at the same time. Farmers seem to rely more on the advices of their fertilizer and chemical suppliers than on the extension service.

The Agricultural Research Corporation (ARC) has the task to conduct applied research in agriculture in order to develop sustainable agro production systems in different regions in Sudan. The results of their research have to be shared within the Ministries of Agriculture and the Universities. The ARC's too lack sufficient budget for fulfilling their task, facilities are outdated and there is only limited or no capacity for working on vegetable and minor crops.

3.3 Farmers' needs for sustainable production

Farmers in the rural areas in Sudan have a great need of practical knowledge on sustainable production of their crops and management of their farms. Especially for small holder farmers in Kassala and other rural regions far away from Khartoum State. For knowledge and cultivation advice many farmers rely on the expertise of the local Agrishops.

Sicko de Vries[6] concluded the following findings in the Agro input study:

- Farmers need agricultural knowledge and skills in the use and effects of agro-inputs on their crops, the environment and related health issues – they need education, training and support in monitoring thereof.
- Farmers need to be able to recognize specific deficiencies, diseases and pests and the natural course of these in their crops – they need to have a detection system available outside the expertise of the Agrishops and/or the importers of agro-chemicals.
- Farmers apply pesticides in violation with the recommendations on the packaging (safety and environment) and/or in violation with an approval on the product to be used in a particular crop.

[5] H.P. Beukema, J.T.M van Ham, B.J.M. Meijer. Proposal potato development project in the Sudan, 1987. Government of the Netherlands Ministry of Economic Affairs; Directorate General of International Development Cooperation.

[6] More information on Knowledge transfer to farmers in Sudan can be found in the following report: Sicko de Vries. Fact-finding Agro inputs Sudan, 2017. Wageningen University & Research Report.

- Farmers need to be familiar with the soil properties (stock) on nutrients – there is no data available through soil sampling and/or there is no service provider active on soil analysis (soil lab).
- Farmers need to be familiar with the nutrient uptake of their crops, the effects of the different nutrients during the growing period and/or the removal of nutrients at time of harvest – there is no (regional) practical research data available.

Next to this farmers need adequate expertise on the cultivation of the crops which they produce or in which they are interested. Crop cultivation manuals should be made available for farmers in their own language. A very practical guide for potato production is the manual *Potato Signals* published by Roodbont in Zutphen, The Netherlands. This manual has been translated in different languages is now being used in various countries worldwide. Translation in Arabic and adjusting the content to Sudanese conditions is highly recommended, not only for the new potato farmers in Kassala, but also for potato farmers all over Sudan. Similar manuals for a successful cultivation of onions, tomatoes and other crops have been developed for vegetable growers in Tanzania within the SEVIA project. This could also be done for Sudan.

3.4 Recommendations for knowledge improvement

There is a strong need for capacity building on crop cultivation of vegetable crops, including potatoes, in Sudan. The knowledge institutes like Universities, Extension services and the Agricultural Research Corporations lack practical knowledge on crop production of vegetable crops, especially the minor crops like potatoes. This is especially true in the areas far away from Khartoum.

We recommend to organize long lasting training programs for capacity building, starting with training the trainers and other experts who advice farmers in all aspects of crop cultivation. These training programs could be organized in close cooperation with the ARC and knowledge institutes from the Netherlands who have proven their success with similar programs in other parts of Africa.

Proven techniques for improving knowledge on crop cultivation of farmers are:

- Technical support of famers through e-learning. Wageningen Research has developed several modules for e-learning, like fertilization, crop protection, transplant raising. New modules for successful cultivation of vegetable crops are under construction.
  Next to that a pesticide selection tool is available to support farmers in choosing the right agency for treatment of weeds, pests and diseases.
- Creating network groups of farmers. Farmers can easily exchange knowledge on practical crop related issues, by regular meeting, discussions and field visits. These meetings can gain added value by having an expert / researcher join the team meetings.
- Practical field trainings and demonstrations are of utmost importance in training farmers on specific items on crop cultivation. The extension services and/or ARC's are the most appropriate institutes to organize these trainings.

Training of farmers should not be a once in a lifetime event. Circumstances often differs a lot from year to year, making it difficult for farmers to take the right actions at the right time. Newly gained knowledge has to be applied in day today's practice. This is especially true for vegetable crops where the costs of inputs are high and the risks as well.

Practical determination of Late Blight or Early Blight

4 Opportunities for improving potato production and financial results

4.1 Introduction

Potato is gradually becoming more and more important on the Sudanese dish. Not only in terms of fresh potatoes but also as processed food products like French fries and potato chips. As there is hardly any potato production in Kassala region, potatoes - either as a fresh produce or after storage for several months in cold stores - have to be transported to Kassala by truck over many hundreds of kilometres. From long time ago we know that Kassala has the possibilities for potato production. The NSAL project results have doubtfully proven the opportunities for potato production in Kassala. If the current innovative potato farmers succeed in their potato business, potato production in Kassala region has the potential to become a new potato producing hub in Eastern Sudan. Therefore it is not only necessary that the current performance of potato production will be developed to a higher level, but also investments in storage facilities and perhaps processing of potatoes are needed.

4.2 Improving potato production

At the end of the second season the following list of recommendations has been discussed with the farmers in Kassala region:

- **Select sound fields**; conduct soil analysis and proper crop rotation in relation to reducing soil borne diseases, pests and weeds .
- **Use healthy, locally (in Sudan) multiplied seed potatoes** as such seeds fit better in the potato cropping season when compared to imported seed. Order your seed in time; preferably around February-March before the planting season starting by the end of October.
- **Early planting** is essential in order to have a production period as long as possible. Early planting may be around end October-early November.
- **Apply first irrigation before field preparation and planting**.
- **Stabilize planting depth** to achieve regular emergence and early and even crop development.
- **Irrigation** during cropping season needs to be regular (short intervals: seven days) and sufficient to avoid heat burn in foliage and high potato ridge temperatures.
- **Weed control**, mainly Sid'a, is essential to reduce the competition for nutrients with the potato crop. Reducing weed (Sid'a) pressure is a long term effort combining both mechanical and chemical control actions.
- **Alternaria solani / alternata** causing early blight is to be controlled by mancozeb sprayings. First spray should be before the disease hits the crop: at some 25 cm plant height and/or when the plants start to touch each other in the row.
- Alternaria alternata is likely to occur as a weak fungus affecting poor field crop stands and is likely to be having much lesser impact when water supply is more regular. The impact will also be lessened if you don't let your crop become stressed. **Good crop management, appropriate fertilizer applications and irrigation best practice reduces disease impact**.
- A green crop is, basically, a productive crop and needs to be left in the field till maturity. Ridges should be kept moist to **cool ridge and tuber** temperature up to a few days before harvesting. Be aware: irrigation must not lead to rotten tubers.
- Harvested potatoes need to be picked and removed from the field very soon after lifting. The approach will reduce development of black heart caused by high direct sun radiation. **Harvested potatoes need to be put in the shade and need to be moved into a cool environment as soon as possible.**

4.3 Improving financial results of potato growers

As the production volume of potatoes is expected to increase by a growing number of potato farmers in Kassala, it is necessary to spread the marketing of potatoes over a longer period of time. Adequate storage facilities for being able to preserve the potatoes at low temperatures during several 6 – 8 months at maximum are urgently needed as no cold store facilities are available yet. The farmers cooperation's are the appropriate bodies to establish and explore these facilities for their farmers.

Financial performances of potato cultivation can be improved even more by gaining higher yields and better qualities of potatoes at lower costs. The, in paragraph 4.2, mentioned practical recommendations are very important for the potato growers to improve their results in the short term. Applying modern irrigation techniques, like the use of drip irrigation, can both improve yield and quality of potatoes and meet the social demands for water use efficiency as well. Besides, the necessary investments seems to be within reach of the small scale potato growers in Kassala.

Over-irrigation at ARC trial field

5 Recommendations

5.1 Recommendations for potato growers

After two years of practical experience on potato production in Kassala region it has become clear that imported seed potatoes from the Netherlands are not available at time of planting and/or are still to dormant for an quick development of the crop. There is only a limited timeframe, restricted by day/night temperatures, in which a successful crop can develop. Farmers should start planting by the end of October using fully matured seed potatoes to be able to harvest end of January – beginning February.

Nowadays seed potatoes from local origin of good quality are available in Sudan. These potatoes have been multiplied once in other regions, out of imported, high quality seed potatoes from the Netherlands. These local seed potatoes have proven to produce at least the same but usually higher yields than imported seed.

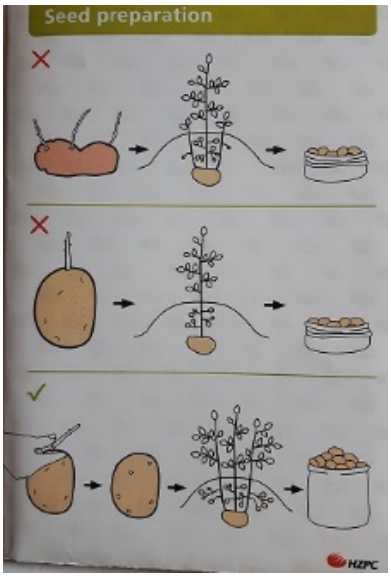
As farmers in Kassala region still remember having bad experiences with local seeds (most of the times left overs of bad quality meant for Eritrea), it is very important that they order local seed in time and buy from well-known suppliers of local seeds, not from unknown traders. Local representatives of the Netherlands seed potato companies have a long lasting experience in selling quality seed potatoes to Sudanese farmers.

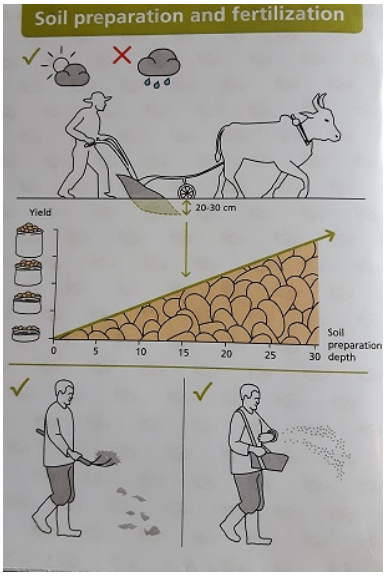
Potato field – same planting date – left side out of local in Sudan produced seed – right side out of imported seed from Northern Europe.

5.2 Recommendations to NSAL

With the extension of the NSAL project for year 2017-18 in sight, we do have some recommendations to the NSAL consortium. In order to make the project and the cropping of potatoes more sustainable, it is recommended for this extension; to intensify the guidance on crop cultivation, to develop within El Acha a “lead-responsibility” to organise and implement “net-work group meetings, to incorporate research (ARC) - extension services (TTEA) and business partners (chemicals / fertilizers) in all the activities with the farmers, to mobilize knowledge transfer (agro-services) via business partners and El Acha and to apply for an extension of K2K alongside NSAL.

- Develop a “potato department” within El Acha
  the department is to organise the potato crop; seed – agro inputs – machines – knowledge
  the department is to organise the growers group into a “net-work” group
- Intensified crop guidance through NSAL
  every 3 weeks a visit of the fields with the complete growers-group – input on knowledge / training and discussions on crop development / cultivation interventions
- Organize the growers for the next crop into a “net-work group”
  all activities to take place within this group – the group will meet every week as a group in the fields of one or more of its members – the purpose is to track (together) the crop development and discuss and share experiences from their own farm and interventions.
- Invite research / extension / business to be a member of this net-work group
  besides the input from the experts from Holland (NSAL) they are to be considered the local experts on their own terrain and they are invited to share their expertise
- Development of a simple and readable crop guidances on potatoes – Arabic and lots of pictures (good and bad situations), see an HZPC example below.
- Apply for K2K involvement
  assistance to El Acha in the development and organisation of the net-work group(s) – development of El Acha’s expertise as a service provider – organising knowledge transfer within the net-work group(s) – intermediate between Dutch experts and the local growers – tracking & collecting relevant potato cropping data in Kassala





Example of HZPC - Manual for a successful potato production (Tanzania)

5.3 Policy Recommendations

Farmers need to be supported with practical knowledge and skills for sustainable production of high quality vegetables, like onions, tomatoes and potatoes. The existing institutes like the extension services TTEA and the ARC’s lack practical knowledge on vegetable production in the Kassala region. They have to organize their capacity building on the vegetable sector before being able to support farmers in their regions. NSAL has the opportunity to extend their (research & extension) involvement in the potato crop with their membership of the potato net-work groups. This will work both ways – bringing knowledge and gaining knowledge.
Cooperation with knowledge institutes from outside Sudan who have proven their success in capacity building and practical training of farmers can help to speed up in bridging the gap with other regions and other sectors (cereals, dairy) within Sudan and/or surrounding countries.

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Annex 1 Guidelines for collection and analysis of crop production data

On behalf of the K2K-team in Kassala, 3 different observation “tools” where developed:

- Activity report
- Nutrient (fertilizer) Calculator
- Potato yield sampling

Activity reporting
With the format “Potato activity Report” the team was able to put down their observations in an orderly fashion and track the crop development during the growing season. In this way, they and the farmers, could understand the variances between the different growers and the impact & success of the grower’s decisions on crop development and crop management. The team kept track and shared their findings with the growers and ARC on the following items:

- Planting
- Seed source
- Germination
- Crop development
- Fertilization
- Weeds – Diseases – Pests control
- Irrigation
- Labour input

Nutrient Calculator
As part of the practical training in November 2016, a “fertilizer calculator” was developed. Soon we found out that the most “common” fertilizers where not always available in the Kassala market. For instance we had to work with compost made out of bat-manure, with no indication on nutrient contents.
As a future policy it is advisable that growers elaborate on a fertilization scheme for their (entire) farm and order their fertilization needs prior to the growing season. Products can then be ordered straight from Khartoum which will give them a cost benefit and in the end the right product and the right dosage . Furthermore we saw that the growers mainly rely on the primary elements like N-P-K (esp. N – Nitrogen) and disrespect the secondary elements Ca-Mg-S and tracer elements. Detailed information see annex 2 and 3.

Nutrient calculator - per Feddan

Fertilization at 10 ton per feddan	Yield	N	P_2O_5	K_2O	CaO	MgO	SO_3
	10	52	16	72	12	10	14
Ammonium Nitrate		0	-	-	-	-	-
Ammonium Sulfate	10	2	-	-	-	-	2
Blend 18-18-5+1.5MgO		0	0	0	-	0	-
Blend 12-12-17+2MgO		0	0	0	-	0	-
Calcium Nitrate		0	-	-	0	-	-
Calcium Ammonium Nitrate (CAN)	85	20	-	-	7	-	-
Diammonium Phosphate (DAP)		0	0	-	-	-	-
Monoammonium phosphate (MAP)		0	0	-	-	-	-
Muriate of Potash (MOP)		-	-	0	-	-	-
Potassium Nitrate	130	18	-	60	-	-	-
Sul-Po-Mag	55	-	-	12	-	10	12
Sulphate of Potash (SOP)		-	-	0	-	-	0
Single Super Phosphate (SSP)		-	0	-	0	-	0
Triple Super Phosphate (TPS)	34	-	16	-	5	-	-
Urea	25	12	-	-	-	-	-
	under-over	0	0	0	0	0	0

Potato Yield sampling

In order to track the development of the potato crop and to have an insight in the potential harvesting results – a "potato yield sampling" protocol was established. The protocol was put in place as off January 2017.

Sampling procedure per origin

- Sampling once a week – each time the same day with an interval of 7 days
- Take pictures of the spot to be sampled - use bamboo sticks to indicate the spot(s). The picture is to show the stage of the crop / potato plants in time.
- Take soil temperature readings at seed potato level
- Do a moisture observation test at seed potato level – the so called "soil-ball" method / classify in;
  very elastic – elastic – crumbling
- Dig up potatoes from 2 (random) positions (sample spots) in the field, in each position you dig up 1.33 meter of row length. *Total sample consist of 2 x 1.33 meter = 2.66 meter row length = 2 m^2*
- Count the number of plants per 2,66 meter (= number of plants in your sample)
- Count the number of stems per plant
- Count the number of tubers per plant
- Weigh the total potato sample
- Weigh & count the potatoes which size is smaller than 35 millimetre
- Weigh & count the potatoes which size is in between 35 – 50 millimetre
- Weigh & count the potatoes which size is bigger than 50 millimetre

use something like this (photo) to establish the size of the potatoes – right-angled type. Measurement is to be done over the cross-section of the potato – **not lengthwise**!! Do not force the potatoes through

- Do the calculation on kilograms per feddan / kilograms per hectare
  sample size = 2 m^2 / 1 feddan = 4,200 m^2 / 1 hectare = 10,000 m^2

Example of one of the yield samples d.d. February 15th at Ali Zain farm

Ali Zain	**local seed - 8 ridges**
sample date	15 February 2017
sample size in m^2	2.00
soil temperature	24.7
moisture	sticky

= automatic calculation

= fill in by hand

Total number of plants	stems per plant	tubbers per plant	< 35 mm number	< 35 mm weight	35 - 50 mm number	35 - 50 mm weight	> 50 mm number	> 50 mm weight
5	5	5	6	116	28	2,410	4	535
	4	5		4%		79%		17%
	3	9						
	9	11						
	5	8						
Average	**5.2**	**7.6**	**38**	**3,061**	**6,428**	**15,305**	**6,185**	**14,725**

total tubber count	total sample weight	total yield in kilogram feddan	total yield in kilogram hectare	market yield in kilogram feddan	market yield in kilogram hectare
38	3,061	6,428	15,305	6,185	14,725

Annex 2 Practical training - fertilization

Fertilizer spreading by hand

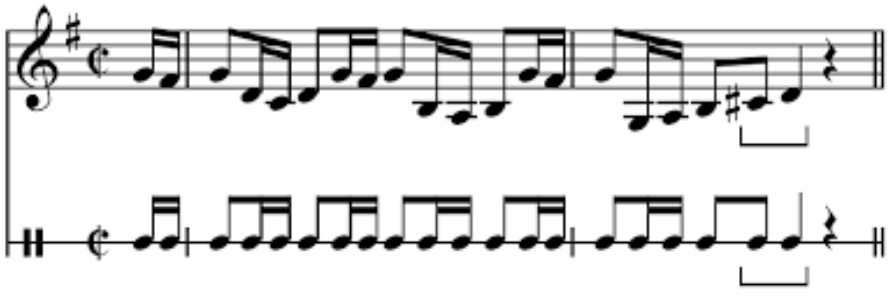
Practical exercise on an even distribution and ways of applying fertilizers:

Things to consider while working:

- Single or dual spreading
  * either left & right hand at the same time = one direction
  * left hand forwards / right hand backwards = up and down same track

- Bigger particles / granules fly higher and further
  wind has a negative impact on even distribution – compensate when necessary

- Walking and spreading movement should be in an cadence – like a melody



- What will be your working with – how much overlap do you need

- Divide your total amount in two and do a crosswise application

- With small amounts per feddan or powdery granules do apply additional (non fertilizers) ballast products: coarse sand

-

- Check – Control - Adjust

Advised fertilizer application per feddan at an approximate yield of 10 ton/feddan:

Fertilizers in kg per feddan **1 feddan = 4,200 m^2**	**Yield**	**N**	**P_2O_5**	**K_2O**	**CaO**	**MgO**	**SO_3**
	10	**52**	**16**	**72**	**12**	**10**	**14**

Demo-field Kassala town

demo field 1.600 m^2
field = 0.38 feddan

	Yield	N	P_2O_5	K_2O	CaO	MgO	SO_3
	4	20	6	27	5	4	5
Ammonium Sulfate	24	5	-	-	-	-	6
Blend 12-12-17+2Mgo	50	6	6	9	-	1	-
Potassium Nitrate	42	6	-	19	-	-	-
Urea	6	3	-	-	-	-	-
		0	0	-0	5	3	-0

Exercise

- Measure up your plot – 10 meter wide / 40 meter long = 400 m2
- Divide the plot in 4 sections of 10x10 meter = 100 m2
  so now you have created 4 plots total = 4 exercise repetitions
- The broadcasting width with fertilizer spreading by hand is roughly three (3) to four (4) meters wide. So each plot consists of 3 tracks
- Prepare the mixture for each plot = 4 mixtures total
  per plot: 1,5 kg Ammonium Sulphate / 3,1 kg Blend 12-12-17+2MgO
  2,6 kg Potassium Nitrate / 0,4 kg Urea - mix it all well
- Plot size = 100 m2 - total 7,6 kg per plot = 76 grams per m2
- Place in the middle of the plot you are working in - the two one square meter (1 m2) plastic covers on either side of the middle walking track = track number 2
- **Fertilize your plot**
- After working in a plot – weigh the amount of fertilizer per square meter separately
  * determine the distribution by comparison of the two 1 m2 plastics
  * determine the total kg applied per plot and for the whole field
  do the calculations based on the combined weight of the 2 plastics (2m2)

Annex 3 Nutrient calculator and fertilization in practise

Since there is no data available on soil born nutrient stock, available to plant growth, and/or local research on cropping potatoes – we made up a table on Yield potential & Nutrient uptake (source M. Vermeer, DLV Plant – Potato Signals). As goal for this year cropping of potatoes, we put in a yield potential of 25 ton per hectare = 10 ton per feddan. These 10 tons per feddan was used as the base of the Nutrient Calculator.

Roughly we observed that the growers mainly rely on the primary elements like N-P-K (esp. N – Nitrogen) and disrespect the secondary elements Ca-Mg-S and tracer elements. Another observation is that our farmers applied a fertilization scheme which was able to supply a yield in between 6 and 10 ton per feddan.

Yield Potential & Nutrient Uptake

Expected yield	Uptake by whole plant					
ton/ha	N	P_2O_5	K_2O	CaO	MgO	SO_3
10	55	15	75	15	10	20
15	85	25	115	20	15	25
20	110	30	150	25	20	30
25	**130**	**40**	**180**	**30**	**25**	**35**
30	145	50	210	35	30	50
40	180	65	270	45	40	60

Expected yield	Uptake by the whole plant					
ton/feddan	N	P_2O_5	K_2O	CaO	MgO	SO_3
4	22	6	30	6	4	8
6	34	10	46	8	6	10
8	44	12	60	10	8	12
10	**52**	**16**	**72**	**12**	**10**	**14**
12	58	20	84	14	12	20
16	72	26	108	18	16	24

Fertilization scheme NSAL small demo field – including a topdressing of 23 kg N extra in January.

NSAL - small demo Kassala	Fieldsize	N	P_2O_5	K_2O	CaO	MgO	SO_3
	0.4						
Ammonium Sulfate	24	5	-	-	-	-	6
Blend 12-12-17+2Mgo	50	6	6	9	-	1	-
Potassium Nitrate	42	6	-	19	-	-	-
Urea	26	12	-	-	-	-	-
Total		29	6	28	0	1	6
per feddan		75	16	73	0	3	15
advice		52	16	72	12	10	14
differences		23	-0	1	-12	-7	1

Ali Zain	Fieldsize	N	P_2O_5	K_2O	CaO	MgO	SO_3
	5.7						
Foliar application + TE	80	12	-	36	-	-	-
Sulphate of Potash (SOP)	140	-	-	70	-	-	25
Single Super Phosphate (SSP)	650	-	98	-	0	-	0
Urea	350	161	-	-	-	-	-
Total		173	98	106	0	0	25
per feddan		30	17	19	0	0	4
advice		52	16	72	12	10	14
differences		-22	1	-53	-12	-10	-10

Hayder	Fieldsize	N	P_2O_5	K_2O	CaO	MgO	SO_3
	1.3						
Foliar application + TE	0.5	-	-	-	-	0.00	-
Foliar application	3	0.3	0.3	1.2			
Foliar application	1.5	0.2	0.4	0.2			
Ammonium Sulfate	75	16	-	-	-	-	18
Diammonium Phosphate (DAP)	100	18	46	-	-	-	-
Potassium Nitrate	50	7	-	17	-	-	-
Urea	100	46	-	-	-	-	-
Total		87	47	18	0	0	18
per feddan		67	36	14	0	0	14
advice		52	16	72	12	10	14
differences		15	20	-58	-12	-10	-0

Omar - 1	Fieldsize	N	P_2O_5	K_2O	CaO	MgO	SO_3
	2.0						
compost	430	4	43	4	65	0	-
Ammonium Sulfate	250	53	-	-	-	-	60
Blend 11-11-43	50	6	6	22	-	-	-
Diammonium Phosphate (DAP)	150	27	69	-	-	-	-
Potassium Nitrate	100	14	-	46	-	-	-
Total		103	118	72	65	0	60
per feddan		51	59	36	32	0	30
advice		52	16	72	12	10	14
differences		-1	43	-36	20	-10	16

Ali Ibrahim	Fieldsize	N	P_2O_5	K_2O	CaO	MgO	SO_3
	5.0						
Ammonium Sulfate	350	74	-	-	-	-	84
Diammonium Phosphate (DAP)	100	18	46	-	-	-	-
Urea	75	35	-	-	-	-	-
Total		126	46	0	0	0	84
per feddan		25	9	0	0	0	17
advice		52	16	72	12	10	14
differences		-27	-7	-72	-12	-10	3

Annex 4 Results of the Nitrogen fertilizer experiment at the ARC

During the first year of the NSAL /K2K project discussions between the experts form the Netherlands and the ARC about the amounts of Nitrogen to be applied remained unsolved. For this reason high priority has been given by the partners of NSAL to conduct a Nitrogen fertilizer experiment – the effects of different Nitrogen application levels on growth and yield of potato – at the ARC experimental station in Kassala.

Before soil preparation and planting the field has been given a basic fertilization of 75 kg 20-18-30 (NPK) per feddan, which corresponds to 15 kg Nitrogen per feddan as basic fertilization. The fertilizer experiment consisted of four treatments (0 (control), 24, 36 and 48 kg Nitrogen per feddan) with four replications. The experiment was carried out with imported seed potatoes of the variety Bellini. The trial field has been irrigated 12 times from planting to harvesting, with an interval of approximately 10 days.
Unfortunately the potato trials fields were severely affected by spider at the end of the growing season, causing a rather early harvest of the potatoes. The total growing season was only 88 days, which short compared to the other NSAL potato fields (approximately 110 days).

Table 1 *Yield in ton per feddan at 4 different Nitrogen levels.*

N-input	Repl. 1	Repl. 2	Repl. 3	Repl. 4	Average Yield
0	2.8	3.0	3.4	3.0	3.1
24	7.1	7.3	11.8	11.1	9.3
36	9.3	13.3	10.7	6.4	9.1
48	7.6	6.9	11.0	9.6	8.8

Table 2 *Total number of tubers at 4 different Nitrogen levels.*

N-input	Repl. 1	Repl. 2	Repl. 3	Repl. 4	Average Yield
0	100	136	122	114	118
24	234	230	331	313	277
36	227	335	228	225	254
48	242	173	308	259	246

Table 3 *Number of big tubers at 4 different Nitrogen levels.*

N-input	Repl. 1	Repl. 2	Repl. 3	Repl. 4	Average Yield
0	0	0	0	0	0
24	43	43	87	48	55
36	90	81	69	30	68
48	47	39	75	48	52

Table 4 *Number of medium sized tubers at 4 different Nitrogen levels*

N-input	Repl. 1	Repl. 2	Repl. 3	Repl. 4	Average Yield
0	35	25	34	38	33
24	153	121	200	187	165
36	106	185	166	147	151
48	139	92	188	148	142

Table 5 *Number of small tubers at 4 different Nitrogen levels*

N-input	Repl. 1	Repl. 2	Repl. 3	Repl. 4	Average Yield
0	70	69	71	74	71
24	30	56	40	75	50
36	36	66	51	38	48
48	41	34	37	36	37

Table 6 *Number of other tubers (damaged, etc.) at 4 different Nitrogen levels*

N-input	Repl. 1	Repl. 2	Repl. 3	Repl. 4	Average Yield
0	15	17	13	19	16
24	8	10	4	3	6
36	5	23	12	10	13
48	15	8	8	27	15

Table 7 *Number of stems per plant at 4 different Nitrogen levels*

N-input	Repl. 1	Repl. 2	Repl. 3	Repl. 4	Average Yield
0	1.3	1.4	1.4	1.3	1.4
24	2.6	1.6	2.2	2.6	2.3
36	1.6	1.6	1.6	2.2	1.8
48	1.2	2.4	2.2	3.0	2.2

Table 8 *Plant high in cm at 4 different Nitrogen levels*

N-input	Repl. 1	Repl. 2	Repl. 3	Repl. 4	Average Yield
0	40	20	35	25	30
24	36	50	50	51	47
36	48	42	51	52	48
48	41	53	50	50	49

The following cautious conclusions can be drawn.

1. There are big differences in yield between some of the replications. For instance from 6.4 to 13.3 ton per feddan at the input of 36 kg N.
2. The same conclusion can be seen at the number of big tubers, from 30 to 90 at the input of 36 kg N.
3. There is no clear difference in yield per feddan and number of tubers between the 3 Nitrogen application levels. Whether or not the early harvest of the trial fields - due to severe spider attack – has influenced this conclusion is not clear.
4. There were no visual differences in the colour of the leaves between the 3 Nitrogen application levels.
5. The basic fertilizer application is not enough for a good potato production. The yield per feddan but also the number of tubers of the untreated (zero) experiment remain far behind compared to the other fields.

Annex 5 Potato growing and Sieda

Sieda or Si'dah or yellow nutsedge is known as Cyperus esculentus. This tuber forming grass type weed is a real plague in agriculture, mainly in Mediterranean countries.

The plants are difficult to control and the small tubers give the plant the opportunity to restart after insufficient measures of control.

In potatoes the damage is two way.

- Harvest losses because of competition for light, water and nutrients.
- Quality losses because of stolon growing trough tubers.

In earlier days, the roots were harvested and consumed. They taste a bit like almonds and have a high content of fatty acids, starch and proteins.

Potential measures to minimize the damage:

Mechanically / by hand:

- Checking the field and removing visible plants, if possible with the small tubers.
- Repeated soil preparation with machines.
- Harvesting and removal of the tubers.

Physical:

- Covering the soil with black plastic for some weeks to months.
- Inundation for a longer period. (2-3 months.)

Crop rotation:

- Good developed crops minimize the growing possibilities of the Sieda plants.

Chemical:

- In empty fields a soil fumigation with Metam-Sodium on wet soils can be applied. (700 l/ha)
- Roundup (Glyphosate) treatments before planting the next crop. (8 l/ha)
- Full treatment with Sencor (Metribuzin) before planting the next crop. In potatoes before emergence of the potatoes. (1-2 l/ha)
- In potatoes, repeated applications of low doses of Sencor (50-100 gr/ha) during the growing season.
- In potatoes or corn, Titus (Rimsulfuron) on young Sieda Plants.
- In potatoes or corn, Basagran (Bentazon), 3 liter per ha.
- In several crops, Dual Gold (S-metolachloor), 1,6 l/ha before emergence.
- In corn there are several chemicals available, always to be used on young Sieda plants with ~3 leaves. Best is Calaris (Mesotrione + Terbuthylazine)

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