Current potato production in Algeria

An explorative research of the current potato production systems in two regions

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Summary

While Algeria is among the countries with the lowest renewable water resources per capita in the world, agriculture accounts for 70-80% of the total water use and municipal water use is expected to almost double in the next twenty years. As potato is in Algeria the main irrigated crop and the first vegetable crop in terms of area and production, improving the potato production system and rationalizing the use of water is key to sustain the production in the future and to maintain and enhance food safety. Coherent information of the current potato production system is crucial to improve a system and since this is lacking, we research what is the current situation for potato production in two main production areas of Algeria, in a Mediterranean and desert climate. Through interviews with farmers, other stakeholders and field visits in both areas the current systems are described, analysed on main weaknesses, followed by and advice regarding improvement and implementation of the subsequent project which will be a setup of a demonstration farm to introduce a more productive and sustainable system. It was found that the systems have many points for improvement regarding productivity and sustainability. That both regions have a lack of technology and accurate data of 1) the exact inputs applied, and 2) the exact requirements, especially regarding water supply, lies on the basis of most weaknesses, resulting in rough irrigation, fertilizer and pest management. The main recommendation is to elaborate research of the current system with productivity as focal point to make clear what are the economic advantages for a farmer to adapt the new system. Farmer Field Schools are proposed as a practical and hands-on management approach to implement suggested improvement practices and to introduce a new production system.

To give an impression of the enthusiastic welcome and willingness to cooperate with us, Mr. Ammar Hettiri (potato farmer in El Oued) sent us after our internship the following message:

Video by Mr. Ammar Hettiri

1. Introduction

Potato (*Solanum spp*) is among the five most important staple food crops in the world, and it is cultivated along a wide range of climatic conditions (Kromann et al., 2014). It also has a low water footprint and a high nutritional value (Wolters et al., 2016). These features make it an interesting crop for Algeria, where potato production and consumption has expanded considerably the last three decades. Currently, large potato production areas (in total 90,000 ha) are found in several regions in this large North African country, and the sector is still growing fast. Most potatoes produced in Algeria are also consumed in the country, and Algeria is self-sufficient in its potato consumption (Huizenga & te Maarn, 2013). Potato in Algeria represents the first vegetable crop in terms of area and production, with an area of 156,176 ha, a production of 4,673.5 million tons with a return rate of 29.9 tons/ha (Ministry of Agriculture). As shown in figure 1, there are large production concentrations in Mostaganem, Aïn defla, Boumerdes and Bouira (Mediterranean climate), as well as in the region around El Oued (desert climate).

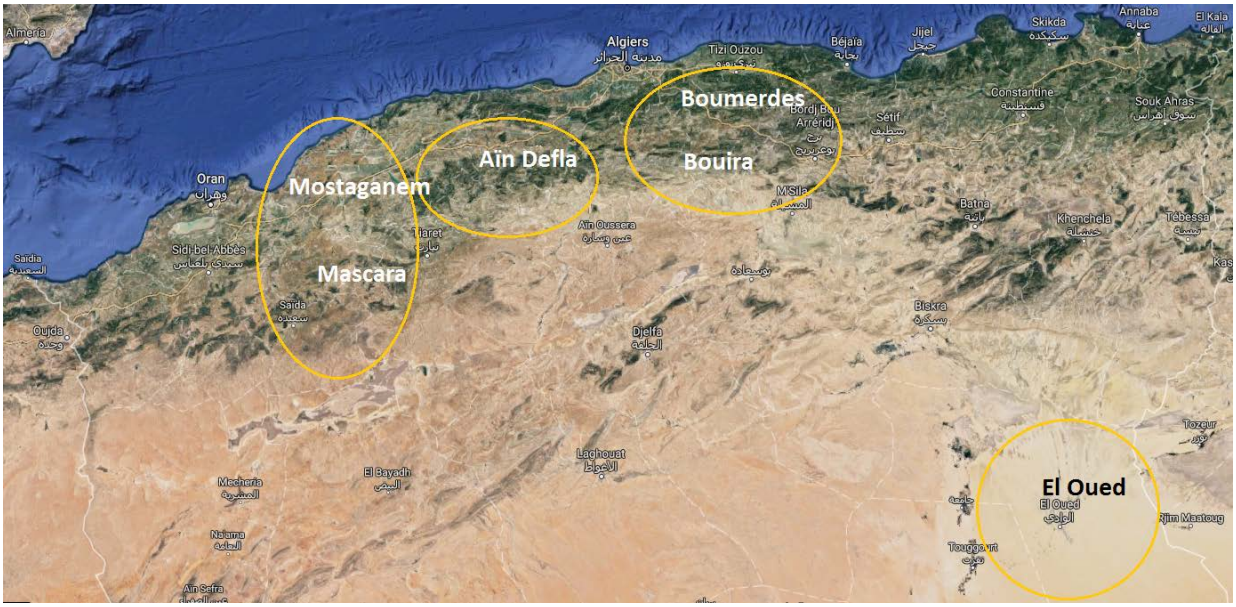

Fig. 1: Main potato production areas of Algeria (yellow cirkels)

Important characteristics of potato production in Algeria are its heavy reliance on irrigation and its low mechanization rate, so that large quantities of manual labour are required. This poses several challenges, because working in agriculture has a low status, and it is increasingly hard to find enough labour for harvesting, planting and irrigating (Huizenga & te Maarn, 2013). Another major challenge of the potato sector in Algeria is the water use. In the coastal region, as well as in El Oued, production relies on (daily) irrigation, and water is often applied wastefully, with large losses. This is a severe problem, because Algeria is among the countries with the lowest renewable water resources per capita in the world (Mohtar, Assi and Daher, 2017, WRI, 2005), and the water demand is expected to increase drastically in the near future (Serbi, 2016). The coastal region of Algeria has already seen a decrease in annual precipitation of more than 50 mm per year since 1950, and climate models predict a temperature rise and a further precipitation decrease in the future. As a result, groundwater levels, as well as inputs in storage reservoirs are expected to decline (García-Ruiz et al., 2011). Currently, agriculture accounts for 70-80% of the total water use in Algeria (Huizenga & te Maarn, 2013), but

municipal use of water is expected to almost double in the next twenty years (Serbi, 2016), which further underlines the urgency to increase water use efficiency in agriculture.

As potato is the main irrigated crop in Algeria (Huizenga & te Maarn, 2013), improving the potato production system and rationalizing the use of water is key to sustain the production in the future and to maintain and enhance food safety.

Because of its importance (Algerians self-sufficiency of this staple crop) and its along coming impacts (wasteful water use while renewable resources are low), the potato production system of Algeria calls for improvement. In a 2 years project within the framework of the Partners for Water Programme, a new system will be introduced to achieve a better production and more efficient use of resources, especially water. To design and succeed a more sustainable production system, it is necessary to know how the current systems perform, in order to know what to improve but also to show what difference the new system would make from an environmental and economical perspective. Besides that, it is essential to be aware of the conditions formed by external factors such as legislation and access to inputs. Currently there is no coherent documentation of the potato production systems in Algeria. Therefore, this exploratory research describes the potato production system of two major production areas of Algeria, namely the region of El Oued and the Mediterranean region.

Both systems are exclusively supplied by groundwater but have a different climate and management. To compare both areas, the research question as formulated below will be answered based on interviews with farmers, other stakeholders and field visits in both regions, supplemented by our own observations.

What is the current situation for potato production in Algeria?

After a description of the system, main bottlenecks are summarized and analysed, in order to give advice for improvement of the system and a good implementation of the subsequent project which will be a setup of a demonstration farm in El Oued to introduce a new, more productive and sustainable system.

Chapter 2 describes the methods followed to research the current situation for potato production in the Mediterranean and El Oued region of Algeria.

The Algerian production system of potato is first described from the organizational perspective (chapter 3) in general, which applies for both regions. The following chapter describes for each region specifically (paragraph 4.1 and 4.2) the production system of potato and its setting regarding access to inputs, production methods, problems and so on. Chapter 5 concludes with a summary of the main bottlenecks and important considerations and advice for the setup and implementation of the demonstration farm.

2. Methods

Because access to the research areas, time and resources were limited, the research of the current system went through many adjustments. The research was finally done through interviews, followed by a short literature review of a proposed method to organize the introduction of a new system in the subsequence project.

Interviews

To get a good insight in the production of potatoes for two entire regions and its setting, potato farmers from small to large-scale farms and other stakeholders and experts in Mediterranean and El Oued region were interviewed. Interviews were conducted following the semi-structured interview technique, meaning that "*the interviewer follows the guide (the question list), but is able to follow topical trajectories in the conversation that may stray from the guide when he or she feels this is appropriate*." (Cohen & Crabtree, 2006). This so called semi-structured interview technique goes well with the explorative approach of this research because it provides some structure based on our information requests, while it allows room for the respondent's spontaneous descriptions and additions (O'Keeffe et al., 2015). The explorative approach is strongly related to the limited research conditions combined with the limited presence of coherent data and practical information of potato production in Algeria, especially for the two regions specifically. Other research showed that semi-structured interviews are an efficient and effective method to collect qualitative and quantitative information for assessment of drivers, behaviour and their consequences in a data scarce region (O'Keeffe et al., 2015).

In total 28 interviews were conducted, of which 16 were with farmers. Others were with experts in the field of fertilization, irrigation and water use, agronomy and legislation related to potato production, and other stakeholders such as suppliers and directors of the farmer cooperatives (see Appendix 2).

The interviews were held at the farmers' field, to use the opportunity to demonstrate their experiences in practice. Each interview took approximately 2 hours and was held with each farmer personally, eventually accompanied by our colleagues for translation. Questions were prepared in advance and formulated as open questions, to lead the conversation in a standardised way while allowing the opportunity to identify relevant issues besides the requested information (O'Keeffe et al., 2015).

Interview questions covered the following subjects:

- Institutional setting, policy and infrastructure
- Land ownership and access to inputs
- Site description
- Planting (row distance, planting depth, ridges yes/no, planting on or between ridges, use of machinery, time)
- Crop cycle
- Crop management (nutrient, pest, irrigation management)
- Description of the irrigation system
- Irrigation method and timing (how do farmers decide when to irrigate)
- Harvesting (machinery/by hand, method, time)

- Costs of water
- Experiences of farmers (i.e. problems they face)

Description of the system and advice regarding introduction of a new system

For each region, the interviews were processed into a description of the production system and its framework, with special attention for bottlenecks regarding productivity (profitability for the farmer) and sustainability, as well as for opportunities. The current system as described in this report, is based on our conversations with these farmers and stakeholders. Thus, all information without a reference, refers to the respondents and our own observations because references for each statement would obstruct the readability. If data is retrieved from another source, it is referenced.

For a full understanding of the main bottlenecks and their interrelations, the weaknesses and issues were listed for each component of the system. Through brainstorms and further dividing of the problems an overview was made in the form of a table. With this overview as starting position, suggestions for improvement of the system and advice regarding introduction of a new system are given. Additional, as organizational structure for the introduction of a new system in the subsequence project, farmer field schools were discussed based on a literature review.

3. Institutional setting, policy and infrastructure

As legislation and its consequences are similar for both regions, this chapter describes the institutional setting and infrastructure regarding potato production in Algeria. Region specific deviations are described in the following chapters.

The country is divided in 48 provinces, the so called Wilaya's for which each has its institutes to govern the sectors of agricultural production directly or through the lower levels of government. The wilayas are divided respectively in 547 daïras (districts) and 1,541 baladiyahs (municipalities). Farms in Algeria are organized as registered companies at the Chamber of Agriculture of each Wilaya.

It is not obligatory to register as a farmer but most farmers do so because it is essential to receive subsidies and to have access to chemical fertilizer. Farmers who do not register are not necessary small farmers but just people who think they do not need the government. These farmers buy their fertilizer from other growers. When farmers are registered, they receive a card to proof they are a farmer, which is used to get fertilizer and for other official events.

3.1 Policy and restrictions

The Algerian government aims to develop the agricultural economic sector in order to limit import and increase the self-sufficiency of the country. The government achieves this by enhancing the production practices, to increase productivity. Therefore, there are not many restrictions and there is financial support given by means of subsidies on inputs.

Discounts are given by the government for purchasing the following products:
- 25% discount on fertilizer;
- 20-30% discount on machinery;
- 20-30% discount on irrigation systems;

There is also a subsidy constructed by the Ministry of Agriculture to help growers to store their potatoes, with the aim to ensure the potato supply in times of scarcity. This fund, called *Le Système de régulation des produits agricoles de large consommation* (SYRPALAC), can be utilized by farmers if they declare how many potatoes they store and where. When the potatoes are stored, they cannot be sold without permission of the governing organ *Office National Interprofessionnel des Légumes et des Viandes* (ONILEV).

Seed potato production is also financially supported by the government, to promote but also to control when and where the seeds are planted. Seed potatoes are controlled on their quality by Centre national de contrôle et de certification des semences (CNCC). Farmers have to declare to the Ministry of Agriculture before they start growing seeds. CNCC then examines the sanitary situation at the plot before starting and conduct regular check-ups during the season.

Restrictions apply to the amount of fertilizer a farmer can buy and farmers must pay for the water retrieved from the dams that the government facilitates, because this water supply is important for general water supply to the community. Also establishment of a well is restricted in order to limit ground water exhaustion. Water from the well, so pumped up by the farmers themselves, is for free.

For the latter, farmers need a permit from the Wilayas' *Le Direction de hydrolique* (The Department of Water) where it will be assessed whether a well can be established at the requested location. Approval depends on the representation of other wells and the underground water resource status. The costs for water of the dams is calculated based on the total amount of water output and the farmers' share which is based on his field surface.

The amount of fertilizer farmers can use is restricted by the government because fertilizer can be used to build explosives. The *Direction Service Agricol* (DSA) of each Wilaya calculates the average yield of specific crops in their region, to decide how much of each nutrient a farmer needs for one hectare to reach this average yield. Based on this calculation farmers get a permit for a maximum amount of fertilizer based on their field surface. Thus, some farmers who want to optimize their yield (thus pass the average) get more fertilizer e.g. by applying for 20 hectares while they plant only 15 of it.

The chemical fertilizer market is thus very well controlled. Farmers even get escorts to safely transport their fertilizer from the supplier to their storage, depending on the region and the quantity. Suppliers have to inform governmental institutes who bought which amount of fertilizer.

3.2 Financial support by banks

Financial support by means of loans is only provided by a governmental bank named *Banque d'Agriculture de Development Rurale* (BADR), which only offers loans to farmers who are creditworthy, so in practice only the big farmers. Thus, to establish a farm (or to expand the business), farmers really need to have their own money. For buying inputs a system arose in which the small farmers get their inputs via the bigger farmers as if it were a loan. After the harvest, the small farmers pay (with interest) for the costs of the inputs. This is a win-win for the bigger farmers since they get interest from the small farmers and get more discount from the importers because they buy a greater quantity. BADR offers two kinds of loans which were initiated by the Ministry of Agriculture. One loan is constructed for operating, to buy inputs etc., the other is for investment, but both are only supplied to creditworthy clients.

3.3 Farmers organisation

Farmers can join one of the cooperatives to have access to cheaper inputs, exchange knowledge and to get help from services such as agronomists and information on new products. There are national and regional cooperatives. To start a growers cooperative in Algeria, you have to be a group of minimum 9 growers. In El Oued there are two, namely *Coopérative Agricole de Services des Approvisionnements* (CASAB) and *Cooperative d'Agricole de Guemar*. The latter is the oldest, setup in 1986 in Guemar, a daïra of El Oued, around the same time that potato production started in El Oued. The organisation counts 2012 farmers from different crops. The main activity of both cooperatives is to provide cheaper inputs and advice. CASAB was setup in 2015 in the daïra Rabah, by 9 growers, where after 30 more growers joined the cooperative. Neither of the cooperatives supply machinery or tools yet, but they are willing to do so if there is sufficient demand. At the moment there is a minor demand and farmers also borrow from each other.

3.4 The market

The market for potato is an open market, closely followed by the government (Ministry of Trade). The structure of the market is shown in fig. 2. To know the entire chain and origins of products, the Ministry of Trade obliges farmers to give a kind of receipt to their buyers. Most farmers refuse to do this, so in practice farmers go to wholesale markets or directly to middlemen to sell their potatoes.

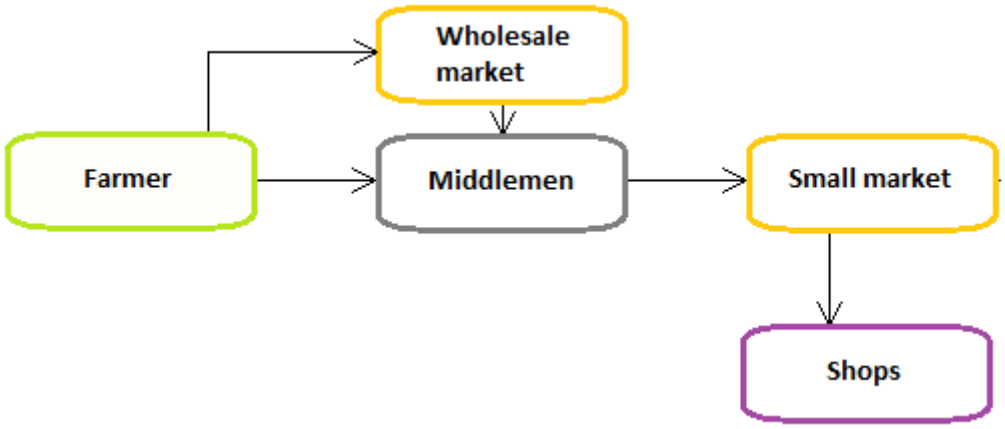

Fig 2. Structure of the potato market.

The processing industry for potatoes is not well developed since there is no process company for fries, only some for chips. All the fries which are sold at every street corner, are still peeled and processed by hand. <1% of Algerian potatoes are processed. This could change within the coming years, since there is quite some interest by business men to start a processing factory and feasibility studies are being conducted.

4. Production systems

The Algerian production system of potato is first described in general, which applies for both regions. The following two paragraphs (4.1 and 4.2) describe for each region specifically the production system of potato and its setting regarding access to inputs, production methods, problems and so on. The system itself consists basically of several steps as shown in Fig. 3 for the main season of each region.

Activity	Part of the season					
	1st	2nd	3rd	4th	5th	
Soil preparation	*ploughing (tractor)* *loosen & furrows (tractor)*					
Fertilizer application NPK	*1st if possible* *manure, spread by workers*	*mainly chemical, preferred before planting. Otherwise 10-15 days after* *chicken manure or chemical*	*2nd application*	*organic or chemical*		
Natural defense promoting fertilisation and other nutrition		*DAP, repeated every 2 weeks*	*K and P* *K and P*	*Potassium* *Potassium*		
Planting	*planting machine + 5 workers, at 15 cm depth* *after manure, by hand*					
Ridging	*tractor*					
First irrigation event						
Irrigation	*After each 7 days per spot for 4 hours*					
Pesticide application	*soil insects and weeds* *soil insects and weeds*	*mainly against mildew* *mainly against nematodes*				
Harvest					*tractor + workers* *Whenever the prices are good, All by hand, commonly sold directly*	*Harvest sold or stored*

El Oued region
Mediterranean region

Fig 3. Overview of the potato production system during the main season in both regions.

An overview of farm scales in the two regions is given in fig 4. However, in El Oued it is common to use only a part of the pivots, because of the crop cycle (fallow system) and limited water supply.

Region	Small scale	Mid scale	Large scale
Mediterranean	3-5 ha	5-20 ha	20-40 ha
El Oued	1-2 pivots	10-20 pivots	20-70 pivots

Fig. 4. Farm scales in the two regions.

Thanks to the warm and varied climates within the country, almost all months of the year (9 months) potatoes are grown somewhere in Algeria. Farmers in Algeria talk about 3 seasons:

- *Premiere saison*, further referred to as 'the season' which starts in January-March and ends in May-July;
- *Arrière saison*, further referred to as 'last season' which starts after 'the season', from August (North)/September (El Oued) till December;
- *Primeur saison*, which accounts only for 5%, thus is not further mentioned.

Most farmers of the Mediterranean region focus on 'the season', while the majority in El Oued focus on the 'last season'. An overview of the seasons is given in fig. 5.

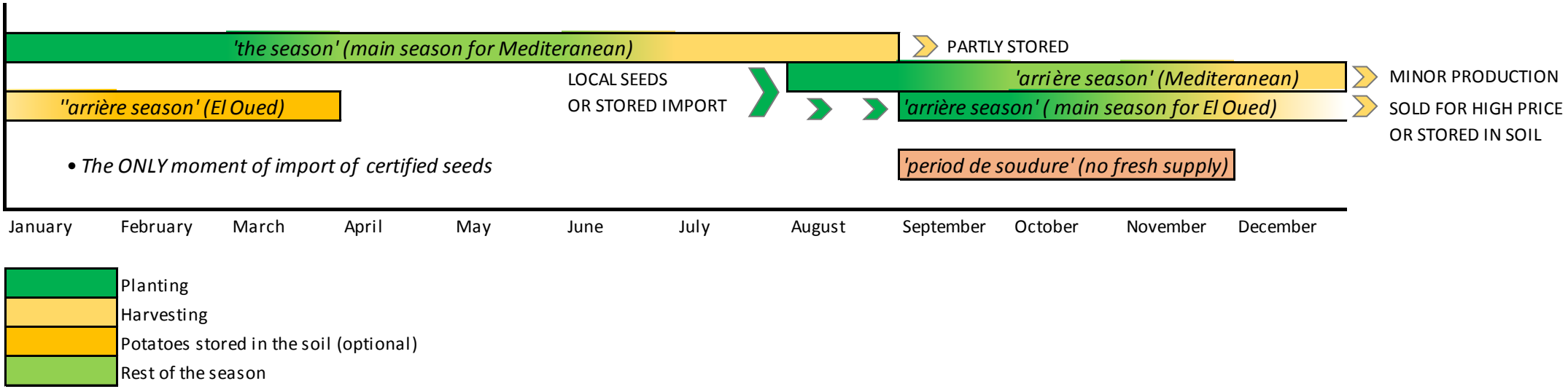

Fig. 5. The main seasons for potato production in Algeria.

4.1 Mediterranean region

Being the most intensively populated part of the country, mainly because of its water supply, the Mediterranean region produces a wide range of agricultural products, including potato. The majority of the potato farmers grow potato as their main crop, commonly rotated with cereal or water melon. Farm sizes range from 3 to 40 ha, but small farms are most present. Potato farmers use to grow 5-20 ha and it is common to hire land from other farmers too. Mainly potato farmers tend to do so because it is a reliable crop in terms of the demand – after bread it is the most popular food. Other crops are grown on a smaller scale.

Potato production used to take place only in specific areas in the Mediterranean, such as Mascara. In the 70's potatoes in Mascara were grown on big governmental-owned farms with seed potatoes mainly imported from The Netherlands. After the government divided their fields over private companies and farmers in the 90's, the production became widely spread throughout the Mediterranean and later even the desert region. The great expansion of potato production throughout the country resulted in the current situation in which 10 months of a year, potatoes are harvested somewhere in Algeria so there is always a fresh supply of potatoes.

Most of the soils in the North are heavy clay soils (40% clay content at the research farm in Boumerdes and 35% clay content is common in Aïn Defla). The soils can contain big stones and the landscape varies from flat to hilly (fig 6).

Fig. 6. Hilly fields characteristic for the Mediterranean region.

Potatoes in the Mediterranean are grown during 2 seasons, 'the season' from February till the end of May/July, and the 'last season' from August/September to December. The main season however is from February till the end of May/July. The end and start of a season stretches over quite a long period of time, because harvesting is done by hand and the climate allows it.

Common varieties in the Mediterranean region among others are Condor, Désirée, Fabula and Ultra and Spunta is the main variety (about 40% of the production is Spunta).

4.1.1 Land ownership and access to inputs

Land ownership

Land is privately owned or belongs to the state, which can be rented over a short period, or a 35 years long 'ownership'. The price for ownership in Boumerdes is 120,000 DA/ha/year (960 euro/ha/year[1]) while for the rental land it is 150,000 DA/ha/year (1,201 euro/ha/year[1]). Land for sale is scarce and expensive.

Inputs

The inputs for potato production in the Mediterranean are:

- Regular tractor
- Crawler track tractor
- Planting machine (only bigger farmers)
- Pesticide application device (spray)
- Well
- Pump
- Irrigation pipes and sprinklers
- Fertilizer
- Pesticides
- Seed potatoes
- Labour

The system of inputs supply is shown in fig 7.

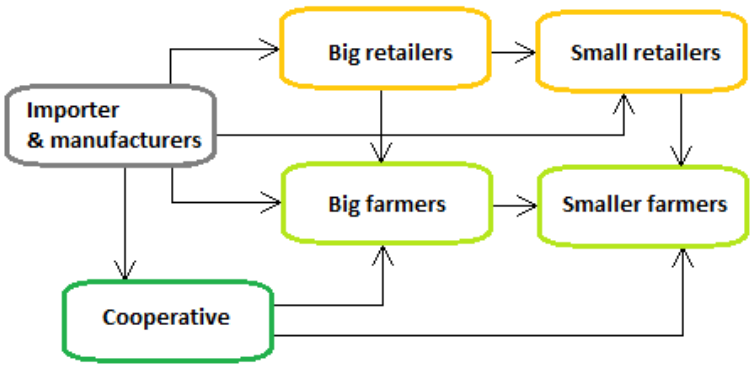

Fig 7. The system of inputs supply for potato production (excluding labour).

Seed potato classes

There are 4 classes of seed potatoes to buy, from higher to lower quality respectively:

- Super Elite (SE) for multiplying purposes
- Elite (E) for both multiplying and production purposes
- Class A for production purposes
- Class B for production purposes

[1] XE Currency converter, July 2017

Some bigger growers produce potatoes for both consumption and multiplying, using Super Elite, Elite and class A varieties. The cycle of seed potatoes is given in fig. 8. Small scale farmers tend to buy the cheaper classes A and B, resulting in a lower quality and lower yield. Potatoes can be bought from the importer, local producers, a big farmer or a cooperative who buys bulk quantities from importers. Some bigger farmers multiply potatoes themselves or buy bigger quantities to sell to smaller farmers. Imported seeds come mainly from the Dutch growers Agrico and ZPC.

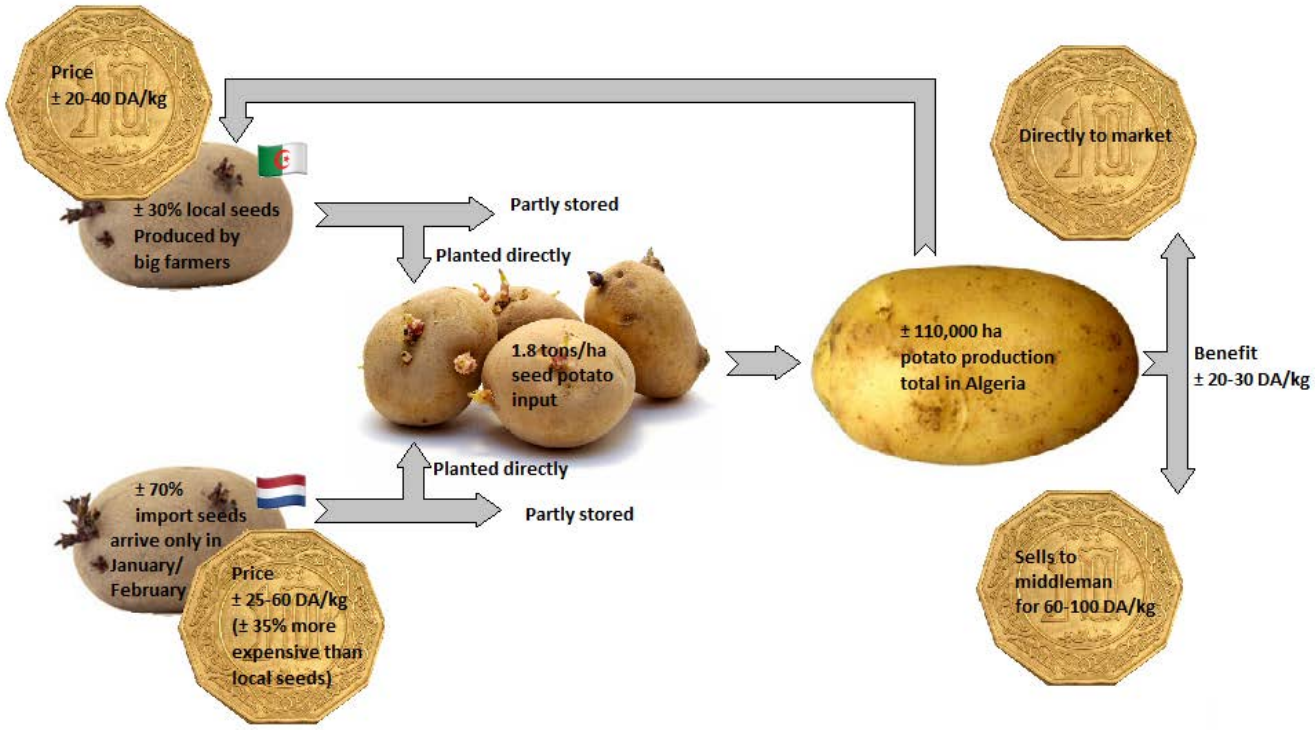

Fig. 8. The cycle of seed potatoes in Algeria.

Labour

Much of the work in potato production is still done by hand because machinery is most times higher in costs (compared to labour), requires an investment and is not always suitable for the local circumstances. For instance, farmers state that there is no suitable harvesting machine available which can deal well with the heavy soil. This could also be a mentality issue, there are importers who already imported such machines but farmers do not buy them. It is not clear whether these machines really do not adapt or that farmers have other reasons.

Another labour intensive activity is irrigation. Rather than irrigating the entire field at the same time, farmers irrigate the fields with only one line of sprinklers at the same time because it is cheaper to permanently pay labour who replace the pipes every 4 hours than to buy all the lines and sprinklers for the entire field.

Large scale farmers have managers and agronomists in service. Although labour is still well available, it is a trend that young people prefer other jobs over agricultural work, as farm workers do not get insurance and retirement. Workers are hired for the harvest, planting and the full-season activities such as irrigating.

Hardware

Irrigation systems by means of sprinklers and pipes are both imported and locally produced. It is possible to hire a tractor and tools. Also it is common to borrow from other farmers. Machinery however is not provided by the official farmer cooperatives.

The heavy clay soils require strong tractors and ploughing is essential. The soil is even prepared an extra time with a crawler tractor. Machinery is bought, hired or borrowed from other farmers. There are also contractors providing services as ploughing.

Fertilizer and pesticides

While the Mediterranean soils are already short in organic matter (1.7% at the research farm in Boumerdes while most productive agricultural soils contain 3-6%[2]), organic fertilizer is scarce and expensive, resulting in minor use of organic fertilizer compensated by chemical fertilizer. Also the quality of the organic fertilizer is not good, since it is not well organized and processed. Farmers buy fresh manure directly from cattle or poultry farmers and it is not composted. Neither there are regulations on transport etc. Prices are high due to its scarcity and competition with farmers from the South, who in general can afford more. Middlemen buy the organic manure in the North to transport it to the South to get a higher price. Since there are only 2 companies producing fertilizer in Algeria, most of the chemical fertilizer is imported.

Pesticides can be bought without a permit at regular retailers. Pesticides within the country are produced by only 1 state company, called ALPHYT. Farmers are therefore very much depending on the import. A lot of legislation around the import and sale of fertilizer results in unavailability and fluctuating prices. Pesticides are a big costs post for the farmer.

Storage

Although storage of harvested crops is promoted by the government, there is a shortage in storage facilities, especially in the Mediterranean region. Therefore a state group invests in storage facilities and more facilities are being constructed. Now that farmers of the South also start to grow more in the season February-July they need even more storage facilities. Potatoes are really processed (< 1%), apart from some chips. During some periods there is an overproduction and an export market is not really present, thus there is a call for more storage facilities.

4.1.2 Planting

Potatoes in the Mediterranean are planted in January/February ('the season') or August/September ('last season') and it takes up to 1 month to plant a field. Small farmers tend to plant by hand while bigger farmers use a planting machine pulled by a tractor, followed by 4-5 men to control and correct errors of the machine. Farmers can also hire contractors who do the ploughing and/or planting. Ploughing is done mechanically by all farmers. Depending on the moment of planting, land is ploughed with a simple plough or first by a special tractor because the soil is otherwise too tough for the regular plough to get through.

[2] http://franklin.cce.cornell.edu/resources/soil-organic-matter-fact-sheet

Farmers prefer to apply the first fertilizer application but because farmers are depending on a license they require to buy the fertilizer, they can be delayed so much that they decide not to wait and plant in advance. Unfortunately that is mostly the case, so the fertilizer is applied at 80% plant emergence. Other farmers fertilize 10-15 days after planting.

Seed potatoes are cut in half (to save costs) when they are very big and planted at 15 cm depth, at 25-30 cm planting distance and 65-75 cm row distance. With 4-5 workers and 1 planting machine it takes 1 day to plant about 4 hectare. Directly after planting the ridges are constructed mechanically, and the potatoes are irrigated by the sprinkler system. Ridges are created one time per season and not earthed again.

4.1.3 Crop cycle

In the Mediterranean it is common to have a rotation of potato and cereal or potato and water melon. Also mixed systems of livestock and crops exist, but then the crops are mostly forage. 25-30% of the farmers have a mixed system. Farmers apply rotation because they are aware of its importance regarding diseases and pests. Rotation can also be economically attractive, for instance by producing forage, a subsidized crop, in the winter.

4.1.4 Nutrient management

Just before or 10-15 days after planting the first fertilisation is applied. In the Mediterranean region potatoes are fertilized with NPK for 2 times, while in El Oued this is 3 times.

The fertilizer scheme does not differ between small, mid and large scale farmers, but the concentrations differ, according to the farmers' financial capacity and their vision on the necessity. Because of this, small farmers apply less fertilizer. Normally, farmers follow the scheme which is advised by agricultural engineers sent by the importers. Most farmers follow the moments of application but give lower quantities (75-80%), based on their own reasoning. Fig. 9 shows the schedule and proposed concentrations of fertilizer and pesticide applications throughout one growing season.

The NPK applications normally have a ratio of 15-15-15 or 11-15-15 but it depends per farm. For instance, the farm of Haouchine is fertilized with respectively 8-15-21 and 8-15-24 NPK. Some farmers use partly organic fertilizer (2-3 ton/ha) but because of its scarcity and high price it is less common. Because the soil is saturated by Mg++ and Ca++ farmers apply acidifying fertilizer to lower the PH (7.4 at the research farm in Boumerdes) and make the nutrients accessible for plant

Treatment	Phenologic state > Need / disease / pest [v]	Planting	Sprouting	Active growth	Tuber formation	Tuber growth	Senescence / Harvest
Sowing	Seed potatoes	*2.5 - 3 T/ha*					
Fertilisation	NPK (soil application)	*900 kg/ha*					
	NPK (soil application)		*800 kg/ha*				
	Humic acid	*2 applications of 25 L/ha before each fertilizer application*					
	Amino acids		*2 applications of 2 L/ha*				
	K and P for stimulation natural defense				*2 applications of ± 3 L/ha*		
	Trace elements			*3 applications of ± 1 kg/ha*			
	Potassium					*2 applications de ± 3 L/ha*	
Pesticides	Soil insects (soil application)	*1 application of Force 15 kg/ha*					
	Weeds	*Sencor 0.8-1 kg/ha*					
	Alternaria			*Score 0.3 L/ha or Consento 2 L/ha*			
	Mildew		*Bravo 2 L/ha*	*Revus 0.5L/ha or Carial 4-5kg/ha or RidomiiGold 2.5kg/ha or Consento 1.5L/ha*			
	White fly		*Proclaim 250 g/ha or Engeo 0.2 L/ha*				
	Aphids			*Engeo 0.2 L/ha and Cobra 2 L/ha*			
	Mites			*Vertimec 50 ml/h*			
	Tuber moth			*Engeo 0.2 L/ha*			

Fig. 9. Schedule for fertilizer and pesticide application throughout the season.

4.1.5 Pest management

Plants are treated both preventative and curative for diseases and pests, as advised by the agricultural engineers, shown in fig. 9. The majority of farmers however, wait till they see symptoms so they skip the preventative application.

As with fertilizer use, the quantity of pesticides depends on the economic strength of a farmer. The fields of a big farm as that of Haouchine, are treated 2-3 times per season with preventative insecticides, basically against aphids and tuber moth while most smaller farmers cannot afford to buy these inputs. It can be said that smaller farms use less pesticides. Big wealthy farmers tend to follow the schedule of the importer or even have their own (independent) engineer in service.

The Mediterranean region deals more or less with the same problems as the El Oued region but differ in occurrence. In the Mediterranean mildew is the main problem, wherefore the crops are normally treated every 7-8 days, or more when symptoms are observed. A farmer who tried the variety Everest for the first time, experienced that the variety appeared to be more vulnerable and was therefore treated every 5 days this season. When mildew is observed, the entire field is treated.

Other important diseases are Phytophthora, Rhizoctonia, Black legs, Ralstonia, and sometimes Fusarium is observed. Phytophthora is prevented by most of the farmers based on their 'feeling' and experience from previous seasons. It was said that farmers tend to use a lot of pesticides, probably more than necessary. Farmers are aware of the uncertainty and see potential to save costs by extending knowledge on Phytophthora. Note that this is contradicting with the principle that farmers tend to apply less pesticides than the agricultural engineer advises. The same goes for fertilizer and water management, it is all applied on the farmers' financial capacity, their feeling, experience, what they observe in the field, and advise from the agricultural engineers who are sent by the pesticide importer. Weeds are not a severe problem since they are controlled with herbicides. During field visits we observed that weeds occur basically at the end of the season when the potato foliage was already decaying. Nevertheless, some weeds become resistant for the herbicides.

4.1.6 Irrigation management

The irrigation system of the Mediterranean region is described in detail in the report 'Irrigation system performance in potato production in Northern Algeria' of my colleague Harmen den Braber, for the research farm in Boumerdes. This system, a portable sprinkler system, is the common way to irrigate potatoes in this region.

Main observations in our study were that the irrigation systems were leaking at many places (fig. 10) and that the water is not well distributed over the field. Also major runoff was observed during irrigation events (fig. 11).

Fig. 10. An example of leakage of the supply pipe of a sprinkler system in the Mediterranean region.

Fig. 11. Traces of runoff between the ridges in a potato field in the Mediterranean region.

4.1.7 Harvesting

'The season' is the main season for the Mediterranean, thus potatoes are planted in January-February and harvested from the end of May until the beginning of July. This wide range is related to differences between varieties but basically because harvesting is done by hand and is therefore very time consuming.

Haulm destruction is not applied. Instead, the harvesting time is adjusted to the moment that the plants are considered mature and to the market price. The latter is a strong factor, since the prices for potatoes fluctuate a lot. When the prices are good, potatoes are harvested early, even before the potatoes reached their maximum volume. Potato is considered mature when it is impossible to remove the skin by rubbing it with the thumb and when the foliage is decaying.

Harvesting is normally done by digging up the potatoes with a harvesting machine. Most of the time the vegetation is already quite wilted at the moment of harvesting, so then the tubers are directly dug up by the harvesting machine. After that the workers collect the tubers by hand and put them in crates. If the vegetation is too large it is first cut off mechanically.

Opinions on availability of sufficient harvesting machines differ. For so far farmers state that there is no sufficient machine present to harvest potatoes from these heavy soils fully mechanically. One of the farmers tried a machine which was imported by a local supplier but he considered the result was disappointing; while 1 harvest machine was able to harvest 1 load of tubers, 40 workers were able to harvest 10 loads. Another farmer used a self-made harvesting tool to dig up the potatoes (fig. 12). A machinery supplier in Aïn Defla however has a harvesting machine available (fig. 13) but for some reason farmers were not convinced by its benefits.

Fig. 12. Self-made harvesting tool from a farmer in Bouira.

Fig 13. Harvesting machine at a machinery supplier in Aïn Defla.

When harvested in December, there is no storage needed because farmers sell the potatoes directly to the retailer. In the other season potatoes are both sold directly and stored. Whether a farmer stores his potatoes, also depends on the actual market price and his access to storage. Since the Mediterranean region mainly produces in 'the season' and resulting in over production, part of these potatoes are stored.

The less wealthy farmers use the small tubers from their harvest as seed potatoes in the next season. If farmers can afford it however, they grow only original seed potatoes. One of the farmers interviewed, Haouchine, is a professional producer of seed potatoes. He treats the seed potatoes as follows: Small tubers are stored for 45 days in a cold storage (+4°C), where temperature will rise throughout time to 6, 7, ..., 10°C. Then for 7-10 days the potatoes are kept in an open shed, where after they will be planted.

Large-scale farmers leave the rest of their harvest which is not dug up by the machine and invite people to harvest this for own consumption.

2 Weeks to 2 months after harvesting the land is ploughed. Depending on the soil status it is determined whether to irrigate in advance or not, to be able to plough smoothly. After ploughing the land is left bare for the winter, while others grow a winter crop because they cannot afford to leave it bare or because they see good opportunities.

4.2 El Oued region

Potato production is a relatively new economic activity in El Oued. Traditionally, inhabitants used to grow palm trees for date production (fig. 14) with about 100 palms per hectare. 20 years ago a great deal of that was replaced by potato production, since it became a profitable crop and the region is well provided by (though non-renewable) water resources. Currently, around 40% of the total potato production in Algeria originates from El Oued (PotatoPro, 2017). About 47,000 growers in El Oued are registered at the Chamber of Agriculture (Khalifa, director of cooperative CASAB). Most growers are registered, otherwise they will not receive any subsidy.

Fig. 14. Traditional date production in El Oued where palms are planted in a pit to access ground water.

El Oued's enterprising people combined with its good water access, at some places already at 10-20 meters depth, results in a flourishing agricultural sector. Agricultural and livestock investment development generates more than 120,000 permanent and seasonal jobs, accounting for 45% of the local labour force, especially during planting and harvesting (Emergent, 2017, Agricultural Services Directorate (DSA)). Almost all inhabitants of El Oued are somehow connected to agricultural business, also as a side activity. There is a large variety of legumes produced, such as tomato, melon, dates, tobacco, grain, but potato is the major crop.

In the wilaya of El Oued 35,000 ha of the land is used for potato growing. Potato fields are all irrigated by a center-pivot system (fig. 15); bigger potato farmers have about 30 pivots, only a few have even about 70 pivots, and the majority has 5-10 pivots. One pivot is normally about 0.9 hectare and most work is done by hand, since the soil is loose sand and labour is not expensive. Farmers grow mostly potatoes but also combine it with other productions such as peanuts for oil, or grain which is attractive because it is a subsidised crop.

Fig. 15. Example of a typical field in El Oued with its center-pivot irrigation system.

El Oued counts the same seasons as the Mediterranean region (fig. 5). El Oued's main season is the *last season* (planting in September), although it is becoming a trend for farmers to include or even replace it by the 'the season', despite the fact that they have to compete with the Mediterranean farmers. The major variety is Spunta.

4.2.1 Land ownership and access to inputs

Land ownership

As for the rest of Algeria, land belongs to the government and can be rented for a short or longer period. Because there is so much space in the Sahara and possibilities of land use are limited, the government stimulates people to utilize it for agriculture by providing land for free to conduct agricultural activities. After 5 years of farm activities at one location, the government can give the farmer his 'ownership'. The most limiting factor to start a farm are the investment costs for levelling the land/ the field because normally it is a sand dune. Furthermore it takes some effort to create a sufficient wind shield and an irrigation system must be installed.

Apart from the soil levelling, wind protection and irrigation installation, there are not many investment posts. Large scale producers have their own equipment and small producers do everything by hand, apart from preparing the soil before planting which is done by tractor, whether it is hired, borrowed or owned. Since the soil is very loose it is not necessary to have machinery throughout the growing season.

Inputs

The system of inputs supply as described for the Mediterranean applies also for El Oued (fig.7), as well as the classes for seed potatoes (see 4.1.1 Land ownership and access to inputs, sub chapter seed potato classes).

Apart from the equipment for establishment which is rented (soil excavators), inputs for potato production are the following:

- Regular tractor (only large scale farmers)
- Pesticide application device
- Pivot installation
- A pump
- A Well
- Palm leaves to establish a wind shield
- Fertilizer
- Pesticides
- Seed potatoes
- Labour

Farmers buy their seed potatoes from a cooperative, a private supplier or they use small potatoes of their previous season. Seed potatoes are only imported once a year in February. The cycle of seed potatoes as described for the Mediterranean applies the same for El Oued, as shown in fig. 8.

Labour

Normally a farmer hires workers for planting and harvesting. 15-20 men take 4 hours to plant 1 pivot (0.9 ha). Workers are hired as groups, kind of enterprises. One worker for one day costs around 1300 DA. In total it costs the farmer about 15,000 DA/day (120 euro/day[1]) to hire labour for planting. If a farmer has more pivots and sometimes far away from each other, he pays others to manage his pivots.

Hardware

The pivot installations are produced locally, made of aluminium and iron. As in the Mediterranean region, a tractor is either own property, borrowed or hired from another farmer.

Because the competition in potato production is increasing and labour availability decreases, it is expected that it becomes more and more necessary to mechanize. At the moment there is no sufficient machine present anywhere to harvest potatoes from such a sandy soil because the machines originating from The Netherlands and other potato experienced countries are constructed to harvest from ridges, which is not done in El Oued.

Fertilizer and pesticides

Legislation of fertilizers and pesticides, thus the consequences are the same as for the Mediterranean region. What differs, is the use of it. Although there is locally almost no organic fertilizer available, most farmers in El Oued apply organic fertilizer, trucked in from the North. This costs the farmer around 12,000,000 DA/ton (96,374 euro/ton[1]) manure.

Storage

Storage facilities in El Oued are few and not really used till now. In the 'last season', potatoes can be stored under the sand for 1 (if harvested first) to maximal 3 (when plants remain intact) months, but irrigation is required. Nowadays, farmers start to grow more in 'the season' (February-July), therefore more storage facilities are needed and there is a risk for overproduction. Although the government is not content with this trend because of the competition with farmers in the North, the state company just set up a storage facility in El Oued for mainly potatoes and dates.

4.2.2 Planting

Potatoes are planted 2-3 years after each other at the same field, after that the soil is removed and replaced by fresh soil (to get rid of diseases and pests, mainly nematodes) or a new pivot is constructed. To establish a new field, bulldozers and excavators are hired to equalize the dunes (fig. 14). It takes 15-20 days to prepare 1 hectare. A good wind shield is important for crop protection in many ways, especially at higher locations where wind is more severe:

- prevent from sanding the leaves;
- prevent from complete cover of the crop;
- prevent exposure of tubers;
- limit evapotranspiration;

Fig. 16. Excavator to equalize dunes or remove soil from an existing pivot.

To protect the plants against wind damage a windshield is constructed, consisting of a sand dune around the plot and a fence of palm leaves braided together on top of the dune (fig. 17). A good wind shield is especially important during 'the season' when there are more sand storms. A good shield is about 2 meters high, measured from field level. Lower wind shields appeared to be insufficient as can be seen in the field of a farmer who constructed a minor wind break, resulting in part of the potatoes

covered by sand (fig. 18a and c), open spots in the field (fig. 18b) and exposed potatoes (fig. 18d). Most of the plants in this field have no tubers developed at all.

Fig. 17. Wind protection made from palm leaves.

Fig. 18. Consequences of wind with insufficient protection (a: sand covers plants, b: no production due to sand loss, c: sand scours the leaves, d: seeds become bare).

There are no ridges constructed, because it is impossible with the loose sand. Before sowing, the soil is prepared with a tractor, just to loosen the sand. Then, cow manure is shipped into the field by a tractor and split in small piles in the pivot. Normally the farmer hires a group of labour, who spread the manure piles over the field, using shovels. Circular or straight furrows both apply, even combined (fig. 19) drawn with a locally produced tool behind the tractor, while workers plant the potatoes by hand in the drawn furrows. At the same time of drawing the furrow, the adjacent furrow is covered with sand by the same tool. The planting depth is 10 cm and planting distance 30 cm. Because of the high water demand and wind damage small pivot fields are preferred. Costs for the farmer to hire labour for planting costs 15,000 DA/day (120 euro/day[1]).

Fig. 19. Circular and straight furrows combined in one field.

El Oued counts 2 seasons for potato production: seeds are planted either in February and/or September. For the main season of El Oued, potatoes are planted in September and harvested from December onwards, at any moment the farmer can get a good price. Potatoes are even harvested before they reach their mature stage when the market prices are high. Growing potatoes in 'the season' (planted in January/February) is better regarding the productivity. Since the price is much higher in the 'last season', the majority of farmers produce in the 'last season'. The lower yield is thus compensated by the high price. Some farmers prefer 'the season' because of the higher quality of the (freshly imported) seed potato, more and more farmers start to grow in this season. This results in low prices and overproduction because it is already the main season of the Mediterranean growers. Besides that, there is a shortage of storage facilities to overcome these situations, neither there is a sufficient export chain.

Important considerations for farmers to grow either in 'the season' or the 'last season' are given in fig. 20.

Season	Planting time	Advantages	Disadvantages
'The season'	February	Good quality seeds (fresh) Higher production	Longer season Demand less sure Damage by wind Lower price for product
'Arriere season'	September	High price for product Demand assured Shorter season	Seeds more expensive Low production Harder to access water

Fig. 20. Advantages and disadvantages of both seasons for farmers in El Oued.

4.2.3 Crop cycle

Instead of a crop rotation, farmers in El Oued mostly apply a fallow system. Fields are left bare for 1 season or longer, as long as the farmer can afford. It is becoming more common to grow twice a year, as shown in the example of fig 21. Sometimes farmers grow a crop between the two seasons, such as garlic or onion. It is estimated that about 80% of all pivots in the region stay unplanted in the season (example 3 in fig 19) because farmers apply the fallow period and are limited by the water supply (2-3 pivots can be irrigated per well). Planting potatoes in February does not have the preference of the majority of farmers, therefore farmers tend to grow peanuts in this season.

One location or pivot is normally used for 2-3 years or the soil is replaced. Small growers are forced to use the same soil more times, due to the high investment costs of a new field (levelling of a new location costs about 400,000 dinar). Therefore crop rotation is depending on the actual profit perspective of alternative crops such as peanuts.

Farmers are aware of the fact that the soil gets less profitable when growing 2 times or more after each other at the same place. Nevertheless, farmers even tend to grow potatoes 4-5 years after each other at the same field, although only 1 season per year. It all depends on a farmers' financial strength, related to his number of pivots.

Year	Season	Planting time	Land use *Example 1*	*Example 2*	*Example 3*	*Example 4*
1	'The season'	February	Potato	Potato	Bare soil	Arachide
	Between			garlic/onion		
	'Arriere season'	September	Potato	Potato	Potato	Potato
2	'The season'	February	Bare soil	Bare soil	Bare soil	Arachide
	Between					
	'Arriere season'	September	Bare soil	Bare soil	Potato	Potato
3	'The season'	February	Potato	Potato	Bare soil	Arachide
	Between			garlic/onion		
	'Arriere season'	September	Potato	Potato	Potato	Potato

Fig. 21. Several examples of cropping schemes for potato production in El Oued.

4.2.4 Nutrient management

Farmers use chemical and organic fertilizer, the latter retrieved mainly from the North (poultry and cattle) with minor inputs from local cattle such as sheep, goat or dromedary. Although farmers in El Oued use more organic fertilizer than farmers in the Mediterranean, in general they follow the scheme advised by the fertilizer importer (fig. 22). The amount applied depends on the financial strength of the farmer.

Before planting, cow manure is piled at random places in the field, from where it is spread over the rest of the field. In practice not all piles are finished well, so these spots become top-dressed. The plants which grow here, grow big with thick roots and no tubers.

Treatment	Phenologic state > Need / disease / pest [v]	Planting	Sprouting	Active growth	Tuber formation	Tuber growth	Senescence / Harvest
Sowing	Seed potatoes	*2.5 - 3 T/ha*					
Fertilisation	NPK (soil application)	*500 kg/ha*					
	NPK (soil application)		*600 kg/ha*		*400 kg/ha*		
	NPK (soil application)					*400 kg/ha*	
	Humic acid	*2 applications of 25 L/ha before each fertilizer application*					
	Amino acids		*2 applications of 2 L/ha*				
	K and P for stimulation natural defense				*2 applications of ± 3 L/ha*		
	Trace elements			*3 applications of ± 1 kg/ha*			
	Potassium					*2 applications de ± 3 L/ha*	
Pesticides	Soil insects (soil application)	*1 application of Force 15 kg/ha*					
	Weeds	*Sencor 0.8-1 kg/ha*					
	Alternaria			*Score 0.3 L/ha or Consento 2 L/ha*			
	Mildew		*Bravo 2 L/ha*	*Revus 0.5L/ha or Carial 4-5kg/ha or RidomiiGold 2.5kg/ha or Consento 1.5L/ha*			
	White fly		*Proclaim 250 g/ha or Engeo 0.2 L/ha*				
	Aphids			*Engeo 0.2 L/ha and Cobra 2 L/ha*			
	Mites			*Vertimec 50 ml/h*			
	Tuber moth			*Engeo 0.2 L/ha*			

Fig. 22. Schedule for fertilizer and pesticide application throughout the season.

4.2.5 Pest management

El Oued experiences the same pests and diseases as the Mediterranean but the occurrence differs per region, with addition of one pest, namely herds of dromedaries (*Camelus dromedarius*, fig. 23). As farmers do not really apply a rotation scheme against nematodes, nematodes are the major disease related problem, especially in the soils used before for potato production. Therefore farmers change fields every 2-3 years or replace the sand, which is both expensive. Other problems are mildew, Alternaria (*Alternaria solani* and *A. alternata*) and the leaf miner (*Liriomyza huidobrensis*) (fig. 24) for which they are threated chemically (fig 22), as much as the farmer can afford or considers necessary. Less severe are the problems with weeds, which come along with the organic fertilizer and are controlled with herbicides. Apart from the scheme, pesticides are applied whenever the farmer sees symptoms or risks.

Fig 23. A herd of dromedaries in a potato field in El Oued.

Fig 24. Results of a leaf miner (*Liriomyza huidobrensis*) in a potato plant in El Oued.

4.2.6 Irrigation management

Since El Oued has a desert climate and the sandy soil is extremely permeable, the potato fields are irrigated every day in all seasons. In 'the season' fields are irrigated for 6-8 hours/day while in the 'last season' this goes up to 18 hours. In this season most farmers start irrigating approximately at 6 PM and finish at 11 AM, to avoid heat stress.

The irrigation system is a centre pivot, resulting in circular plots (fig. 25) differing in surface from 0.5 to 1.3 ha, 0.9 ha is most common. The equipment is a metal arm, turning around from the centre where the water enters the arm under high pressure (fig. 26). On top of the arm nozzles supply the water in a mist (fig. 27). The arm is powered by an electric engine. Irrigating the whole field takes around 2.5 to 3 hours. Drip irrigation systems are being tried by some farmers but so far it appears to be not profitable enough because it requires more labour, according to farmers. The pivot irrigation needs only some maintenance to prevent it from leaking but it is easily established and is simple in use.

Fig. 25. The circular plot of a pivot.

Fig. 26. A pivot irrigation system in El Oued.

Fig. 27. The arm of a pivot with its nozzles.

Between 5 and 21 PM the electricity costs are high, therefore the farmers tend to irrigate before and after that period, nonstop. If a farmer irrigates less, he believes the plants wilt within a few hours so in practice farmers do not take the risk. Day and night irrigation is being alternated. Some farmers take the heat moments into account by avoiding irrigation between 11 AM and 5 PM, others irrigate all day long.

Water is retrieved from different aquifers through a simple well (fig. 28), which is normally good to supply 1-3 pivots on a daily basis. As accurate data of the water resources and water use in Algeria is incoherent, it is not very clear where exactly aquifers are, neither the water reserve. According to the information from different farmers however, it is expected that there are several sub aquifers in three main aquifers. The aquifers are said to be found at approximately the following depths:

- Aquifer 1 at 10-50 m depth;
- Aquifer 2 at 180-250 m depth;
- Aquifer 3 at 1000 m depth.

Fig. 28. A simple well to supply water to the pivots

The first sub aquifer is said to be found at 20 meters depth and appears to be depleted most of the time (no water coming up). After 20-30 meters there is a second sub aquifer, which water is lower in quality and it would be silty. Farmers are starting now to utilize the aquifer at 60 meters depth.

In the 'last season', farmers experience water problems because they have to reach deeper aquifers, which is also lower in quality. Although farmers report that water levels are dwindling, it is still relatively easy to find water and cheap to pump it up. Use of water is free and in practice it is not restricted. Some farmers suggest that water is wasted because of its free access.

The locally produced pivot costs 150,000 DA (1,174 euro[1]) for a 1 ha field and can be used for a period of 20 years. Nozzles are not being replaced throughout time. During the field visits, quite some installations appeared to be broken and not maintained well. This causes major water losses, as seen on the fig. 29, as well as low water pressure, resulting in weak plants.

Fig. 29. Leakage in a pivot irrigation system.

4.2.7 Harvesting

The farmer harvests his crop when the foliage starts to decay. Harvesting is done by hand, normally by hired workers who show up in groups, as kind of enterprises (fig. 30). Haulm killing is not applied, plants are just taken out where after directly the tubers are dug out. It is uncommon that women work in the field, potato production is exclusively men work.

Fig. 30. Harvesting in El Oued.

18 Workers take 2 days to harvest one average field. Workers are paid per crate (60 DA or 0.47 euro). Normally a farmer harvests 40 tons/pivot (0.9 ha) from ‘the season’ and 30 tons/pivot from the ‘last season’. With other varieties, a higher yield could be achieved but the market is not asking for these varieties and farmers don’t tend to take the risk to introduce new products.

When planted in September, potatoes are harvested from December, or eventually stored in the soil while the foliage is left attached to the tubers. The latter is only sometimes done till the moment that farmers can get a higher price for their goods. Normally this is not needed since the price is most times very good because of the scarcity. Storing in the soil requires irrigation and has the risk of a lower quality product due to sun burn.

5. Conclusions and advice

The institutional setting and market perspectives determine for a great deal the current situation for potato production and form the framework for opportunities. While taken these into account we focus on improvement of the potato production itself. Thus legislation and governmental approaches are not discussed. This chapter has three aims, namely:

- To summarize the current situation for potato production and its challenges;
- Suggestions for improvement and considerations when introducing a new system;
- To discuss the suitability of farmer field schools as a framework to implement the majority of the suggestions given in this report to improve the system.

To conclude, further recommendations which we consider most important for introducing a new system, especially for practical implementation, will be given.

Current situation, its challenges and opportunities

Figure 31 shows an overview of the main weaknesses of the production system and other issues affecting the current situation (1st column), followed by suggestions for improvement. The 2nd column gives an explanation of the consequences and interrelations and the 3rd column gives suggestions for improvement or important considerations when implementing a new system.

Weaknesses per component of the and experienced problems	Explanation	Suggestion for improvement
External factors		
Competition between growers (related to the seasons)	- Overproduction in some periods results in fluctuating prices	- Grow varieties for the export market - Development of the processing chain - Development of better storage facilities
Market: fluctuating prices	- Fluctuating prices encourage farmers to stick to their practices, they rather take no risk to switch e.g. to another production system or variety	- Find ways to give farmers trust or space to trial a new system: overview of costs vs profits, measuring data are convincing
Market: Import seeds	- For seeds dependant for ± 70% on the international seed market, import only once a year	
Market: National sales market	- Basically only a national market for potatoes, so export can't be used for overproduction	- Development of better storage facilities - Development of export market
Shortage of storage facilities	- Overproduction and scarcity at different moments are hard to overcome without storage	- Development of better storage facilities
Processing industry barely developed	- Overproduction could be partly solved if the processing industry is further developed	
Lack of exact data and knowledge	- Results in inefficient fertilizer, pest and irrigation management - Better sure than sorry: overuse of inputs as fertilizer, pesticides and water	- Further research on current application amounts, soil requirements - Further research on effects of current management - Costs benefits analysis
4.1.1 Land ownership and access to inputs		
No sufficient harvesting machine available	- Are the available machines really not sufficient or is it a mentality issue?	- Further research on current machinery, availability on world market, the farmers perspective and preferences
(ME) Land ownership	- Limited expansion possibilities because it is hard to buy good land, farmers have fields spread around the region, inefficient management	
No loans available for uncreditworthy business	- Limited expansion possibilities - Limited opportunity to change the system (e.g. shift to drip irrigation)	- Find ways to offer farmers a loan/time to invest and/or provide machinery/inputs : e.g. micro credits "
Amounts of fertilizer limited by legislation	- To increase the production above the average, fertilizer access could be a limit	- Chance for a new system with exact applications
Shortage in organic matter in soil	- Soils are low in organic matter, high demand for organic fertilizer	
(EO) Sandy soil: very low holding capacity soil	- Lot of waste due to leaching	- Opportunity for high productivity if treated as a substrate with exact applications
Shortage of organic fertilizer	- Results in lower productivity and high costs	- A system with minimum chemical fertilizer applications
Low quality organic matter	- Manure is sold directly, without composting: results in diseases, weeds etc. and inefficient nutrient supply	- Avoid a system dependent on organic fertilizer or include composting in the system
(EO) fertilizer from far away	- Comes from >700 km distance, thus unsustainable and high costs post	- A system with exact chemical fertilizer applications, soil considered as substrate
Labour dependent system	- Labour high costs post and uniformity of growth is low, partly related to long planting time	- Chance for a new system with saved labour costs
Trend labour availability	- Not yet a problem but it becomes harder to find labour	- Chance for a new system with saved labour costs.
		- Inspire young people by outlining perspective

Fig. 31. Overview of the main weaknesses and problems for potato production and suggestions, (EO) means it applies only for El Oued and (ME) applies for Mediterranean region (*Continues on next page*).

Weaknesses per component of the and experienced problems	Explanation	Suggestion for improvement
4.1.2 Planting		
Heavy clay soils	- farmers experience insufficiency of current machinery during harvest and planting	- Review current supply of machinery - Demonstrate benefits of machinery
Sandy soils, no ridges	- Ridges are impossible due to loose soil composition, planting machines insufficient	- System or machinery must be adjusted
Small seeds from previous season and half seeds used	- Small seeds and cut seeds are weaker and vulnerable for diseases, or even spread them	- Advise farmers about risks
(EO) Wind	- Good protection required, high costs and effort - Small fields are preferred to avoid wind damage	
4.1.3 Crop cycle		
(EO) fallow system / a little rotation	- Potatoes are rotated with only one crop or bare soil	- Research on the effect of more varied rotation schemes in order to have less nematodes and other pest issues
Little of soil life	- Possibly caused by low organic matter content, soil exhaustion, water stress or too many chemical pesticides	- Further research
4.1.4 Nutrient management		
Depends on economical strength of the farmer	- Amounts are supplied along the farmers' financial strength	- Lower costs for farmer in a system with exact applications
Advice of the engineers possibly quite high	- Because this service is related to the supplier, it is expected to be high, thus the starting position for plant development is already high	- Too high Nitrogen gift in early stage can result in too much vegetative development compared to tubers, thus exact data and adjusted data could improve productivity
(EO) fertilizer piles in field	- Plants at these locations suffer from top-dressing	
4.1.5 Pest management		
advice of the engineers possibly quite high	- Because this service is related to the supplier, advice is expected to be high, thus possible overusage	Data collection
Mildew treatment to entire field, no precise treatment	- Mildew is a major pest issue, as well a high costs post	Increase knowledge and acquire data to improve management with less pesticides to save costs and minimize losses
(EO) nematodes	- Nematodes are the main pest issue, now solved by shifting to a new location or - Replacement of the soil, both an expensive and time consuming effort	Better rotation and further research, also on the effect of organic fertilizer of a better quality
4.1.6 Irrigation management		
(ME) Labour dependent	- Requires permanent labour day and night, to shift the pipes to the next rows in the field - Since weather conditions (wind) can differ between the events, irrigation distribution is very uneaven, resulting in lower productivity	Chance for a new system with saved labour costs
Leaking irrigation systems	- A lot of leakage, resulting in water stress, runoff (affects soil quality) and waste of water	Consider possible errors of a new system
Water is for free	- It seems that many farmers do not care about the leakages, possibly since it's not a costs post - No urgent need for determining exact requirements, possibly causing water stress - Leakage results in lower pressure, thus less water to plants, lower productivity	- Research the possibility of water pricing - Increase awareness
Hot climate + high humidity	- High water consumption resulting in high humidity, plants tend to put energy in foliage rather than tubers - Attractive micro climate for funghi and related diseases, especially mildew	Chance for a new system with less water stress, thus higher productivity Chance for a new system with a better micro climate
4.1.7 Harvesting		
Labour dependent or labour preferred	- (ME) completely mechanized harvesting is not applied, a high costs post	Further research on the farmers' perspective

Fig. 31. (*Continued*) Overview of the main weaknesses and problems for potato production and suggestions, (EO) means it applies only for El Oued and (ME) applies for Mediterranean region.

Both regions have a lack of technology and accurate data of 1) the exact inputs applied, and 2) the exact requirements, especially regarding water supply since this is not covered by the services of the agricultural engineers sent by the pesticide and fertilizer importers. This results in rough irrigation, fertilizer and pest management, what lies on the basis of most weaknesses and problems. It also shows the potential of the current system to reach a higher level by means of sustainability as well as productivity. It is therefore strongly advised to do extended research to collect accurate data on amounts of inputs/outputs and especially on water use, soil characteristics and crop performance.

Productivity here is considered to be the ratio between inputs and outputs. Considering the issues from fig. 31, knowledge of the current situation (e.g. exact requirements and current application amounts) could lead to a great increase of efficiency and productivity. We consider productivity as an important focal point for a successful implementation of the new production system since farmers will be encouraged to adapt when there is an economic advantage, in other words, more income or less costs.

Fertilizer is a pressing issue on both the farmers' wallet and the environment. Assuming the organic fertilizer is of a low quality since it is not being composted, it is likely that alternative fertilization will add up to the productivity. Chances lay in a system which combines efficient water use with efficient use of inputs, such as a drip irrigation system with integrated fertigation. Such a system could lead to both economic and environmental improvements:

- Lower CO_2 footprint, since transport from >700km expires;
- Minimum loss of fertilizer and water through e.g. deep percolation and runoff;
- Higher productivity;
- Save costs of fertilizer;
- Lower water use.

Many of the issues require further research. Related to the subsequence project, we suggest to give priority to further research on exact amounts of inputs and outputs. Only then it could be made clear what's in it for a farmer, as well how much efficiency could be achieved for the different components.

Although this research is focussed on the production system itself we experienced that the limitations of the framework for potato production creates opportunities for implementation of a new system. One of them is strongly related to the system issue of competition between the farmers from different regions; if the export market and processing industry develop it might be interesting to grow varieties which are suitable for these 'new' markets. This even could open doors to encourage farmers to adapt the new system, by linking the new varieties to a growing market and their performance in the new system. The trend that farmers from El Oued start to produce in the main season of the Mediterranean increases the problem of overproduction and thus fluctuating prices.

Farmer field schools

As many issues require a change in the system and successful adaptation of a new system truly depends on the farmers willingness and mentality, it is crucial to have a good framework for introduction of a new system. Based on our findings from the interviews and own, together with the request of our supervisor from Agrosystems Research, Dr. ir. Greet Blom-Zandstra, this section discusses the potential of farmer field schools (FFS) to function as a framework for improvement of the potato production system in Algeria.

FFS, once initiated in the 80's through a FAO programme in Indonesia to introduce new Integrated Pest Management approaches, is now applied worldwide to introduce new practices in any field of agriculture. FFS are developed particularly for field studies and consists basically of groups of people with a common interest, gathering together frequently to study for example potato production practices. A list and explanation of essential and original elements of a FFS is included in appendix 1.

FFS are considered to be a sufficient method to introduce new production practices in Algeria with the aim to increase productivity and sustainability, because FFS improves productivity and farmers income (Davis et al., 2012) and has proven to be empowering in a wide range of developing countries (Braun et al., 2006; Davis et al.,2012; Godtland et al., 2004). The educational concepts supporting the FFS approach arise from adult informal education, which have been found to be relevant across the many countries and cultures where FFS is used (Braun & Duveskog, 2011) and makes a very suitable framework for improvement of Algerian potato production because:

- The FFS approach does not rely on highly trained external advisors but on farmers' own experiences and reflection;
- Algerian farmers are used to learn by doing, this fits well to the practical approach of FFS;
- The subsequence project will be a demonstration farm to introduce the new system, an ideal location to gather together, demonstrate new practices and discuss the 'how and why' of more productive and efficient potato production;
- The present farmer cooperatives are a good structure to reach and organise the participating farmers;
- Many of the issues shown in figure 31 can be addressed through the FFS approach;
- The FFS approach can easily be modified to many different topics and settings, thus fits well to the idea to start in main production areas and later on extend to other areas or even other crops.

There are already successful experiences of FFS in Algeria with other crops, e.g. the FFS for Anchoring Sustainable Integrated Pest Management By Small Farm Holders in the NENA Region, coordinated by FAO and Near East Plant Protection Organization (NEPPO). Existing projects can be utilized to gain information on successes and bottle necks to run a FFS for potato production.

FFS can also contribute to a better market perspective, as we can learn from existing locations with relatively large scale FFS interventions. There, farmer networks and associations as an after effect of FFS have created access to lucrative markets by progressively breaking manipulative relationships with trade middlemen (Braun & Duveskog, 2011). FFS being a practical and hands-on management approach could be a good basis to implement improvement practices such as suggested in figure 31 and to introduce a new production system.

Further recommendations regarding introduction of the new system

Perhaps most important to mention is that as long as changes include high risks and increase the work pressure or make the work complex while there is no economic advantage, shifting is irrelevant from a farmers perspective. We strongly advise to focus the design of a new system on saving currently high costs because these strongly appeal to the farmers imagination, and cost savings are relatively easy to quantify. Sustainability issues thus should be translated to economic advantages. Therefore an economic analysis is strongly advised as well.

According the plot design we advise to limit the surface to 1 hectare, to assure good wind protection from the field borders. As long as the current wind protection technique is applied in good order, i.e. 2 meters high and with palm leaves, it should be sufficient.

Furthermore, with the introduction of any system it is good to know that the current pivot system in El Oued is locally produced of which farmers are very proud. It might be interesting to explore the possibilities to produce (parts of) the new system in cooperation with local companies who are now producing the pivots.

The Algerian farmers can roughly be divided in a conservative group which tend to stick to their current management and a group which is very much interested in high-tech and new approaches. All farmers we have spoken, are eager to become knowledgeable on exact requirements for e.g. fertilization and pesticides. Through farmer field schools the more innovation oriented farmers can encourage the conservative farmers to consider new approaches.

To conclude, Algeria has great opportunities to develop the potato production on all its facets, since the Algerian farmers are eager to learn and lift their systems to a higher level. As well they are very cooperative, also when it comes to give information about their business. The farmers' approach in combination with the many opportunities for improvement, a strong and well adaptable framework such as FFS and a practical oriented approach of the subsequence project have a great chance for successful improvement of the potato production system, from both an economical and environmental perspective.

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Appendices

Appendix 1. The essential and original elements of a farmer field school

This content is adapted from Gallagher (2003). These elements present the main elements of the approach that were present when it was developed in 1989 and are still in use during current FFS implementation.

The group
A group of people with a common interest form the core of the FFS. The group may be mixed with men and women together, or separated, depending on culture and topic. The group could be an established one, such as a self-help, women's, or youth group. Participatory technology groups, for example, sometimes undertake a season of study in FFSs before starting their research. The FFS tends to strengthen existing groups or may lead to the formation of new groups. Some FFS groups do not continue after the study period. The FFS is not developed with the intention of creating a long-term organisation - although it often becomes one.

The field
FFSs are about practical, hands-on topics. Study Circles and other study methods do not take place in the field, as they are about more theoretical topics. In the FFS, the field is the teacher, and it provides most of the training materials like plants, pests and real problems. Any new "language" learned in the course of study can be applied directly to real objects, and local names can be used and agreed on. Farmers are usually much more comfortable in field situations than in classrooms. In most cases, communities can provide a study site with a shaded area for follow-up discussions.

The facilitator
Each FFS needs a technically competent facilitator to lead members through the hands-on exercises. There is no lecturing involved, so the facilitator can be an extension officer or a Farmer Field School graduate. Extension officers with different organisational backgrounds, for example government, NGOs and private companies, have all been involved in FFS. In most programmes, a key objective is to move towards farmer facilitators, because they are often better facilitators than outside extension staff - they know the community and its members, speak a similar language, are recognised by members as colleagues, and know the area well. From a financial perspective, farmer facilitators require less transport and other financial support than formal extensionists. They can also operate more independently (and therefore cheaply), outside formal hierarchical structures. All facilitators need training. Extension facilitators need season-long training to (re)learn facilitation skills, learn to grow crops with their own hands, and develop management skills such as fund-raising and development of local programmes. Computer literacy is often included in the training of facilitators, especially for preparing local training materials, budgets and project proposals. Email is also becoming more widely available. Once the facilitators have completed their training and are leading the FFS process, it is easy to identify capable farmers who are interested in becoming facilitators. Farmer Field School graduates are usually given special farmer facilitator training (10-14 days) to improve technical, facilitation and organisational skills.

The curriculum
The FFS curriculum follows the natural cycle of its subject, be it crop, animal, soil, or handicrafts. For example, the cycle may be "seed to seed" or "egg to egg". This approach allows all aspects of the subject to be covered, in parallel with what is happening in the FFS member's field. For example, rice transplanting in the FFS takes place at the same time as farmers are transplanting their own crops - the lessons learned can be applied directly. One key factor in the success of the FFSs has been that there

are no lectures – all activities are based on experiential (learning-bydoing), participatory, hands-on work. This builds on adult learning theory and practice. Each activity has a procedure for action, observation, analysis and decision making. The emphasis is not only on “how” but also on “why”. Experience has shown that structured, hands-on activities provide a sound basis for continued innovation and local adaptation, after the FFS itself has been completed. It is also one of the main reasons that farmer facilitators can easily run FFSs - once they know how to facilitate an activity, the outcomes become obvious from the exercise itself.

Activities are sometimes season-long experiments - especially those related to soils or plant physiology (for example soil or variety trials, plant compensation trials). Other activities in the curriculum include 30-120 minutes for specific topics. Icebreakers, energisers, and team/organisation building exercises are also included in each session. The curriculum of many FFSs is combined with other topics. In Kenya, for example, the FFSs follow a one-year cycle including cash crops, food crops, chickens or goats and special topics on nutrition, HIV/AIDS, water sanitation and marketing. FFSs for literacy are also promoted where there is a need.

The programme leader
Most FFS programmes exist within a larger programme, run by government or a civil society organisation. It is essential to have a good programme leader who can support the training of facilitators, get materials organised for the field, solve problems in participatory ways and nurture field staff facilitators. This person needs to keep a close watch on the FFSs for potential technical or human relations problems. They are also the person likely to be responsible for monitoring and evaluation. The programme leader must be a good leader and an empowering person. He or she is the key to successful programme development and needs support and training to develop the necessary skills.

Financing
FFSs can be expensive or low-cost, depending on who implements them and how they are conducted. When carried out within a World Bank-type programme, they are usually expensive, due to high allowances, transportation costs and several layers of supervision (about US$30-50 per farmer). Obviously, the greater the distance that facilitators need to travel to get to the field, the higher the cost of transport. Transport is one of the biggest costs in any extension programme. When the FFS is carried out by local organisations and farmer facilitators, initial start-up costs may be moderate, but the running costs will be much lower (about US$1-20 per farmer). A trend in East Africa is to manage small commercial plots alongside the FFS study plots, so that the FFS can actually raise more funds than it uses for inputs and stationary (Okoth p. 27).

Final word
Farmer Field Schools are not difficult or mysterious. However, they are meant to empower through education on skills and concepts (how’s and why’s) and therefore, require an empowering environment. The basis for a successful FFS starts with the programme’s culture of operation - from a nurturing and empowering programme leader and good facilitators, to transparent budgets and open management. FFSs are not difficult to set up if there is a commitment to, and faith in farmers’ and facilitators’ ability to learn locally and apply learning to local problems themselves.

Appendix 2. List of respondents

Name	Function
Mr Brahim Mouhouch	Professor at Ecole Nationale Supérieure d'Agronomie - El Harrach - Alger
Mr. Kaci Assiless	Farmer in Bouira
Mr. A. Reguig	Owner of the machinery supply company SMCI - Bouchaoui - Alger
Mr. Hadj Tidjani	President de la cooperative agricole de Guemar - Oued Souf
Mr. Khalifa Debbar	President de la cooperative CASAB, El Oued
Mr. Ammar Hettiri	Potato farmer El Oued
Mr. Haouchine	Director and owner of Haouchine etablissement
Mr. Hakim Messaoudi	Agronomist at Haouchine etablissement
Mr. Murat Atif	Director of the applied agricultural center of the 'Institut Technique des Cultures Maraichères & Industrielles' (ITCMI)

Note: The list is incomplete, as not all names of the respondents are noted down.

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