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Hydroponic Forage Production and Water Use Efficiency of Some Forage Crops under Palestinian Conditions

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Dedication

Greatest dedication to our Prophet Muhammad peace be upon him. Special dedication and thanks to lovely mother and father.

To my sister " Hiba "and brother " Amjad ".

To my family, friends and everyone who supported me.

Acknowledgment

In the beginning I thank God "Allah" who gave me the opportunity to continue my higher studies and finish this research.

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الإقرار

أنا الموقع أدناه، مقدم الرسالة التي تحمل العنوان:

Hydroponic Forage Production and Water Use Efficiency of Some Forage Crops under Palestinian Conditions

أقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وأن هذه الرسالة ككل أو أي جزء منها لم يقدم من قبل لنيل أي درجة علمية أو بحث علمي أو بحثي لدى أي مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name:	**اسم الطالب:**
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List of Abbreviations

DM	Dry Matter
Ca	Calcium
P	Phosphorus
Fe	Iron
Mn	Manganese
CF	Crude Fiber
CP	Crude Protein
AOAC	Association of Official Chemist
AOCS	American Oil Chemists' Society
WU	Water Use
WUE	Water use efficiency
SPSS	Statistical Package for the Social Sciences
ANOVA	Analysis of variance
GF	Green Fodder
°C	Degree Celsius
g	Gram
Kg	kilogram
ha	Hectare
IBM	International Business Machines
L	Liter
N	Nitrogen
K	Potassium

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Abstract

Hydroponic system is growing plants without soil, using continuous water flow. In this research, three hydroponic forage crops wheat (*Triticum aestivum*), beka (*Vicia sativa L*) and vetch (*Vicia ervilia* (*L.*) Willd) were investigated to green and dry biomass production, nutritive value, and the water use efficiency. Grains of all crops were placed in the planting trays. The seeding rates used in this experiment were 300g of each seed/ trays. Trays were irrigated manually with tap water twice a day at a fixed rate of 500 ml/ tray / day. Drained water out of irrigation was collected and measured for to compute water use and water use efficiency. Chemical analysis was performed at the faculty of agriculture labs and the center for chemical analysis of An Najah National University. The fresh fodder yields were 1.39, 1.23 and 0.91 Kg/tray for vetch, wheat and beka, respectively. Use of water was significantly different among the fodder crops. Water consumed was 2.41, 2.21 and 2.84 L/tray for wheat, beka and vetch, respectively. Water use efficiency for wheat, beka and vetch were 0.51, 0.41 and 0.49 Kg/L, respectively.

Fat content was the highest in wheat fodder at the three days of measurement (6, 9 and 12). At day 6, 9 and 12 after seeding, dry matter was the highest for beka compared to vetch and wheat. Ash content at day 12 for wheat, beka and vetch was (3.13%, 3.75% and 5.24%), respectively.

Fiber content was highest for wheat at day 9 (8.74%) and (14.7%) at day12. Highest crude protein content was observed in beka at day 12 (37.22%). Calcium content was highest for vetch at day 12 about (0.54%). At day 6, 9 and 12 after seeding, vetch was highest phosphorus content (0.05%). Under Palestinian condition, taking these results into consideration, hydroponic wheat, beka and vetch can be used as livestock feed, to increase the water use efficiency and quality of forages.

Key words: Hydroponic, water use efficiency, forages, beka, vetch, nutritive value.

Chapter One
Introduction

In many countries around the world, agricultural sector suffers from many problems. These problems was appeared, due to increase in world population. Some of these problems are shortage of water for irrigation for agricultural activities, and then scarcity of plant production (Castañeda et al., 2016).

In the recent years, acute decreasing in forage supplies for livestock nutrition have been witnessed in Palestine, as well as other countries in some arid and semiarid regions, due to limitation of water supplies and continues droughts(Al-Karaki and Al-Hashimi, 2012; Saidi and Abo Omar, 2015; Badran et al., 2017).

With time, the demand on scare water for agricultural and nonagricultural activities is increasing (Al-Karaki and Al-Hashimi, 2012). Recently, animal feed cost makes up to 75% of total input costs of any livestock operation (Badran et al., 2017; Gupta, 2014).

Forage is an important component in livestock rations. However, roughages as part of animal rations are severely affected by climate change, scarcity of land, poor soil quality and lack of water. The demand of these green fodder is increasing when availability of forage is limited (Kide et al., 2015a).

Recent research showed that a major part of the problem can be solved through adoption of the hydroponic system.

Hydroponic system is growing plants without soil(Ponce et al., 2014; Ronay and Dumitru, 2015), using continuous water flow. This system can be used for production of crops for livestock feeding (Al-Karaki and Al-Hashimi, 2012).

The hydroponic system offers many benefits for agricultural sector, such as high fodder yield (*i.e.* producing 6 to 10 Kg of fresh forage from 1Kg of seeds) (Emam,2016).

Moreover, the hydroponic system can use water more efficient compared to traditional forage production. It has been documented that forage production by this system used only 2-3% of water that requires in field agricultural (Al-Karaki and Al-Hashimi, 2012). The green fodder produced by the hydroponic system is characterized by high nutrient contents, high protein, minerals, vitamins (Al-Karaki and Al-Hashimi, 2012), and with high levels of sugar (Kide et al., 2015a). Feeding these nutritious fodders to animals will improve their wellbeing and performance then increase productivity along with reducing the feed costs (Kide et al., 2015a).

Feeding animals by green fodder will improve palatability and digestibility.

There is no literature related to hydroponic system in regard to water use and water use efficiency under Palestinian conditions, therefore, the objectives of this research are to investigate three hydroponic forage crops (wheat, beka and vetch) for green and dry biomass production, nutritive value and the water use efficiency.

Chapter Two

Literature Review

The agricultural sector in regions like Palestine suffers from decrease of forages productions and scarcity of water (Badran et al., 2017; Saidi and Abo Omar, 2015). Water shortage with the need to maintain agricultural production are a major challenges in this region, where irrigated agriculture consumes the bulk of freshwater (Al-Karaki and Al-Hashimi, 2012).

Moreover, a rapid growth of the world population and their demand on the natural resources such as agricultural lands and water, are also serious problems of the agricultural sector (Kumar and Cho, 2014; Castañeda et al., 2016; Saha et al., 2016).

Dairy farming suffers from several problems, like small or unavailability of cultivation lands, shortage of water or saline water, more labor requirements, longer growth period(45-60days), requirement of manure and fertilizer (Naik et al., 2015).

Due to the increasing demand on water resources, and severe shortage of livestock feed, resulting by drought and lack of irrigation water, many projects have been established to overcome these problems (Al-Karaki and Al-Hashimi, 2012). The hydroponic technology has become more important in animal farming as an alternative technology for forages traditional farming (Naik et al., 2015; Kumalasari et al., 2017; Kumalasari et al., 2009).

Hydroponically grown forages are a good solution to several problems, such as the world's hunger issues, resulting from the lack of agricultural land (Buchanan and Omaye, 2013), and facing other challenges of traditional agriculture (Saha et al., 2016). Moreover, it contributes to improve water use efficiency and productivity by producing green and dry forages. It has been shown that this type of agriculture consumes 2-3% of the water used in traditional agriculture to produce the same amount of forage (Al-Karaki and Al-Hashimi, 2012).

2.1 History of Hydroponics

In late 1600, Woodward, an English scientist, made his first attempt to grow plants in different water sources (Sneath, and Mclntosh, 2003). In mid-1800, the nutritional requirements of plants cultivated without soil were verified by the French scientist Jean Boussingault. In 1860 the work was then completed in England by Sachs and Knope using techniques called “nutriculture”. Between 1920 and early 1930, Dr. Gericke developed methods of growing plants in nutrient solutions on a large scale. In 1939, Leitch reviewed several experiments using various forages for some poultry and cattle. The aim of these experiments was to commercially produce feed in the aquatic way. In 1950, hydroponic agricultural moved from Europe to the USA. In 1970, numbers of units were manufactured. In some countries such as Europe and USA hydroponic forges were produced at significant scale (Naik et al., 2015).

In the late 1980s, attempts were made to spread hydroponic technology to feed production (Pandey and Pathak, 1991; Rajendra et al., 1998). In 2011, hydroponics where introduced into Goa _state in India_ by establishing some of hydroponic feed production units (Naik and Singh, 2014; Naik et al., 2015).

2.2 Hydroponic system:

The term Hydroponics derives from two Greek words–'hydro' meaning water and 'ponic' meaning labor or working (Naik et al., 2015 and Langenhoven, 2016; Naik, 2014).

Hydroponic technology is a section of soilless culture (without soil) (Treftz et al., 2015; Castañeda et al., 2016;Liang and Chien, 2013; Buchanan and Omaye, 2013). A continuous water flow is used for growing plants (Ruiz et al., 2014).

The grains used to germinate green fodder are characterized by high germination rates and have short growing period (Badran et al., 2017; Fazaeli et al., 2012; Saidi and Abo Omar, 2015). These grains are cultivated in closed room with fully controlled environmental conditions (Badran et al., 2017; Fazaeli et al., 2012; Molders et al., 2012 and Buchanan and Omaye, 2013).

In many previous studies, several cereals grains were used under hydroponic conditions. For example: alfalfa, barley, cowpea, sorghum, and wheat for production of green fodder and water use efficiency (Al-Karaki and Al-Hashimi, 2012). However, production of fresh forage was attempted from oats, barley, wheat and other grains (Muela et al., 2004), Similarly the production of hydroponics maize (Zea mays L.) fodder (Naik et al., 2016).

2.3 Plant requirements in hydroponic production (Keith Roberto, 2003):

The hydroponic system must provide the main plant requirements:

1. Keep the roots fresh.
2. Balance between water and nutrient supply.
3. Keep high level of aeration (gas exchange) between roots and nutrient solution.
4. Protect the roots from dehydration.

2.4 Types of hydroponics (Keith Roberto, 2003):

Hydroponics is either passive or active.

In active system, nutrient recirculation system is used, so this system can be established in automated greenhouses. On other hand, the passive system depends on root absorption of nutrient solution or capillary action, this system has a high productivity and more efficient.

2.5 Nutrients for hydroponics (Keith Roberto, 2003):

Plant needs two types of nutrients: micro and macro nutrient

Macro nutrient:

Macro nutrients that are consumed in large quantities by plant from nutrient solution, these nutrients are well known as (N-P-K).

(N) Nitrogen:

Required for: amino acids, and chlorophyll production.

Deficiency: Nitrogen deficiency leads to yellowish leaves formation.

(P) Phosphorus:

Required for: sugar, ATP(energy), phosphate, flower and fruit production, and for root growth.

Deficiency: lack of phosphorus causes stunt plant, and turn it to dark green color.

(K) Potassium:

Required for: plant needs a high levels of potassium for protein synthesis. K is utilized for root growth, synthesis of sugar and starch, and hardness of plant.

Deficiency: potassium deficiency leads to growth slow, and mottles produced on older leaves.

Micro Nutrient:

Micro Nutrients are consumes in small quantities, these nutrients are available in trace quantities in plants, and are less Known than Macro nutrients, because most of plant are not contain these nutrients.

(Ca) Calcium:

Required for: cell wall building.

Deficiency: lack of calcium causes crinkling leaves, stunting, flowers fall from the plant and young shoot die.

(Fe) Iron:

Iron required for chlorophyll synthesis, and provide energy for plant growth.

Deficiency: lack of iron leads to the pale of new growth plants, and the blossoms from the plants, yellowish color appear between the veins and leaves may die at the margins.

(S) Sulfur:

Required for water absorption, protein synthesis, seeding, fruiting, and it is a natural fungicide.

Deficiency: sulfur deficiency causes yellowish leaves with purple bases.

(Mg) Magnesium:

Required for chlorophyll, and enzyme formation.

Deficiency: causes the old leaves to yellowish spots and curl between leaf veins.

(B) Boron:

Utilized for the cell wall building, in cooperation with calcium .

Deficiency: causes poor growth and brittle stems.

(Mn) Manganese:

Required for oxygen synthesis during photosynthesis.

Deficiency: Bloom leaves formation fails, and yellowish color appear between the leaf veins.

(Zn) Zinc:

Required for chlorophyll formation, nitrogen metabolism and respiration.

Deficiency: A lack of zinc causes crinkling margins in small leaves.

(Mo) Molybdenum:

Required for: Nitrogen metabolism and fixation.

Deficiency: deficiency of molybdenum causes small and yellow leaves.

(Cu) Copper:

Required for respiration and photosynthesis.

Deficiency: A lack of copper causes pale leaves with yellow spots.

2.6 Advantages of Hydroponic System:

Hydroponic technique has many advantages, such as using lands that is unsuitable for conventional agricultural (Azzi et al., 2015; Hikashi et al., 2013; Saha et al., 2016; Al-Karaki and Al-Hashimi, 2012; Putra and Yuliando, 2015), and when there is a shortage of arable lands(Saha et al., 2016; Medina et al., 2016), as this system needs a small piece of land for agricultural production (Al-Karaki and Al-Hashimi, 2012; Kumar and Cho, 2014; Ata, 2016; Emam, 2016 andMooney, 2005)., and this is technology is simple and can be established in anywhere (Pascual et al., 2018). Moreover, the hydroponic cultivation technique can be applied all over the year because it is independent to weather conditions (Azzi et al., 2015; Fazaeli et al., 2012; Fiaz et al. 2016; Emam, 2016; Pascual et al., 2018), and enhancement the early crop yields planted in cold season; because the temperature in root zoon is increased during the day(Putra and Yuliando, 2015).

El- Morsy et al., (2013) reported that the plant cycle for hydroponic plant about is seven days (from planting to harvest) where a carpet view was obtained, with white root and green shoot. This system reduces the plant cycle from7 to 10 days. (Ata, 2016; Al-Karaki and Al-Hashimi, 2012; Emam, 2016; Naik et al., 2015; Al-Karaki and Al-Momani 2011 andAl-Ajmi et al.,2009), leading to decrease the harvest –production times (Castañeda et al., 2016).

On the other hand, the produced yields were increased by hydroponic system, when compared with conventional agricultural (Al-Karaki and Al-Hashimi, 2012; Castañeda et al., 2016; Fiaz et al. 2016; Treftz and Omaye, 2015; Ata, 2016; Putra and Yuliando, 2015; Pascual et al., 2018).

It was estimated that 1 kg of grains produce about 10 kg of green fodder (Fazaeli et al., 2012; Emam, 2016; Abouelezz and Hussein, 2017), which is about 10 times yields of traditional systems (Riuz et al., 2014; Kide et al,. 2015a), leading to ensure the maximum production rate for plant and animal species around the year (Pascual et al., 2018).

Additionally, the hydroponic green forages have high quality content, as rich in proteins, vitamins, minerals (Kide et al., 2015a;Fazaeli et al., 2012;Al-Karaki and Al-Hashimi, 2012; Ata, 2016; Abouelezz and Hussein, 2017), fibers (Fazaeli et al., 2012; Ata, 2016; Al-Karaki and Al-Hashimi, 2012), sugars (Fazaeliet al., 2012; Kide et al., 2015) ,grass juice (Naik et al. 2017), fatty acid, carbohydrates and enzymes availability (Abuelezz and Hussein, 2017).

Huge nutritional benefits offered by green forages (Gebremedin et al., 2015), such as maximize the performance and general health of young livestock , as a result reducing forages costs (Kide et al., 2015a; and Kumalasari et al., 2017).

increases in milk yield was observed in the fields where these diary animals fed with hydroponics forage (Naik et al.,2013b; Naik et al., 2017), increase in the milk yield is about .5 to 2.5 L/ animal/ day (Naik et al., 2013b).

In many research, livestock's nutritional benefits were obtained from feeding hydroponically forages (Kumalasari et al., 2017).

Farmers observed an increase of nutrient digestibility nutrient contents in hydroponic roughages (Naik et al., 2017). Hydroponically green forages have high content of protein and metabolic energy, which is highly digestible by most animals (Emam, 2016).

Feeding of hydroponic maize and barley forages to young Goats increased the nutrient digestion, feed conversion efficiency and gains of body weight (Kide, 2015; Kide et al., 2015b), then economic benefits are obtained (Kide, 2015). Furthermore, the green hydroponic have high palatability in animals (Aboelezz and Hussein, 2017; Badran et al., 2017; Naik et al., 2013b), so the whole plant of hydroponic fodder consumed by animal without any nutrient wastage (Naik et al., 2015; Naik et al., 2017).

In this system, soil- borne pathogens is absent (Putra and Yuliando, 2015). Better control of the hydroponically farm environment prevents entry unwanted pests, and microorganism to crops, and decreases effects weather factors and leaching fertilizer into the groundwater, cause less environmental impacts (Kobayashi et al., 2013).

Unlike conventional agricultural, growing feed hydroponically uses less or no chemicals (Al-Karaki and Al-Hashimi, 2012), like insecticides, fungicide, artificial growth promoters (Emam, 2016; Al-Karaki and Al-Hashimi, 2012), pesticide (Treftz and Omaye, 2015; Treftz et al., 2015), herbicides and chemical fertilizer (Kide et al., 2015a).

Hydroponics reduces the fuel consumption used for transportation (Bakshi et al., 2017) and operation cost of machinery in different stages of agriculture (plowing, seeding, applying fertilizer, weeding, harvesting) (Pascual et al., 2018), previous point minimizes greenhouse gas emissions, and cause less degradation of the environment (Bakshi et al., 2017).

On other hand, this system reduces the use of labor- intensive activities, like soil preparation and weeding (Azzi et al., 2015).

Hydroponic forages can be produced in cheap chamber(greenhouse), this lead to decrease the cost of production (Naik et al., 2013b), so the overall production cost can be decreased by better controlling the production process (Azzi et al., 2015).

Finally, Hydroponic agriculture uses recirculation system (Al-Karaki and Al-Hashimi, 2012), to recirculate the excess irrigation water that used (Katsoulas et al., 2015), so less water consumed (Treftz and Omaye, 2015;Al-Karaki and Al-Hashimi, 2012), and water use efficiency is improved (Katsoulas et al., 2015), this lead to decrease water waste (Kide et al., 2015a), and limit the groundwater pollution (Katsoulas et al., 2015).

Al-Karaki and Al-Hashimi, (2012) reported the hydroponic forage production needs only about 2-3% of water that needs in field agriculture. Moreover, it has been documented that forage production under hydroponic condition used only 2-10% of water that requires in field condition (Fiaz et al., 2016).

2.7 Nutrient changes in forages under hydroponic condition:

2.7.1 Dry matter:

The dry matter in hydroponic wheat was lost as 25% in total DM after 12 days of seeding, while lost as 17% after 5 to 7 days (Shtaya, 2004). Saidi and Abo Omar (2015) reported that the DM in hydroponic barley is 18.3%. Alkaraki, (2011) reported that the dry matter content when tap water used is 16.4%. Fazaile et al., (2012) showed that the dry matter percent was decreased from 91.4% in barley grain to 13.3% in hydroponic barley at day 8 **(**Table 1).

Dry matter in hydroponic maize is 18.48% and 14.2% in hydroponic barley (Kide, 2015). Dry matter in barley was decreased from 88% in grain to 14.6% in sprouts, but in oat was decreased from 89.7% to 13.4% (Sneath and Mclntosh, 2003).

Table 1. Productivity and Nutritive Value of Hydroponic Barley (Fazaile et al., 2012).

Parameters (%)	Barley grain	Day 6	Day 7	Day 8
Dry matter	91.4[a]	19.27[b]	14.35[c]	13.3[c]
Ash	2.81[c]	3.65[b]	3.72[b]	4.11[b]
crude protein	11.73[b]	13.69[ab]	13.68[ab]	14.67[a]
Macro minerals (%)				
Ca	0.26[b]	0.32[a]	0.39[a]	0.36[a]
P	0.42	0.41	0.44	0.43
Micro minerals (mg/kg)				
Fe	96.1[c]	150[b]	147[b]	171[a]
Mn	25.2[a]	20.3[b]	17.5[b]	17.8[b]

2.7.2 Ash content:

Saidi and Abo Omar(2015) reported that the ash content was ranged from 2.9% at day 3 to 3.6% at day8. The ash content was increased from 2.81% in barley grain to 4.11% in barley sprouting at day8 (Fazaeli et al., 2012) (Table1).

Kide, (2015) reported that the total ash in hydroponic maize is 2.3% and 3.4% in hydroponic barley. Ash content was ranged from 2.6%in barley grain to 3.15% in HB, and from 3.2% in Oat grain to 4.3% in oat sprouts (Sneath and Mclntosh, 2003).

2.7.3 Fiber content:

The crude fiber was increased from 5.7% in barley grain to 7.35% in hydroponic barley, but in oat increased from 10.1% to 21.2% (Sneath and Mclntosh, 2003). Kide, (2015) reported that the CF as 12.46% in maize fodder and 13.5% hydroponic barley.

In hydroponic maize the crude fiber was 14.1% compared to maize grains (25.9%) (Naik, 2014). However, crude fiber content of hydroponic barley was 13.2% (Azila, 2001).

2.7.4 Protein content:

Crude protein was 16.13% in hydroponic barley (Snow et al., 2008). But Fazaeli et al., (2012) reported that the CP in barley was increased from 11.73% in barley grain to 14.67% in hydroponic barley(Table1).

Sneath and Mclntosh, (2003) observed that the crude protein in barley was increased from 14% in grain to 24.9% in hydroponic barley, but in oat fodder increased from 12.3% in grain to 20.7% in sprouts.

Kide, (2015) reported that the CP in hydroponic maize fodder as 16.5%, but 14.44% in hydroponic barley fodder. Crude protein in hydroponic barley is 19.7% (Azila, 2001).

2.7.5 Fat content:

Crude fat in hydroponic Barley was 5.2% (Alkaraki, 2011).However, it was 4.4% as estimated by Azila (2001).

2.7.6 Calcium content:

Calcium content in HB was ranged from .07% to 0.16% (Sneath and Mclntosh, 2003). Kide, (2015) reported that the Ca content in hydroponic maize fodder is 0.72%, but in hydroponic barley fodder is 0.68%. Calcium percent was increased from 0.26% in barley grain to 0.36% in hydroponic barley at day 8 (Fazaeli et al., 2012). Calcium content in hydroponic barley is 0.104%(Azila, 2001).

2.7.7 Phosphorus content:

Sneath and Mclntosh, (2003) reported that the phosphorus in hydroponic barley is 0.3%. Phosphorus content in hydroponic maize is 0.64%, and it is 0.46% in hydroponic barley(Kide, 2015).

Fazaeli et al., (2012) reported that the P percent in barley was increased from 0.42% in barley grain to 0.43% in hydroponic barley at day 8 of sprouting. Phosphorus content in hydroponic barley was 0.14% (Azila, 2001).

2.8 Beka (*Vicia sativa*) and vetch (*Vicia ervilia* (L.) Willd) properties:

Vicia sativa and (*Vicia ervilia*) seed are used as animal feed and it used in poultry diets as an alternative source of protein (Farran et al., 2001).

Vicia erivilia (L.) Willd is a legume, it is an ancient crop and is still cultivated in Spain, Greece, Turkey and Cyprus, it is an important legume crop planted for produce seed and forage for ruminant feed, also it is cultivated in West Asia, North Africa and Mediterranean region. *Vicia erivilia* (L.) Willd was used for stimulate milk production in cows (2-4 kg/ head/day), in calves (0.25-0.5 kg/head/day; 3-4 months of age) (Ebubekir Altuntas and Yasar Karadag, 2006).

Vicia erivilia seed is used to help recovery the ruminant animals which are in bad condition. *Vicia erivilia* has a high nutritional value, high capacity of nitrogen fixation and ability to grow in poor soil, high crude protein content about in its seed (Ebubekir Altuntas and Yasar Karadag, 2006).

Vicia sativa L. is used as a green manure, silage, cover crop, pasture and hay. it is considered as a cover crop in annual rotations, due to it has a high dry matter content and nitrogen accumulation and it has not a hard seeds. It is grown in the different areas of Turkey (Sebahattin et al., 2004).

Chapter Three

Materials and Methods

3.1 Experimental Site:

This experiment was conducted at An Najah National University farm (faculty of agriculture and veterinary medicine). A small green house unit was used in this research. The germination unit was full controlled in regard to temperature and humidity. Fluorescent light was used. Temperature inside the growth room was maintained at 22°C, and the relative humidity was maintained at about 70%.

3.2 The Hydroponic System:

The germination room was furnished with three stands to hold the germination with 47x28x2cm dimensions. Each stand contained 8 shelves. Each stand had a space to hold 8 trays.

3.3 Grains of Forage Crops:

Three types of grains were investigated in this study: wheat, vetch, and beka.

3.4 Preparation of Grains before Planting:

Grains were obtained from local market and transported to the experimental site. Prior to introduced to hydroponic system seeds were tested for germination rates.

Grains were cleaned from contaminations of foreign materials, sterilized and soaked in a 20% sodium hypochlorite solution for 30 minutes to control the formation of mould. All trays were also cleaned and disinfected. The seeds were then washed well to remove the residues of bleach and re soaked in tap water overnight (about 12 hours) before planting (Al Karaki and Al Hashimi, 2012).

3.5 Grains Planting and Irrigation:

Grains of all crops were placed in the planting trays which were arranged on the shelves, plastic trays have pores at the bottom at one side of the tray allow drainage of excess water from irrigation. The seeding rates used in this experiment were 300g of each seed/tray. Trays were irrigated manually with tap water twice a day (early in the morning and late in the afternoon) at a fixed rate of 500 ml/ tray /day (fig 1) , to maintain the seed moist. Plastic containers under each planting tray were used to collect drained water out of irrigation, then the collected water was measured, and recorded to compute the total water use and water use efficiency (Al Karaki and Al Hashimi 2012).

3.6 Forage Yield:

After 12 days from seeding, forage biomass was estimated.

Three representative samplers of about 100 g fresh weight were taken from each tray. Biomass for each crop was determined then oven dried at 105 °C

(AOAC,1995). Samples were collected starting from day six of growing cycle (fig 2).

Figure 1: Manually irrigation

Figure 2: Wheat sample at day 6

3.7 Chemical Analysis:

Chemical analysis was performed at the faculty of agriculture labs and the center for chemical analysis of An Najah National University. Crude protein (CP) was determined according to (AOAC, 1984), crude fiber (AOCS, 2008), crude fat (AOAC, 2005), calcium (Flame Photometer PFP7, 2015), phosphorus and ash (AOAC, 1995).

3.8 Water Use and Water Use Efficiency:

The total added consumed and drained water out of trays throughout the course of experiment was recorded to compute for total water use and water use efficiency (Al Karaki and Al Hashimi, 2012).

The total water used by plants (liters/tray) was computed according to the equation:

Total water use =Total added water in irrigation−Total drained water out of trays.

Water use efficiency (WUE) in kg fresh weight/L water was computed according to equation:

WUE=Total green fodder produced (kg/tray)/ total water used (liter/tray).

3.9 Experimental Design and Statistical Analysis:

The completely randomized design was used with 7 replicates. Data was statistically analyzed using analysis of variance (ANOVA) according to the IBM SPSS Statistics, version 21. Duncan (*P*≤0.05) also was used to compare means among treatments.

Chapter Four
Results

4.1 Green Fodder:

Fresh green fodder was not the same among the three crops, wheat(*Triticum aestivum*), beka (*Vicia sativa L*) and vetch (*Vicia ervilia* (L.) Willd). At day 12, the fresh fodder yields were 1.23, 0.91 and 1.39 kg/tray for vetch, wheat and beka, respectively (Table 2; Fig. 3-5).

Figure 3: Vetch green fodder at day 12.

Figure 4: Wheat green fodder at day 12**.**

Figure 5: Beka green fodder at day 12.

4.2 Water Use:

Use of water was significantly different among the fodder crops. Water consumed was 2.41, 2.21 and 2.84 L/tray for wheat, beka and vetch, respectively (Table2).

4.3 Water Use Efficiency:

Water use efficiency was a significantly ($P<0.05$) different among wheat, beka and vetch. Water use efficiency for wheat, beka and Vetch were 0.51, 0.41 and 0.49Kg/L, respectively (Table 2).

Table (2). Fresh green fodder (GF), total water use (WU) and water use efficiency (WUE) for wheat, beka and vetch.

Crop	GF Kg/tray	WU L/tray	WUE Kg/L
Wheat	1.23 ^{a}	2.41^{b}	0.51 ^{a}
Beka	0.91 ^{b}	2.21 ^{b}	0.41 ^{b}
Vetch	1.39 ^{a}	2.84 ^{a}	0.49 ^{a}

In a column , means followed by a same letter are not significantly different ($P\leq0.05$) according to the Duncan test

4.4 Chemical analysis according to dry matter basis:

4.4.1 Fat Content:

Fat content was significantly ($P<0.05$) differs among different crops (wheat, beka and vetch) at days 6, 9 and 12 (table 3).

At day 6, fat content for wheat, beka and vetch was (2.21%, 1.77%, 2.05%) respectively, while at day at day 9 it was (2.38%, 1.66%, 2.15%), respectively, however, at day 12, fat content was 2.7%, 1.7%, 2.14% for hydroponic (wheat, beka and betch), respectively.

Table (3). Fat Content(%) for hydroponic wheat, beka and vetch crops.

Plant/ Day	Day6	Day9	Day12
Wheat	2.21^{a}	2.38^{a}	2.70^{a}
Beka	1.77^{b}	1.66^{c}	1.70^{c}
Vetch	2.05^{a}	2.15^{b}	2.14^{b}

In a column , means followed by a same letter are not significantly different ($P \leq 0.05$) according to the Duncan test.

4.4.2 Dry matter:

Dry matter content was significantly ($P<0.05$) different among hydroponic crops (wheat, beka and vetch) at different days of cultivation (day 6, 9 and 12).

At day 6, dry matter content for wheat, beka and vetch were 40.71%, 53.42%, 26.5%, respectively. Dry matter content at day 9 was highest in beka (47%), then vetch (34.52%). In contrast, the proportion of DM in wheat was the lowest (22.78%). Similarly, at day 12, wheat had the lowest dry matter followed by vetch while beka had the highest dry matter content (Table 4).

Table (4). Dry matter content(%) for hydroponic wheat, beka and vetch crops.

Plant/ Day	Day 6	Day 9	Day 12
Wheat	40.7^{b}	22.78^{b}	22.88^{b}
Beka	53.42^{a}	47.00^{a}	62.48^{a}
Vetch	26.5^{c}	34.52^{ab}	34.55^{b}

In a column , means followed by a same letter are not significantly different ($P \leq 0.05$) according to the Duncan test.

4.4.3 Ash content:

There was a significant ($P<0.05$) difference for ash content among the three hydroponic crops (wheat, beka and vetch) at day 6, 9 and 12 of cultivation.

At day 6, ash content for hydroponic wheat, beka and vetch was (2.05%, 3.47% and 4.9%), respectively. At day 9 of cultivation, the hydroponic vetch was of highest ash content (5.17%), while wheat was of lowest content (1.92%). Ash content at day 12 for wheat, beka and vetch was (3.13%, 3.75% and 5.24%), respectively (Table 5).

Table (5). Ash Content(%) for hydroponic wheat, beka and vetch crops.

Plant/ Day	Day 6	Day 9	Day 12
Wheat	2.05^{c}	1.92^{c}	3.13^{b}
Beka	3.47^{b}	3.54^{b}	3.75^{b}
Vetch	4.90^{a}	5.17^{a}	5.24^{a}

In a column , means followed by a same letter are not significantly different ($P \leq 0.05$) according to the Duncan test.

4.4.4 Fiber content:

Age of plant had variable effect on fiber content. At days 6 and 12, fiber content differ significantly among hydroponic crops. However, fiber content was the same in the three testes crops (Table 6).

Table (6). Fiber content(%) for hydroponic wheat, beka and vetch crops.

Plant/ Day	Day 6	Day 9	Day 12
Wheat	4.99^{b}	8.74^{a}	14.70^{a}
Beka	5.87^{ab}	6.34^{b}	6.64^{b}
Vetch	6.69^{a}	7.29^{b}	8.55^{ab}

In a column, means followed by a same letter are not significantly different ($P \leq 0.05$) according to Duncan test.

4.4.5 Protein content:

There was a significant ($P<0.05$) difference for protein content among different hydroponic crops (wheat, beka and vetch), according to age.

At day 6, crude protein content in vetch was the highest (34.28%), followed by beka (27.95) then wheat (15.97) (table 6).Similarly, at day 9, CP content in vetch was the highest (35.73%), followed by beka (27.02%) then wheat (17.26%) (Table 7).

At day 12, crude protein content in wheat was the lowest (19.68%), followed by vetch (31.86%) then beka (37.22%) (Table 7).

Table (7). Protein content (%) for hydroponic wheat, beka and vetch crops.

Plant/ Day	Day6	Day9	Day12
Wheat	15.97^{c}	17.26^{c}	19.68^{c}
Beka	27.95^{b}	27.02^{b}	37.22^{a}
Vetch	34.28^{a}	35.73^{a}	31.86^{b}

In a column, means followed by a same letter are not significantly different ($P\leq0.05$) according to the Duncan test.

4.4.6 Calcium content:

The calcium content at days 6, 9 and 12 of age was significantly different among crops (Table 8).

At day 6, Ca content in beka was the highest (0.53%), followed by vetch (0.52%) then wheat (0.26%) (Table 8).Similarly, At day 9, Ca content in beka was the highest (0.55%), followed by vetch (0.54%) then wheat (0.26%) (Table 8).

At day 12, Ca content in wheat was the lowest (0.3%), followed by beka (0.47%) then vetch (0.54%) (Table 8).

Table (8). Calcium content (%) for hydroponic wheat, beka and vetch crops.

Plant/Day	Day 6	Day 9	Day 12
Wheat	0.26[b]	0.26[b]	0.30[b]
Beka	0.53[a]	0.55[a]	0.47[a]
Vetch	0.52[a]	0.54[a]	0.54[a]

In a column, means followed by a same letter are not significantly different ($P \leq 0.05$) according to the Duncan test.

4.4.7 Phosphorus content:

Phosphorus content was significantly different among hydroponic crops according to crop age (table 9).

At day 6, P content in wheat, beka and vetch was (0.04, 0.04 and 0.05%), respectively, also at day 9 P content were (0.05, 0.04 and 0.05%), respectively. However, phosphorus content at day 12 for wheat, beka and vetch was (0.05, 0.04 and 0.06%), respectively (Table 9).

Table (9). Phosphorus content (%) for hydroponic wheat, beka and vetch crops.

Plant/ Day	Day6	Day9	Day12
Wheat	0.04[b]	0.05[b]	0.05[b]
Beka	0.04[b]	0.04[c]	0.04[c]
Vetch	0.05[a]	0.05[a]	0.05[a]

In a column, means followed by a same letter are not significantly different ($P\leq0.05$) according to the Duncan test.

4.5 Water use by crop age:

There was a significant ($P<0.05$) difference for water use among hydroponic crops (wheat, beka and vetch) according crop age (from day1 to day12) (Table 10).

At the end of growing period , WU for wheat, beka and vetch was (219.68, 170.77 and 261.32ml), respectively(Table 10).

Table (10). Water use (ml) according to age for hydroponic wheat, beka and vetch crops.

Day/ Plant	Wheat	Beka	Vetch
Day1	131.65^{b}	174.94^{a}	186.77^{a}
Day2	132.77^{b}	192.71^{a}	212.30^{a}
Day3	173.38^{b}	201.45^{b}	253.54^{a}
Day4	159.10^{b}	204.68^{a}	202.49^{a}
Day5	200.61^{c}	227.83^{b}	266.62^{a}
Day6	230.84^{ab}	199.71^{b}	245.14^{a}
Day7	196.48^{a}	160.41^{b}	207.63^{a}
Day8	220.91^{a}	144.40^{b}	222.10^{a}
Day9	281.05^{a}	152.60^{b}	267.24^{a}
Day10	221.02^{b}	170.37^{c}	251.68^{a}
Day11	242.11^{ab}	210.07^{b}	261.48^{a}
Day12	219.68^{b}	170.77^{c}	261.32^{a}
Total	**2409.6**	**2209.94**	**2838.31**

In a raw, means followed by a same letter are not significantly different at ($P \leq 0.05$) according to the Duncan test.

4.6 Fodder heights at different ages:

Plant highest were varied at different days (fig.6). Height of for vetch at all day was the highest except at day 8 and 9, followed by wheat (Fig.7).

Figure 6: Height wheat (left), vetch (right) at day 12.

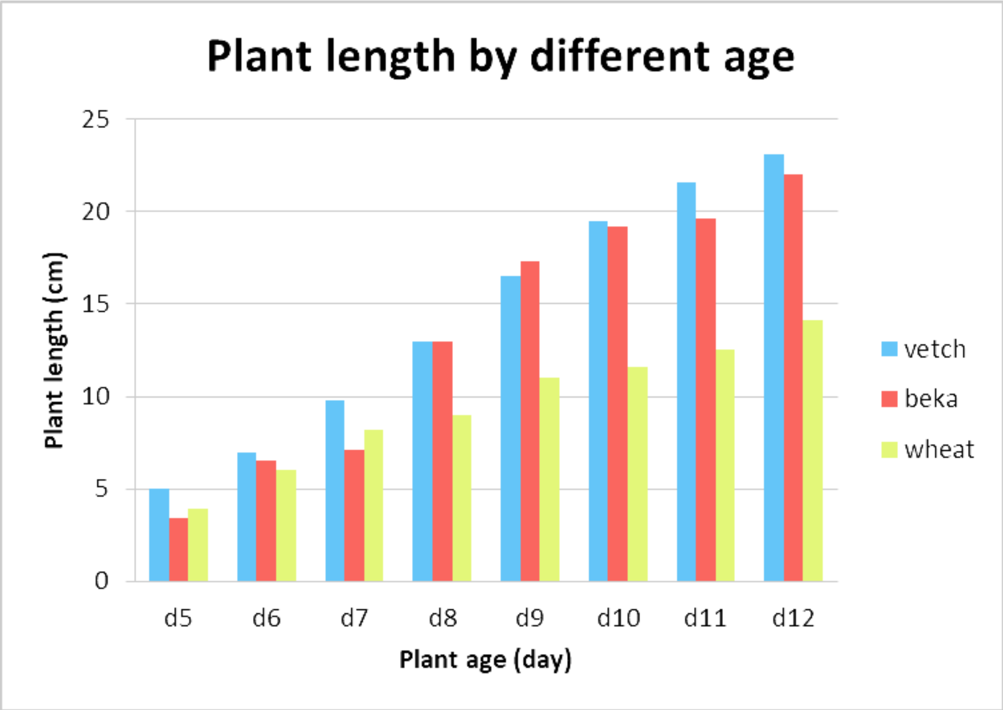

Figure 7: Plants height at different ages.

Chapter Five

Discussion

5.1 Green Fodder:

The fresh green fodder for Vetch was of highest weight (1.39 Kg/tray) compared to the other two crops.

Al-Karaki and Al-Hashimi (2012), reported that the green fodder yield for wheat was about (131 ton/ha), for barley (200ton/ha) and (194ton/ha) for alfalfa, also it was (224 ton/ha) for tap water irrigated barley (Al-Karaki, 2011).

However, the fresh weight of barley fodder when planted at different experiments ranged from 15.9 to 45.1 kg/m^2 (Emam, 2016).

5.2 Water use:

Beka fodder was the lowest compared to fodders of wheat and vetch (2.21, 2.41 and 2.84 L/tray), respectively (Table 1).

However, another cereal (barley) fodder water use was 5.3L/tray (Al-Karaki and Al-Hashimi, 2012)

5.3 Water use efficiency:

The highest water use efficiency was associated with wheat fodder compared to vetch and beka. Water use efficiency values ranged from 0.41 Kg/L to 0.51 Kg/L.

However, barley, wheat and alfalfa were more efficient in water use as reported by Al-Karaki and Al-Hashimi, (2012), where values were (645, 552, 521) Kg fresh matter/m^3 for barley, wheat and alfalfa, respectively.

5.4 Chemical analysis according Dry matter:

5.4.1 Fat content:

Fat content was the highest in wheat fodder at the three days of measurement (6, 9 and 12). The values was increased with time, however, this trend was not the same for vetch and beka. Fat values for hydroponic barley as reported by Azila (2001) were higher (4.4%), similar high values was reprted by Al Karaki (2011). Similar values as reported by this study was reported by Emam (2016) and Ata (2016).

5.4.2 Dry matter:

At day 6, 9 and 12 after seeding, dry matter was the highest for beka compared to vetch and wheat.

Lower dry matter values for hydroponic barley were reported by previous research (Fazaeli et al 2012; Kide, 2015; Al Karaki, 2011; Azila, 2001; Sneath and McIntosh, 2003; Guerrero, 2016; Abuelezz and Hussein, 2017; Ata, 2016; Kide et al, 2015b; Saidi and Abo Omar, 2015). Dry matter values reported in these studies ranged from 6.9 to 18.6%. The cultivation conditions, type of variety may explain the variation in dry matter content.

5.4.3 Ash content:

Ash content at day 6, 9 and 12 was highest for hydroponic vetch, but it was lowest for wheat.

According to (Fazaeli et al., 2012), ash content for hydroponic barley ranged from 3.65% at day 6 to 4.11% at day 8 after cultivation.

Ash content was found 2.3% for hydroponic maize and 3.4% for hydroponic barley (Kide, 2015), but it was 4.3% for oat grass at day 6 after seeding (Sneath and Mclntosh, 2003) .

Moreover, ash content for maize fodder was ranged from 1.67% at day 1 to 3.84% at day 7 (Naik et al., 2015).

According to (Emam, 2016), ash content was ranged from 2.27% to 3.43% for barley sprouted in different areas, and it was reported 3.34% for hydroponic barley fodder (Abouelezz and Hussein, 2017).

Ash content was ranged from 2.9 % at day 3 to 3.6% at day 8 (Saidi and Abo Omar, 2015).

5.4.4 Fiber content:

Fiber content for vetch was highest at day 6 (6.69%), but it was highest for wheat at day 9 (8.74%) and (14.7%) at day12.On other hand, fiber content was 12.46% for hydroponic maize fodder and 13.5% for hydroponic barley fodder (Kide, 2015).

Crude fiber for hydroponic maize was ranged from 2.55% at day1 to 14.07% at day7 (Naik et al., 2015), also it was found 10% for hydroponic maize and 13.5% for hydroponic barley (Kide et al., 2015b).

Moreover, crude fiber was obtained (11.4%) for hydroponic barley (Ata, 2016), also it was found 15.9% for hydroponic barley fodder (Abouelezz and Hussein, 2017).

According to (Al-Karaki, 2011), crude fiber for hydroponic barley irrigated by tap water was reported about 14.3%.

Azila, (2001) reported that the fiber content for hydroponic barley was 13.2%, while it was ranged from 4.9% at day 3 to 8.0% at day 8 after seeding (Saidi and Abo Omar, 2015).

Crude fiber was 21.2% for oat grass at day 6 after seeding, and it was ranged from 7.35% to 15.2% for barley grass (Sneath and Mclntosh, 2003).

5.4.5 Protein content:

Crude protein was highest for vetch at day6 and 9 (34.28 and 35.73%), respectively. However, highest crude protein content was observed in beka at day 12 (37.22%).

According to (Fazaeli et al., 2012), crude protein for hydroponic barley was ranged from 13.69% at day 6 to 14.67% at day 8 after seeding, while it was for hydroponic maize fodder (16.5%) and (14.44%) for hydroponic barley fodder (Kide, 2015).

Crude protein for hydroponic maize was ranged from 8.88% at day 1 to 13.57% at day 7 after seeding (Naik et al., 2015), also it was reported for hydroponic maize fodder (14.56%) and for hydroponic barley fodder (13.86%) by (Kide et al., 2015b).

Sneath and Mclntosh, (2003) reported the protein content for oat grass at day 6 after seeding about 20.7% and it was ranged from 11.38% to 24.9% for barley grass.

According (Saidi and Abo Omar, 2015), crude protein for hydroponic barley was ranged from 13.0% at day 3 to 19.8% at day 8.

Crude protein for barley irrigated by tap water was 25.2%.Al-Karaki, (2011), also it was found for hydroponic barley (15.75%) (Abouelezz and Hussein, 2017), and 22.5% (Ata, 2016).

Crude protein was obtained about 17.5% for hydroponic wheat (M. Guerrero-Cervantes et al., 2016).

5.4.6 Calcium content:

At day 6 and day 9, calcium content for beka was highest, while it was highest for vetch at day 12 about (0.54%).

According to (Fazaeli et al., 2012), Calcium content was ranged from 0.32% at day 6 to 0.36% at day 8. Moreover it was found 0.68% for hydroponic barley fodder and 0.72% for Maize (Kide, 2015).

Calcium content was ranged from 0.07% to 0.16% for barley grass (Sneath and Mclntosh, 2003).In spite of, Ca content for barley fodder was obtained about (0.1%) by (Azila, 2001), also it was found 3.2% for hydroponic barley (Saidi and Abo Omar, 2015).

5.4.7 Phosphorus content:

At day 6, 9 and 12 after seeding, vetch was highest P content (0.05%).

Phosphorus content of barley fodder was obtained (0.41%) at day 6 (Fazaeli et al., 2012).

Results of Kide, (2015) showed that the P content (0.46%) for barley fodder, and 0.64% for maize fodder.

Moreover, Sneath and Mclntosh, (2003) reported that the phosphorus content for barley grass about (0.3%).

Azila, (2001) noticed that the P content for barley fodder about (0.47%). Phosphorus content for hydroponic barley was obtained 4.1% by Saidi and Abo Omar, (2015).

Conclusions:

Wheat fodder had the best water use and water use efficiency. Fodder had variable nutrient content. However, no single fodder is superior in nutritive value compared to others. All types of investigated fodder were of high (good) nutritive value and have a potential to be used as animal feed.

Recommendations:

Hydroponic can save water. Based on nutritive value, fodders can be used as feed supplements.

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إنتاج الأعلاف المائية وكفاءة استخدام المياه لبعض المحاصيل العلفية في ظل الظروف الفلسطينية

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أ. د. جمال أبو عمر

قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في العلوم البيئية، بكلية الدراسات العليا، في جامعة النجاح الوطنية، في نابلس– فلسطين.

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الملخص

نظام الزراعة المائية هو تنمية النباتات بدون التربة، باستخدام تدفق مستمر من المياه. في هذا البحث، تم استخدام ثلاثة أنواع من المحاصيل العلفية المائية (القمح، البيكا والكرسنة) لفحص الكتلة الخضراء والجافة الناتجة، القيمة الغذائية وكفاءة استخدام المياه. تم وضع بذور جميع المحاصيل في صواني الزراعة، حيث تمتلك هذه الصواني البلاستيكية مسام في القاع. كان معدل البذور المستخدمة في هذه التجربة 300 غم من كل نوع بذور / صينية. تمري الصواني يدويًا بماء الصنبورمرتين في اليوم بمعدل ثابت قدره 500 مل / صينية / يوم. جُمعت المياه الزائدة المصفاة من الري وتم قياس حجمها لحساب استخدام المياه وكفاءة استخدام المياه. تم إجراء التحاليل الكيميائية في مختبرات كلية الزراعة ومركز التحاليل الكيميائية في جامعة النجاح الوطنية.بلغت انتاجية العلف الأخضر 1.39، 1.23، و0.91 كغم/ صينية للكرسنة، القمح، والبيكا، على الترتيب. استخدام الماء كان مختلف بشكل كبير بين المحاصيل، حيث كان الماء المستهلك 2.41، 2.21، 2.84 لتر/ صينية للقمح، البيكا و الكرسنة على الترتيب. كانت كفاءة استخدام الماء للقمح، البيكا والكرسنة0.51، 0.41 و0.49 كغم/ لتر، على الترتيب. نسبة الدهون كانت اكبر ما يمكن في القمح في الثلاث ايام (6، 9 و12) بعد الزراعة. في اليوم 6، 9 و12 بعد الزراعة، المادة الجافة كانت اعلى ما يمكن في محصول البيكا بالمقارنة مع الكرسنة و القمح. نسبة الرماد في اليوم 12 للقمح، البيكا و الكرسنة كانت 3.13، 3.75 و 5.24%، على الترتيب. نسبة الالياف في البيكا كانت الاعلى في محصول القمح في يوم 9 (8.74%) و (14.7%) في يوم 12. نسبة البروتين الخام كانت الاعلى في محصول البيكا في يوم 12 (37.22%). نسبة الكالسيوم في محصول الكرسنة كانت الاعلى في اليوم 12 تقريبا (0.54%). في يوم 6، 9 و 12

بعد الزراعة، الكرسنة كانت تحتوي على نسبة فسفور اعلى (0.05%). تحت الظروف البيئية الفلسطينية، وعند أخذ هذه النتائج بعين الاعتبار، يمكن استخدام نظام الزراعة المائية للقمح، البيكا والكرسنة، واستخدام المحاصيل الناتجة كأعلاف ومكملات غذائية للماشية، حيث ان لديها كفاءة في استهلاك الماء وقيمة غذائية عالية.