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EFFECT OF ORGANIC AND MINERAL FERTILIZATION ON POTATO GROWTH AND YIELD

by
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ABSTRACT
OF THE THESIS OF

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Title: Effect of Organic and Mineral Fertilization on Potato Growth and Yield

Many potato farmers in the Beqaa plain use excessive quantities of mineral and organic fertilizers to grow their crops trusting that the more they add fertilizers the more they increase their yield. This practice contributed to the pollution of ground and surface water including the Litany River and its tributaries and waterways (Darwich *et al*., 2018), increase the cost of production and reduce the sustainability of the cropping system. Studying the effects of different combinations of organic and mineral fertilizers on growth and yield of potato could help in establishing sustainable practices for potato production. This includes recommendations for alternative practices, better selecting fertilizers types, and accurately estimating the rate of application of fertilizers. A field study was carried on in spring of 2021 in the Advancing Research Enabling Communities Center (AREC) in the Beqaa plain Northeast of Lebanon to evaluate the effects of different organic and mineral fertilizers combinations on the growth (emergence, plant height, shoot biomass) and yield (total, marketable and non-marketable yield) of potato. A Completely Randomized Block Design (CRBD) with seven different treatments and four replicates was used. Our results showed no significant differences neither in growth nor in potato yield among the different treatments including the control. Nevertheless, high potato yields were obtained from all the treatments including the control, ranging from 55 to 69 tonnes of potato per hectare. This yield exceeded by far the average yield produced by conventional local potato farmers in the Beqaa plain.

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CHAPTER 1

LITERATURE REVIEW

1.1. General description the potato plant

Potato or *Solanum tuberosum L.* belongs to the *Solanaceae* family is an herbaceous plant that grows from 40 - 100 cm tall and may range from erect to fully prostrate. Stems vary from nearly hairless to densely hairy with green, purple, or mottled green and purple colors. Leaves are pinnate in shape with a single terminal leaflet and three or four pairs of large, ovoid leaflets with smaller ones in between (Spooner & Knapp, 2013). The blades range in size from 8-22 x 5-13 cm with the petioles ranging from 2-6 cm in length. They are medium to dark green, and like the stems, may range in hairiness from nearly hairless to densely hairy on both sides.

Potato plants produce stolons that are hooked at the tip. They grow below ground from the basal stem nodes with up to three stolons per node (Struik, 2007). Tubers, range in shape from spherical to ovoid, are enlargements of the stolon. The flesh of the tubers varies in color from white to yellow to blue and the skin varies from white through yellow to tan and from red through blue. The texture of the surface may vary from smooth to netted or russetted (Spooner & Salas, 2006). On the surface of the tuber are axillary buds with scars of scale leaves that are called eyes (Struik, 2007).When tubers are planted, the eyes develop into stems to form the next vegetative generation.

1.2. Origin of potato

Potato is one of the ancient cultivated crops. It is well known that potato was domesticated in South America. It was most probably introduced to Europe by the

Spanish troops that invaded the South American countries during the sixteenth century. Potato was further dispersed to the other regions of the world from Europe. The details of its introduction and where it was initially grown are still inconclusive (Hawkes, 1978).

1.3. Potato production in Lebanon

The introduction of potatoes into Lebanon is not well documented. During the 1970s, however, Lebanon was one of the main potato producers in the region with a total production of around 100,000 tonnes. During the civil war that began in the mid-1970s, production fell sharply to about 30,000 tonnes in 1976. After the end of the civil war and the stabilization of the political and security situation, total potato production inland increased again and averaged around 435,000 tonnes between 2003 and 2013, in 2017 the total cultivated area reached 15,246 hectares with a total production of 384,259 tonnes, and an average calculated yield of 25.2 tonnes per hectare (*PotatoPro - the Global Potato Industry Information Source*). The main potato-producing region is the Beqaa Plain, which accounts for about 65% of the cultivated area. The Akkar Plain in northern Lebanon accounts for about 30% of the total potato growing area. In the Beqaa, farmers plant potato at any time between February and August, and harvest between June and December. While, in North-Lebanon, the plain of Akkar, is planted in December and harvested in April-May.

Most of the potato farmers in Lebanon used to implement inherited practices in growing potato; they had the belief that adding more fertilizers (organic and mineral) will continuously increase their yield. Consequently, 2500-3500 Kilograms per hectare of inorganic fertilizers used to be applied by many farmers to potato fields with a production range of 25 to 40 tonnes per hectare. Similarly, the use of chemical pesticides was also exaggerated. Farmers used to spray their potato with a mix of chemical pesticides composed of 3 to 6 pesticides for 3 times per season following a preset spraying calendar and depending on the growing season. In addition, extra sprays of herbicides to control mainly perennial and parasitic weeds including the most damaging weed, Hemp broomrape (*Phelipanche ramosa* (L.)) are usually applied especially during the summer season (July). Pesticides and herbicides applications are more frequent during the summer growing season compared to the winter season. Pests and diseases incidences are more prominent during summer because of the favorable weather conditions for pest development including weeds.

The irrigation needs of the winter grown potato season (February) are partially covered by rainwater. Irrigation is initiated after the cessation of rain through either harvested rainwater (very little) or water pumped from wells. The irrigation of the summer planted potato season relies entirely on water pumped from wells

1.4. Potato varieties grown in Lebanon

The most important and common varieties of potato grown in the Beqaa plain are, Spunta, Agria, Hermes, Fontaine, Farida, Fabula, Asteix and others. The variety is selected based on its productivity, suitability and usage. Spunta is the favorite variety grown by farmers in the Beqaa and Akkar plains that could be grown in both winter and summer seasons. Spunta is an early-medium (115-125 days in Lebanon) maturity variety that produces very large long oval tubers with yellow skin and light yellow flesh. The variety is highly productive with 20% dry matter that is suitable for fries when freshly consumed. Agria, the second most favorable variety in Lebanon was developed in Luneburg, Germany in the 1980s by an agricultural company called Kartoffelzucht Bohm (https://www.agricopotatoes.com/en/overview/agria,). It is a dual-purpose variety that could be marketed for fresh consumption or processing (potato chips) and is very suitable for French Fries because of its high dry matter content of about 22%. It produces large oval tubers with white to yellow skin and yellow flesh. Agria is a medium late maturity potato variety (130-140 days in Lebanon) that is mainly grown during the winter season (https://www.agricopotatoes.com/en/overview/agria,).

Many other potato varieties including Fontaine, Farida, and Fabula were also introduced and are gaining popularity among farmers because of their very high yields. Detailed characteristics of the main grown varieties are summarized in Appendix I.

1.5. Fertilization requirements of potato

Fertilization requirements of potato vary according to variety and targeted yield. Potato requires high quantities of nitrogen and potassium for vegetative growth and tuber setting and bulking. A lesser quantity of phosphorous is needed compared to nitrogen and potassium.

Many studies were conducted on the nutrient demand/uptake/removal of potato from macronutrients. We believe that the values summarized in Table 1 are the most realistic based on calculations of nutrient sufficiency levels and amounts found in plant tissues and tubers by lab analysis taking into consideration targeted tuber yield.

Table 1: Nitrogen, phosphorous and potassium uptake/demand/removal by potato.

Tuber Yield tonnes/ha	**N**	**P_2O_5**	**K_2O**
	Kg/ha		
100	250-450	35-65	350-550
50	242	63	314
37	113	45	196
25	96	31	129

(FAO: 2006)

Potato fertilization practices varies between different countries even when the planted variety is the same. This may be due to different soil types and condition, geographical location, growing season, prevailing environmental conditions and available fertilizers types and target yield. Table 2 summarizes the recommended rates of N, P_2O_5 and K_2O in some countries.

Table 2: Recommended nitrogen, phosphorous and potassium rates for potato in some countries.

Country	**N**	**P_2O_5**	**K_2O**
	Kg/ha		
Egypt	300	145	115
Turkey	150-170	80-100	80-100
Pakistan	175-250	112-150	75-100
Syria	Autumn: 150 Summer: 180	Autumn: 150 Summer: 120	- -
Uzbekistan	120-150	85-100	6-75

(FAO: 2006)

Potato undergoes four distinct phenological stages with different requirements in nutritional elements quantities and ratios as per the below illustration:

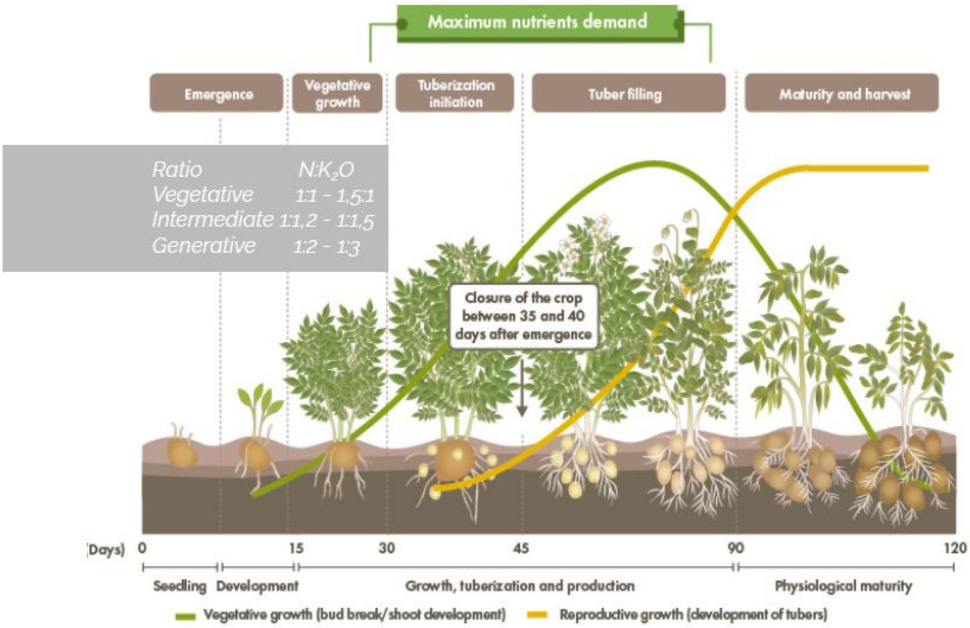

Figure 1: Potato vegetative/generative growth balance (*Potato Vegetative/Generative Growth Balance - SQM Specialty Plant Nutrition*, n.d.)

The different vegetative and generative stages described above are:

1- Planting to emergence
2- Emergence to tuber initiation
3- Tuber initiation to tuber bulking
4- Tuber bulking to maturity

Because multiple organs are usually developing at the same time and competing for the photoassimilates produced by the plant, each of these stages has definite nutritional requirements to achieve the growth purposes of the various organs. The vegetative and propagative growth of the potato crop are therefore balanced.

A vegetative balance favors the development of stems and foliage, whereas a propagative balance favors tuber production and bulking. The N: K ratio determines the nutritional balances of vegetative and generative growth. A high N: K ratio promotes vegetative growth while a low N: K ratio promotes propagative growth. Therefore, it is essential to provide essential nutritional elements in suitable amounts and ratios at the suitable potato phenological stage to achieve the maximum fertilizers use efficiency.

1.6. Functions of nitrogen phosphorous and potassium in potato

The functions of nitrogen, phosphorous and potassium are shown in Table 3.

Table 3: Summary of main functions of N, P & K.

Nutrient	**Functions**
Nitrogen (N)	Synthesis of proteins (growth and yield). Nitrogen is important for leaf and tuber growth. Like potassium, a lot of nitrogen is recycled from the leaf to the tuber during bulking
Phosphorus (P)	Cellular division and formation of energetic structures. Phosphorous is also needed in relatively large quantities, particularly during early growth, to encourage rooting and tuber set, and then again during the late season for bulking.
Potassium (K)	Transport of sugars, stomata control, cofactor of many enzymes, reduces susceptibility to plant diseases. Potassium is particularly important for high yields but also for maintaining tuber integrity. "Luxury uptake" of potassium is typical in potatoes.

(*Potato Nutritional Summary | Yara UK*, 2017)

1.7. Mineral fertilizers

The essential mineral fertilizers sold in Lebanon and were used in the experiment are the following:

1.7.1. Di-Ammonium Phosphate (DAP)

The standard grade of DAP is 18-46-0 (N-P-K).

Ammonium phosphate fertilizers initially became accessible in the 1960s, and Di-Ammonium Phosphate (DAP) became a very popular product in this category.

Formed from two common fertilizers materials, Di-Ammonium Phosphate also, is the most used phosphorus (P) fertilizer in the world. DAP has become so popular because of its high nutritional content and good physical properties.

When combined together in a chemical reaction, phosphoric acid and ammonia, generate a hot slurry of DAP, which is then cooled, granulated, and sieved.

To produce one tonne of DAP, 1.5 to 2 tonnes of phosphate rock, 0.4 tonnes of sulfur (S) to dissolve the rock, and 0.2 tonnes of ammonia are needed. DAP's high nutritional content helps to reduce handling, freight, and application costs. DAP has good handling and storage characteristics.

DAP fertilizer is a great source of phosphorus (P_2O_5) and nitrogen (N) for plant nutrition. It is extremely soluble and hence dissolves fast in soil, releasing plant-available phosphate and ammonium.

The ammonium in DAP is a great N source that will be progressively transformed to nitrate by soil microbes, leading in a pH reduction. As a result, the increase in soil pH surrounding DAP granules is a transient impact. This early elevation in soil pH near DAP might affect the micro-site interactions of phosphate and soil organic matter.

The first chemical response of various commercial P fertilizers in soil varies, but these differences become minimal with time (within weeks or months) and are irrelevant in terms of plant nutrition. With appropriate management, most field comparisons of DAP and mono-ammonium phosphate (MAP) show very little or no differences in plant growth and yield due to P source.

The chemical formula of DAP is: (NH_4)2HPO4, it contains 18% Nitrogen in the form of N and 46% Phosphorous in the form of P_2O_5 equivalent to 20% P. Its solubility in water at 20 ºC is 588 g/L and the pH of DAP solution is 7.5 to 8 (http://www.ipni.net/specifics-en#).

1.7.2. Sulfate of Potash (SOP)

The standard grade of SOP is 0-50-0 (N-P-K).

Potassium fertilizer is commonly added to improve the yield and quality of plants. Most potassium fertilizers come from ancient salt deposits located throughout the world. The word “potash” is a general term that most frequently refers to pot ash, but it also applies to all other potassium-containing fertilizers, such as potassium sulfate (K_2SO_4, commonly referred to as sulfate of potash or SOP).

Potassium is a relatively abundant element in the Earth’s crust and production of potassium fertilizers occurs in every inhabited continent. However, K_2SO_4 is rarely found in a pure form in nature. Instead, it is naturally mixed with salts containing Mg, Na, and Cl. These minerals require additional processing to separate their components. Historically, K_2SO_4 was made by reacting KCl with sulfuric acid. However, it was later discovered that a number of earth minerals could be manipulated to produce K_2SO_4 and this is now the most common method of production. For example, natural K-containing minerals (such as kainite ($K(MgCl(SO_4)).3H_2O$) and schoenite ($K_2MgO_8S_2$) are mined and carefully rinsed with water and salt solutions to remove byproducts and produce K_2SO_4. A similar process is used to harvest K_2SO_4 from the Great Salt Lake in Utah, and from underground mineral deposits.

In New Mexico (USA), K_2SO_4 is separated from langbeinite ($Mg_2K_2(SO_4)_3$) minerals by reacting it with a solution of KCl, which removes the byproducts (such as Mg) and leaves K_2SO_4. Similar processing techniques are used in many parts of the world, depending on the raw materials accessible.

Potassium is needed to complete many essential functions in plants, such as activating enzyme reactions, synthesizing proteins, forming starch and sugars, and regulating water flow in cells and leaves.

Potassium sulphate is an excellent source of nutrition for plants. The K portion of the K_2SO_4 is no different from other common potash fertilizers. However, it also supplies a valuable source of S, which is sometimes helpful for plant growth. Sulphur is required for protein synthesis and enzyme function.

K_2SO_4 is frequently used for crops where additional Cl- from more common KCl fertilizer is undesirable. The partial salt index of K_2SO_4 is lower than some other common potassium fertilizers, so less total salinity is added per unit of potassium. Where high rates of K_2SO_4 are needed, it is generally recommended to divide the application into multiple doses. This helps avoid surplus K accumulation by the plant and minimizes any potential salt damage. The chemical formula of potassium sulphate is K_2SO_4, it contains 48 to 53% of Potassium under the K_2O form equivalent to 40 - 44% of K form of potassium. The sulphur content of potassium sulphate is between 17 to 18%. The solubility of potassium sulphate at 25 ºC is 120 g/L, and its solution pH is approximately 7 (http://www.ipni.net/specifics-en#).

1.7.3. Urea

The standard grade of Urea is 46-0-0 (N-P-K).

Urea is the most widely used solid Nitrogen fertilizer in the world. Urea is also commonly found in nature since it is expelled in the urine of animals. The high N content of Urea makes it efficient to transport to farms and apply to fields.

The production of Urea fertilizer involves controlled reaction of ammonia gas (NH_3) and carbon dioxide (CO_2) with elevated temperature and pressure. The molten Urea is formed into spheres with specialized granulation equipment or hardened into a solid prill while falling from a tower.

Urea manufacturing plants are located throughout the world, but most commonly located near NH_3 production facilities since NH_3 is the major input for Urea. Urea is transported throughout the world by ocean vessel, barge, rail, and truck.

Urea is used in many ways to provide Nitrogen nutrition for plant growth. It is most commonly mixed with soil or applied to the soil surface. Due to the high solubility, it may be dissolved in water and applied to soil as a fluid, added with irrigation water, or sprayed onto plant foliage. Urea in foliar sprays can be quickly absorbed by plant leaves.

After Urea contacts soil or plants, a naturally occurring enzyme (Urease) begins to quickly convert the Urea back to NH_3 in a process called hydrolysis. During this process, the Nitrogen in Urea is susceptible to undesirable gaseous losses as NH_3.

Urea hydrolysis is a rapid process, typically occurring within several days after application. Plants can utilize small amounts of Urea directly as a source of Nitrogen, but they more commonly use the ammonium ($NH4^+$) and nitrate ($NO3^-$) that are produced after Urea is transformed by Urease and soil microorganisms.

Urea is an excellent nutrient source to meet the Nitrogen demand of plants. Because it readily dissolves in water, surface-applied Urea moves with rainfall or irrigation into the soil. Within the soil, Urea moves freely with soil water until it is hydrolyzed to form $NH4^+$. Care should be used to minimize all N losses to air, surface water, and groundwater. Avoid Urea applications when the fertilizer will remain on the soil surface for prolonged periods. Undesired N losses may also result in loss of crop yield and quality.

Urea is a high N-containing fertilizer that has good storage properties and when properly managed, Urea is an excellent source of N for plants.

The chemical formula of urea is: $CO (NH_2)_2$ it contains 46% nitrogen in N form. Its water solubility at 20 ºC is 1,080 g/L (http://www.ipni.net/specifics-en#s).

1.8. Organic fertilizers

Organic fertilizers are also necessary to improve soil texture and could supply potato with macro-elements in smaller proportions than mineral fertilizers.

1.8.1. Chicken manure

CHICKPOST is a chicken manure produced by GreenCo, Terbol, Beqaa, Lebanon. It is made of imported chicken manure, pelleted and heat dried. A certificate of analysis of a batch of the product shows that the content of Nitrogen is 4.65%, Phosphorous (P_2O_5) is 3.12%, and Potassium (K_2O) is 5.56% with a C/N ratio of 9:1 and a pH of 7.1.

1.8.2. Cow manure

COWPOST is an organic compost produced by GreenCo, Terbol, Beqaa, Lebanon. It is made 100% from cow manure and wheat straw. A certificate of analysis of a batch of the product shows that the content of Nitrogen is 1.27%, Phosphorous (P_2O_5) is 1.58%, and Potassium (K_2O) is 2.41% with a C/N ratio of 15:1 and a pH of 7.8.

1.9. Crop rotation

Crop rotation is one of the foundations of sustainable agriculture, with the prospective to affect pest and disease incidence, crop productivity, and maintain soil health.

Continuous potato cropping has been reported to cause a decline in soil fertility and increase in disease incidence thus negatively affecting productivity. Also, continuous potato cropping increases the aggravation of toxic effect in root secretion such as palmitic acid and phthalic acid dibutyl, and also increases the pathogenic microbes (fusaria and Mortierella) which suppress plant growth and development.

The results of a study conducted in China in 2017 suggest that adopting a potato–legume rotation system has the potential to improve the soil biology environment, alleviate continuous cropping obstacle, and increase potato tuber yield in semi–arid region (Qin *et al*., 2017).

Overall, cropping systems that incorporate management practices such as increased rotation length and the use of cover crops, green manures, reduced tillage, and particularly, organic amendments, can substantially improve potato crop growth and yield (Larkin *et al*., 2021).

A treatment combination of 5 t/ha of farmyards manure and 2.5 t/ha fresh Sesbania (*Sesbania grandiflora*) green manure and clover-wheat-potato rotation system in the third year, increased total potato tuber yield by 140% and 41% over that of the first and the second years and would be recommended as ecologically sound option in improving the productivity of potato (Shibabaw *et al*., 2018).

Furthermore, the use of disease-suppressive rotation crops, such as *Brassica* spp. (mustards, rapeseed) and sudan grass, has shown potential for management of soil borne diseases and enhanced yield in various crop production systems (Larkin & Halloran, 2014).

Yields under continuous potato culture were lower than yields in the corn-potato rotation. Soil infestation with *Verticillium* wilt (*Verticillium albo-atrum*) was a factor contributing to this yield reduction (O'Sullivan, 1978).

Crop rotation can be an effective mechanism for reducing disease incidence and contributing nitrogen (N) to succeeding crops. Interactions of plant pathogen suppression and soil nutrient availability may also exist, adding to the cropping system complexity.

The findings of a study that examined the impact of crop rotation, N fertilization, and their interaction on growth, yield, and *Rhizoctonia solani* incidence in potato (*Solanum tuberosum* L. Norwis) have shown that studied crop rotations appeared to enhance potato production by reducing stem infection by *R. solani*. Vetch and alfalfa provide additional benefits through their N contributions (Honeycutt *et al*., 1996).

1.10. Herbicides

The herbicide that was used in the experiment was Metribuzin.

A very commonly used selective herbicide on potato in Lebanon to control broadleaf weeds and grasses, Metribuzin 70% WP was first introduced in Germany as a new potato herbicide, was used to manage weeds in the potato plot. Metribuzin is a widely used herbicide applied as pre-emergence and early post-emergence herbicide on intensive vegetable crops (Armendáriz *et al*., 2014). Metribuzin was launched in 1970 by Bayer under the trade name Sencor™, it is also sold by DuPont under the trade name Lexone™ for control of certain broadleaf weeds and grassy weed species.

Metribuzin is a member of the Triazinone chemical class. It acts by inhibiting photosynthesis through interference with photosystem II electron transport in plant chloroplasts (Simoneaux & Gould, 2008).

1.11. The Beqaa plain

The Beqaa plain is located 30 km East of Beirut between the eastern and western mountain ranges. The elevation of the Beqaa plain varies from 600 m in the Qaa area to 1250 m above sea level in the town of Baalbek. The weather in Beqaa is cold in winter and hot and dry in summer ("Https://En.Wikipedia.Org/Wiki/Beqaa_Valley," 2022). The average annual temperature in Baalbek is about 15 degrees and the average annual precipitation is about 379 mm with an average of 54 rainy days per year. The size of the plain is on average 120 km long and 16 km wide. It forms the largest agricultural area in Lebanon and is planted with a wide variety of fruit trees and field crops including stone fruit, apples, grapes, potatoes, onions, garlic, wheat, maize, leafy vegetables and many other types. To irrigate or supplement the irrigation needs of their crops, farmers pump water from a well or the Litany River or one of its tributaries or adjacent canals. Some farmers harvest rainwater during winter in artificial reservoirs/ponds to use during the dry season to water their summer crops or to supplement the water needs of fruit trees, long-season and spring/ summer crops.

1.12. AREC profile

We have selected the premises of the Advancing Research Enabling Communities Center (AREC) in the Beqaa plain to conduct the experiment (Figure 2). The center was founded in 1953 as an agricultural research and extension center for the American

University of Beirut (AUB). The AREC is located in Haouch Snaid about 75 Km to the east of Beirut at an altitude of 990 m above sea level in a central location in the Beqaa plain. Its area is about 100 hectares devoted for research, education and extension purposes (https://www.aub.edu.lb/fafs/arec/Pages/default.aspx) .

Figure 2: AREC campus- Haouch Snaid (source: https://www.enicbcmed.eu/nawamed-prof-yaser-abunnasr-presents-lebanons-pilot-areas)

1.13. Thesis position/ Research questions

This thesis investigates the effects of different combinations of organic and inorganic fertilizers on the growth and yield of potatoes in the Beqaa-AREC area.

Responding to the research problem the thesis raises the following primary questions:

How the different combinations of organic and/or inorganic fertilizers affect potato growth and yield?

Which type or combination of organic and inorganic fertilizers gives the best yield?

Is there an effect of the type or combination of organic and inorganic fertilizers on the marketable yield of potato?

The hypothesis was that applying different types and/or different combinations of organic and/or inorganic fertilizers would affect potato growth differently and consequently would give different yields.

CHAPTER 2

MATERIALS AND METHODS

2.1. Materials

2.1.1. Seed potato

The Spunta cultivar was chosen and planted in the experimental plot. It was chosen because it is the preferred and most extensively produced variety by potato farmers in the Beqaa plain and Akkar. Oldenburger (1968), a plant breeder from Holland, developed the Spunta variety (Hutten & Berloo, 2001). According to HZPC's description ((https://www.hzpc.com/our-potato-varieties/spunta, n.d.) of the Spunta cultivar has the following characteristics:

- High yield
- Big size tubers
- Good drought and heat resistance
- Good dry matter content
- Broad adaptation

The recommended rate of potato seeds is 2.5 tonnes/ha.

Figure 3: Seed potatoes used in the study

2.1.2. History of the experimental plot

The selected experimental field was planted with chickpea in 2017-2018, left fallow in 2018-2019 and planted with lentils in 2019-2020 (Source: AREC Farm Manager).

2.2. Methods

2.2.1. Seedbed preparation

On March 1, 2021, a preliminary deep plowing tillage at a depth of 35 cm using the Kuhn Reversible Moldboard Plow with three blades mounted on a 125 hp tractor type John Deere model 7700.

On March 12, 2021, a secondary tillage was conducted, consisting of disk harrow tillage using a John Deer Tandem Disk Harrow mounted on the same John Deer 7700 Tractor to break the soil. On March 17, 2021 a rotavator tillage followed using a Maschio Rotary Tiller mounted on a 75 hp John Deere 5510 Tractor.

Figure 4: Deep plowing and disk harrow tillage

On March 17, 2021, a soil sample was collected and analyzed before planting, the content in N, P and K are shown in Table 4, and the complete results of the analysis are listed in (Appendix II).

Table 4: Soil sample Content in N, P_2O_5 and K_2O

Element Analysed	Analysis Result	Interpretation
Organic Nitrogen N (%)	0.11	Poor
Available Phosphorous P_2O_5 (PPM)	51.6	Medium/Acceptable
Exchangeable Potassium K_2O (PPM)	700	High/Acceptable

2.2.2. Treatments

The experiment consisted of seven different treatments as shown in Table 5.

Table 5: Description of different treatments

Treatment	Description Kg/ ha
1	Control: No fertilizers added
2	250 Kg DAP +100 Kg SOP + 37.5 Kg Urea
3	500 Kg DAP +200 Kg SOP + 75 Kg Urea
4	15 tonnes of chicken manure + 250 Kg DAP +100 Kg SOP + 37.5 Kg Urea
5	20 tonnes of cow manure + 250 Kg DAP +100 Kg SOP + 37.5 Kg Urea)
6	30 tonnes of encapsulated chicken manure
7	40 tonnes of encapsulated cow manure

All the organic and mineral fertilizers in Table 5 were added just before planting. Only one fourth of the initially planned quantity of urea was actually added because we noticed that the vegetative growth of potato crop was very good during the season, and no additional amounts of urea were applied.

The equivalent quantities of each treatment in Nitrogen, Phosphorous and Potassium are shown in Table 6.

Table 6: Content of treatments in nitrogen, phosphorous and potassium

Treatment	**N**	**P_2O_5**	**K_2O**
	Kg/ha		
1	0	0	0
2	62	115	50
3	125	230	100
4	760	583	884
5	316	431	532
6	1395	936	1668
7	508	632	964

The experimental design and treatment distribution are shown in Table 7.

The experiment followed a Completely Randomized Block Design (CRBD) with seven treatments with four replicates (Table 7). The experiment consists of twenty-eight plots, each plot was 6.75 m in length and 3 m in width, with a total area of 20.25 m^2 per plot. The total experimental area including aisles was 993.25 m^2.

The collected data from the experimental plot were subject to ANOVA statistical analysis at 95% confidence level using SPSS 26 statistical analysis software.

Table 7: The design of the field experiment

Block #	**Treatments**						
1	7	3	4	1	6	5	2
2	5	1	7	2	6	4	3
3	4	2	6	5	7	3	1
4	3	7	2	4	1	5	6

The experiment followed a Completely Randomized Block Design (CRBD) with seven treatments replicated four times (28 plots). The plot length was 6.75 m and 3 m width, with a total area of 20.25 m^2. The total experimental area was 993.25 m^2.

The collected data from the experimental plot were subject to ANOVA statistical analysis at 95% confidence level using SPSS 26 statistical analysis software.

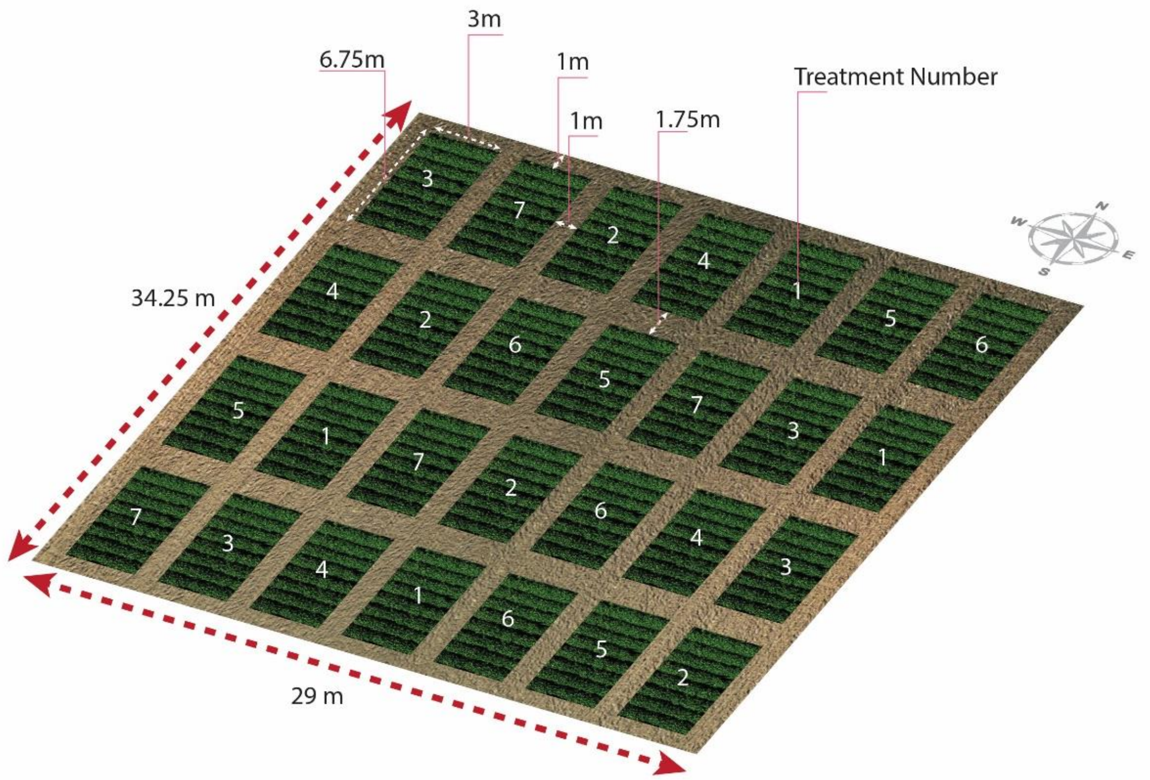

Figure 5: Study field map

2.2.3. *Fertilizers applications*

All the needed quantities of organic and mineral fertilizers per plot per treatment were weighed, packed and labelled. On March 19, 2021, mineral fertilizers were mixed with sand and broadcasted by hand to help in even distribution over the soil. Both organic and mineral fertilizers were broadcasted manually by hand, first the mineral fertilizers and second the organic fertilizers. Afterwards, and just before planting the seed potatoes, the field was ploughed with a five blades cultivator to break the soil and mix the dispersed fertilizers.

Figure 6: Application of organic and mineral fertilizers

2.2.4. Plantings

On March 15, 2021, Elite class seed potatoes of the Spunta variety, size 35-55mm were previously cut into 40-50 grams pieces and treated by dipping in a solution of 250 grams of Fosethyl-aluminium 80% WP dissolved in 100 Liters of water. The seeds were drained, and then spread over a clean concrete floor in a cool room for 48 hours to dry before planting. Two hundred and fifty kilograms of seeds were prepared for planting at the field experiment.

The seeds were loaded into a SPEDO automatic potato planter mounted on a 75 hp John Deere 5510 tractor. The tractor moving at 4 km per hour planted the seeds at 25 cm depth, 28 cm in-row distance, and 75 cm between rows .Two hundred fifteen kilograms of potato seeds were planted in the whole experiment of 993.25 m^2 including the aisles and the borders. The direction of planting was East-West resulting in 8 rows (6.75 m divided by 0.75 m) per plot and a sum of 567 m^2 (28*(6.75*3m).

Figure 7: Planting seed potatoes

2.2.5. Weed control

On April 8, 2021 Metribuzin (70% WP) was applied at the rate of 1 Kilogram commercial product per hectare using an Agromaster boom sprayer mounted on tractor: John Deere model 5310 (55 hp.)

Figure 8: Herbicide application and irrigation

2.2.6. Irrigation

The established irrigation system was a sprinkler type mounted at 12 m by 12 m spacing. The total number of sprinklers was 12 with a nozzle diameter of 11/64x3/32. The sprinklers were used at a 3.8 bar pressure with a flow rate of 1.9 m^3/hour per sprinkler and a 14 mm/hour precipitation. The total precipitation of the twelve sprinklers is 22.8 cubic meters/hour. The first irrigation was conducted on April 23, 2021. The total quantity of irrigation water used for the experiment was 500 mm.

2.2.7. Measured parameters

- Number of plants in the middle two rows of each plot 75 days after planting.
- Height of 10 potato plants per plot, 75 days after planting.
- Plant biomass of two potato plants per plot from the border, 96 days after planting.
- Potato tuber yield from the middle four rows per plot (10.125 m^2).
- Yield quality (grading) was determined by separating harvested tubers into two classes: marketable (> 5.0 cm in diameter) and non-marketable tubers (< 5.0 cm in diameter) (Robinson, *et al.*, 1996).

2.2.8. Harvesting

Harvesting was conducted on (August 2, 2021) using a Potato Cultivator mounted on a 75 hp John Deere model 5510 Y tractor. Potato tubers from the middle four rows per plot was collected and weighed separately, then sorted into marketable and non-marketable sizes.

Figure 9: Harvesting of potato tubers

CHAPTER 3

RESULTS AND DISCUSSION

3.1. Results

3.1.1. Number of emerged potato plants

The number of emerged plants was recorded in the middle two rows, seventy-five days after planting. The average number of emerged plants per treatment is shown in Table 8.

Table 8: Average number of emerged plants per treatment

Treatment	**Readings per two rows per replicate**								**Average number of emerged plants in two**
1	14	15	15	15	16	17	17	16	15.625
2	15	14	15	16	16	16	16	17	15.625
3	16	14	16	15	18	15	17	16	15.875
4	17	15	14	15	16	16	15	17	15.625
5	17	15	16	15	18	16	17	16	16.25
6	16	16	16	15	17	17	17	16	16.25
7	15	15	15	15	16	17	16	16	15.625

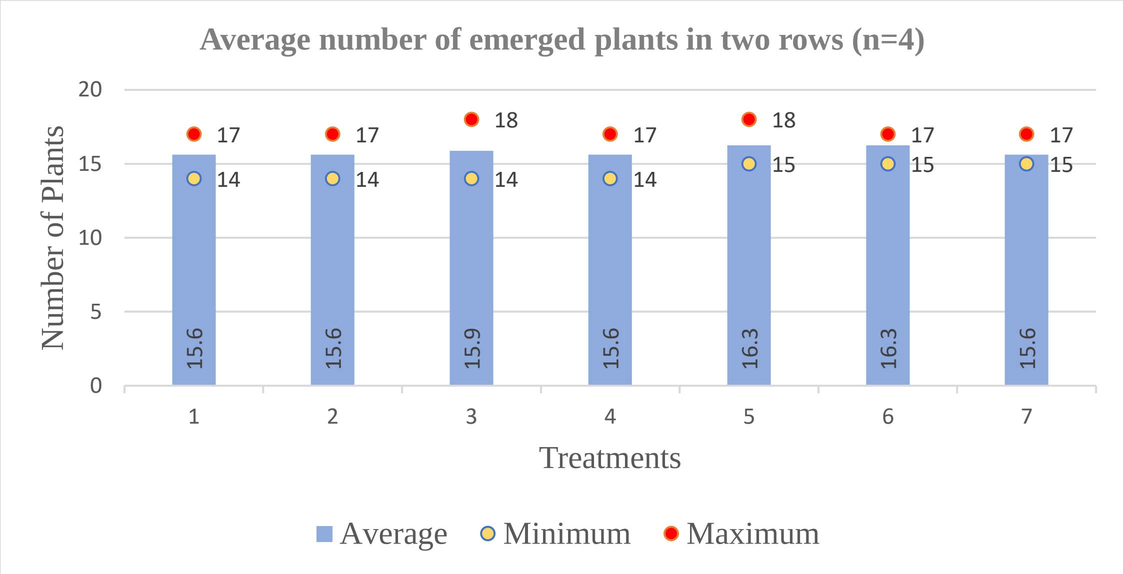

Figure 10: Effect of different fertilization treatments on the average number of emerged potato plants.

Figure 10 shows no significant effects among the different fertilization treatments on the number of emerged plants compared to the control. This indicates that the experiment plot had enough humidity and nutrients necessary for shoot emergence and seedling development. The uniformity of treatments between each other and with the control indicates that, the nutrients were already present in suitable amounts. Most probably, the reason behind availability of sufficient nutritional elements is the adopted crop rotation and fertilization practices conducted prior to the experiment at AREC. These practices might have guaranteed and sustained sufficient levels, of suitable nutrients, necessary for the shoot emergence of potato seeds, and development of potato seedlings into full grown and healthy shoot emergence.

3.1.2. Potato plant height

The height of ten randomly selected plants per plot was measured seventy-five days after planting (Table 9).

Table 9: Average height of 10 randomly selected plants per treatment

Treatment	**1**	**2**	**3**	**4**	**Average Height (n=40 plants) (cm)**
1	74	80.1	87.5	69.8	77.85
2	69.6	64.3	75.8	73.9	70.9
3	75.8	68.6	73.7	70.6	72.175
4	78.2	89.6	74.3	73.4	78.875
5	61.8	80.6	68.5	65.4	69.075
6	82.5	64.8	82.9	67.4	74.4
7	69.6	70.6	76.9	77	73.525

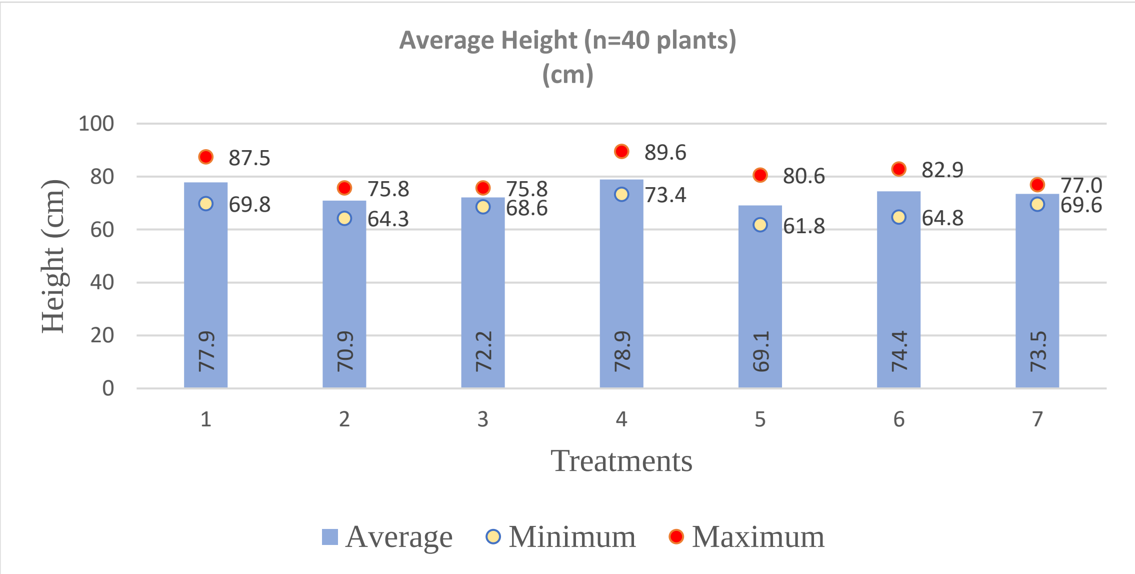

Figure 11: Effect of different fertilization treatments on the average height of potato plants

In spite of the large differences in added fertilizers including nitrogen, the main element affecting vegetative growth, Figure 11 shows no significant differences in plant height among treatments, in comparison to the control. This indicates that the potato crop might had enough nutritional elements in the soil to induce optimum vegetative growth. Accordingly, the decision not to add the remaining 3/4 of urea was a wise one.

3.1.3. Dry potato plant shoot biomass

The dry biomass of two potato shoots per plot per treatment was also measured ninety-six days after planting (Table 10).

Table 10: Average dry biomass of two dried potato shoots per treatment

Treatment	**1**	**2**	**3**	**4**	**Average biomass (n=8) (g)**
1	80	170	150	120	130
2	70	100	110	240	130
3	60	130	100	120	102.5
4	250	120	70	140	145
5	100	270	80	30	120
6	170	60	50	110	97.5
7	80	270	160	80	147.5

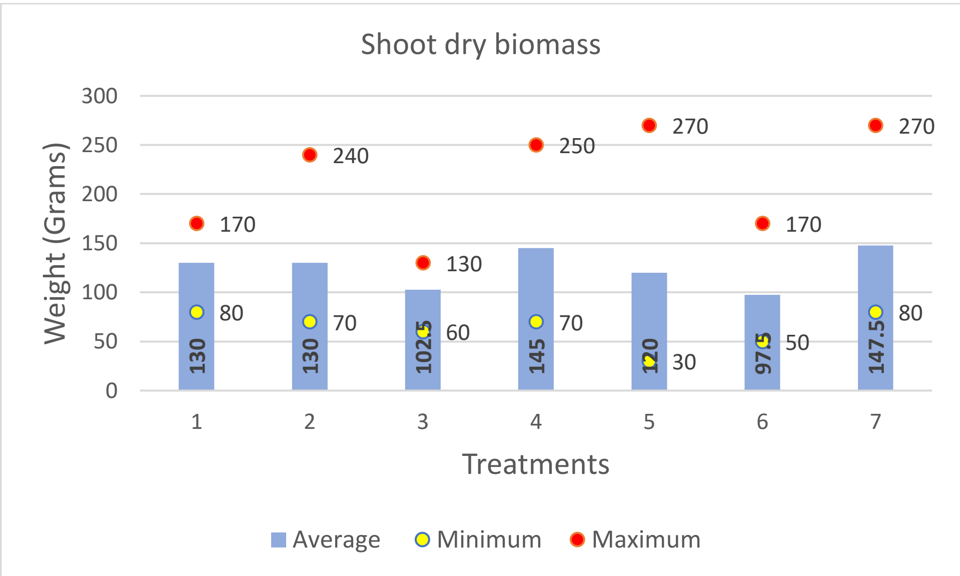

Figure 12: Effect of different fertilizers treatments on potato shoot biomass

The data in Figure 12 shows a big discrepancy in the values within the same treatment which indicates that an error took place during data collection and therefore it will be ignored. However, the height values are consistent and will be used to discuss the growth parameter.

3.1.4. Total potato yiel

The total yield of the middle four rows per plot per treatment was harvested and weighed 135 days after planting as shown in Table 11.

Table 11: Average total potato yield per treatment per hectare

Treatment	**1**	**2**	**3**	**4**	**Total Yield (tonnes/ha)**
1	67	51	67	54	60
2	82	61	49	71	66
3	63	65	51	51	58
4	67	90	56	64	69
5	60	41	56	62	55
6	46	67	47	62	56
7	61	63	60	56	60

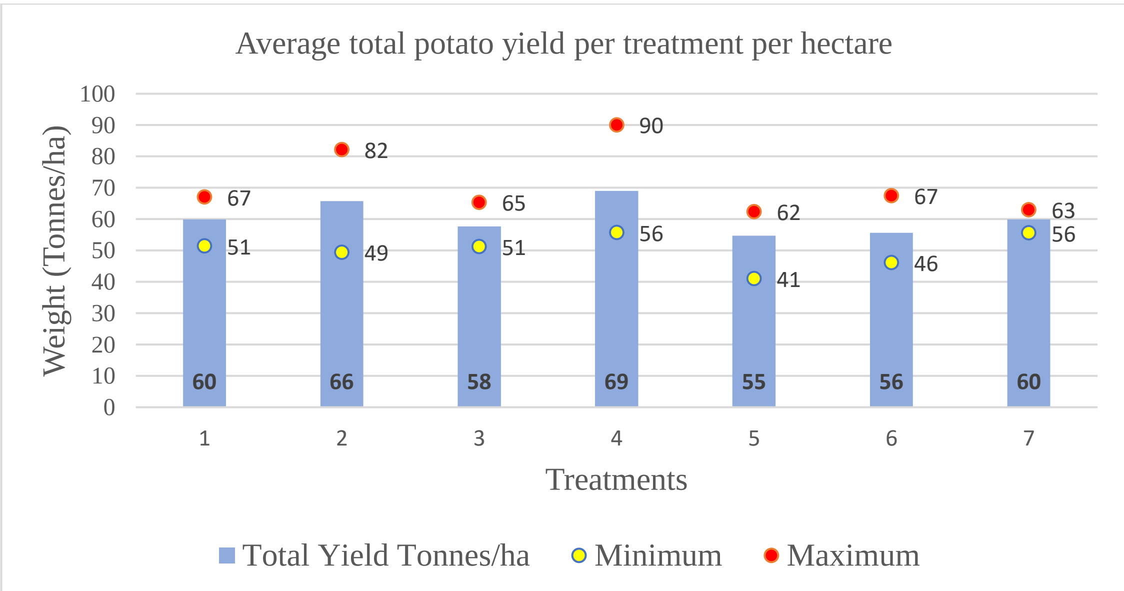

Figure 13: Effect of different fertilizers treatments on potato tuber yield

Figure 13 also shows no significant differences in the total yield of different treatments in comparison to the control. This confirms again that the field might had enough nutrients needed for adequate growth and optimum yield.

3.1.5. Marketable and non-marketable yield

The total yield was graded into marketable and non-marketable tuber sizes and weighed (Table 12).

Table 12: Total yield, marketable yield and non-marketable yield per treatment per hectare

Treatment	Total yield (tonnes/ha)	Marketable yield (tonnes/ha)	Marketable yield (%)	Non-marketable yield (tonnes/ha)	Non-marketable yield (%)
1	60	51	85%	9	15%
2	66	56	85%	10	15%
3	58	48	83%	10	17%
4	69	55	79%	14	21%
5	55	45	82%	10	18%
6	56	44	80%	12	20%
7	60	49	82%	11	18%

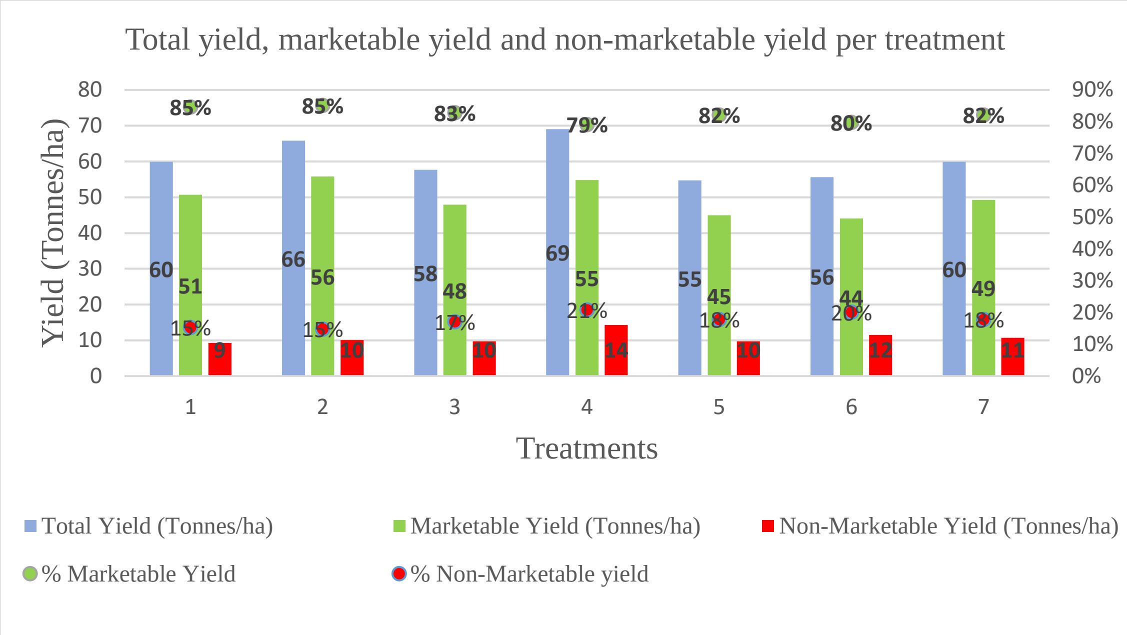

Figure 14: Effect of different fertilizers treatments on the proportion of marketable and non-marketable yield

Once again, and in consistency with the previous figures, Figure 14 shows there is no significant differences among treatments in comparison to the control in both the marketable and the non-marketable yield. This confirms our previous conclusions, that the implemented crop rotation practices conducted in the field prior to our experiment might have provided the soil with sufficient amounts of nutritional elements, including N, P & K to support a healthy crop and get an excellent yield.

3.2. Discussion

At the beginning, the objective of this study was to monitor the incidence of potato pests and compare between traditional and Integrated Pest Management practices. Later, and since there are no significant pests on potatoes at AREC, it was decided to change the objectives of the study to look for the effects of different organic and mineral fertilizers on growth and yield of potato.

The statistical analysis (APPENDIX III) did not reveal any significant differences among the various organic and mineral fertilizers treatments including the control on all the measured parameters (Number of emerged plants, plant height, shoot biomass, total yield, marketable yield and non-marketable yield). Similarly, the conducted Multiple Comparisons Analysis (APPENDIX IV) did not show any significant differences among the treatments.

The insignificant effects of the organic and mineral fertilizers treatments on growth and yield of potato revealed that the possibility of available nutrients in the soil of the experimental plot. Thus, the added quantity of fertilizers most probably have been added as surplus or in excessive amounts. The results of the initial soil analysis supports our obtained analysis of all parameters because it showed that nitrogen, phosphorous and potassium were found in sufficient amounts for vegetative growth and tuber production. It seems that, the addition of organic and mineral fertilizers at all tested rates were unnecessary.

Unluckily or maybe luckily, we did not encounter any pests incidence on potatoes during the whole season, which might be due to various reasons, among them are: cold winter, dry spring and summer seasons, and crop rotation practices implemented during the previous years.

Our results revealed that potato yields in all treatments including the control (60 Tonnes/ha) was greater than potato yields obtained by the local farmers in the Beqaa plain. Our observations suggests that the crop rotation implemented on the experimental plot during the previous years with chickpeas (2017-2018), followed by fallow (2018-2019) and lentils (2019-2020), and in addition to the good farm management practices (irrigation, weed management, hilling) could have largely contributed to the increase in the production of potatoes. In addition, it could have largely contributed to enriching the experimental plot with the necessary nutritional elements to grow potato successfully and profitably.

The experiment has demonstrated that crop rotation with legumes is an important practice in enriching the soil with nitrogen and other organic materials. Thus, adding additional organic and mineral fertilizers is a waste at the economic and environmental levels. In addition, various studies showed that crop rotation plays an important role in managing soil-born pests and diseases by reducing their incidence and minimizing their negative effects on potato health and productivity (Larkin, 2008).

CHAPTER IV

CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

In spite of the interesting obtained results, it is too early at this stage to make any recommendations to the potato producers in the Beqaa. However, our results revealed that adding organic and mineral fertilizers after a rotation with legumes is not recommended. Results showed that the potato yield per hectare in the control (6 tonnes/ ha) was almost the same as in all tested organic and mineral treatments. In addition, the amount of potato yield (quantity and quality) we got in the control and all other treatments was significantly higher than the yield obtained by potato farmers in the Beqaa plain.

4.2. Recommendations

Based on this field study, it is recommended that:

- Soil analysis one month prior to planting potato is necessary to determine the right amounts of organic and mineral fertilizers per unit area. It is very important that the soil analysis of nitrogen should include both organic and inorganic content.
- Rotation with legumes and/or green manure with legumes, must be considered whenever farmers decide to plant potatoes.
- Further studies should be conducted to investigate the effects of different organic and mineral fertilizers on poorly managed soils, marginal lands and after rotation with cereals in various locations in the Beqaa plain.
- Further studies should be conducted to help potato farmers sustainably manage their economic, agricultural, and environmental resources by

reducing their complete reliance on commercial organic and inorganic fertilizers.

APPENDIX I

Summary of characteristics of major potato varieties grown in Lebanon

Variety	Spunta	Agria	Hermes	Fontane	Farida	Fabula	Asterix
Usage	Retail	Retail/processing	Processing	Processing	retail	Retail	Processing (French fries)
Maturity	Early Medium	Medium Late	Medium	Early Medium	Medium late	Medium late	Late
Tuber Shape	Long oval	Oval	Round	Oval	Long oval	Oval	Long oval
Flesh color	Light yellow	Yellow	Light Yellow	Light Yellow	Light Yellow	Light Yellow	Light yellow
Skin color	Yellow	White to Yellow	Yellow	Yellow	Yellow	Yellow	Red
Yield	Very High	Very High	High	Very High	Very High	Very high	High
Tuber Size	Very Large	Large	Large	Large		Very Large	Large
Nbr of Tubers	9-11	8		high		9 - 11	12 -14
Dry Matter	20%	22%	High	23.20%	18.90%	17.50%	23.40%
Late Blight Foliage	Susceptible	Susceptible	Average resistance	Susceptible	Resistant	Average resistance	Average susceptibility
Late Blight Tuber	Susceptible	Minimal susceptibility	Good resistance	Minimal susceptibility	Medium resistant	Average resistance	Medium resistance
Fusarium	Susceptible	Medium resistance	High	Minimal susceptibility			
Rhizoctonia		Resistant		Minimal susceptibility			
Alternaria	Medium resistance				Medium resistance	High Resistance	Medium resistance
Nematode	Susceptible	Resistant	Resistant	Resistant		Resistant	
Drought Resistance	High	High	High		High		High
Frost Resistance	Medium	Medium					

Susceptible Deficiency	Magnesium						
Nitrogen requirement	250 kg/ha				250 kg/ha	250 kg/ha	200 kg/ha
Storage Ability	Poor	Moderate					High at 8 degrees
Bruising	Susceptible	Resistant		Susceptible	Moderate	Resistant	Sensitive

Source: https://www.europotato.org/varieties

APPENDIX II

Soil sample analysis result

Element Analyzed	Analysis Reference	Analysis Result	Interpretation	Poor/ Inacceptable	Medium/ Acceptable	High/ Acceptable
Soil composition (%)		Sand: 40 Silt: 34 Clay: 26	Silty soil			
Soil type	USDA Texture Triangle	Silty soil				
pH	ISO 10390:2005	**7.6**	Neutral			
Conductivity MS.cm^{-1}	ISO 11265:1994	**0.17**				
Organic matter (%)	Walkely-Black 1947	**1.85**	Poor	< 2	2< <2.5	>2.5
Total lime (%)	HCL attack dosage	**10**	Medium/ Acceptable	<1 From 0 to 1	1< <30 From 1- to 30	>30 More than 30
Active lime (%)	NF X31-106:1998	**3.3**	Medium/ Acceptable	< 3 0 to 3	3< <7 3 to 7	>7 More than 7
Organic Nitrogen N (%)	By calculation	**0.11**	Poor	< 0.15	0.15< <0.2	> 0.2
Available Phosphorous P_2O_5 (PPM)	ISO 11263: 1994 (Olsen Method)	**51.6**	Medium/ Acceptable	< 35	35< <92	>92
Exchangeable Potassium K_2O (PPM)	NF X31-108:1998	**700**	High/ Acceptable	< 216	216< <360	>360
Exchangeable Calcium CaO (PPM)	NF X31-108:1998	**14985**	High/ Acceptable	< 700	700< < 3500	>3500
Exchangeable Magnesium MgO (PPM)	NF X31-108:1998	**586**	High/ Acceptable	< 240	240< <400	>400
Exchangeable Sodium Na (PPM)	NF X31-108:1998	**123**	Low/ Acceptable	< 300 Acceptable		>300 Inacceptable

APPENDIX III

ANOVA

ONEWAY NbPlants PltHeight Biomass Production MarketProduc BY Group						
/MISSING ANALYSIS						
/POSTHOC=BONFERRONI ALPHA(0.05).						
Notes						
Output Created		30-DEC-2021 14:18:43				
7ments						
Input	Data	/Users/macuser/MS Thesis Potato.sav				
	Active Dataset	DataSet0				
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	Split File	<none>				
	N of Rows in Working Data File	28				
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.				
	Cases Used	Statistics for each analysis are based on cases with no missing data for any variable in the analysis.				
Syntax		ONEWAY NbPlants PltHeight Biomass Production MarketProduc BY Group /MISSING ANALYSIS /POSTHOC=BONFERRONI ALPHA(0.05).				
Resources	Processor Time	00:00:00.04				
	Elapsed Time	00:00:00.00				
ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
NbPlants	Between Groups	2.089	6	0.348	0.639	0.698
	Within Groups	11.438	21	0.545		
	Total	13.527	27			

PltHeight	Between Groups	303.857	6	50.643	1.086	0.402
	Within Groups	979.220	21	46.630		
	Total	1283.077	27			
Biomass	Between Groups	8971.429	6	1495.238	0.291	0.934
	Within Groups	107725.000	21	5129.762		
	Total	116696.429	27			
Production	Between Groups	685.678	6	114.280	1.042	0.427
	Within Groups	2303.944	21	109.712		
	Total	2989.622	27			
MarketProduc	Between Groups	495.851	6	82.642	1.072	0.410
	Within Groups	1618.572	21	77.075		
	Total	2114.423	27			

APPENDIX IV

Multiple Comparisons

Post Hoc Tests							
Multiple Comparisons							
Bonferroni							
Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
NbPlants	1	2	0.00000	0.52184	1.000	-1.8020	1.8020
		3	-0.25000	0.52184	1.000	-2.0520	1.5520
		4	0.00000	0.52184	1.000	-1.8020	1.8020
		5	-0.62500	0.52184	1.000	-2.4270	1.1770
		6	-0.62500	0.52184	1.000	-2.4270	1.1770
		7	0.00000	0.52184	1.000	-1.8020	1.8020
	2	1	0.00000	0.52184	1.000	-1.8020	1.8020
		3	-0.25000	0.52184	1.000	-2.0520	1.5520
		4	0.00000	0.52184	1.000	-1.8020	1.8020
		5	-0.62500	0.52184	1.000	-2.4270	1.1770
		6	-0.62500	0.52184	1.000	-2.4270	1.1770
		7	0.00000	0.52184	1.000	-1.8020	1.8020
	3	1	0.25000	0.52184	1.000	-1.5520	2.0520
		2	0.25000	0.52184	1.000	-1.5520	2.0520
		4	0.25000	0.52184	1.000	-1.5520	2.0520
		5	-0.37500	0.52184	1.000	-2.1770	1.4270
		6	-0.37500	0.52184	1.000	-2.1770	1.4270
		7	0.25000	0.52184	1.000	-1.5520	2.0520
	4	1	0.00000	0.52184	1.000	-1.8020	1.8020
		2	0.00000	0.52184	1.000	-1.8020	1.8020
		3	-0.25000	0.52184	1.000	-2.0520	1.5520
		5	-0.62500	0.52184	1.000	-2.4270	1.1770
		6	-0.62500	0.52184	1.000	-2.4270	1.1770
		7	0.00000	0.52184	1.000	-1.8020	1.8020
	5	1	0.62500	0.52184	1.000	-1.1770	2.4270
		2	0.62500	0.52184	1.000	-1.1770	2.4270
		3	0.37500	0.52184	1.000	-1.4270	2.1770
		4	0.62500	0.52184	1.000	-1.1770	2.4270
		6	0.00000	0.52184	1.000	-1.8020	1.8020
		7	0.62500	0.52184	1.000	-1.1770	2.4270

	6	1	0.62500	0.52184	1.000	-1.1770	2.4270
		2	0.62500	0.52184	1.000	-1.1770	2.4270
		3	0.37500	0.52184	1.000	-1.4270	2.1770
		4	0.62500	0.52184	1.000	-1.1770	2.4270
		5	0.00000	0.52184	1.000	-1.8020	1.8020
		7	0.62500	0.52184	1.000	-1.1770	2.4270
	7	1	0.00000	0.52184	1.000	-1.8020	1.8020
		2	0.00000	0.52184	1.000	-1.8020	1.8020
		3	-0.25000	0.52184	1.000	-2.0520	1.5520
		4	0.00000	0.52184	1.000	-1.8020	1.8020
		5	-0.62500	0.52184	1.000	-2.4270	1.1770
		6	-0.62500	0.52184	1.000	-2.4270	1.1770
PltHeight	1	2	6.95000	4.82854	1.000	-9.7239	23.6239
		3	5.67500	4.82854	1.000	-10.9989	22.3489
		4	-1.02500	4.82854	1.000	-17.6989	15.6489
		5	8.77500	4.82854	1.000	-7.8989	25.4489
		6	3.45000	4.82854	1.000	-13.2239	20.1239
		7	4.32500	4.82854	1.000	-12.3489	20.9989
	2	1	-6.95000	4.82854	1.000	-23.6239	9.7239
		3	-1.27500	4.82854	1.000	-17.9489	15.3989
		4	-7.97500	4.82854	1.000	-24.6489	8.6989
		5	1.82500	4.82854	1.000	-14.8489	18.4989
		6	-3.50000	4.82854	1.000	-20.1739	13.1739
		7	-2.62500	4.82854	1.000	-19.2989	14.0489
	3	1	-5.67500	4.82854	1.000	-22.3489	10.9989
		2	1.27500	4.82854	1.000	-15.3989	17.9489
		4	-6.70000	4.82854	1.000	-23.3739	9.9739
		5	3.10000	4.82854	1.000	-13.5739	19.7739
		6	-2.22500	4.82854	1.000	-18.8989	14.4489
		7	-1.35000	4.82854	1.000	-18.0239	15.3239
	4	1	1.02500	4.82854	1.000	-15.6489	17.6989
		2	7.97500	4.82854	1.000	-8.6989	24.6489
		3	6.70000	4.82854	1.000	-9.9739	23.3739
		5	9.80000	4.82854	1.000	-6.8739	26.4739
		6	4.47500	4.82854	1.000	-12.1989	21.1489
		7	5.35000	4.82854	1.000	-11.3239	22.0239
	5	1	-8.77500	4.82854	1.000	-25.4489	7.8989
		2	-1.82500	4.82854	1.000	-18.4989	14.8489
		3	-3.10000	4.82854	1.000	-19.7739	13.5739
		4	-9.80000	4.82854	1.000	-26.4739	6.8739
		6	-5.32500	4.82854	1.000	-21.9989	11.3489

		7	-4.45000	4.82854	1.000	-21.1239	12.2239
	6	1	-3.45000	4.82854	1.000	-20.1239	13.2239
		2	3.50000	4.82854	1.000	-13.1739	20.1739
		3	2.22500	4.82854	1.000	-14.4489	18.8989
		4	-4.47500	4.82854	1.000	-21.1489	12.1989
		5	5.32500	4.82854	1.000	-11.3489	21.9989
		7	0.87500	4.82854	1.000	-15.7989	17.5489
	7	1	-4.32500	4.82854	1.000	-20.9989	12.3489
		2	2.62500	4.82854	1.000	-14.0489	19.2989
		3	1.35000	4.82854	1.000	-15.3239	18.0239
		4	-5.35000	4.82854	1.000	-22.0239	11.3239
		5	4.45000	4.82854	1.000	-12.2239	21.1239
		6	-0.87500	4.82854	1.000	-17.5489	15.7989
Biomass	1	2	0.00000	50.64465	1.000	-174.8857	174.8857
		3	27.50000	50.64465	1.000	-147.3857	202.3857
		4	-15.00000	50.64465	1.000	-189.8857	159.8857
		5	10.00000	50.64465	1.000	-164.8857	184.8857
		6	32.50000	50.64465	1.000	-142.3857	207.3857
		7	-17.50000	50.64465	1.000	-192.3857	157.3857
	2	1	0.00000	50.64465	1.000	-174.8857	174.8857
		3	27.50000	50.64465	1.000	-147.3857	202.3857
		4	-15.00000	50.64465	1.000	-189.8857	159.8857
		5	10.00000	50.64465	1.000	-164.8857	184.8857
		6	32.50000	50.64465	1.000	-142.3857	207.3857
		7	-17.50000	50.64465	1.000	-192.3857	157.3857
	3	1	-27.50000	50.64465	1.000	-202.3857	147.3857
		2	-27.50000	50.64465	1.000	-202.3857	147.3857
		4	-42.50000	50.64465	1.000	-217.3857	132.3857
		5	-17.50000	50.64465	1.000	-192.3857	157.3857
		6	5.00000	50.64465	1.000	-169.8857	179.8857
		7	-45.00000	50.64465	1.000	-219.8857	129.8857
	4	1	15.00000	50.64465	1.000	-159.8857	189.8857
		2	15.00000	50.64465	1.000	-159.8857	189.8857
		3	42.50000	50.64465	1.000	-132.3857	217.3857
		5	25.00000	50.64465	1.000	-149.8857	199.8857
		6	47.50000	50.64465	1.000	-127.3857	222.3857
		7	-2.50000	50.64465	1.000	-177.3857	172.3857
	5	1	-10.00000	50.64465	1.000	-184.8857	164.8857
		2	-10.00000	50.64465	1.000	-184.8857	164.8857
		3	17.50000	50.64465	1.000	-157.3857	192.3857
		4	-25.00000	50.64465	1.000	-199.8857	149.8857

		6	22.50000	50.64465	1.000	-152.3857	197.3857
		7	-27.50000	50.64465	1.000	-202.3857	147.3857
	6	1	-32.50000	50.64465	1.000	-207.3857	142.3857
		2	-32.50000	50.64465	1.000	-207.3857	142.3857
		3	-5.00000	50.64465	1.000	-179.8857	169.8857
		4	-47.50000	50.64465	1.000	-222.3857	127.3857
		5	-22.50000	50.64465	1.000	-197.3857	152.3857
		7	-50.00000	50.64465	1.000	-224.8857	124.8857
	7	1	17.50000	50.64465	1.000	-157.3857	192.3857
		2	17.50000	50.64465	1.000	-157.3857	192.3857
		3	45.00000	50.64465	1.000	-129.8857	219.8857
		4	2.50000	50.64465	1.000	-172.3857	177.3857
		5	27.50000	50.64465	1.000	-147.3857	202.3857
		6	50.00000	50.64465	1.000	-124.8857	224.8857
Production	1	2	-5.95750	7.40647	1.000	-31.5335	19.6185
		3	2.28250	7.40647	1.000	-23.2935	27.8585
		4	-9.22500	7.40647	1.000	-34.8010	16.3510
		5	5.29000	7.40647	1.000	-20.2860	30.8660
		6	4.37250	7.40647	1.000	-21.2035	29.9485
		7	0.01250	7.40647	1.000	-25.5635	25.5885
	2	1	5.95750	7.40647	1.000	-19.6185	31.5335
		3	8.24000	7.40647	1.000	-17.3360	33.8160
		4	-3.26750	7.40647	1.000	-28.8435	22.3085
		5	11.24750	7.40647	1.000	-14.3285	36.8235
		6	10.33000	7.40647	1.000	-15.2460	35.9060
		7	5.97000	7.40647	1.000	-19.6060	31.5460
	3	1	-2.28250	7.40647	1.000	-27.8585	23.2935
		2	-8.24000	7.40647	1.000	-33.8160	17.3360
		4	-11.50750	7.40647	1.000	-37.0835	14.0685
		5	3.00750	7.40647	1.000	-22.5685	28.5835
		6	2.09000	7.40647	1.000	-23.4860	27.6660
		7	-2.27000	7.40647	1.000	-27.8460	23.3060
	4	1	9.22500	7.40647	1.000	-16.3510	34.8010
		2	3.26750	7.40647	1.000	-22.3085	28.8435
		3	11.50750	7.40647	1.000	-14.0685	37.0835
		5	14.51500	7.40647	1.000	-11.0610	40.0910
		6	13.59750	7.40647	1.000	-11.9785	39.1735
		7	9.23750	7.40647	1.000	-16.3385	34.8135
	5	1	-5.29000	7.40647	1.000	-30.8660	20.2860
		2	-11.24750	7.40647	1.000	-36.8235	14.3285
		3	-3.00750	7.40647	1.000	-28.5835	22.5685

		4	-14.51500	7.40647	1.000	-40.0910	11.0610
		6	-0.91750	7.40647	1.000	-26.4935	24.6585
		7	-5.27750	7.40647	1.000	-30.8535	20.2985
	6	1	-4.37250	7.40647	1.000	-29.9485	21.2035
		2	-10.33000	7.40647	1.000	-35.9060	15.2460
		3	-2.09000	7.40647	1.000	-27.6660	23.4860
		4	-13.59750	7.40647	1.000	-39.1735	11.9785
		5	0.91750	7.40647	1.000	-24.6585	26.4935
		7	-4.36000	7.40647	1.000	-29.9360	21.2160
	7	1	-0.01250	7.40647	1.000	-25.5885	25.5635
		2	-5.97000	7.40647	1.000	-31.5460	19.6060
		3	2.27000	7.40647	1.000	-23.3060	27.8460
		4	-9.23750	7.40647	1.000	-34.8135	16.3385
		5	5.27750	7.40647	1.000	-20.2985	30.8535
		6	4.36000	7.40647	1.000	-21.2160	29.9360
MarketProduc	1	2	-6.61250	6.20785	1.000	-28.0494	14.8244
		3	1.29500	6.20785	1.000	-20.1419	22.7319
		4	-5.63750	6.20785	1.000	-27.0744	15.7994
		5	4.29500	6.20785	1.000	-17.1419	25.7319
		6	5.23500	6.20785	1.000	-16.2019	26.6719
		7	-1.45250	6.20785	1.000	-22.8894	19.9844
	2	1	6.61250	6.20785	1.000	-14.8244	28.0494
		3	7.90750	6.20785	1.000	-13.5294	29.3444
		4	0.97500	6.20785	1.000	-20.4619	22.4119
		5	10.90750	6.20785	1.000	-10.5294	32.3444
		6	11.84750	6.20785	1.000	-9.5894	33.2844
		7	5.16000	6.20785	1.000	-16.2769	26.5969
	3	1	-1.29500	6.20785	1.000	-22.7319	20.1419
		2	-7.90750	6.20785	1.000	-29.3444	13.5294
		4	-6.93250	6.20785	1.000	-28.3694	14.5044
		5	3.00000	6.20785	1.000	-18.4369	24.4369
		6	3.94000	6.20785	1.000	-17.4969	25.3769
		7	-2.74750	6.20785	1.000	-24.1844	18.6894
	4	1	5.63750	6.20785	1.000	-15.7994	27.0744
		2	-0.97500	6.20785	1.000	-22.4119	20.4619
		3	6.93250	6.20785	1.000	-14.5044	28.3694
		5	9.93250	6.20785	1.000	-11.5044	31.3694
		6	10.87250	6.20785	1.000	-10.5644	32.3094
		7	4.18500	6.20785	1.000	-17.2519	25.6219
	5	1	-4.29500	6.20785	1.000	-25.7319	17.1419
		2	-10.90750	6.20785	1.000	-32.3444	10.5294

		3	-3.00000	6.20785	1.000	-24.4369	18.4369
		4	-9.93250	6.20785	1.000	-31.3694	11.5044
		6	0.94000	6.20785	1.000	-20.4969	22.3769
		7	-5.74750	6.20785	1.000	-27.1844	15.6894
	6	1	-5.23500	6.20785	1.000	-26.6719	16.2019
		2	-11.84750	6.20785	1.000	-33.2844	9.5894
		3	-3.94000	6.20785	1.000	-25.3769	17.4969
		4	-10.87250	6.20785	1.000	-32.3094	10.5644
		5	-0.94000	6.20785	1.000	-22.3769	20.4969
		7	-6.68750	6.20785	1.000	-28.1244	14.7494
	7	1	1.45250	6.20785	1.000	-19.9844	22.8894
		2	-5.16000	6.20785	1.000	-26.5969	16.2769
		3	2.74750	6.20785	1.000	-18.6894	24.1844
		4	-4.18500	6.20785	1.000	-25.6219	17.2519
		5	5.74750	6.20785	1.000	-15.6894	27.1844
		6	6.68750	6.20785	1.000	-14.7494	28.1244

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