Characterization and Assessment of Genetic Diversity of Wild Date Palm (*Phoenix dactylifera*) in Jordan

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1. Introduction

Date palm (Phoenix *dactylifera* L.) is an angiosperm that belongs to monocots, and is considered the most important and ancient cultivated species in the Arab world (Elshibli, 2009). It was found in Iraq and Egypt before 3000 BC (Al– Ekidy, 2000), but a recent study reported an archaeological evidence on date cultivation in the eastern Arabia in 6000 BC. However, Al–Ekidy (2000); reported that the native land of date palm is the Arabian Gulf, and this claim was supported by (De Candolle, 1883) who pointed out that the origin of date palm trees was the semi dry and hot region stretching from Senegal to Andalusia. Date palm trees are classified as dioecious, perennial, monocotyledon, diploid (2n= 36).

1.1 Date palm importance

Date palm is of a high value in the Arab world and an Islamic country because of the religious believes. Its pollination was considered as a religious tradition up to Babylonian and Sumerian (Hussein, 1987)**. ()** Fruit is of a high nutritional value with carbohydrates representing 75- 80% of dry matter with some other mineral elements (USDA Nutrient Data Base, 2010). Date palm tree has played a significant role in humans' life especially in hot, dry and semi-dry regions because it provides food, shelter and serve as an ornamental tree in many cases. Date palm is relatively salt and drought tolerant and has a significant impact in combating desertification (Ibrahim**,** 2010).

The world harvested area of date palm was almost doubled in the last two decades (625,085 ha in 1990 to 1,195,426 ha in 2010), with a total production nearly 7.9 million tons in 2010, so the average annual production was increased by almost 4.1 %.

Nowadays the total number of date palm trees is about 100 million worldwide, distributed in 30 countries, most of which are in Asia with 60 million trees, while Africa is the second with 32.5 million (André Bote and Zaid, 2002) with a productivity of 7.86 million tons of the total worlds' production (FAO Statistics, 2010). The main producing countries and the amount produced are shown in Table 1. (FAO Statistics, 2010).

Table 1: Top ten countries of date's production, 2010.

Country	Production quantity (Thousand tons)
Egypt	1,353
Saudi Arabia	1,078
Iran	1,023
United Arab Emirates	825
Pakistan	759
Algeria	710
Iraq	567
Sudan	431
Oman	276
Libya	161

Source: FAOSTAT, 2010

In Jordan, the harvested date palm area increased more than five folds in the last two decades. Production was increased from 281 tons in 1990 to 1124 tons in 2010 (FAO Statistics, 2010). Number of cultivated trees was 20560 and 93184 in 1994 and 2004, respectively (Department of Statistics, Agricultural Statistics, 1994-2004).

1.2 Date palm cultivars

Phoenix is a genus of 14 species of palms, that are frequently hybridize where they grow in proximity, it could be grown as ornamental plants, or used as food for livestock and poultry, While *P. dactylifera* is grown for its edible dates. There is a large number of date palm cultivars distributed around the world, but each country has its own cultivars. For example, in Saudi Arabia Ajwah, Al-Barakah, Khadrawy, Khalasah, Huffuf, Mishriq, Nabtat-seyf , Sag'ai , Sekkeri, and Umelkhashab are considered the most common; while in Libya Haleema, Mgmaget Ayuob, Saidy, Tagyat, and

Umeljwary are most important. In Iraq, Amir Hajj, Dayri, Halawi, Khastawi and Zahidi. However, in Jordan some popular cultivars grown in other countries are commonly cultivated because of the similarity in environmental conditions and requirements. Medjool or Mejhool, Barhee, Khadrawy, Deglet Noor, and Hayany are commonly cultivated. The cultivar Deglet Noor is common in several countries including Jordan, Saudi Arabia, Libya and Tunisia.

The above mentioned cultivars can be differentiated by morphological and fruit characters such as shape, color, dimension, consistency and date of maturity. Recently, the use of molecular marker techniques is employed in distinguishing different cultivar.

1.3 Agricultural practice

Date fruit passes through several maturity stages, which are distinguished by changes in color, texture and taste (Kasapis, 2010). These include; "Hababouk", during which date fruit has a green color and small size and it is the first stage of fruit growth after set. The second is the green color stage "Kimri" where fruit contains high moisture and a firm texture. The third is "Khalal", at which fruit moisture content is low with some accumulation of sugar. The fourth stage is "Rutab" characterized by loss of moisture, and soft texture. The final is the mature stage "Tamar", at which the fruit contains minimum moisture and the sweet taste is developed.

For maximum yield of date Palm trees, basic requirements should be fulfilled, and are summarized as below:

1. Determination of the suitable environmental condition for optimum production.
2. Selection of a well adapted cultivar.
3. Proper use of agricultural practices; propagation, pollination, pest and disease control, and harvest method and time.

The edible date palm trees are considered as desert plants, not grown well in areas receive high rainfall during the growing season (Al– Ekidy, 2000.), but it needs sufficient water with acceptable quality to reach its potential yield, the quantity of water made available to date palm in Jordan valley is about 25,000 - 32,000 m^3/ha per year (Liebenberg and Zaid, 2002). Date palm needs moderate temperature, because the date leaves are injured by prolong temperatures at -6°C or lower**.** Dates need at least six warmest months to flourish, fruit maturation and giving high yield. The summer season must be hot, dry, and provides 3000 heat units for fruit maturation. Optimum temperature for growth and fruit ripening is between 25-29°C, although it can withstand higher temperature up to 50°C (Chandy, 2010).

Propagation of date palm is possible by different methods including seeds, off shoots or through tissue culture. Trees propagated by seeds have a high genetic variation and are not true to type with longer juvenile stage than those by other methods, it requires 4-10 years to flower, so the commercial propagation methods are usually achieved by off shoots and tissue culture.

The date palm growers should be aware about the main agricultural pests that harm or reduce yield. Such information is helpful in minimizing their negative impact on crop yield. Zaid, et al. (2002), reported the most common pests and disease that affect date in the Middle East region.

1.4 Date palm challenges

Date palms face serious problems such as low yield, marketing constraints, climate change, soil salinity, and agricultural pests. Red palm weevil that recently became one of the major problems, and Bayoud disease that caused by a parasitic fungus are common threats in North Africa (El-Juhany, 2010).

Al-Moshileh, et al. (2004) reported that productivity of date can be vertically or horizontally increased. Characterization and analysis of the available genetic diversity is considered as a major step with regard to the development of breeding strategies that participate in productivity increment. To solve these problems; breeders tried to modify varieties, although any breeding program should consider a wide base of genetic variation between the palms to select for the desirable trait, while for any improvement and management in germplasm, breeders should consider the phenotypic and genotypic diversity.

Abd El-Wahab and Wahdan, (2007) characterized the salt tolerant species of date palm genetic resources that growing naturally in Egypt and they recommended that the wild date palm should have a special concern within the protectorate as an important hot spot for *in situ* conservation of date palm genetic resources.

Genetic variation of date palm has not been studied on cultivated varieties or wild types in Jordan. Therefore, the objectives of this study are to:

1. Survey the wild type/s of date palm in Jordan.
2. Study the phenotypic, chemical, physical properties and genetic diversity within and among wild date palm populations in Jordan.

2. Literature review

Understanding the date palm genetic diversity and structure in different populations and cultivars is essential for dynamic conservation and sustainable use. This information is essential for germplasm collection and use of the cultivated species and wild relatives. The cultivated date palms resulted from vegetative propagation, (since it can produce easily transferable suckers) can promote and accelerate the genetic uniformity and erosion and vulnerability in the cultivar.

The wild date palm that distributed in dry Middle Eastern regions as well as north Arabian deserts is closely related to the cultivated date palms. It shows morphological similarities, climatic requirements and producing the basal suckers, therefore the botanists place it under *P. dactylifera* L. The wild date palms were characterized by having small fruits containing relatively little edible flesh, dark brown to dark grey bark, does not grow much more than cultivars in height at often, occurs in dense stands, leaves are roughly scarred and the reproduction mode is sexual rule. Most of these wild trees resulted from human exploitation or natural selection over thousands of years, but few of them apparently growing around oases and valleys.

1.1 Phenotypic characterization

The criteria related to the phenotypic parameters are useful for cultivar characterization, diversity analysis and phylogenic relationship exploration among date palm ecotypes. Evaluation of the phenotypic diversity constituted an available basic step for the elaboration of a program to improve germplasm management and utilization. So that, there are many related studies that characterize and evaluate the date palm either by depending on morphological parameters or vegetative traits or fruit characteristics or all of them.

Rizk and El Sharabasy, (2007) proposed a descriptor for date palm trees to provide a standardized information set to characterize and evaluate activities for date palm in genebanks, *in situ* and *ex situ* conservation activities, and diversity studies. Salem et al, (2008) used eighteen phenotypic traits to describe the vegetative system and characterize twelve Mauritanian date palm ecotypes that currently grown by farmers. They developed vegetative traits suitable in the cultivar identification and established a catalogue for the most important date palm cultivar in their region. They reported the phenotypic variability and relationships among a set of Mauritanian date palm ecotypes as revealed by vegetative parameters. Hammadi et al. (2009) investigated the genetic diversity of Tunisian date palm cultivars by using some vegetative morphometric characters to obtain an accurate description and knowledge of these genetic resources and to understand the distinctive performance of these cultivars. Rabei et al. (2012) studied the morphometric taxonomical relationships of 52 date palm cultivars in Egypt and concluded that analytical methods are suitable for classification of date palm cultivars.

On the other hand, Metwaly et al. (2009) studied the fruit physical properties for ten seeded date palm trees grown in Fayoum to obtain the promising date palm trees in their region. Also, Osman, (2008) evaluated Zaghloul and Samany date palm cultivars by studying the physical and chemical characteristics of fruits under two region conditions. Markhand et al. (2010) characterized the quality of different Pakistani dates through some physical and chemical characteristics of the fruits. Soliman, (2006) evaluated the physical and chemical properties of Zaghloul date palm grown in two different regions in Egypt. He found significant differences in the parameters that used under the two regions for the same cultivar. Jaradat and Zaid, (2004). Characterized some of the date palm cultivars through studying the quality traits and economic value

of fruits to quantify diversity in fruit quality and identify ecogeographical regions rich in one or more desirable variants of quality traits. El-Wakeel and Harhash, (1997) evaluated seven domesticated varieties of date palm grown in Egypt considering some physical and chemical fruit characteristics in order to rank the cultivars according to fruit quality.

Ben Ismail et al. (2013) evaluated and characterized six Tunisian dates' cultivars with morphological and physicochemical parameters. Vij, et al. (2005) evaluated the performance of various cultivars grown in northern Punjab through vegetative, flowering and fruit characters, they revealed variations among the different characters because the different genotypes

Jubrael et al. (2005) showed the complexity of the identification and characterization of date palm varieties because it relays on a small number of phenotypic traits, mainly of leaves and fruits, greatly influenced by environment. They emphasized the need of molecular markers to identify, characterize, and estimate the genetic diversity of this crop. An integrated approach is needed to incorporate morphological and genetic studies and to improve the knowledge on date palm taxonomy and diversity. However, the genetic diversity must also be studied at the DNA level.

Eissa et al. (2009) used important morphological traits and DNA markers (RAPD and SSR techniques) to identify, characterize, evaluate and document the genetic diversity of nine soft date palm cultivars grown in Egypt.

2.2 Genetic diversity

Genetic diversity represents the heritable variation within and among populations of organisms. This pool of genetic variation is the basis for selection as well as for plant improvement, and plant genetic conservation,. In recent years, there has been an increase awareness in the importance of adopting a holistic view of biodiversity, including agricultural biodiversity and conservation for sustainable utilization and development. The extent and distribution of genetic diversity in a plant species depends on its evolution and breeding system, ecological and geographical factors, past bottlenecks, and many human factors (Ramantha and Hodgkin, 2002).

A large amount of diversity of a species may be found in wild type within individual populations, or partitioned among a number of different populations.

Genetic diversity and its distribution are essential for determining what to conserve as well as where to conserve. Thus our understanding of taxonomy, origin and evolution of plant species of interest will be substantially improved. In order to mange conserved germplasm better, there is also a need to understand the genetic diversity of collections, which helps rationalize collections, develop and adopt better protocols for regeneration the germplasm, this will improve the characterization and development of core collections that based on genetic diversity information, so, the available resources in more valuable ways, will be possible exploited (Ramantha and Hodgkin, 2002).

Genetic diversity of date palm

The Genetic diversity and structure of date palm have been greatly altered by natural and human selection, clonal propagation, and spatio- temporal exchange and movement of germplasm. Jaradat, (2011) suggested that wild type will play a vital role in the maintenance of date palm genetic resources and their genetic diversity through multiple processes and dynamic conservation practices. Other workers (Salem et al. 2008 and Eisaa, et al. 2009), suggested that improvements of any genetic material of crop species are corresponding with selecting a promising plant material or genetic resource. Genetic variation within a species is needed to ensure its present and future adaptability to the continued evolution and to maintain genetic improvement in domestication and plant breeding programs (Elshibli, 2009). Genetic resources provide a basic material for selection and improvement of any crop production through breeding. Conservation and utilization of plant genetic resources are important components (Upadhyaya et al. 2008). Wild types are considered as most important to any breeder to incorporate desirable traits into a new variety or cultivar and to enable them to survive under specific environmental condition. Zehdi, et al. (2004) evaluated and preserved the Tunisian date palm germplasm to reduce genetic erosion that could occur by growing elite variety.

Determination of genetic variability in date palm is of importance in improvement programs and in germplasm characterization and conservation to control genetic erosion (Hussein et al. 2005). Morphological characters have traditionally provided signatures of varietal genotype and purity. However, molecular characters that more quickly and accurately reveals genetic differences without occurrence of environment provide significant advantages in genetic analysis, germplasm characterization, and improvement of programs.

A number of molecular techniques are available for characterization of the variation at the DNA level, e.g. RAPD, AFLP and SSR. These techniques are able to reveal a virtually unlimited number of markers.

Al-moshileh et al. (2004) tested the suitability of 20 RAPD markers in five Saudi date palm cultivars, and found only 12 primers were successfully used to differentiate the genotypes. Sedra et al, (1998) Analyzed genetic variation of 43 date palm varieties using RAPD markers technique, and have very effective accession identification of date palm using this technology.

Jubrael et al. (2005) used AFLP markers to discriminate and estimate the genetic relationship among 18 Iraqi date palm varieties was and ordered date palm varieties into two broad groups at 27 % similarity levels.

Kumar et al. (2010) employed RAPD and SSR markers to validate the genetic stability of 27 date palm multiplication with rapid *invitro* micropropagation protocol and found that somatic embryogenesis can also be used as one of the safest mode for production. Hussein et al. (2005) used RAPD and SSR primers to assay the genetic variability and relationships among some of Egyptian date palm cultivars and found he level of polymorphism revealed by RAPD and SSR was 25.2 % and 28.6 %, respectively. These studies showed that SSR technique is a powerful, rapid, simple, reproducible and inexpensive way to assess genetic diversity or to identify closely related cultivar of many species, including fruit trees. SSR technique permits the detection of polymorphism in microsatellite loci without previous knowledge of the DNA sequence.

Khierallah et al. (2011) used 22 microsatellite SSR primers to investigate genetic diversity in 30 male and female date palm cultivars in Iraq. They found a high level of polymorphism with heterozygosity average 0.503 and genetic distance among cultivars varied from 0.171 to 0.938. Abd-Alla, (2010) utilized five SSR primers to

assess the genetic stability of the micropropagated Karama date palm variety while Akkak et al. (2009) evaluated a set of 31 cultivars and clones from Algerian and Californian germplasm using forty one Simple Sequence Repeats isolated from two microsatellite libraries of date palm and expected them as very effective tool in evaluating genetic diversity of date palm germplasm.

Zehdi et al, (2004) used seven SSR primers to assess and cluster the genetic diversity among twelve of Tunisian date palm varieties. They indicate the interrelationship between the date palm ecotypes in spite of their agronomic divergence. Also SSRs have been successfully employed to identify date palm cultivars and germplasms by (Adawy et al. 2002 and 2004; Ben Saleh and El Helaly, 2003).

3. Material and methods

Three experiments were conducted during 2012 to evaluate the wild date palm that surveyed among twenty four populations within eleven locations (Table 2) distributed in northern, central and southern Jordan (Figure 1). The first experiment studied the phenotyping of seventy two wild date palm trees under field condition in the twenty four populations. The second experiment was conducted to analyze some physical and chemical properties of soil population's while the third studied the genotyping of the collected samples and comparing these genetically with Medjool cultivar to obtain the genetic diversity within and among population.

The number of populations in each location was depended on some terms and conditions to be considered as a representative population including:

1. The total number of trees in each population should not be less than ten trees.
2. The female tree number in each location is not less than three.
3. The geographical site nature for each population.
4. The distance between two populations not less than 500 meter.
5. Location size

Table 2 Locations names, population numbers and geographic site information

No.	Location Name	Population No.	Altitude (mt)	Longitude	Latitude
1.	Aqaba (Bwairdah)	Pop 1	25	35.19463	30.3318
		Pop 2	46	35.20031	30.33057
		Pop 3	15	35.19217	30.33328
2.	Al Shoubk (WadiAlnkheel)	Pop 4	363	35.31247	30.37106
3.	Ma'an (Wadi Mdsos).	Pop 5	75	35.23598	30.40101
		Pop 6	70	35.23571	30.40119
4.	Ghour Alssafi (Al Bokharieh)	Pop 7	-385	35.27089	31.02508
5.	Ghour Fifa (Al Dabbah)	Pop 8	-389	35.23575	30.54543
6.	Ghour essal (Alm'amorah)	Pop 9	-342	35.28425	30.54233
7.	Al Tafilah (Senfha)	Pop 10	-56	35.29154	30.5258
		Pop 11	-75	35.29188	30.53222
8.	JordanValley (Azzarah)	Pop 12	-360	35.35038	31.41457
		Pop 13	-360	35.33563	31.40233
		Pop 14	-370	35.33319	31.34452
		Pop 15	-257	35.33355	31.33385
9.	Ma'een (Humrat ma'een)	Pop 16	-51	35.35087	31.39362
		Pop 17	45	35.35226	31.39342
		Pop 18	110	35.36073	31.38244
		Pop 19	150	35.36288	31.40137
10	AlAzraq (Wadi Alhazeem)	Pop 20	518	37.15108	31.3547
		Pop 21	525	37.14592	31.36223
11.	AlKarak (Wadi Ibn Hammad)	Pop 22	172	35.38445	31.18081
		Pop 23	70	35.37547	31.18095
		Pop 24	35	35.37346	31.1807

Source: Collecting data.

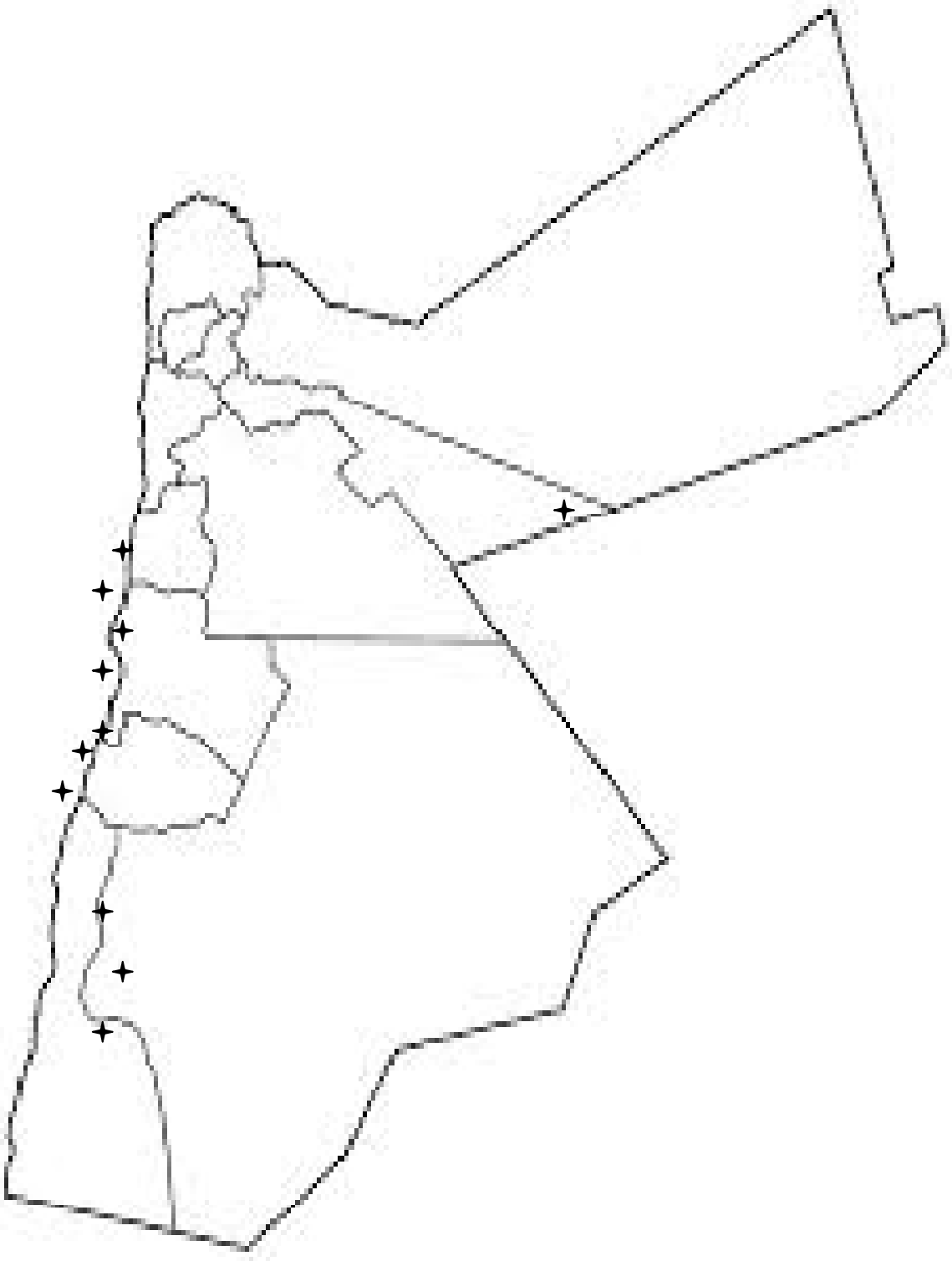


Fig.1 Jordan map showing the distribution of wild date palm collected from 11 locations.

3.1 Locations:

The locations were determined upon the suggestions of Dr. Jamal Qasem (personal communications) and advice of local inhabitants in their regions. All geographical sites information's were mentioned in Table 3.

3.1.1 Aqaba (Bwairdeh): It's located about 270 Km south of Amman, a desert habitat.

3.1.2 Al Shoubk (Wadi Alnkheel): It's a valley habitat and located at about 250 Km south of Amman. Trees were characterized by their great heights.

3.1.3 Ma'an (Wadi Mdssos). Regionally belongs to Ma'an governorate, it's on the way of wadi Arabah road, and located about 230 Km south of Amman, it is a valley

3.1.4 Ghour Alssafi (Al Bokharyeh): Seaboard region, and regionally belongs to AlKarak governorate, at about 50 Km west of Alkarak.

3.1.5 Ghour Fifa (Al Dabbeh): It's on the west side of Jordan, located about 25 km west of Alssafi, it is considered as a seaboard and border region with Palestine

3.1.6 Ghour essal (Alm'amorah): It belongs to Al Tafilah region, but close to Fifa Ghour, about 17 Km to the south eastern of Alssafi region. It is considered as a mountainous location.

3.1.7 Al Tafilah (Senfha): Located about 7 Km to the eastern side of Alm'morah location characterized as a hilly location.

3.1.8 Jordan Valley (Alzzarah): about 65 Km south of Amman, has many scattered trees, it is a valley and hilly location

3.1.9 Ma'een (Humrat Ma'een): About 15 Km to the north of Alzzarah (closer to Amman than Alzzarah), A valley habitat.

3.1.10 Al-Azraq (Wadi Alhazeem): It is bordering the Saudi Arabia; (Al Umri border) it is a desert habitat, located about 175 km to the north eastern of Amman.

3.1.11 Al Karak (Wadi Ibn Hammad): It's considered as valleys region, about 130 Km south Amman.

From each population three fruit trees were randomly selected to study (72 trees for all populations).Certain characteristics of the date palm trees, soil, geographical and climatic characteristics were studied using the modified descriptor (El-Wakil and Harhash, 1997; Jaradat and Zaid, 2004; Soliman, 2006; Markhand and Abul-Soad, 2007; Osman, 2008; Hammadi et al. 2009 and Metwaly et al. 2009).

3.2 Phenotypic analysis (Experiment I)

3.2.1 Vegetative properties:

The date tree height and trunk girth were measured at one meter above the soil surface (Metwaly et al. 2009).

3.2.2 Leaf morphology parameters:

Young and full expanded fresh leaves of wild date palm of three replicates from each tree were collected to study Leaf length, midrib length, pinnated part length, spine part length, % of spine midrib part, % of spine at whole leaf and Petiole width. In addition, number of spines on the leaf was counted, density per cm, spine length and width at the middle. Some counts on pinnaes part included number and density per cm, pinnae length at the mid and pinnae length at the top leaf. Figure (2) illustrates a date palm leaf and its main parts.

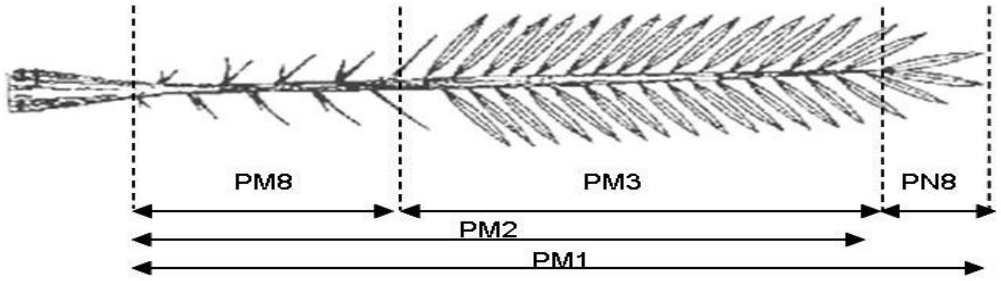


Figure 2. Date palm leaf and its parts

PM1: Leaf Length (cm).

PM2: Midrib length (cm).

PM3: Pinnate part length (cm).

PM8: Spine part length (cm).

PN8: Pinnate length at the top leaf (cm).

3.2.3 Physical and chemical characteristics of fruit:

Samples of fifteen fruits from each tree at "Rutab" stage were gathered and used to determine the physical and chemical fruit properties:

- Fruit color, was visually judged, depending on color chart. The color determination was carried out for each fruit (Eissa, et al. (2009).
- Flesh and seed weight were determined per g by weighing three fruits from each tree on a digital balance and the average was calculated.
- Fruit dimension of individual fruit was measured by a vernier caliper.
- Fruit shape was calculated by dividing fruit length over fruit diameter.
- Moisture content was determined according to A.O.A.C (1995) fresh weight.
- Total soluble solids (TSS): The percentage of TSS was determined in the fruit juice using a digital refractometer.
- Fruit pH: Fruit acidity was determined according to A.O.A.C (1995).

- Consistency of fruit was determined according to moisture content percentage with dry, semi dry and soft fruit texture.
- Fruit content of mineral elements were determined as follows:

  K: Flame photometer method

  Mg, Mn and Fe: Atomic absorption method
- Maturity Date: Access fruit to Rutab stage.

3.2 Soil, Geographic and Climatic characteristics: (Experiment II).

3.3.1 Soil characteristics

Three representative soil samples from each population at 45 cm depth were taken, to determine the physical and chemical soil properties; this part was done mostly at The National Center for Agricultural Research (NCARE) and faculty of agriculture at Mu'tah University.

- Soil moisture %: It was determined according to methods described by Craze (1990) and Standards Association of Australia (1977) dry weight.
- Soil salinity was estimated according to A.O.A.C (1995) and as follows:

  [Na]: Flame photometer

  [Cl]: Titration procedure with AgNo3

  [CaCo3]: Calcimeter method
- Soil pH was calculated according to methods described by Eckert and Thomas (2009) using a pH meter.
- Organic Matter were calculated by using potassium dichromate titration method
- Soil Electric Conductivity (EC) determined by using a conductivity meter.

3.3.2 Geographical and climatic factors:

3.3.2.1 Geographical factors: (Altitude, Longitude and Latitude) were done for each population by Garmen GPS (Global Positioning System).

3.3.2.2 Climatic factors: These were obtained from Jordan Meteorological Department for 2012 year for nearest station of the study location Parameters necessary for the study were:

A) - Maximum and Minimum Temperature from February to, August.

B) - Wind Velocity (knot) from February to August.

C) - Relative Humidity from February to August.

D) - Precipitation for the period from February to April.

All phenotypic traits, Soil, geographic, and climatic characteristics that studied were summarized in Tables (3.1 , 3.2)

Table. 3. 1. Descriptor table based on morphological and vegetative characteristics of wild date palm trees.

Plant part	Characters
Leaf	
	length (cm)
	midrib length (cm)
	pinnated part length (cm)
	spine part length (cm)
	% of spine at midrib part
	% of spine at whole leaf
	Petiole width (cm)
Spine	
	number
	density/cm
	spine length at the mid (cm)
	spine width at the mid (cm)
Pinnaes	number
	density/cm
	pinnae length at the mid (cm)
	pinnae length at the top leaf (cm)
Tree	
	tree height (m)
	trunk girth (m)

Table 3. 2. Descriptor based on fruit physical and chemical properties, geographic and climatic factors of wild date palm locations.

Plant part	Characters
Fruit	
	color
	consistency
	maturity period
	fruit weight (gm)
	flesh weight (gm)
	seed weight (gm)
	fruit shape
	fruit length (cm)
	fruit diameter (cm)
	fruit pH
	moisture percent%
	total soluble solids%
	K %
	Mg %
	Mn (ppm)
	Fe (ppm)
Geographic location	
Soil	
	moisture content
	[Na] meq/ L
	[Cl] meq/ L
	CaCO3 %
	organic matter
	pH
	Ec (ds / m)
Climatic factors	max. & min. temperature (Feb. to Aug.).
	relative humidity (Feb. to Aug.).
	wind velocity (Feb. to Aug.).
	average rainfall (Feb. to Apr.)
	altitude (m)
	latitude N
	longitude E

Data analysis

Analysis of variance (ANOVA) was carried out for evaluating the experimental error variability, estimating the population's means and comparing them for the qualitative traits measured on trees, leaves and fruits. For pairwise comparison of the populations, we used Bonferroni test with an overall level of significance at 5%. Soil parameters observed around the trees were also analyzed for population effects on them using the above procedures. The computations were carried out using codes of Genstat software (Payne 2013).

To examine diversity in the populations for the qualitative traits, Contingency chi-square test was used to assess the association between population and fruit quality parameters (color, consistency, maturity period and shape), where F is a factor vector of the quality parameter.

Simple correlation was used to measure association between two quantitative variables. Its test of significance was performed using t-test. The correlations and their tests of significance were performed for quantitative traits for trees, leaves and fruits, soil parameters, and climatic parameters. Using the vectors of means for 24 population for various traits.

For each phenotypic traits of the population tree, leaves and fruits, soil and climatic variables which showed significant ($P<0.05$) correlations were considered for developing regression model. A search was made using all possible subset selections for high percent of variance accounted for (100 $\check{R}^2$) and a preference for less number of regression variables.

The list of soil and climatic variables selected from all possible combination of variables search corresponding to the highest percent of variance accounted for (100 Ř2) was used to describe the model.

Cluster analyses that represent the interrelationships of the populations were carried out for the phenotypic data, both quantitative and qualitative. The Euclidean distance was used for all quantitative traits and simple matching for the qualitative variables and similarity matrix was formed using Gower (1971) with equal weight for each variable. The clusters were formed using average link option which is also known as UPGMA: (Unweighted Pair Group Method with Arithmetic Mean). The dendrogram figure and the amalgamations of the populations at various levels of similarity were examined and the clusters of populations were saved at 85%, 80% and 75% similarity levels, the variation among and within the clusters was evaluated using ANOVA.

3.4 Genetic assessment (Experiment III)

Genetic diversity of wild date palm in Jordan was examined by analyzing seventy two sampled genotypes and molecular technique to detect differences within and among these accessions and the Medjool cultivar (inter- and intrapopulational genetic diversity). The analysis was carried out in the Plant Molecular Genetics laboratory in Hamdi Mango Center for Scientific Research, University of Jordan.

3.4.1 Extraction of DNA

Young and fresh leaf samples were collected separately from trees for each wild date palm population. The selected leaves were complete and healthy. All samples were stored in an ice box and quickly transferred to laboratory. Plant tissues were ground under liquid nitrogen to a fine powder, and then bulked DNA extraction was performed using QIAGEN DNeasy Plant Mini Kit (Eisssa, et al. 2009).

3.4.2 SSR-PCR reactions

These were conducted using 12 primers suggested by Elmeer et al. (2011). The reaction mixture was placed on a DNA thermal cycler (Technical 512). The PCR was programmed for one cycle at 94°C for 4 minutes followed by 45 cycles of 1 minute at 94°C, 1 minute at 57°C, and 2 minutes at 72°C. Finally, the reaction was stored at 72°C for 10 minutes.

The PCR products were separated on a 1.5 % agarose gel and fragments sizes were estimated with the 100 bp ladder markers (Eisssa, et al., 2009).

Data analysis

For each DNA sample, SSR bands were transformed into a binary matrix where the presence of reproducible polymorphic DNA band at particularly position on gels is scored 1, while a 0 denotes its absence. The matrix was computed with the NTSYSpc program (version 2.02), using the formula of Nei and Li (1979) to generate the genetic distance matrix. The distance matrix was employed to draw the precise relationships among the wild date palm. The resultant tree files were submitted to the TreeView (Win32; 1.5.2) software to map a dengrogam. All this analyses was carried out using NTSYS and Population structure softwares (2.02).

Molecular marker and phenotypic trait association was carried out by calculated the mean values of the phenotypic parameters that were fitted by using a linear model in terms of SSR markers.

The means of various alleles at a locus were estimated with help of an ANOVA procedures and percent variance explained by the marker and test of significance of the marker-trait association was carried using variance ratio p-values obtained.

4. Results

4.1 Presence of wild date palm:

The survey showed that date palm trees are naturally growing in remote areas away from human interventions and in different locations of Jordan, they have the ability to grow in sites that ranging in elevation from -390 m to 525 m above sea level with longitude ranging from 35.19217’ in the south east to 37.15108’ in the west side and the latitudes were ranging from 30.33057’ to 31.40137’**.** The date palms that studied in this thesis had different geographic habitat, desert, coastal and valleys. Fig(3, 4, 5).

Fig 3: wild date palm in the valleys

Fig 4: wild date palm in the desert oases.

Fig 5: wild date palm at coast (Dead Sea)

4.2 Performance of accessions over populations and locations.

The results show large significant differences within and among the populations in the means of fruit weight, flesh weight, fruit length, fruit moisture %, fruit TSS, Manganese and Ferrous content in fruit, leaf length, midrib length, pinnated part length, spine part length, spine density/ Cm, pinnae number, pinnae length at mid, Sodium concentration in the soil, Chlorine content in the soil, Calcium Carbonate concentration in the soil and soil EC, while small significant differences within and among populations in the means of tree height, trunk girth, fruit diameter, fruit pH, Potassium and Magnesium percentage in fruit, fruit color, fruit consistency, maturity period, fruit shape, spine part length, % of spine in midrib, % of spine in all leaf, petiole width, spine number, spine length at mid, pinnae density/cm, pinnae length at top, spine width at mid, soil moisture percent, organic matter percent in the soil and soil pH.

4.2.1 Phenotypic analysis (Experiment I).

4.2.1.1 Vegetative properties:

4.2.1.1.1 Tree height:

Statistical analysis for tree height at all populations showed significant differences among them. The means of Tree height for the populations were ranging from 4.9 m to 9.8 m. The population number seven was ranked as the highest, and the shortest trees were at population number fourteen. Table 4.1 showed the average mean for each population and their significantly symbols under 0.05 level. Among the locations Ghour Fifa (Al Dabbeh) was ranked as the tallest trees and Ghour Alssafi (Al Bokharyeh) location as the shortest trees. Fig (6) showed the average mean for the locations and their arrangement according to tree height under same LSD.

4.2.1.1.2 Trunk girth:

There are small significant differences among all studied populations with trunk girth parameter, the highest value with mean (2.033 m) was recorded for the population of Al Shoubk (Wadi Al Nakheel) location, and the lowest value (1.133 m) was recorded for population of Ghour Fifa (Al Dabbeh) location as shown in table (4.1) and fig (7).

Table 4.1 Means of tree length and trunk girth among the 24 studied populations

No.	Location	Population #	Tree height _m		Trunk Girth _m	
1	Aqaba (Bwairdeh)	Population 1	5.233	ab	1.7	abc
		Population 2	5.867	abcd	1.633	abc
		Population 3	5.533	abc	1.467	abc
2	Al Shoubk (Wadi Alnkheel)	Population 4	9.033	cde	2.033	c
3	Ma'an (Wadi Mdssos).	Population 5	6.9	abcde	1.433	abc
		Population 6	7.867	abcde	1.967	bc
4	Ghour Alssafi (Albokharyeh)	Population 7	4.9	a	1.867	bc
5	Ghour Fifa (Al Dabbeh)	Population 8	9.333	de	1.133	a
6	Ghour essal (Alm'amorah)	Population 9	5.767	abcd	1.733	abc
7	Al Tafilah (Senfha)	Population 10	6.667	abcde	1.633	abc
		Population 11	7.533	abcde	1.667	abc
8	Jordan Valley (Alzzarah)	Population 12	7.333	abcde	1.767	bc
		Population 13	8.6	bcde	1.833	bc
		Population 14	9.8	e	1.733	abc
		Population 15	9.7	e	1.767	bc
9	Ma'een (Humrat ma'een)	Population 16	6.667	abcde	1.467	abc
		Population 17	6.8	abcde	1.5	abc
		Population 18	7.467	abcde	1.633	abc
		Population 19	6.6	abcde	1.367	ab
10	AlAzraq (Wadi Alhazeem)	Population 20	5.867	abcd	1.567	abc
		Population 21	5.567	abc	1.533	abc
11	AlKarak (Wadi Ibn Hammad)	Population 22	7.333	abcde	1.633	abc
		Population 23	7.6	abcde	1.667	abc
		Population 24	5.833	abcd	1.367	ab

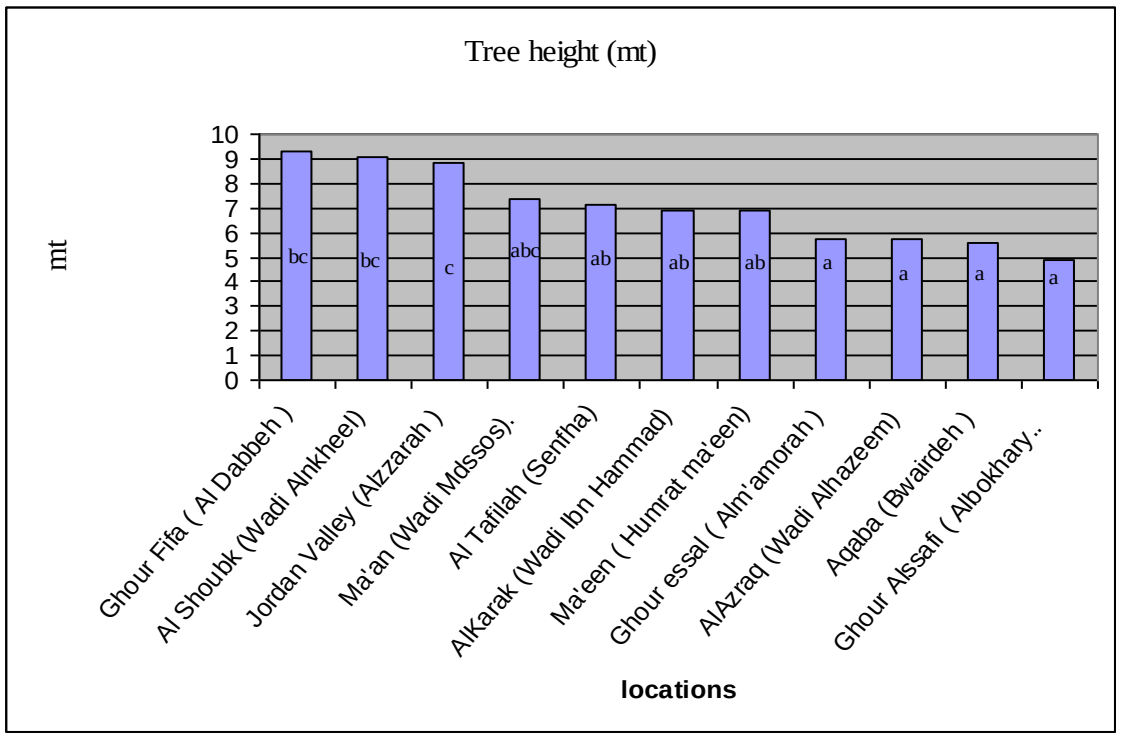


Fig (6). The average means and significantly differences of tree height among locations under 0.05 LSD.

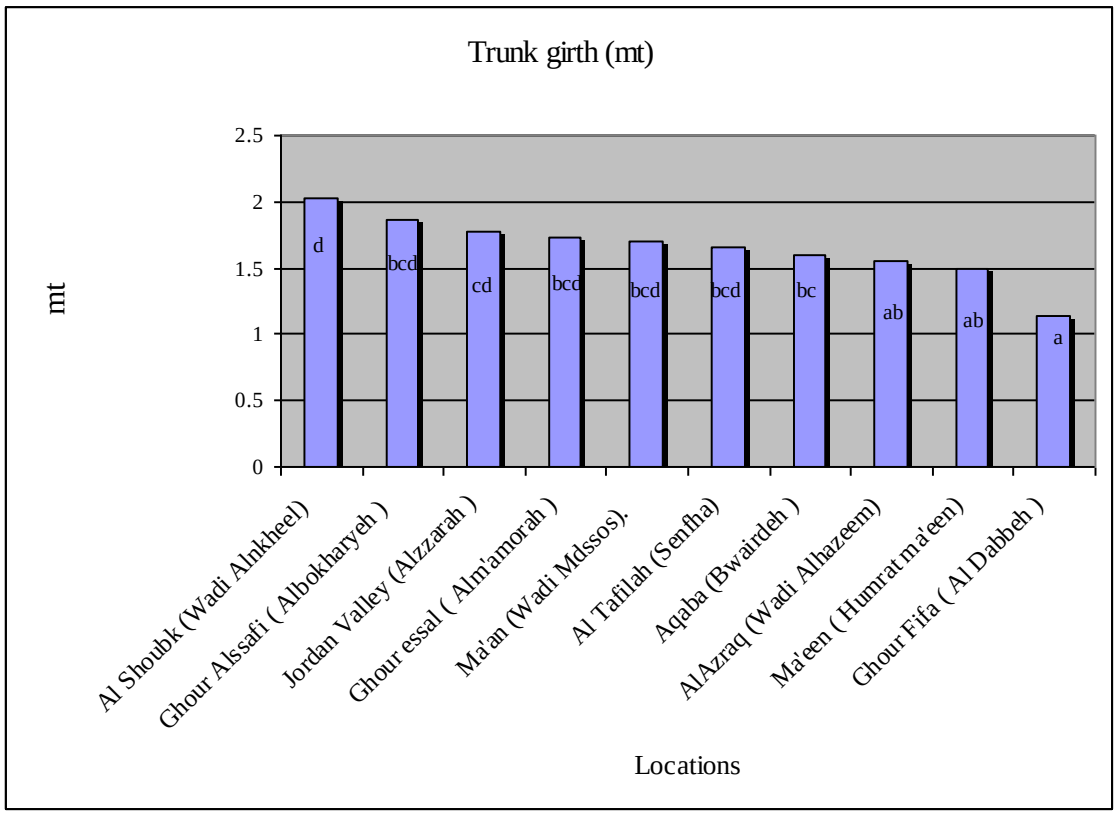


Fig (7). The average means and significantly differences of trunk girth among locations under 0.05 LSD.

4.2.1.2 Leaf morphology parameters:

4.2.1.2.1 Leaf length:

Statistical analysis for leaf length showed significant differences among all populations and locations. Table 4.2 showed the average mean and significantly differences under 0.05 level for each population. The highest means of leaf length was obtained at population number nine that located at Al M'amorah with 349.2 cm, while the lowest leaf length was recorded for population number three at Bwairdeh in Aqaba with 216.1 cm. At location level, the tallest leaf length was scored for Al M'amorah and the shortest was for Bwairdeh with (349.2 cm and 248.4 cm) respectively as shown in fig (8).

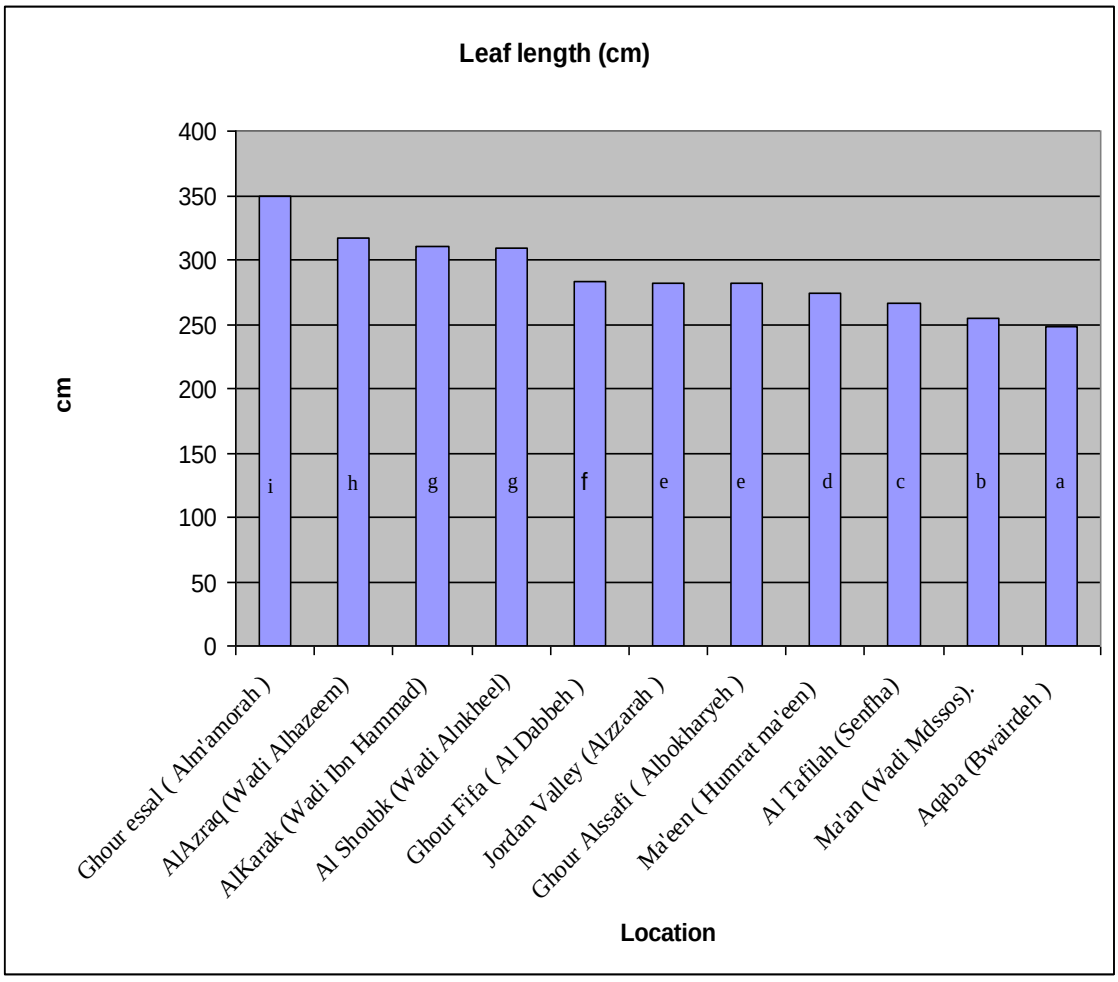


Fig (8). The average means and significantly differences of leaf length among locations under 0.05 LSD.

4.2.1.2.2 Midrib length:

There were significant differences for midrib length within and among populations and locations. The tallest midrib part was observed at population number nine that located at Al M'amorah (294.7 cm) and the shortest was at population number three Bwairdeh and population number eleven that located at Senfha with 189 cm and 188.9 cm respectively. Table 4.2 showed the average mean and it's significantly degree under 0.05 level for each population. Among the locations, the highest value was scored for Al M'amorah and the Lowest was record for Bwairdeh with average mean 222 cm. fig (9).

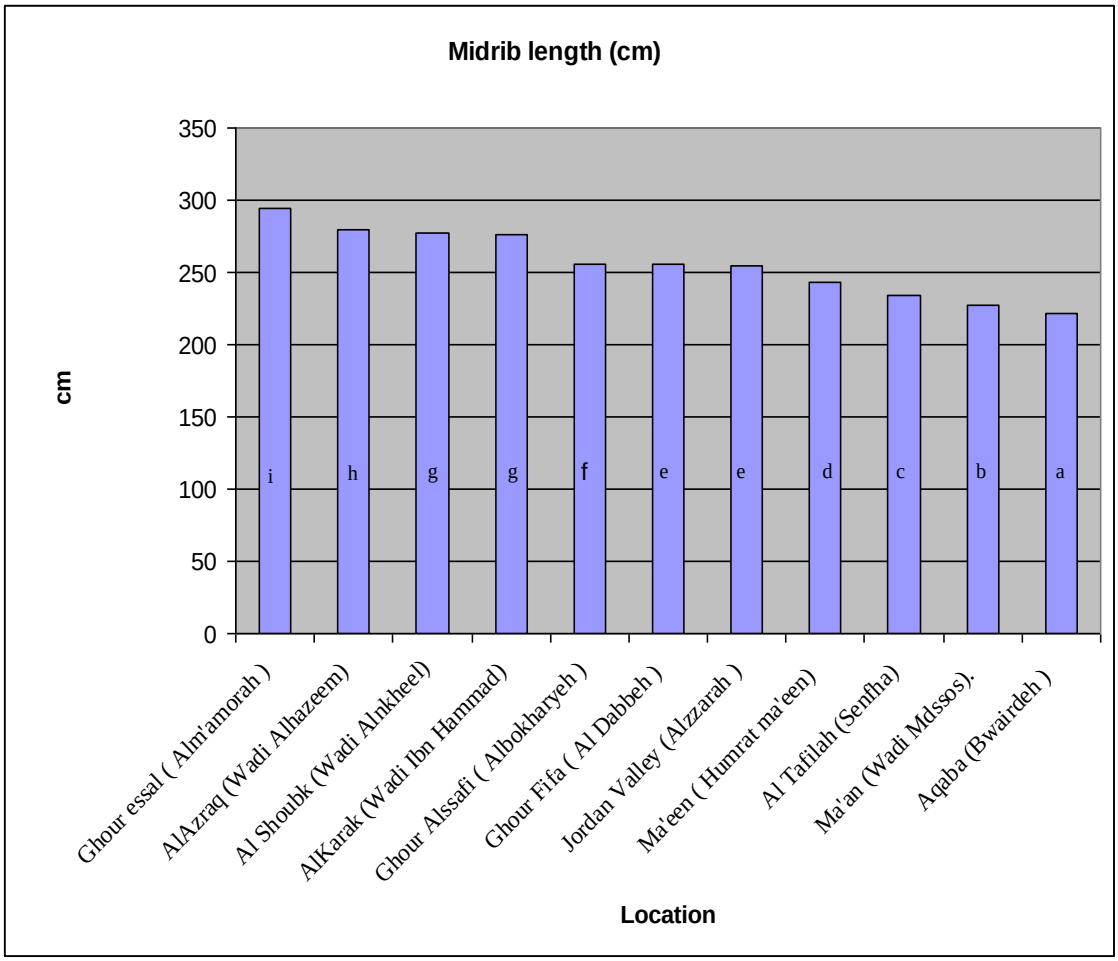


Fig (9). The average means and significantly differences of midrib length among locations under 0.05 LSD.

4.2.1.2.3 Pinnated part length:

Statistical analysis at 0.05 LSD for Pinnated part length showed significant differences within and among populations (Table 4.2). As expected, population at Al M'amorah location gave the tallest pinnated part length (236 cm) and the lowest was for population number three at Bwairdeh with 170.1 cm., also, among locations, the shortest average means of pinnated part length was at Bwairdeh with average mean 198.3 cm fig (10).

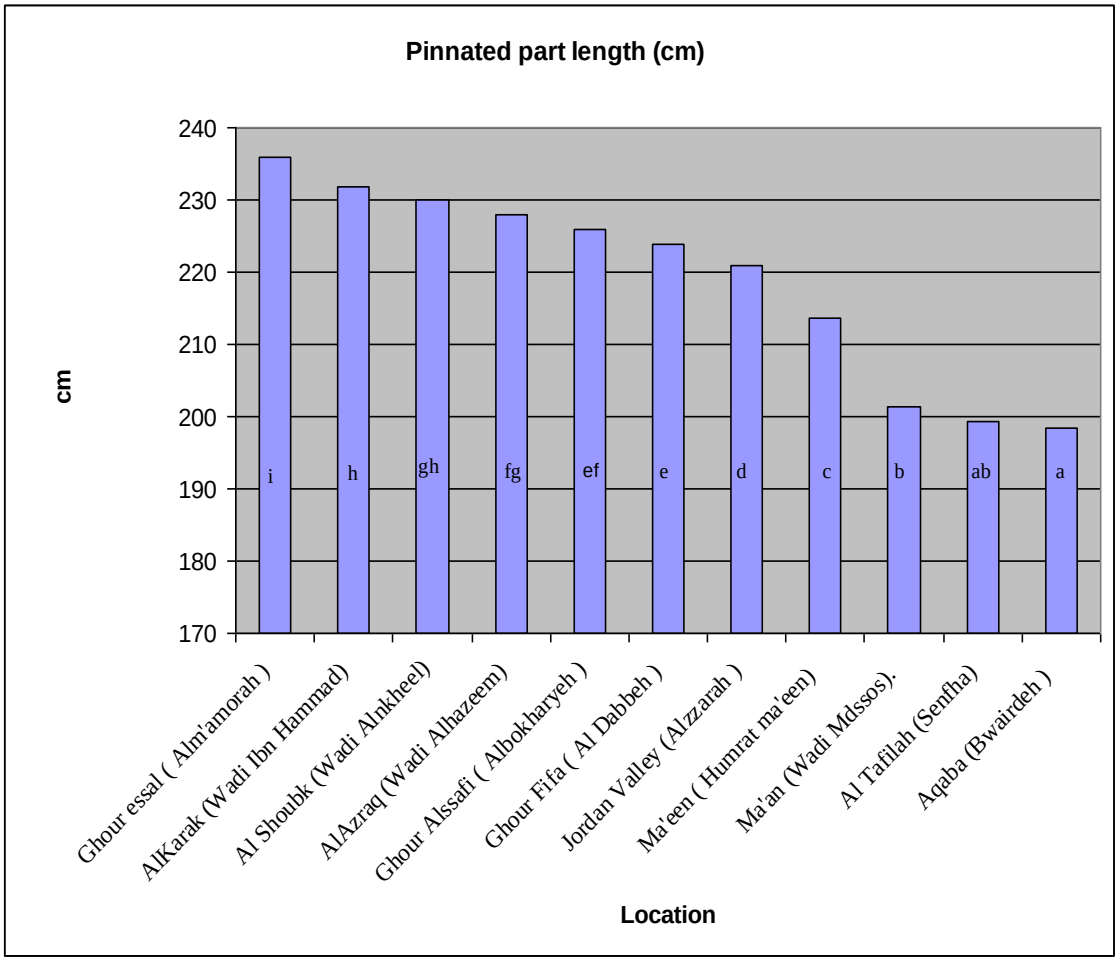


Fig (10). The average means and significantly differences of pinnated part length among locations under 0.05 LSD.

Table 4.2 Means of leaf length, midrib length and pinnated part length among the 24 studied populations

No.	Location	Population #	Leaf Length _Cm		midrib length _Cm		pinnated part length _Cm	
		Population 1	273	h	249.2	g	221.6	e
		Population 2	256	f	227.7	e	203.1	c
1	Aqaba (Bwairdeh)	Population 3	216.1	a	189	a	170.1	a
2	Al Shoubk (Wadi Alnkheel)	Population 4	308.8	p	277	mn	229.9	ij
		Population 5	221.8	c	198	c	177.4	b
3	Ma'an (Wadi Mdssos).	Population 6	287.1	k	256.9	h	225.2	fg
4	Ghour Alssafi (Albokharyeh)	Population 7	281.7	j	256.1	h	226	fgh
5	Ghour Fifa (Al Dabbeh)	Population 8	283.6	j	256	h	223.9	ef
6	Ghour essal (Alm'amorah)	Population 9	349.2	t	294.7	p	236	l
		Population 10	313	q	278.2	mn	229.1	hij
7	Al Tafilah (Senfha)	Population 11	219.3	b	188.9	a	169.8	a
		Population 12	302	n	272.9	kl	233.9	kl
		Population 13	309.3	p	277.3	mn	229.9	ij
		Population 14	267.1	g	243.7	f	218.1	d
8	Jordan Valley (Alzzarah)	Population 15	249.2	e	224.1	d	201.8	c
		Population 16	297.2	m	268.3	j	232.2	jk
		Population 17	276	i	248.1	g	220.6	de
		Population 18	292.2	l	264.2	i	227.9	ghi
9	Ma'een (Humrat ma'een)	Population 19	228.8	d	193.4	b	174.1	b
		Population 20	316.9	r	279.9	no	227.3	ghi
10	AlAzraq (Wadi Alhazeem)	Population 21	316.3	r	280.1	no	228.6	ghi
		Population 22	305.4	o	275.4	lm	233.6	kl
		Population 23	298.8	m	270	jk	234.1	kl
11	AlKarak (Wadi Ibn Hammad)	Population 24	326.3	s	281.6	o	228.1	ghi

4.2.1.2.4 Spine part length:

Statistical analysis for spine part length showed significant differences within and among populations and location (table 4.3 and fig 11). At Al M'amorah location, its Population had the longest means of spine part (58.67cm), while the shortest means was recorded for population number three at Bwairdeh location (18.89 cm), and it was also considered the shortest location with average mean (23.7 cm).

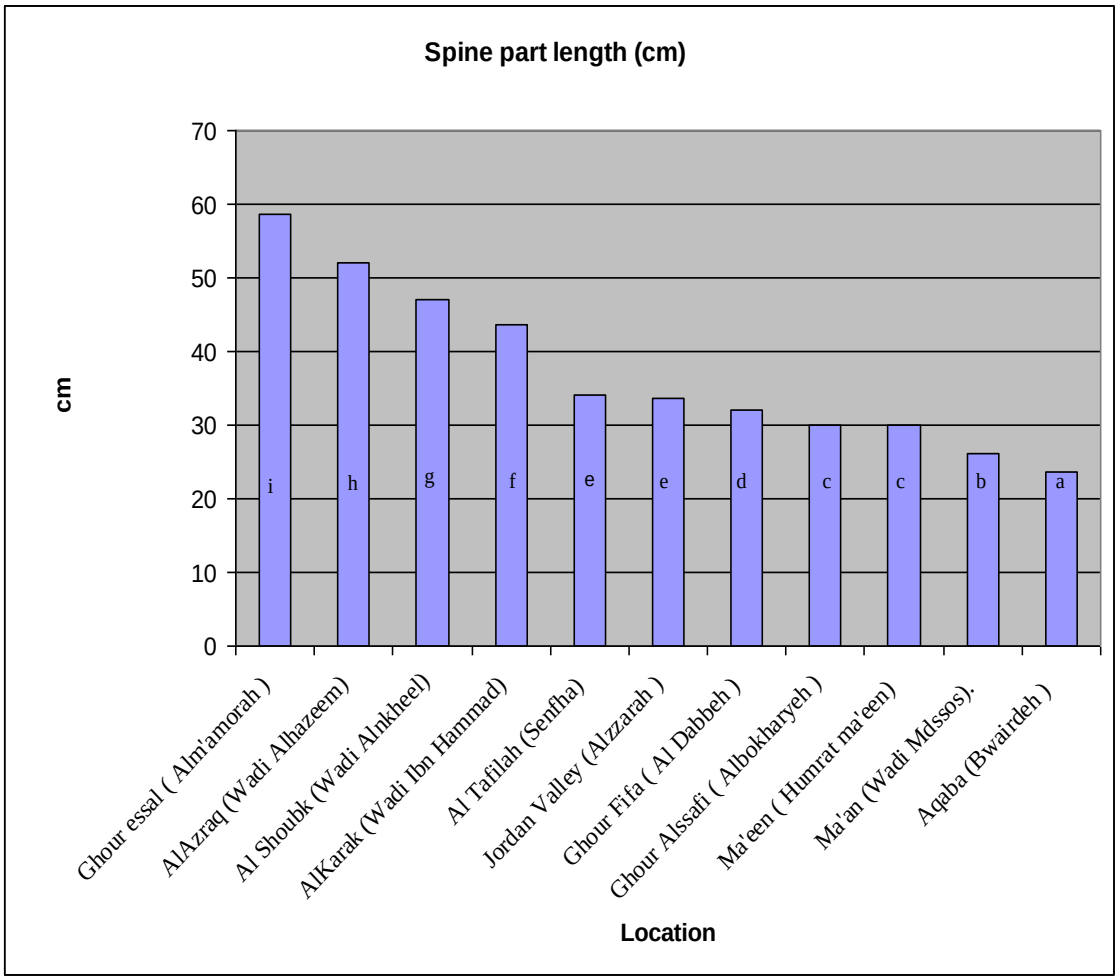


Fig (11). The average means and significantly differences of spine part length among locations under 0.05 LSD.

4.2.1.2.5 Percent of spine at midrib part:

There were significant differences in percent of spine at midrib part within and among populations (Table 4.3). Population number nine with highest percent among the population (19.91) while the shortest percent was for population number nineteen and three with (9.99 and 10) respectively.

Al M'amorah location had the highest percent in the average mean, and the shortest average means (10.62) were scored for Bwairdeh location. Fig (12).

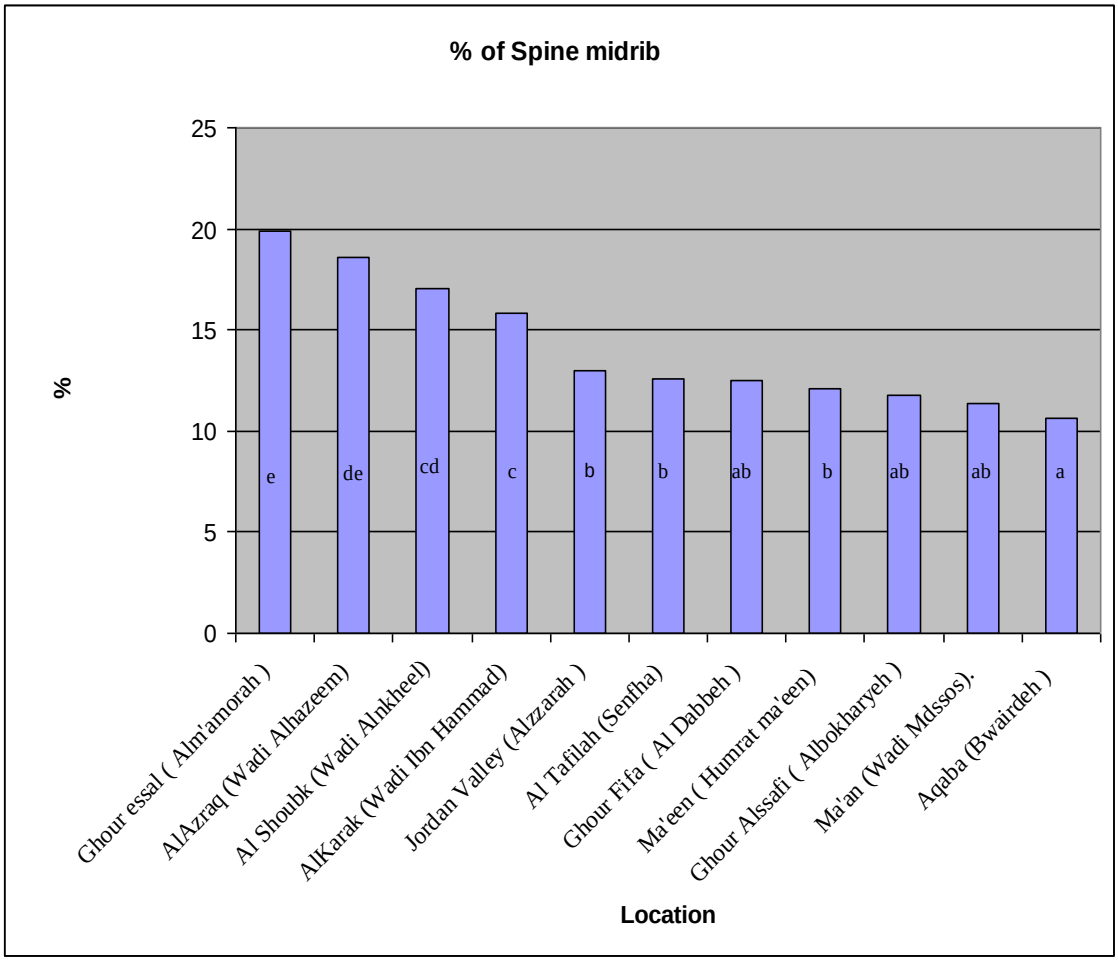


Fig (12). The average means and significantly differences of percent of spine to the midrib part among locations under 0.05 LSD.

4.2.1.2.6 Percent of spine at whole leaf:

Statistical analysis for the percent of spine to the whole leaf showed small significant differences within and among populations, population number nine had the highest mean percent (16.81), while the shortest mean was recorded for population number nineteen. Table (4.3).

Al M'amorah scored the highest value (16.81) while the lowest mean value was recorded for Bwairdeh location (9.47). Fig (13).

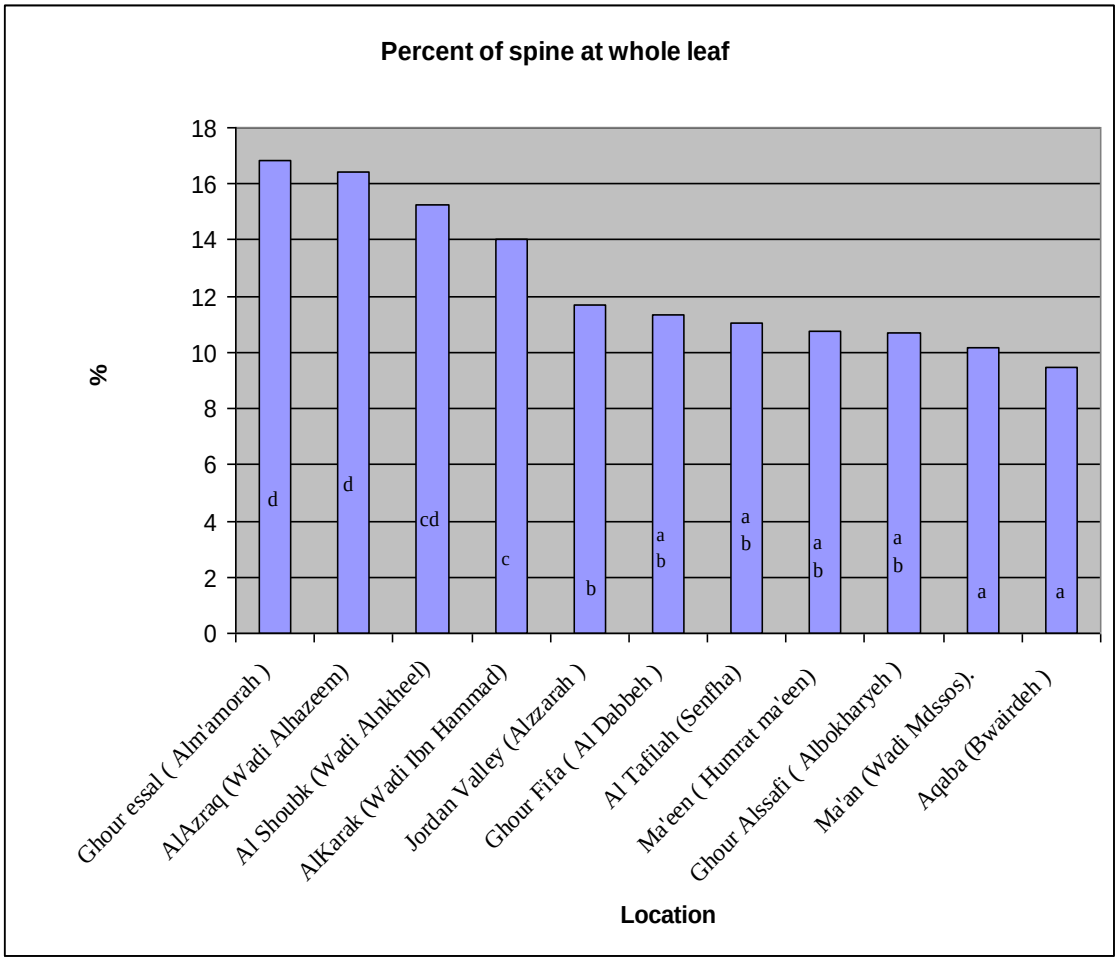


Fig (13). The average means and significantly differences of percent of spine to the whole leaf among locations under 0.05 LSD.

Table 4.3 Means of spine part length, percent of spine at midrib and percent of spine at whole leaf among the 24 studied populations.

No.	Location	Population #	spine part length		% of spine midrib		% of spine leaf	
		Population 1	27.67	d	11.08	abc	10.07	abcdef
		Population 2	24.56	c	10.79	abc	9.59	abcde
1	Aqaba (Bwairdeh)	Population 3	18.89	a	10	a	8.74	ab
2	Al Shoubk (Wadi Alnkheel)	Population 4	47.11	i	17.02	fg	15.26	ijkl
		Population 5	20.56	ab	10.41	ab	9.27	abc
3	Ma'an (Wadi Mdssos).	Population 6	31.67	e	12.34	abcde	11.01	abcdefgh
4	Ghour Alssafi (Albokharyeh)	Population 7	30.11	e	11.76	abcd	10.69	abcdefg
5	Ghour Fifa (Al Dabbeh)	Population 8	32.11	e	12.54	abcde	11.32	bcdefgh
6	Ghour essal (Alm'amorah)	Population 9	58.67	k	19.91	g	16.81	l
		Population 10	49.11	i	15.12	ef	13.36	ghij
7	Al Tafilah (Senfha)	Population 11	19.11	a	10.11	a	8.71	ab
		Population 12	39	g	14.3	def	12.91	fghij
		Population 13	47.44	i	17.11	fg	15.33	jkl
		Population 14	25.56	c	10.48	ab	9.56	abcd
8	Jordan Valley (Alzzarah)	Population 15	22.33	b	9.97	a	8.96	ab
		Population 16	36.11	f	13.47	bcde	12.15	defgh
		Population 17	27.89	d	11.23	abcd	10.1	abcdef
		Population 18	36.33	f	13.74	cde	12.43	efghi
9	Ma'een (Humrat ma'een)	Population 19	19.33	a	9.99	a	8.45	a
		Population 20	52.56	j	18.77	g	16.59	l
10	AlAzraq (Wadi Alhazeem)	Population 21	51.56	j	18.41	g	16.3	kl
		Population 22	41.89	h	15.2	ef	13.71	hijk
		Population 23	35.89	f	13.3	bcde	12.01	cdefgh
11	AlKarak (Wadi Ibn Hammad)	Population 24	53.44	j	18.97	g	16.38	kl

4.2.1.2.7 Petiole width:

There were small significant differences in Petiole width within and among populations (Table 4.4). At population number nine, the widest petiole means was recorded (4.77 cm) while the most narrowly means was scored for population number three (2.39 cm).

Among locations, the highest mean values were recorded to Al M'amorah location and the lowest average mean was recorded to Wadi Mdssos (4.77 cm and 2.56 cm respectively). (Fig. 14).

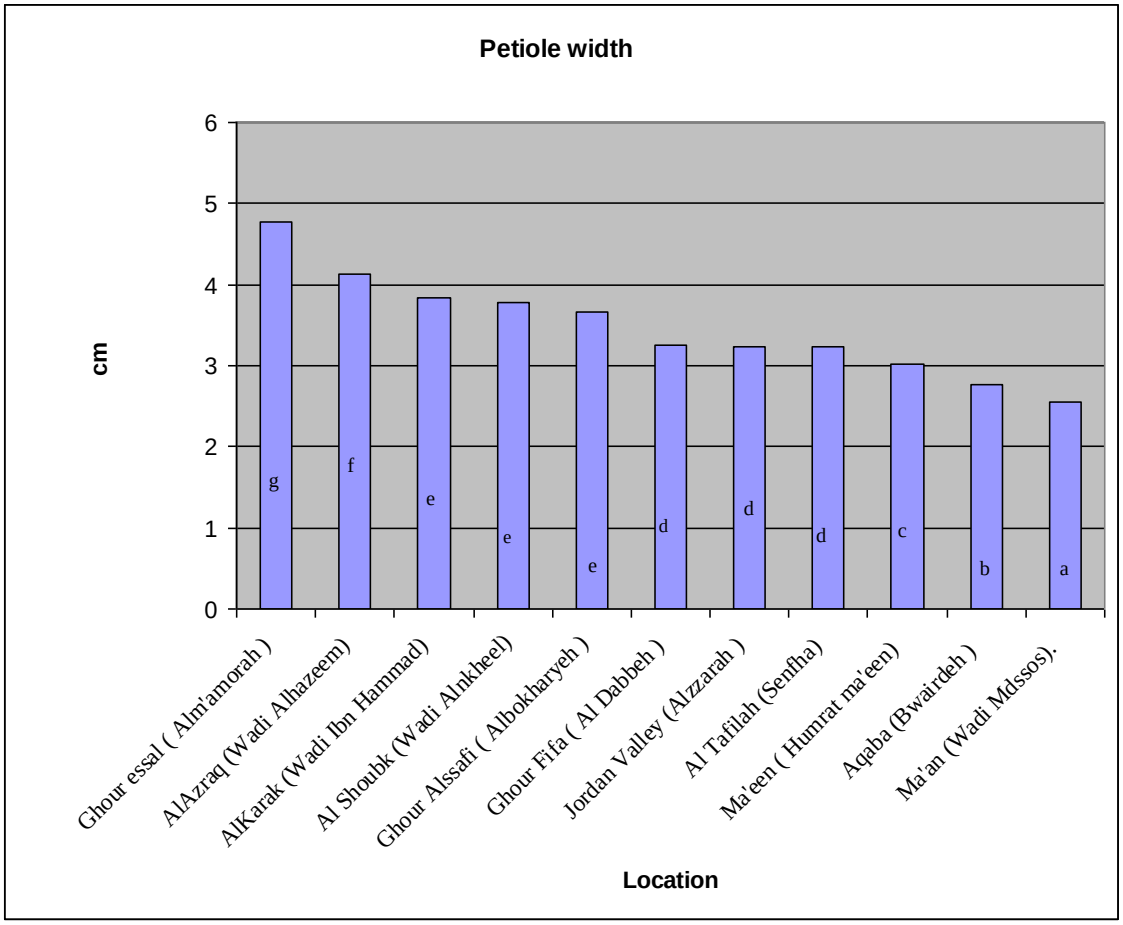


Fig (14). The average means and significantly differences of petiole width among locations under 0.05 LSD.

4.2.1.2.8 Spine number:

Statistical analysis for spine number showed significant differences within and among the populations. Population number eleven gave the highest mean number (25.22) while population number nine scored the lowest mean number (3.44).(Table 4.4).

With related to locations, Bwairdeh recorded the highest average means (20.44) while Al M'amorah scored the lowest average mean (3.44). (Fig. 15).

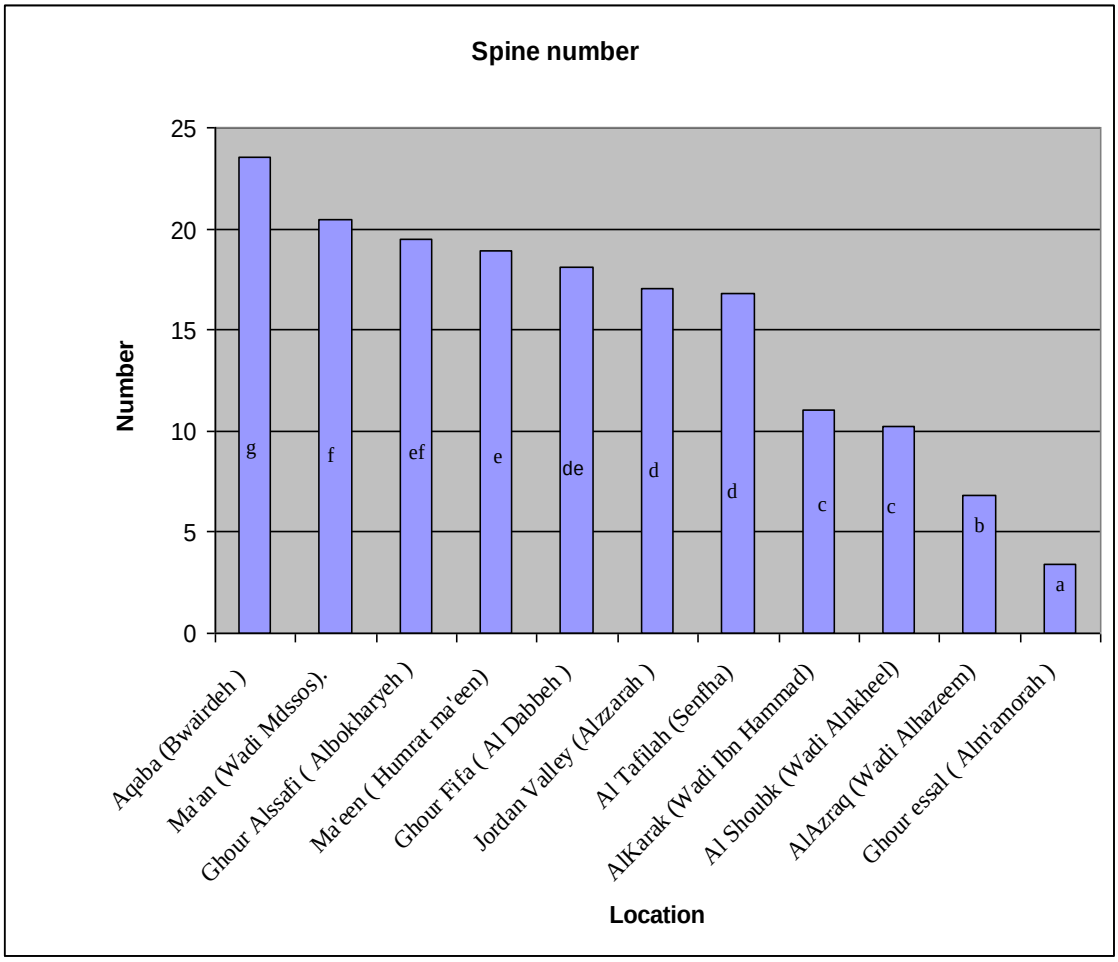


Fig (15). The average means and significantly differences of spine number among locations under 0.05 LSD.

4.2.1.2.9 Spine density per cm:

There were significant differences in spine density per cm within and among populations (Table 4.4). The highest mean value of spine density was recorded for population three (1.32), while the lowest mean value was scored for population number nine (0.06).

At location level, the highest and lowest average means were scored for Bwairdeh (1.03) and Al M'amorah (0.06) respectively. (Fig 16).

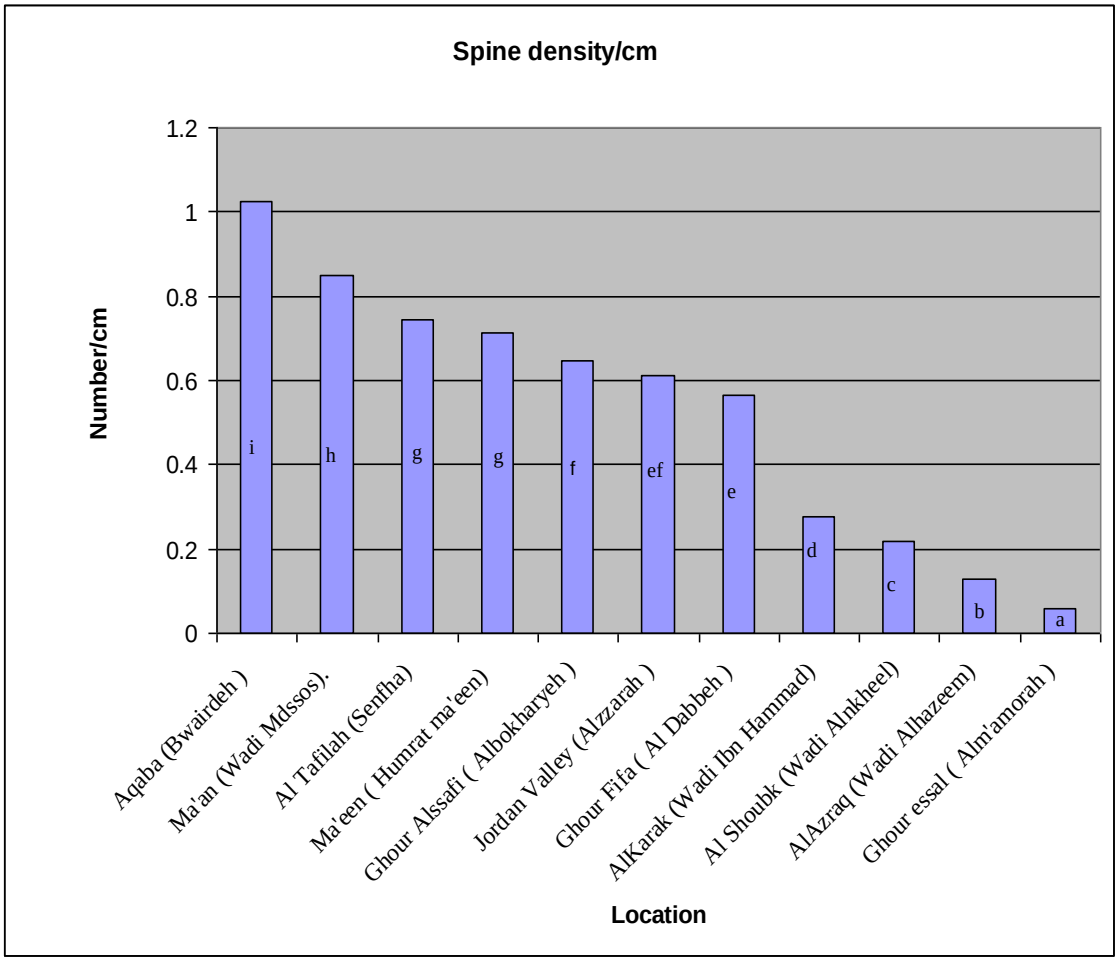


Fig (16). The average means and significantly differences of spine density per cm among locations under 0.05 LSD.

Table 4.3 Means of petiole width, spine number and spine density per cm among the 24 studied populations.

No.	Location	Population #	Petiole width		Spine number		Spine Density/Cm	
		Population 1	3.122	d	22.56	lm	0.8156	ij
		Population 2	2.778	bc	23	lmn	0.937	k
1	Aqaba (Bwairdeh)	Population 3	2.389	a	25	no	1.3243	n
2	Al Shoubk (Wadi Alnkheel)	Population 4	3.778	gh	10.22	de	0.217	d
		Population 5	2.533	ab	23.89	mno	1.1624	m
3	Ma'an (Wadi Mdssos).	Population 6	2.578	ab	17	hi	0.5369	g
4	Ghour Alssafi (Albokharyeh)	Population 7	3.656	fg	19.44	jk	0.646	h
5	Ghour Fifa (Al Dabbeh)	Population 8	3.256	de	18.11	ij	0.5645	g
6	Ghour essal (Alm'amorah)	Population 9	4.767	j	3.44	a	0.0588	a
		Population 10	3.911	gh	8.33	cd	0.1698	cd
7	Al Tafilah (Senfha)	Population 11	2.544	ab	25.22	o	1.3215	n
		Population 12	3.456	ef	12.22	ef	0.3134	e
		Population 13	3.922	gh	10.22	de	0.2155	d
		Population 14	3	cd	22.78	lm	0.892	jk
8	Jordan Valley (Alzzarah)	Population 15	2.578	ab	23	lmn	1.0301	l
		Population 16	3.267	de	14.22	fg	0.3944	f
		Population 17	3.022	cd	21.22	kl	0.762	i
		Population 18	3.167	d	16	gh	0.4404	f
9	Ma'een (Humrat ma'een)	Population 19	2.611	ab	24.22	mno	1.2563	n
		Population 20	4.244	i	6.33	bc	0.1206	abc
10	AlAzraq (Wadi Alhazeem)	Population 21	4.011	hi	7.22	c	0.1399	bcd
		Population 22	3.689	fg	15.44	gh	0.3692	ef
		Population 23	3.244	de	13.33	f	0.3722	ef
11	AlKarak (Wadi Ibn Hammad)	Population 24	4.589	j	4.44	ab	0.0831	ab

4.2.1.2.10 Spine length at mid:

There were significant differences within and among populations. The longest mean of spine was recorded for population number eleven, While the shortest mean of spine was scored for population number nine (19.33 cm and 4.78 cm respectively). (Table 4.4).

Among the locations, Bwairdeh had the highest average mean of length of spine (17.52 cm), while Al M'amorah scored the shortest average mean (4.78 cm). (Fig. 17)

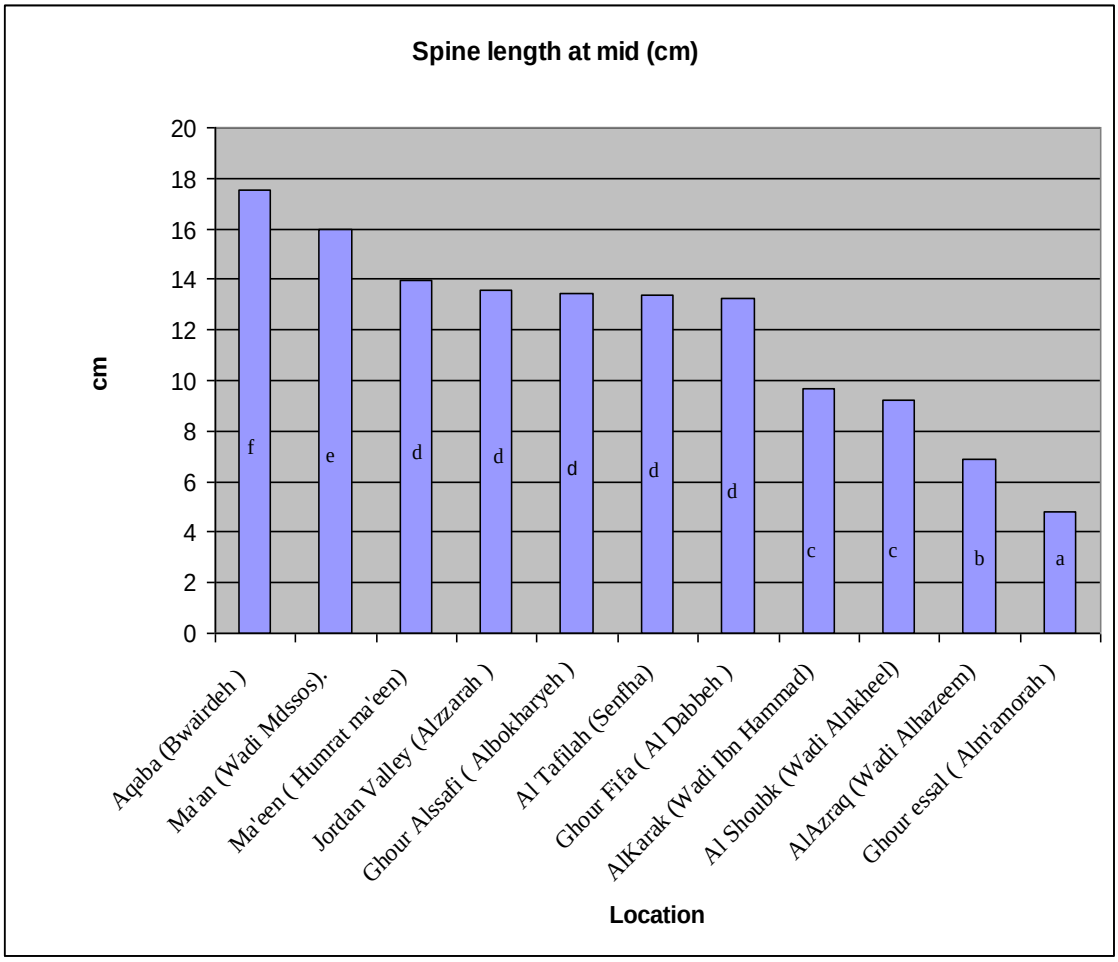


Fig (17). The average means and significantly differences of spine length among locations under 0.05 LSD.

4.2.1.2.11 Spine width at mid:

Data analysis showed weak significant differences within and among populations. Table 4.4 illustrated that the highest mean value of the spine width was be at population number sixteen (0.978 cm) and the shortest mean value was recorded at populations numbers six, nine and twelve (0.767 cm).

AlBokharyeh had the highest average mean among the locations (0.97 cm) while AlM'amorah scored the lowest average mean of spine width (0.767 cm). (Fig.18).

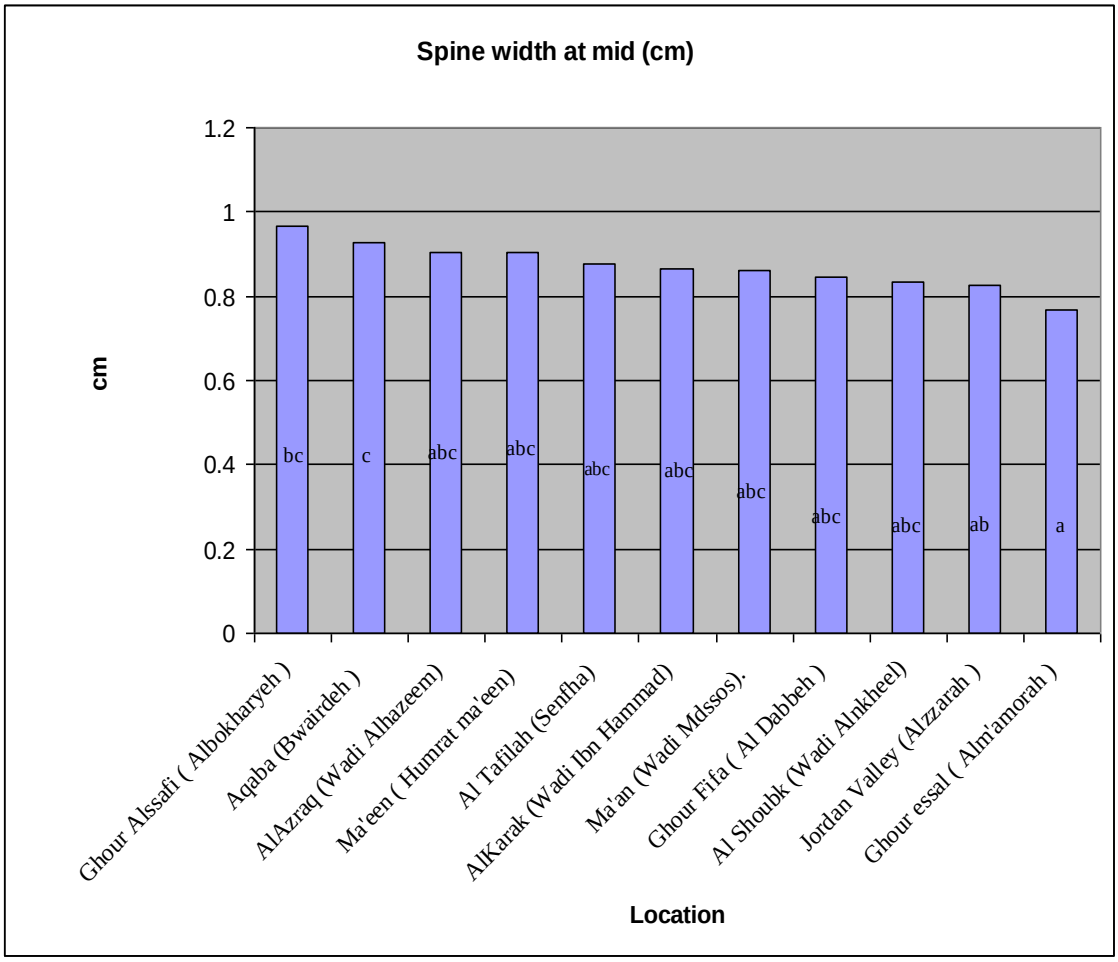


Fig (18). The average means and significantly differences of spine width among locations under 0.05 LSD.

4.2.1.2.12 Pinnae number:

Statistical analysis for Pinnae number showed large and significant differences within and among the twenty four populations. Table 4.4 showed the highest mean number was obtained from population number nine (175.1), and the lowest mean number was scored at population number three (110.9). Among eleven locations (Fig 19), Al M'amorah gets the highest average mean (175.1) while the lowest average was scored for Bwairdeh (118.6).

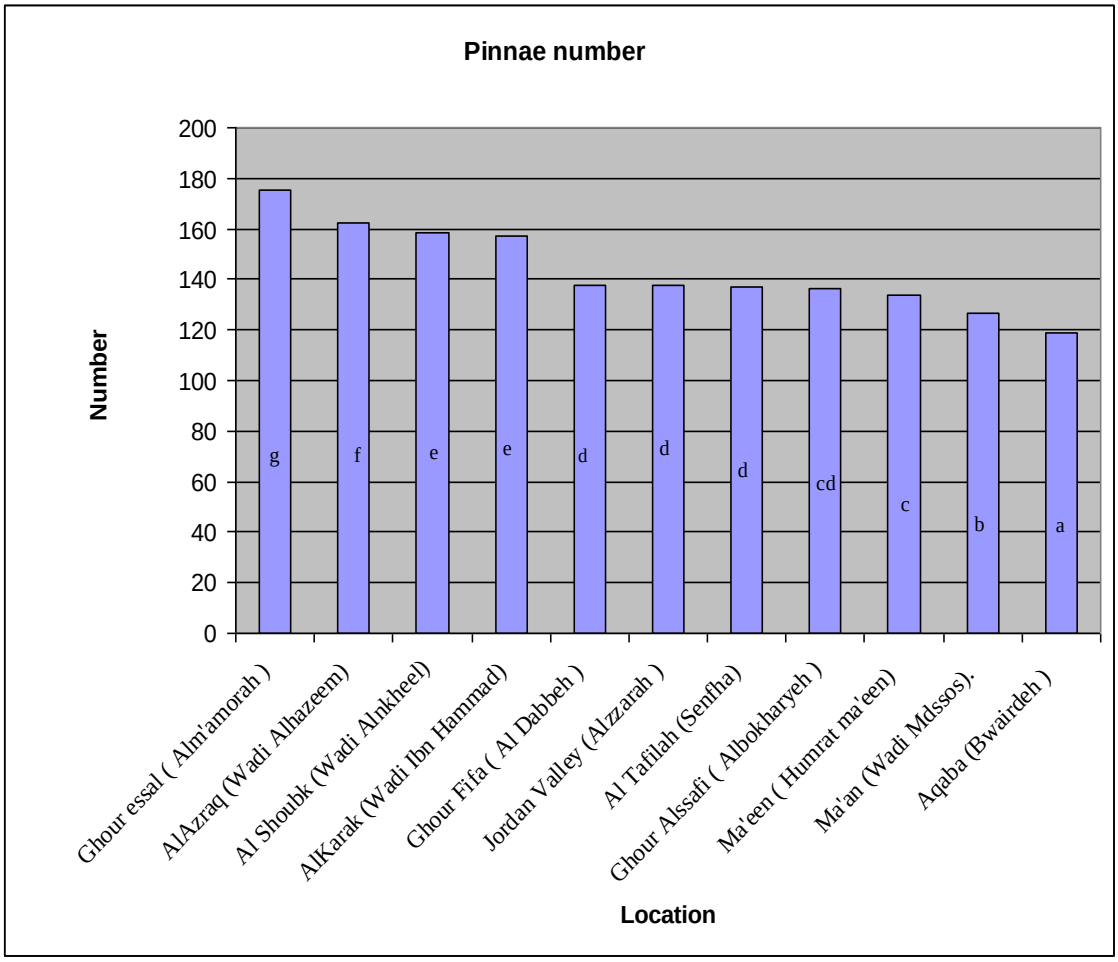


Fig (19). The average means and significantly differences of pinnae number among locations under 0.05 LSD.

Table 4.4 Means of spine length at the mid, spine width at the mid and pinnae number among the 24 studied populations.

No.	Location	Population #	Spine length at mid _Cm		Spine width at mid _Cm		Pinnae number	
		Population 1	16.22	ij	0.5708	a	49.33	fg
		Population 2	17.11	jk	0.5832	ab	46.22	e
1	Aqaba (Bwairdeh)	Population 3	19.22	l	0.6519	fghi	29.44	a
2	Al Shoubk (Wadi Alnkheel)	Population 4	9.22	cd	0.6892	jk	62.11	lm
		Population 5	18.67	kl	0.6349	defg	34	b
3	Ma'an (Wadi Mdssos).	Population 6	13.33	fgh	0.6236	cde	54.22	h
4	Ghour Alssafi (Albokharyeh)	Population 7	13.44	gh	0.6028	bc	52.44	h
5	Ghour Fifa (Al Dabbeh)	Population 8	13.22	fgh	0.6154	cd	53.44	h
6	Ghour essal (Alm'amorah)	Population 9	4.78	a	0.742	m	69.11	o
		Population 10	7.44	bc	0.7052	kl	64	mn
7	Al Tafilah (Senfha)	Population 11	19.33	l	0.665	ij	31.44	a
		Population 12	10.56	de	0.6518	fghi	59.33	jk
		Population 13	9	cd	0.6892	jk	62.22	lm
		Population 14	17.11	jk	0.5635	a	47.56	ef
8	Jordan Valley (Alzzarah)	Population 15	17.67	jkl	0.5793	ab	44.11	d
		Population 16	11.33	ef	0.6383	defgh	58.22	ij
		Population 17	14.22	hi	0.5834	ab	50.22	g
		Population 18	12.11	efg	0.629	def	56.56	i
9	Ma'een (Humrat ma'een)	Population 19	18.22	jkl	0.6586	ghi	38.44	c
		Population 20	6.33	ab	0.7185	lm	65	n
10	AlAzraq (Wadi Alhazeem)	Population 21	7.44	bc	0.7078	kl	65.11	n
		Population 22	12.22	efgh	0.6622	hi	60.44	kl
		Population 23	11.33	ef	0.6446	efghi	58.33	ij
11	AlKarak (Wadi Ibn Hammad)	Population 24	5.44	ab	0.7238	lm	67.33	o

4.2.1.2.13 Pinnae density per cm:

There were significant differences for pinnae density within and among the populations (Table 4.5). The highest mean value was observed at population number nine (0.742), while lowest mean value was recorded at population number one (0.570).

At Location level (Fig. 20), the highest and lowest average mean was scored at Al M'amorah (0.742) and Bwairdeh (0.602) respectively.

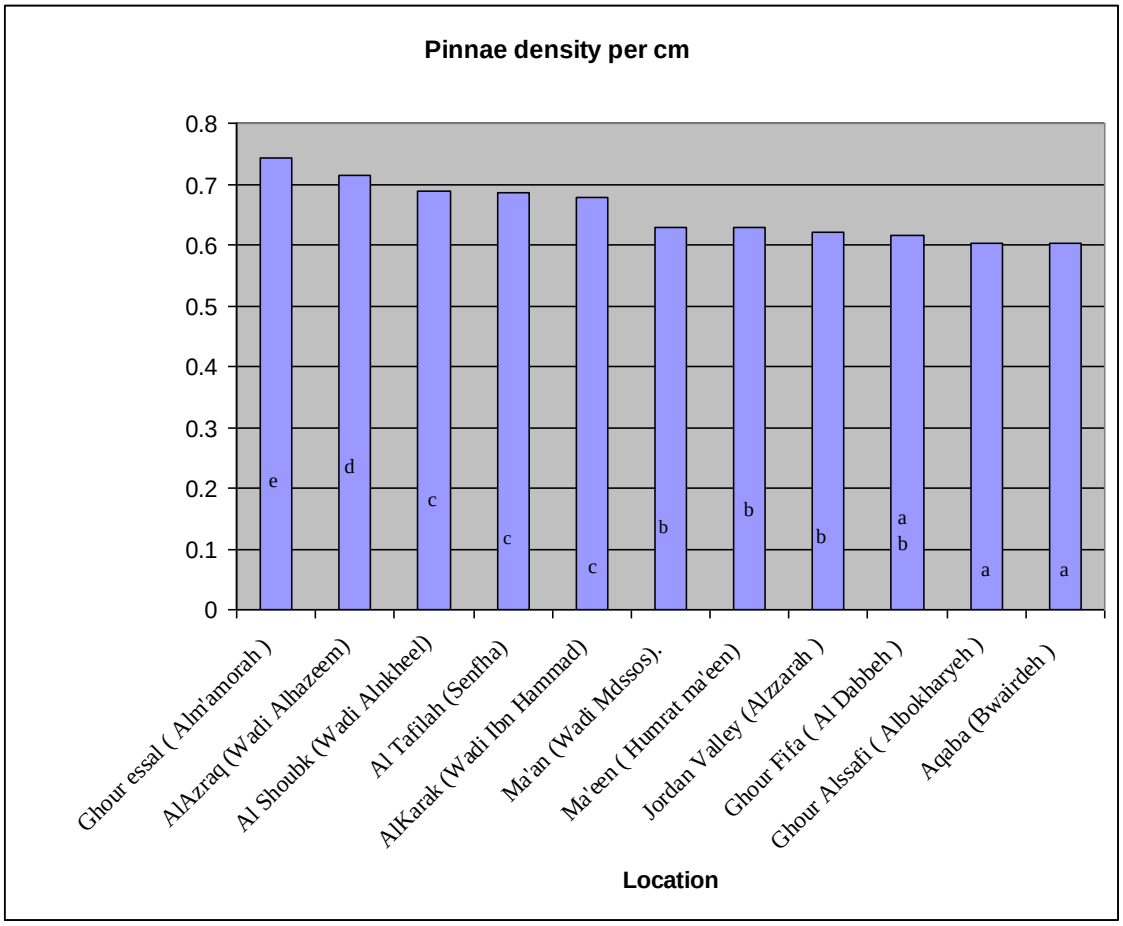


Fig (20). The average means and significantly differences of pinnae density per cm among locations under 0.05 LSD.

4.2.1.2.14 Pinnae length at mid:

Statistical analysis for pinnae length showed large significant differences within and among populations (Table 4.5). As expected, population number nine was had the longest mean (69.11 cm) and population number three had the shortest mean (29.44 cm).

Figure (21) showed that the highest average mean was recorded at Al M'amorah (69.11cm), while the shortest average mean was scored at Bwairdeh (41.67 cm).

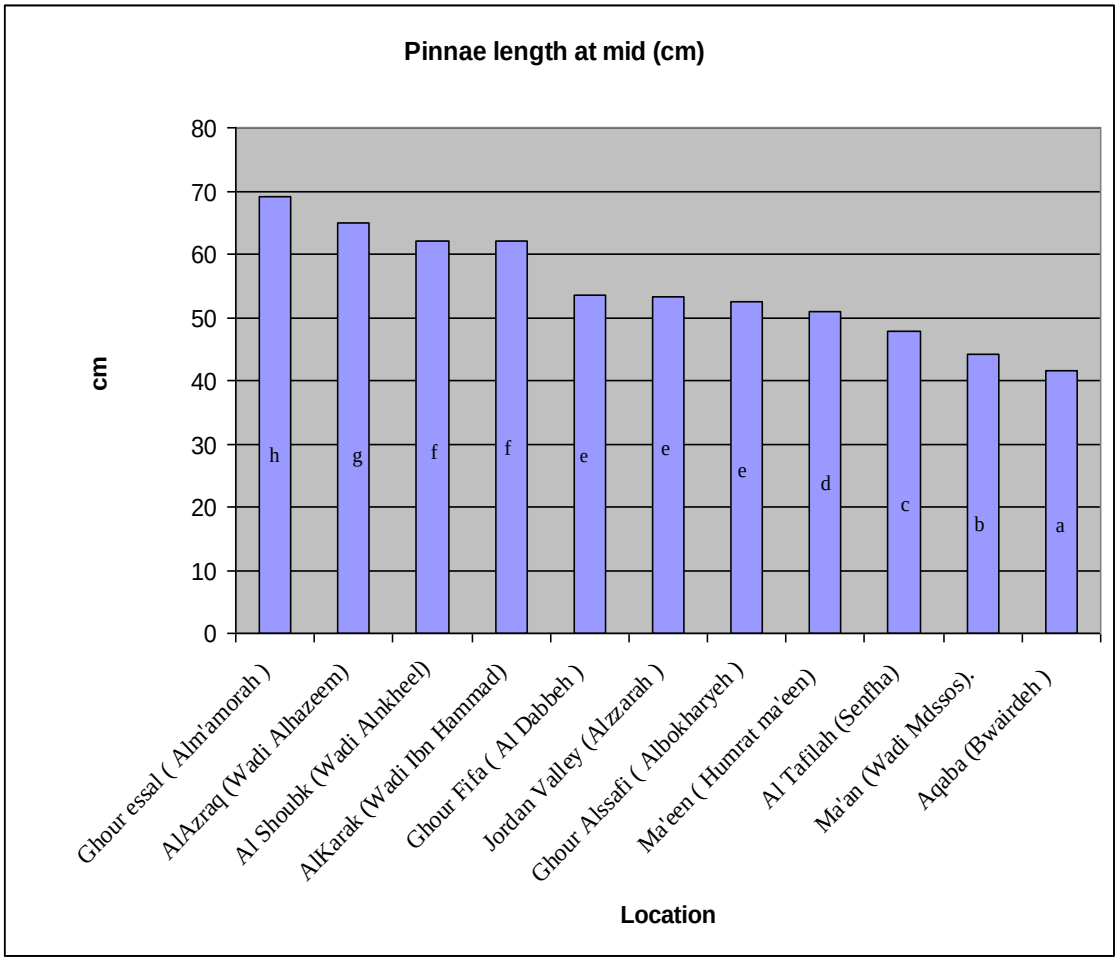


Fig (21). The average means and significantly differences of pinnae length at the mid among locations under 0.05 LSD.

4.2.1.2.15 Pinnae length at the top:

Statistical analysis for pinnae length at the top of the leaf showed significant differences within and among the populations (Table 4.5). At population number nine the longest mean was scored (54.56 cm), while the shortest mean value was recorded at populations number one and five (23.78 cm).

Among the eleven locations (Fig. 21), Al M'amorah get the highest average mean (54.56 cm) while the shortest average mean was observed at Bwairdeh (26.41 cm).

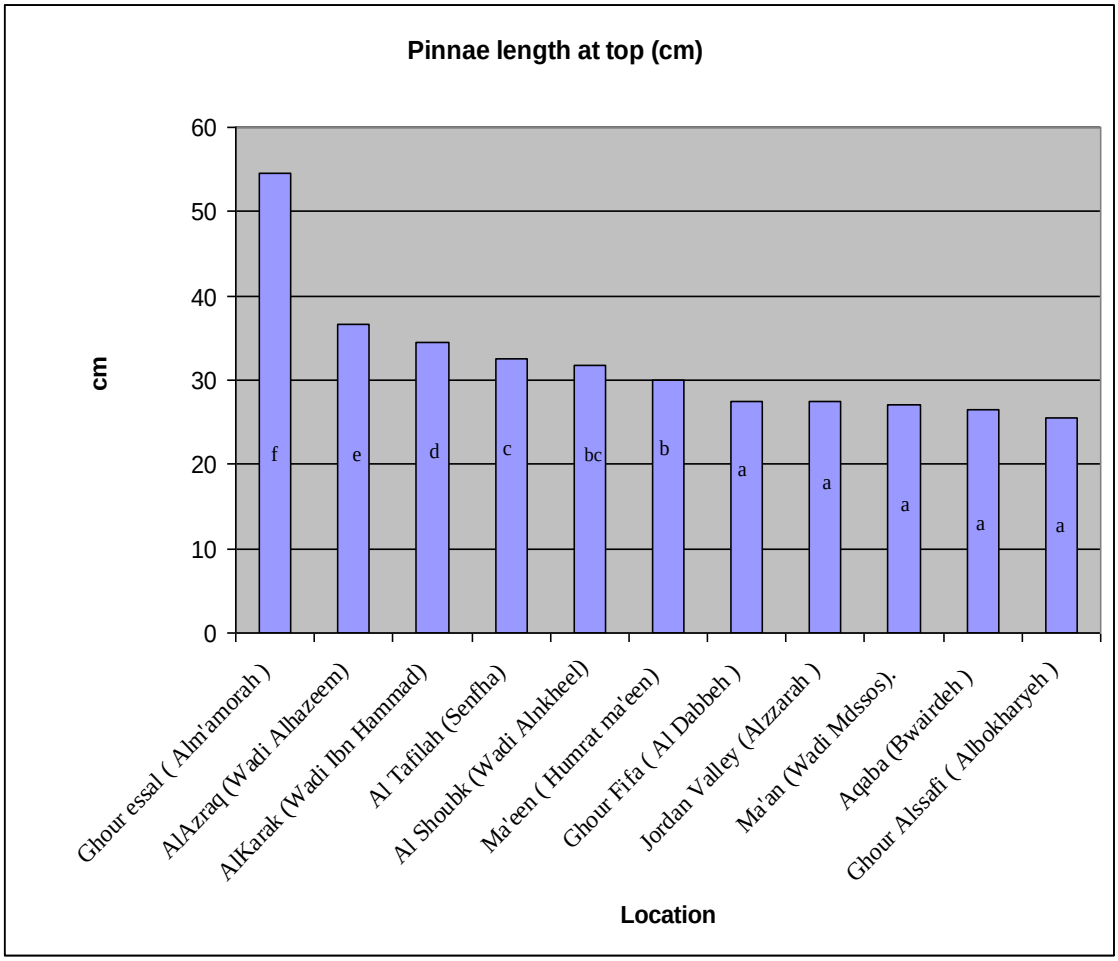


Fig (22). The average means and significantly differences of pinnae length at the top of the leaf among locations under 0.05 LSD.

Table 4.5 Means of pinnae density per cm, pinnae length at the mid and pinnae length at the top of the leaf among the 24 studied populations.

No.	Location	Population #	Pinnae Density/Cm		Pinnae length at mid _Cm		Pinnae length at top _Cm	
		Population 1	0.5708	a	49.33	fg	23.78	a
		Population 2	0.5832	ab	46.22	e	28.33	cde
1	Aqaba (Bwairdeh)	Population 3	0.6519	fghi	29.44	a	27.11	bcd
2	Al Shoubk (Wadi Alnkheel)	Population 4	0.6892	jk	62.11	lm	31.78	fgh
		Population 5	0.6349	defg	34	b	23.78	a
3	Ma'an (Wadi Mdssos).	Population 6	0.6236	cde	54.22	h	30.22	efg
4	Ghour Alssafi (Albokharyeh)	Population 7	0.6028	bc	52.44	h	25.56	abc
5	Ghour Fifa (Al Dabbeh)	Population 8	0.6154	cd	53.44	h	27.56	bcde
6	Ghour essal (Alm'amorah)	Population 9	0.742	m	69.11	o	54.56	k
		Population 10	0.7052	kl	64	mn	34.78	hi
7	Al Tafilah (Senfha)	Population 11	0.665	ij	31.44	a	30.44	efg
		Population 12	0.6518	fghi	59.33	jk	29.11	defg
		Population 13	0.6892	jk	62.22	lm	32	gh
		Population 14	0.5635	a	47.56	ef	23.44	a
8	Jordan Valley (Alzzarah)	Population 15	0.5793	ab	44.11	d	25.11	ab
		Population 16	0.6383	defgh	58.22	ij	28.89	def
		Population 17	0.5834	ab	50.22	g	27.89	bcde
		Population 18	0.629	def	56.56	i	28	bcde
9	Ma'een (Humrat ma'een)	Population 19	0.6586	ghi	38.44	c	35.33	i
		Population 20	0.7185	lm	65	n	37	i
10	AlAzraq (Wadi Alhazeem)	Population 21	0.7078	kl	65.11	n	36.22	i
		Population 22	0.6622	hi	60.44	kl	30	defg
		Population 23	0.6446	efghi	58.33	ij	28.78	def
11	AlKarak (Wadi Ibn Hammad)	Population 24	0.7238	lm	67.33	o	44.78	j

4.2.1.3 Physical and chemical characteristics of fruit:

4.2.1.3.1 Fruit weight (gm):

There were large significant differences in fruit weight within and among the populations (Table 4.6). Population number 21 was considered as the highest mean weight (10.6 gm) while the lowest mean was recorded at population number ten (0.5 gm).

Among the eleven locations, Wadi Al Hazeem was recorded the highest average mean (9.683 gm), while Wadi Al Nakheel and Senfha had the lowest average mean (1.167 gm) (Fig 23).

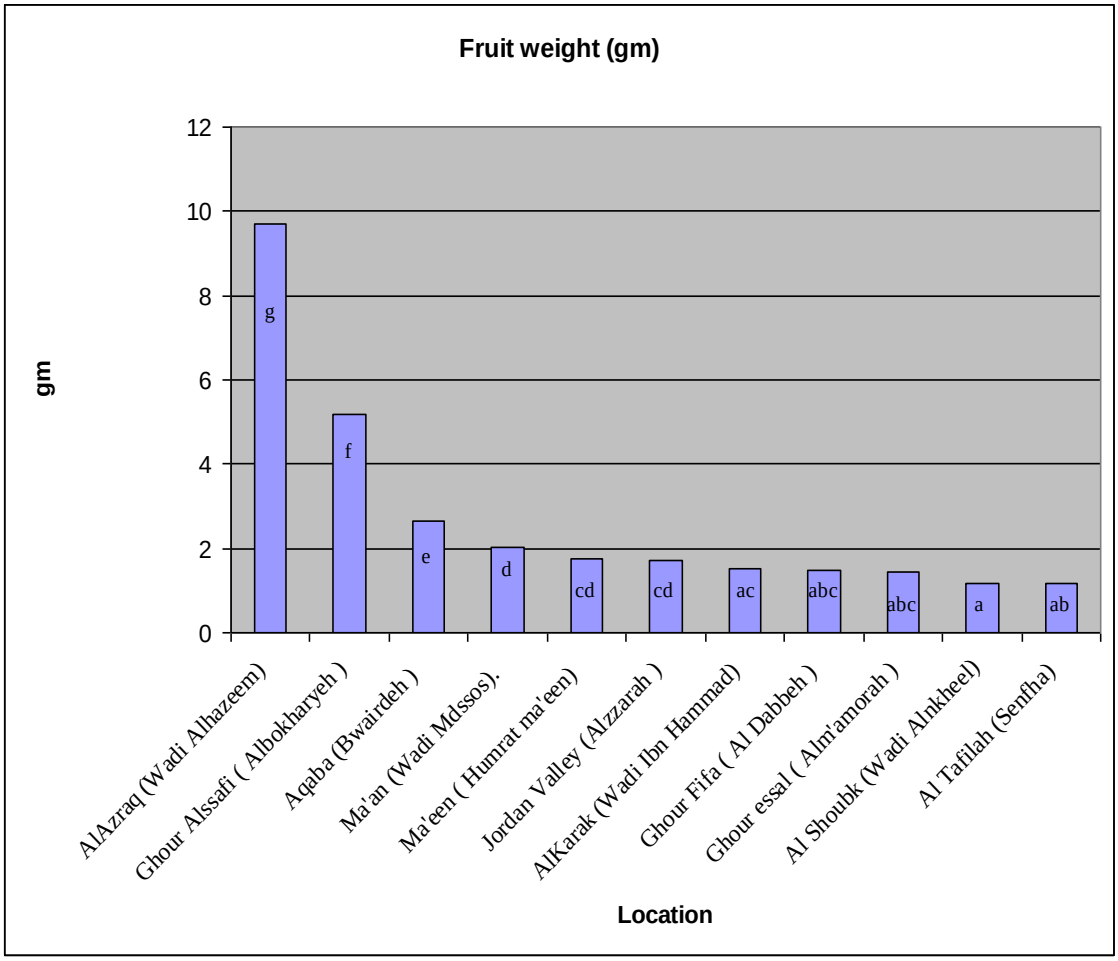


Fig (23). The average means and significantly differences of fruit weight among locations under 0.05 LSD.

4.2.1.3.2 Flesh weight (gm):

Statistical analysis for flesh weight showed small significant differences within and among populations. (Table 4.6) showed that the highest and lowest mean value were scored at populations numbers twenty one (9.2 gm) and ten (0.33 gm) respectively.

At locations level, (Fig. 24) showed that the highest average weight was scored at Wadi Al Hazeem (8.317 gm), while the lowest average weight were obtained at Al Nakheel and Al Dabbeh locations (0.633 gm).

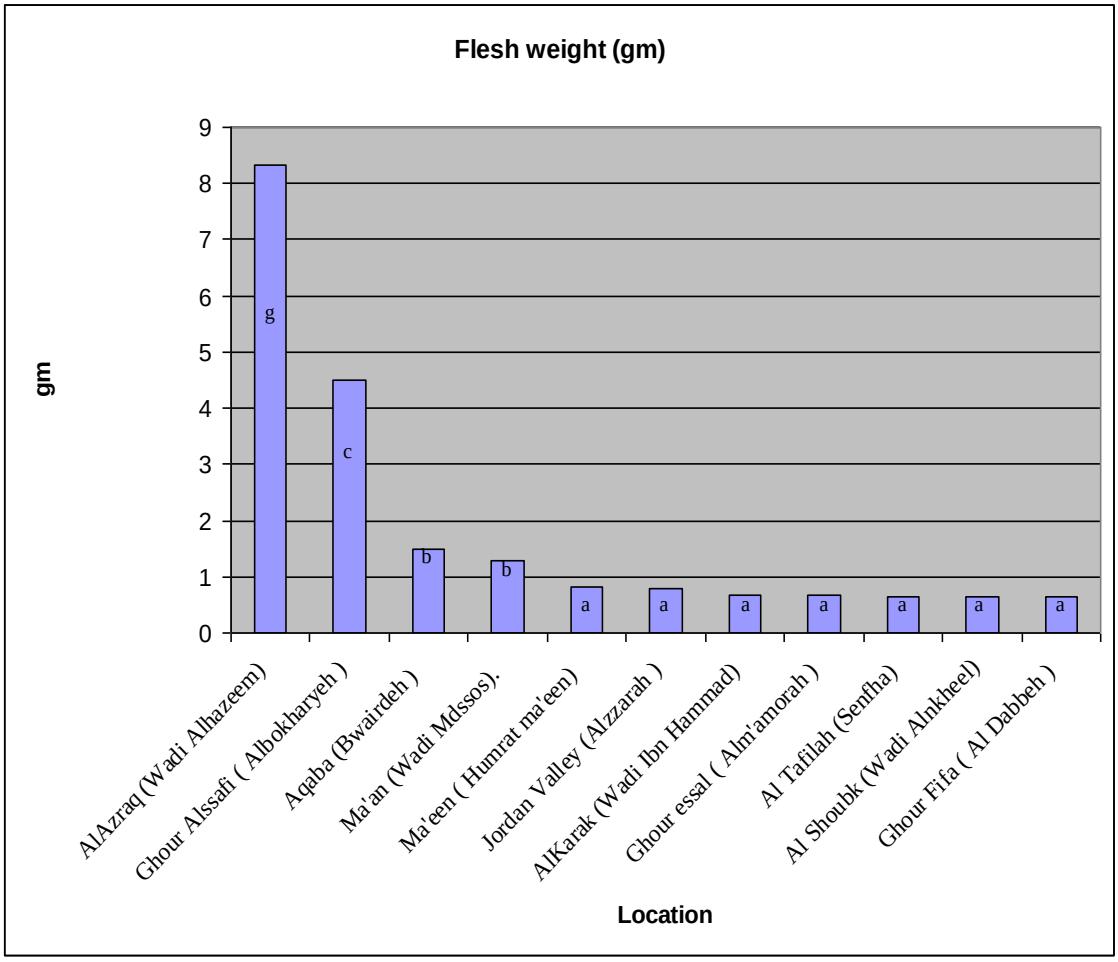


Fig (24). The average means and significantly differences of flesh weight among locations under 0.05 LSD.

4.2.1.3.3 Seed weight (gm):

There were small significant differences in seed weight within and among populations; (Table 4.6) indicated that the highest mean weight (1.4 gm) was scored at population number twenty one, while the lowest mean weight (0.1667 gm) was obtained at population number ten.

Among the locations (Fig. 25), Wadi Al Hazeem recorded the highest average weight (1.3667 gm) and Senfha scored the lowest average weight (0.517 gm).

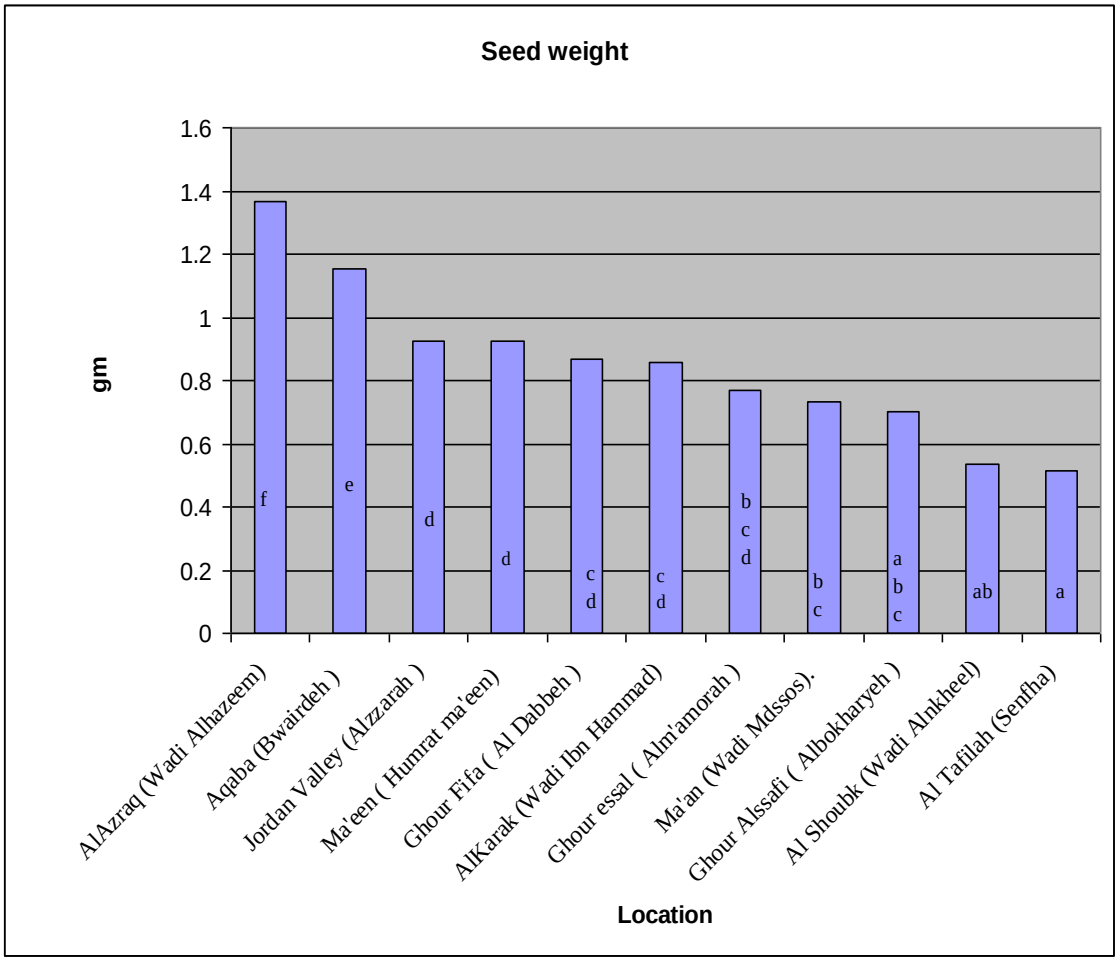


Fig (25). The average means and significantly differences of seed weight among locations under 0.05 LSD.

Table 4.6 Means of fruit weight, flesh weight and seed weight among the 24 studied populations.

No.	Location	Population #	Fruit weight		Flesh Wt		Seed Wt	
		Population 1	3.233	g	1.967	f	1.2667	ghi
		Population 2	2.267	ef	1.233	cde	1.0333	defgh
1	Aqaba (Bwairdeh)	Population 3	2.467	f	1.3	de	1.1667	fghi
2	Al Shoubk (Wadi Alnkheel)	Population 4	1.167	b	0.633	abc	0.5333	b
		Population 5	2.3	ef	1.567	ef	0.7333	bcd
3	Ma'an (Wadi Mdssos).	Population 6	1.767	cde	1.033	bcde	0.7333	bcd
4	Ghour Alssafi (Albokharyeh)	Population 7	5.2	h	4.5	g	0.7	bc
5	Ghour Fifa (Al Dabbeh)	Population 8	1.5	bcd	0.633	abc	0.8667	cdef
6	Ghour essal (Alm'amorah)	Population 9	1.433	bcd	0.667	abc	0.7667	bcde
		Population 10	0.5	a	0.333	a	0.1667	a
7	Al Tafilah (Senfha)	Population 11	1.833	cde	0.967	bcde	0.8667	cdef
		Population 12	1.333	bcd	0.6	ab	0.7333	bcd
		Population 13	1.9	def	0.833	abcd	1.0667	efgh
		Population 14	1.767	cde	0.933	abcd	0.8333	bcde
8	Jordan Valley (Alzzarah)	Population 15	1.9	def	0.833	abcd	1.0667	efgh
		Population 16	1.767	cde	0.8	abcd	0.9667	cdefg
		Population 17	1.867	cde	0.867	abcd	1	cdefg
		Population 18	1.833	cde	0.933	abcd	0.9	cdef
9	Ma'een (Humrat ma'een)	Population 19	1.533	bcd	0.7	abcd	0.8333	bcde
		Population 20	8.767	i	7.433	h	1.3333	hi
10	AlAzraq (Wadi Alhazeem)	Population 21	10.6	j	9.2	i	1.4	i
		Population 22	1.767	cde	0.767	abcd	1	cdefg
		Population 23	1.533	bcd	0.667	abc	0.8667	cdef
11	AlKarak (Wadi Ibn Hammad)	Population 24	1.3	bc	0.6	ab	0.7	bc

4.2.1.3.4 Fruit length (cm):

Statistical analysis for fruit length showed significant differences within and among populations. (Table 4.7) showed the highest mean value was recorded at population number twenty one (4.03 cm), while the shortest means length were been at populations numbers eight, nine and twenty four (1.467 cm).

Wadi Al Hazeem location scored the highest average mean (3.467 cm), while the lowest average mean were recorded at Al Dabbeh and Al M'amorah locations (1.467 cm) (Fig. 26).

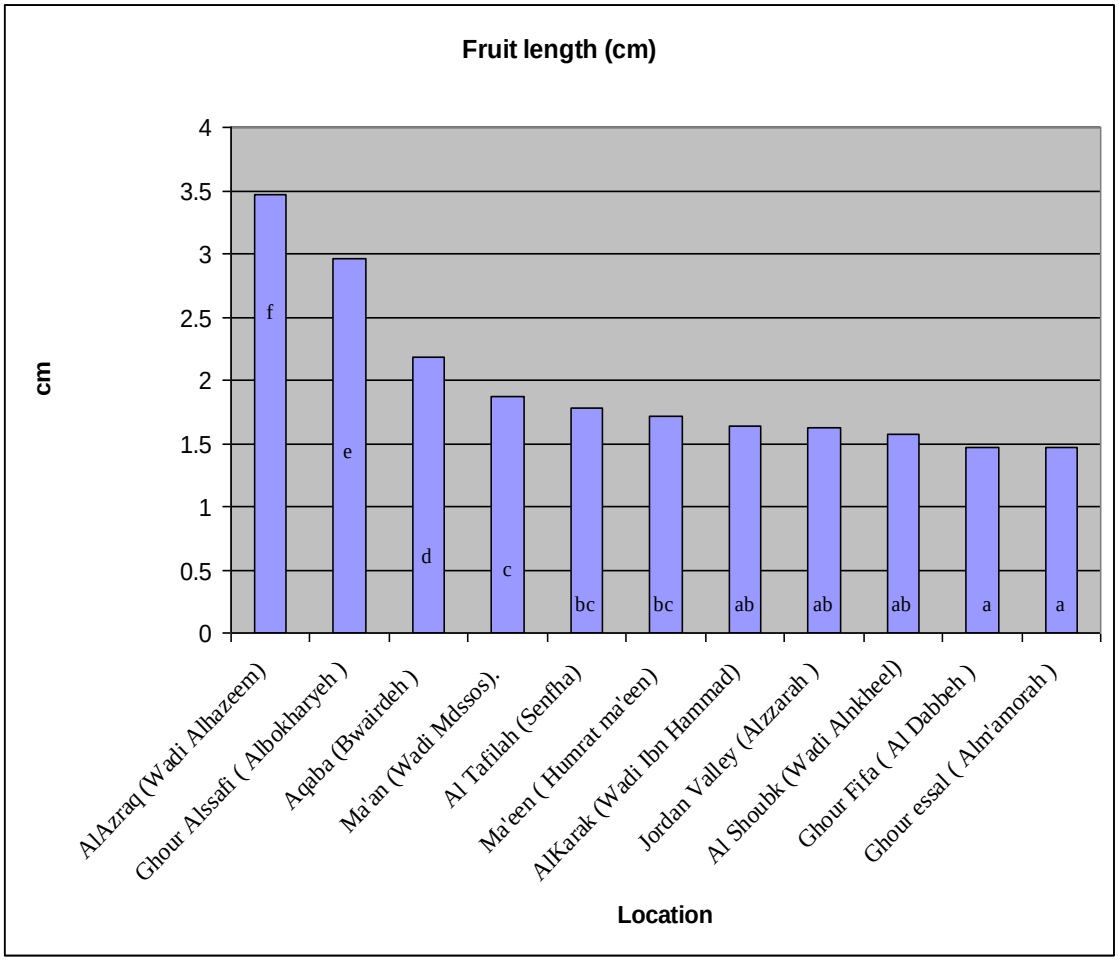


Fig (26). The average means and significantly differences of fruit length among locations under 0.05 LSD.

4.2.1.3.5 Fruit diameter (cm):

There were small differences in fruit diameter within and among the populations (Table 4.7). At population number twenty one, the highest mean value was recorded (1.933 cm) while population number ten gave the lowest mean value (0.633 cm).

Wadi Al Hazeem and Senfha (Fig. 27), were scored the highest and lowest average mean among the locations (1.9 cm and 0.817 cm) respectively.

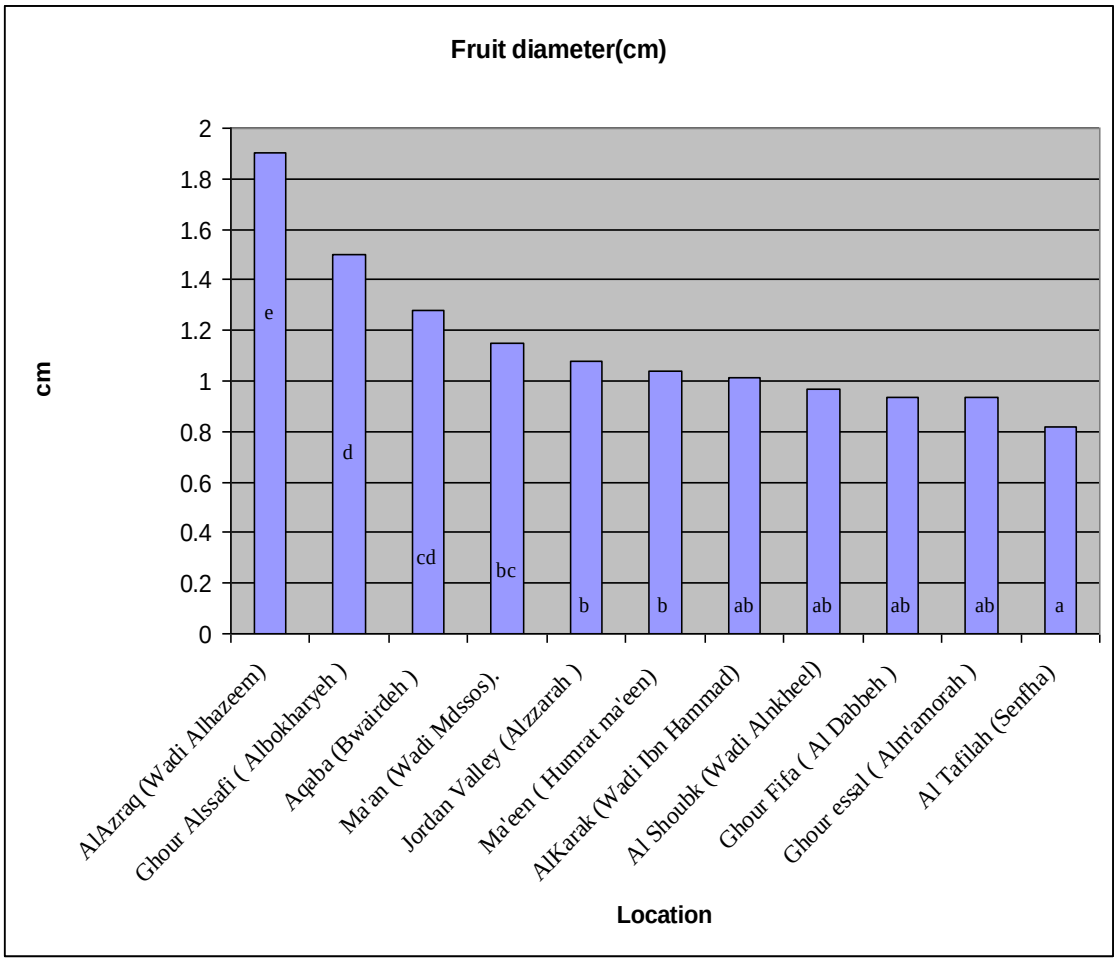


Fig (27). The average means and significantly differences of fruit diameter among locations under 0.05 LSD.

Table 4.7 Means of fruit length and fruit diameter among the 24 studied populations.

No.	Location	Population #	Fruit Length		Fruit Diameter	
1	Aqaba (Bwairdeh)	Population 1	2.2	de	1.3	bcde
		Population 2	1.967	cd	1.167	bcde
		Population 3	2.367	e	1.367	de
2	Al Shoubk (Wadi Alnkheel)	Population 4	1.567	ab	0.967	abc
3	Ma'an (Wadi Mdssos).	Population 5	1.967	cd	1.333	cde
		Population 6	1.767	abc	0.967	abc
4	Ghour Alssafi (Albokharyeh)	Population 7	2.967	f	1.5	ef
5	Ghour Fifa (Al Dabbeh)	Population 8	1.467	a	0.933	ab
6	Ghour essal (Alm'amorah)	Population 9	1.467	a	0.933	ab
7	Al Tafilah (Senfha)	Population 10	1.567	ab	0.633	a
		Population 11	2	cd	1	abcd
8	Jordan Valley (Alzzarah)	Population 12	1.567	ab	1.067	bcd
		Population 13	1.6	ab	1.033	bcd
		Population 14	1.567	ab	1.033	bcd
		Population 15	1.767	abc	1.167	bcde
9	Ma'een (Humrat ma'een)	Population 16	1.767	abc	1.1	bcd
		Population 17	1.7	abc	1.067	bcd
		Population 18	1.8	bc	1.067	bcd
		Population 19	1.567	ab	0.933	ab
10	AlAzraq (Wadi Alhazeem)	Population 20	2.9	f	1.867	fg
		Population 21	4.033	g	1.933	g
11	AlKarak (Wadi Ibn Hammad)	Population 22	1.733	abc	1	abcd
		Population 23	1.7	abc	1.033	bcd
		Population 24	1.467	a	1	abcd

4.2.1.3.6 Fruit color, Fruit consistency, Maturity period and Fruit shape:

Statistical analysis for qualitative traits; fruit color, fruit consistency, maturity period and fruit shape by using chi square showed no significant differences within population (Table 4.8), while significant differences were found among populations and locations (Table. 4.9). Figure 28 shows the two types of the collected fruits from the studied populations.

Table 4.8 Fruit color, fruit consistency, maturity period and fruit shape among the 24 studied populations.

No.	Location	Population #	Fruit Color	Fruit consistency	Maturity Period	Fruit Shape
1	Aqaba (Bwairdeh)	Population 1	Orange	Semi Dry	Early Sep	Ovate
		Population 2	Orange	Soft	Early Sep	Ovate
		Population 3	Orange	Semi Dry	Early Sep	Ovate
2	Al Shoubk (Wadi Alnkheel)	Population 4	Yellow	Soft	Early Sep	Ovate
3	Ma'an (Wadi Mdssos).	Population 5	Orange	Soft	Early Sep	Ovate
		Population 6	Orange	Semi Dry	Early Sep	Ovate
4	Ghour Alssafi (Albokharyeh)	Population 7	Yellow	Dry	Late Aug	Cylindrical
5	Ghour Fifa (Al Dabbeh)	Population 8	Orange	Dry	Late Aug	Ovate
6	Ghour essal (Alm'amorah)	Population 9	Orange	Dry	Late Aug	Ovate
7	Al Tafilah (Senfha)	Population 10	Yellow	Semi Dry	Late Aug	Ovate
		Population 11	Yellow	Soft	Late Aug	Ovate
8	Jordan Valley (Alzzarah)	Population 12	Orange	Soft	Early Sep	Ovate
		Population 13	Orange	Soft	Early Sep	Ovate
		Population 14	Orange	Semi Dry	Early Sep	Ovate
		Population 15	Orange	Soft	Early Sep	Ovate
9	Ma'een (Humrat ma'een)	Population 16	Orange	Soft	Early Sep	Ovate
		Population 17	Orange	Soft	Early Sep	Ovate
		Population 18	Yellow	Soft	Early Sep	Ovate
		Population 19	Orange	Soft	Early Sep	Ovate
10	AlAzraq (Wadi Alhazeem)	Population 20	Yellow	Soft	Mid Sep	Cylindrical
		Population 21	Yellow	Soft	Mid Sep	Cylindrical
11	AlKarak (Wadi Ibn Hammad)	Population 22	Orange	Soft	Early Sep	Ovate
		Population 23	Orange	Soft	Early Sep	Ovate
		Population 24	Orange	Soft	Early Sep	Ovate

Table 4.9 Fruit color, fruit consistency, maturity period and fruit shape among the eleven locations.

No.	Location	Fruit Color	Fruit consistency	Maturity Period	Fruit Shape
1	Aqaba (Bwairdeh)	Orange	Semi Dry	Early Sep	Ovate
2	Al Shoubk (Wadi Alnkheel)	Yellow	Soft	Early Sep	Ovate
3	Ma'an (Wadi Mdssos).	Orange	Soft	Early Sep	Ovate
4	Ghour Alssafi (Albokharyeh)	Yellow	Dry	Late Aug	Cylindrical
5	Ghour Fifa (Al Dabbeh)	Orange	Dry	Late Aug	Ovate
6	Ghour essal (Alm'amorah)	Orange	Dry	Late Aug	Ovate
7	Al Tafilah (Senfha)	Yellow	Semi Dry	Late Aug	Ovate
8	Jordan Valley (Alzzarah)	Orange	Soft	Early Sep	Ovate
9	Ma'een (Humrat ma'een)	Orange	Soft	Early Sep	Ovate
10	AlAzraq (Wadi Alhazeem)	Yellow	Soft	Mid Sep	Cylindrical
11	AlKarak (Wadi Ibn Hammad)	Orange	Soft	Early Sep	Ovate

Fig. 28. Kinds of the wild date palm fruit.

4.2.1.3.7 Fruit pH:

The fruit pH means was ranged from 5.033 at population number eight to 5.867 at population's numbers one and three; so the data analysis showed significant differences within and among populations as shown in (Table 4.10).

Among the locations; Bwairdeh was scored the highest average mean (5.733), while Al Dabbeh recorded the lowest average mean (5.033) (Fig. 29).

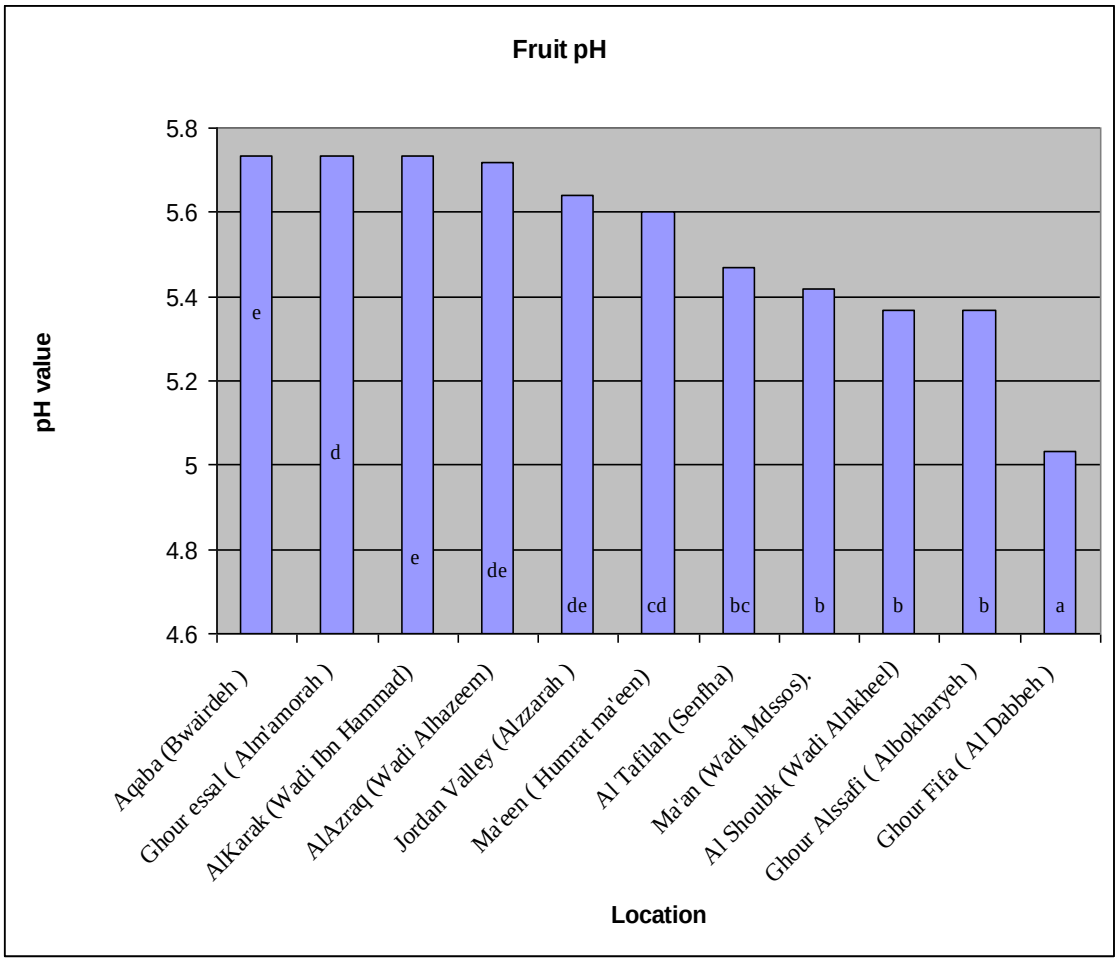


Fig (29). The average means and significantly differences of fruit pH among locations under 0.05 LSD.

4.2.1.3.8 Fruit moisture %:

Statistically, fruit moisture percent had significant differences within and among populations. Table 4.10, illustrated that the highest mean percent (78.33 %) was recorded at population number sixteen, and the lowest mean (13%) was found at population number nine.

Humrat Ma'een fruits recorded highest average mean (71.83 %) among locations, while Al M'amorah scored the lowest average mean (13 %) (Fig. 30).

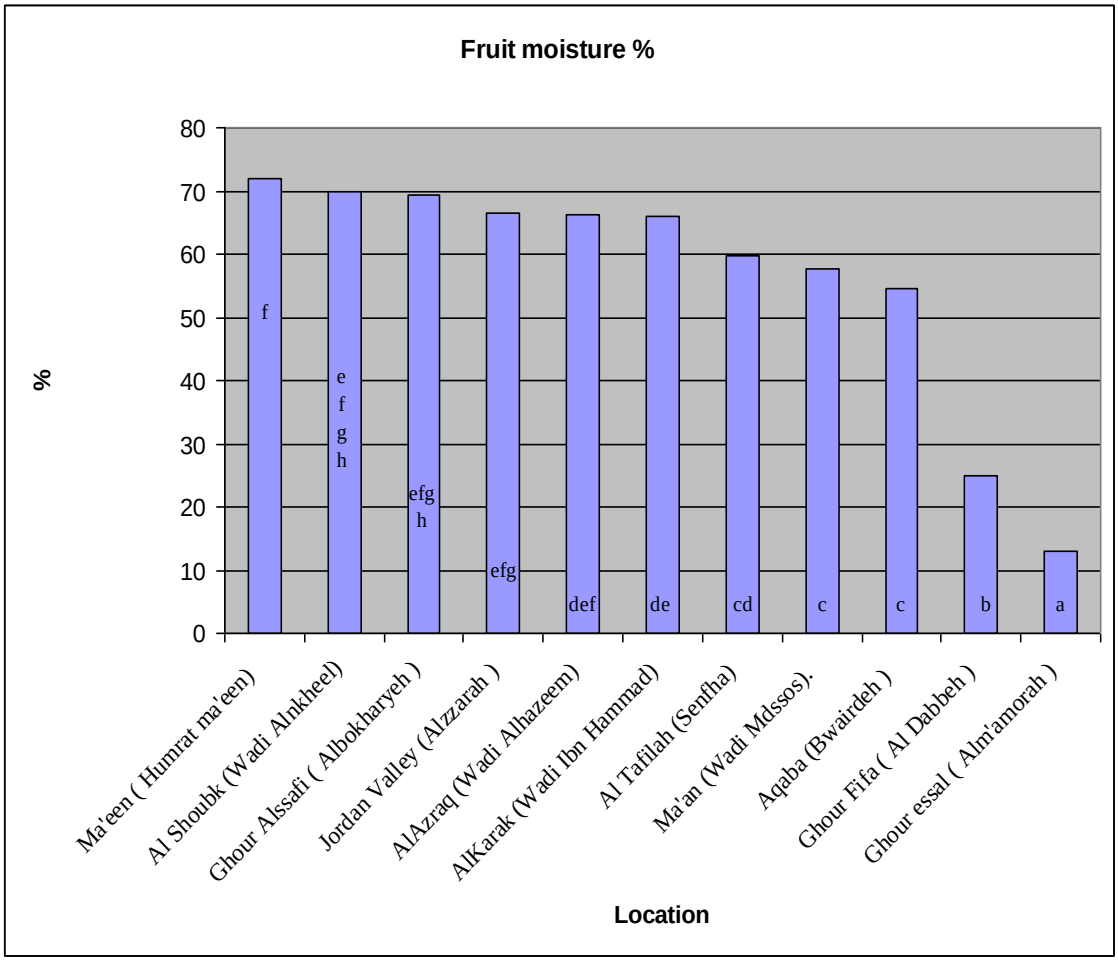


Fig (30). The average means and significantly differences of fruit moisture percent among locations under 0.05 LSD.

4.2.1.3.9 TSS %:

Statistical analysis for Total Soluble Solid percent showed significant differences within and among populations (Table 4.10). The highest and lowest means were recorded at population number four (29.07) and number three (16.07) respectively.

Among locations, the highest average mean of the TSS % was scored at Wadi Al Nakheel (29.07 %), while the lowest percent of the average mean (21.4) was found at Bwairdeh (Fig. 31).

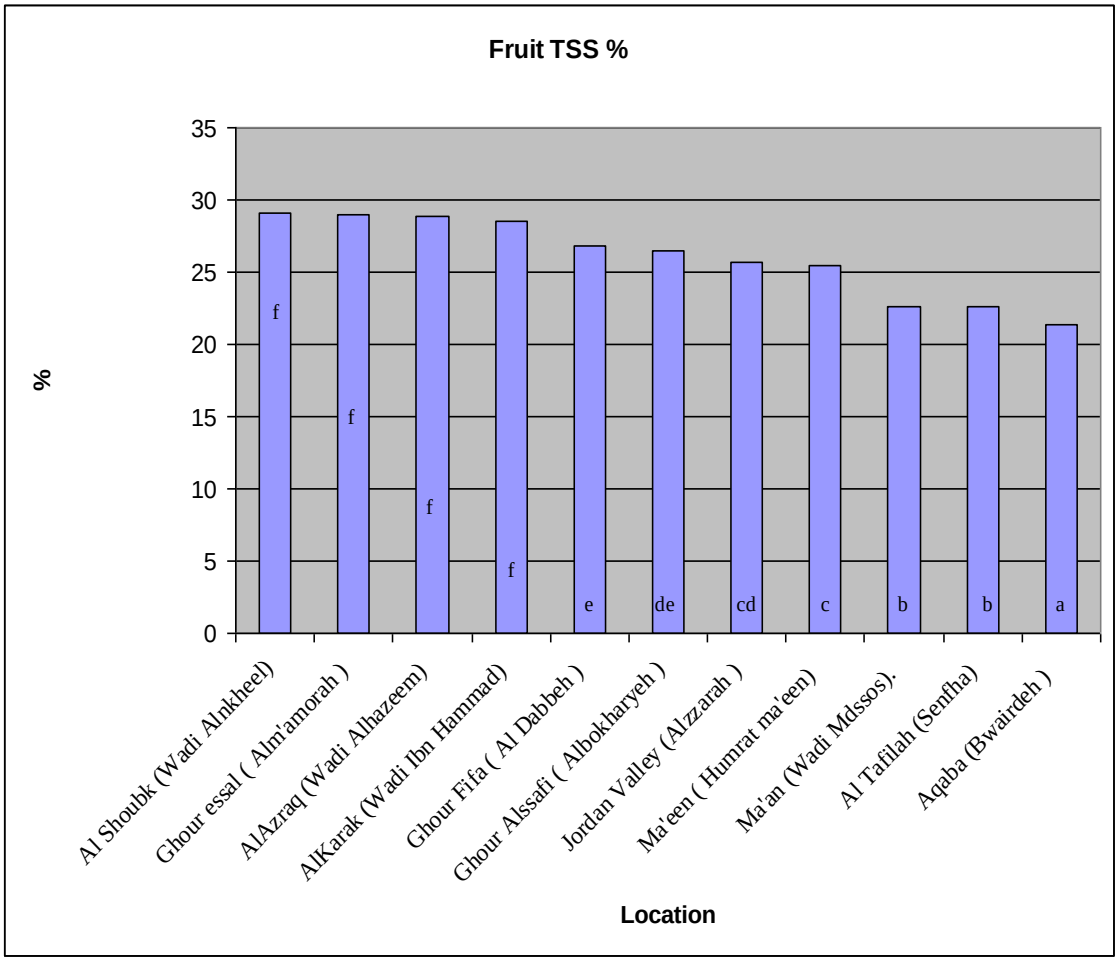


Fig (31). The average means and significantly differences of fruit Total Soluble Solid percent among locations under 0.05 LSD.

Table 4.10. Fruit pH, fruit moisture percent, and total soluble solid percent in fruit among the 24 studied populations.

No.	Location	Population #	Fruit PH		Fruit Moisture %		Fruit TSS %	
		Population 1	5.867	e	40.67	c	25.2	f
		Population 2	5.467	bc	74.33	hi	22.93	de
1	Aqaba (Bwairdeh)	Population 3	5.867	e	48.33	cd	16.07	a
2	Al Shoubk (Wadi Alnkheel)	Population 4	5.367	b	70	ghi	29.07	k
		Population 5	5.367	b	65.67	gh	17.97	b
3	Ma'an (Wadi Mdssos).	Population 6	5.467	bc	49.67	cd	27.33	hij
4	Ghour Alssafi (Albokharyeh)	Population 7	5.367	b	69.33	ghi	26.47	gh
5	Ghour Fifa (Al Dabbeh)	Population 8	5.033	a	25	b	26.87	ghi
6	Ghour essal (Alm'amorah)	Population 9	5.733	de	13	a	28.93	k
		Population 10	5.367	b	50.67	cde	28.43	jk
7	Al Tafilah (Senfha)	Population 11	5.567	bcd	69	ghi	16.73	ab
		Population 12	5.567	bcd	71.33	ghi	28.37	jk
		Population 13	5.7	cde	67.33	ghi	28.6	k
		Population 14	5.667	cde	52.67	def	23.83	e
8	Jordan Valley (Alzzarah)	Population 15	5.633	cde	75	hi	21.83	d
		Population 16	5.667	cde	78.33	i	27.93	ijk
		Population 17	5.567	bcd	70.67	ghi	25.87	fg
		Population 18	5.6	bcd	74.33	hi	27.97	ijk
9	Ma'een (Humrat ma'een)	Population 19	5.567	bcd	64	fgh	20.07	c
		Population 20	5.767	de	66.67	gh	28.93	k
10	AlAzraq (Wadi Alhazeem)	Population 21	5.667	cde	65.67	gh	28.87	k
		Population 22	5.767	de	61.33	efg	28.93	k
		Population 23	5.633	cde	67.33	ghi	27.83	ijk
11	AlKarak (Wadi Ibn Hammad)	Population 24	5.8	de	69	ghi	28.87	k

4.2.1.3.10 K %:

There were significant differences in fruit content of Potassium within and among the populations (Table 4.11). Population number eighteen was scored the highest mean value (2.633 %), whereas, populations numbers one and six had the lowest mean value (0.467 %).

Figure thirty two showed the differences among locations; Humrat Ma'een and Bwairdeh had the highest and lowest average mean percent (2.2 %) and (0.833) respectively.

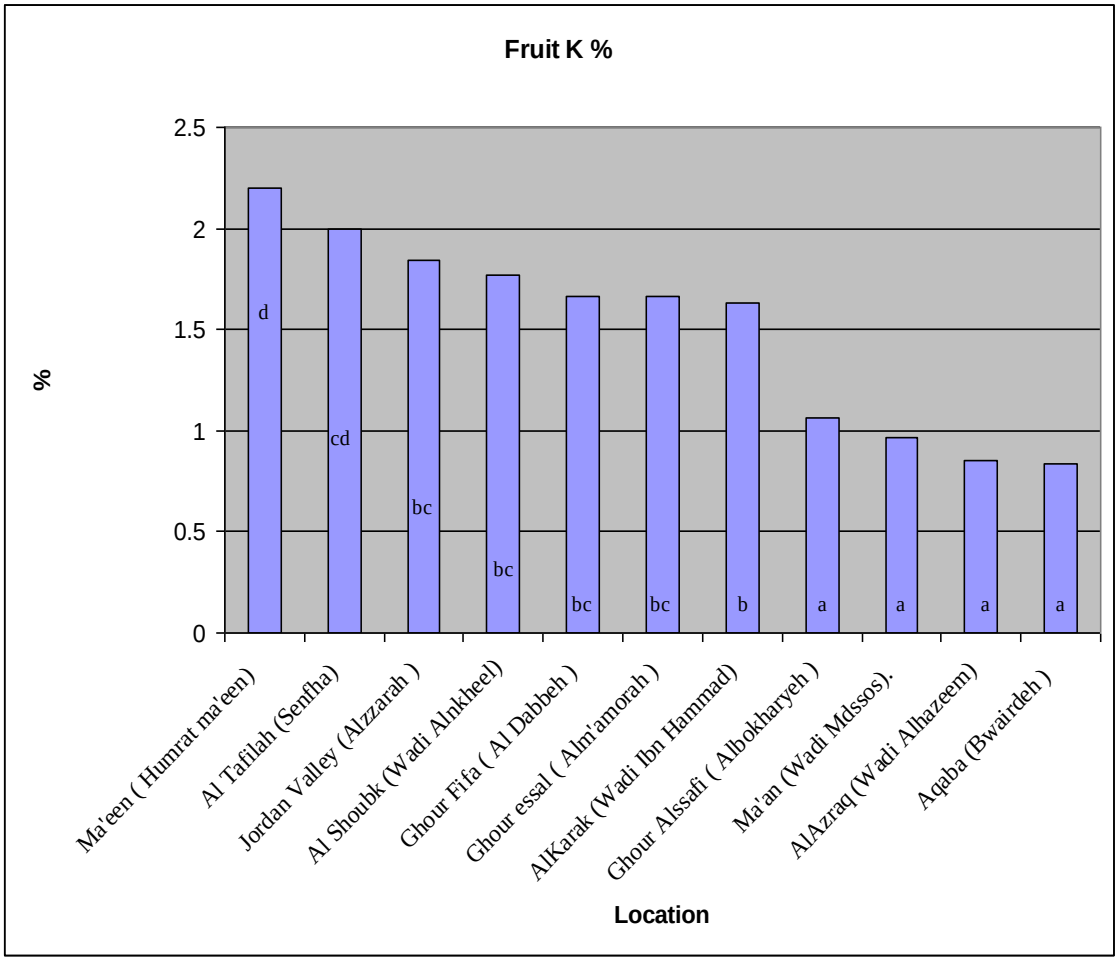


Fig (32). The average means and significantly differences of fruit content of potassium among locations under 0.05 LSD.

4.2.1.3.11 Mg%:

Data analysis for fruit content of Magnesium showed significant differences within and among populations (Table 4.11). The highest mean value was found at population number two, while the lowest mean value was scored at population number five.

Among locations also there were significant differences under 0.05 LSD, Wadi Al Nakheel had the highest average mean (0.44 %) and the lowest average mean (0.0867 %) was recorded at Al Bokharyeh (Fig. 33).

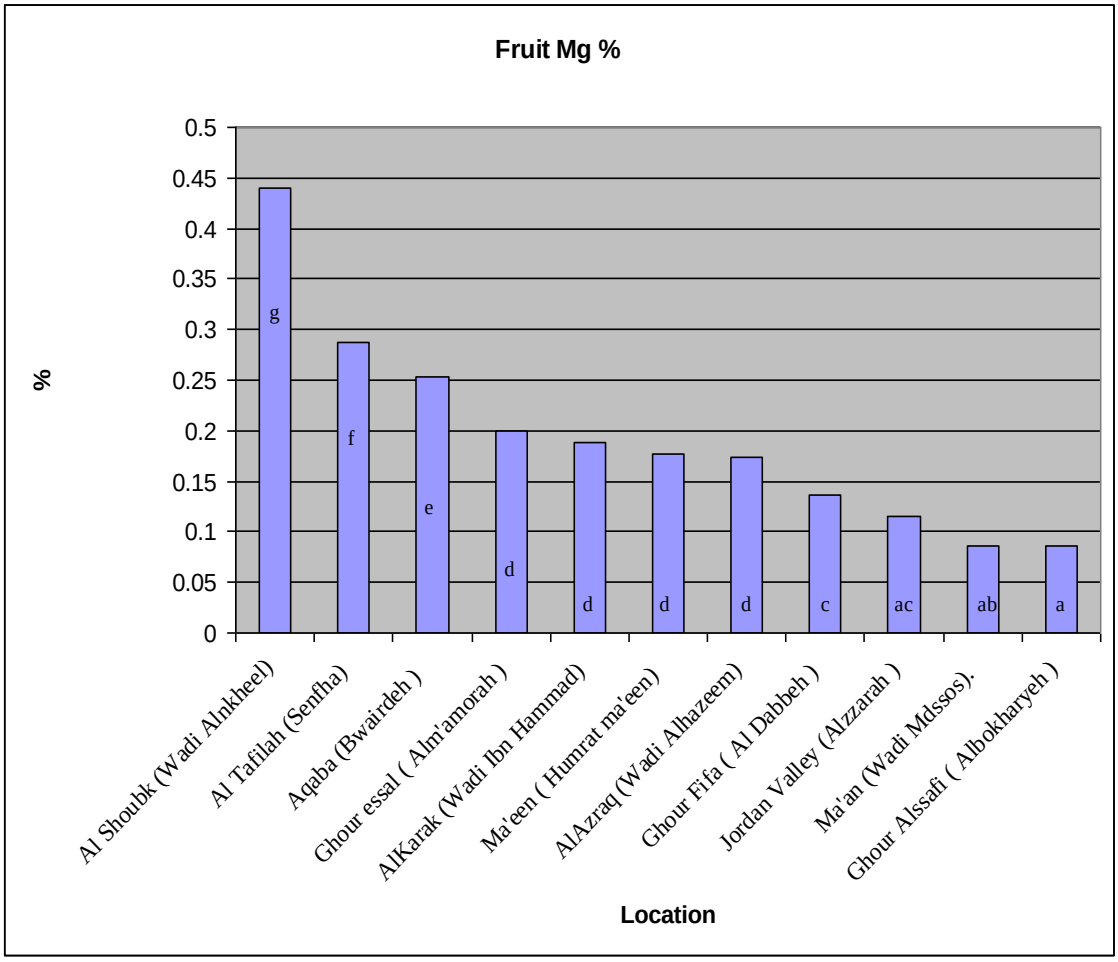


Fig (33). The average means and significantly differences of fruit content of magnesium among locations under 0.05 LSD.

Table 4.11. Potassium and Magnesium percent in fruit among the 24 studied populations.

No.	Location	Population #	Fruit K%		Fruit Mg%	
		Population 1	0.467	a	0.0767	b
		Population 2	0.867	abc	0.4533	m
1	Aqaba (Bwairdeh)	Population 3	1.167	bcde	0.23	jk
2	Al Shoubk (Wadi Alnkheel)	Population 4	1.767	fgh	0.44	m
		Population 5	1.467	def	0.0167	a
3	Ma'an (Wadi Mdssos).	Population 6	0.467	a	0.1567	def
4	Ghour Alssafi (Albokharyeh)	Population 7	1.067	bcd	0.0867	b
5	Ghour Fifa (Al Dabbeh)	Population 8	1.667	efgh	0.1367	de
6	Ghour essal (Alm'amorah)	Population 9	1.667	efgh	0.2	ghij
		Population 10	1.667	efgh	0.2667	kl
7	Al Tafilah (Senfha)	Population 11	2.333	ij	0.3067	l
		Population 12	1.967	fghi	0.13	cd
		Population 13	1.967	fghi	0.2	ghij
		Population 14	1.6	defg	0.0767	b
8	Jordan Valley (Alzzarah)	Population 15	1.833	fghi	0.0567	ab
		Population 16	2.033	ghi	0.3033	l
		Population 17	2.167	hij	0.09	bc
		Population 18	2.633	j	0.1367	de
9	Ma'een (Humrat ma'een)	Population 19	1.967	fghi	0.1767	efgh
		Population 20	1.067	bcd	0.1833	fghi
10	AlAzraq (Wadi Alhazeem)	Population 21	0.633	ab	0.1633	defg
		Population 22	1.933	fghi	0.2233	ij
		Population 23	1.767	fgh	0.2133	hij
11	AlKarak (Wadi Ibn Hammad)	Population 24	1.2	cde	0.13	cd

4.2.1.3.12 Mn content:

Statistical analysis for fruit content of Manganese showed significant differences within and among populations. Table 4.12 illustrated that the highest and lowest mean value of Manganese were recorded at population number two (29.33 ppm) and at population number eleven (3.73 ppm) respectively.

According to the locations comparison; Bwairdeh was had the highest average mean (20.09 ppm) while Al Dabbeh gave the lowest average mean (4.7 ppm) (Fig. 34).

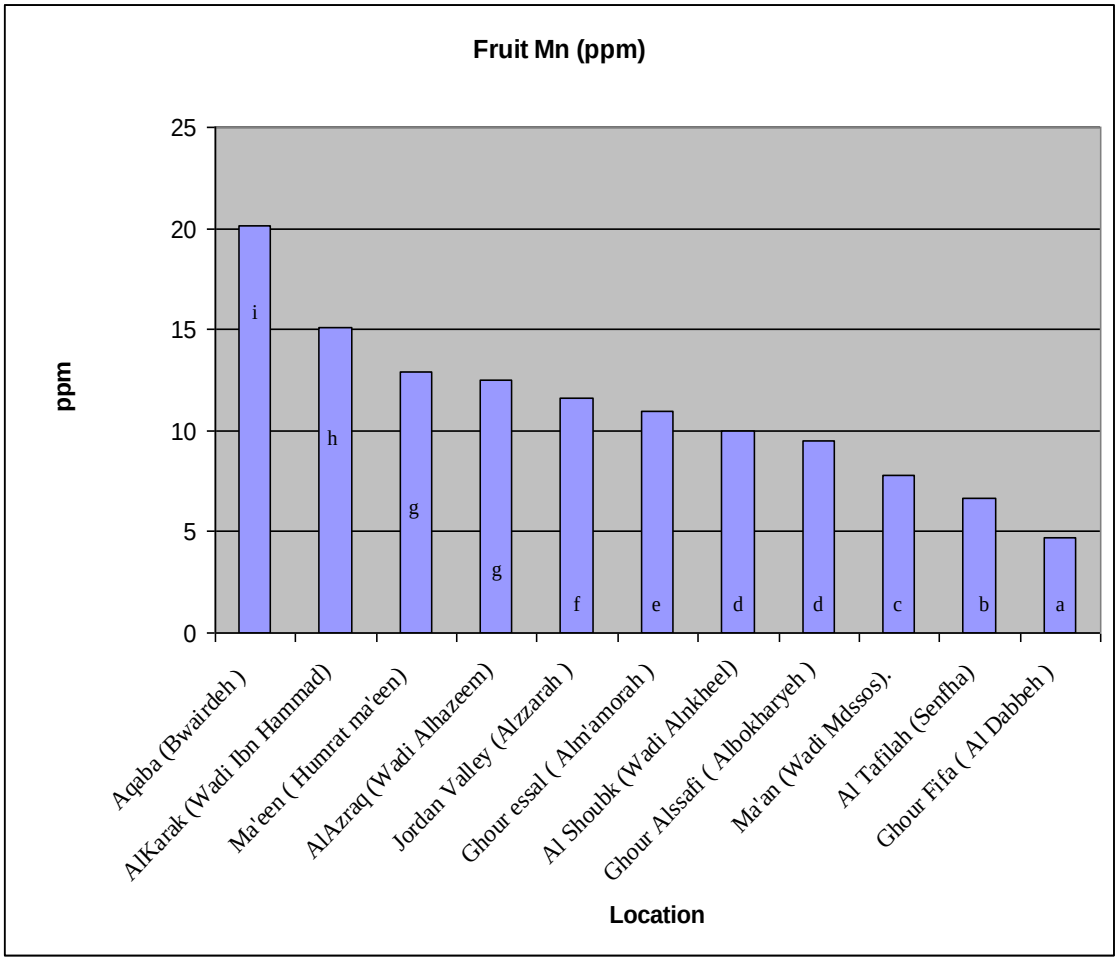


Fig (34). The average means and significantly differences of fruit content of Manganese among locations under 0.05 LSD.

No.	Location	Population #	Fruit Mn	Fruit Fe

4.2.1.3.13 Fe content:

There were significant differences in fruit content of Ferrous within and among the populations (Table 4.12). Population number nineteen was had the highest mean (30.5 ppm), while population number eight was scored the lowest mean (10 ppm).

Among locations, the highest and lowest average means were recorded at Humrat Ma'een (26.05 ppm) and at Al Dabbeh (10 ppm) (Fig. 35).

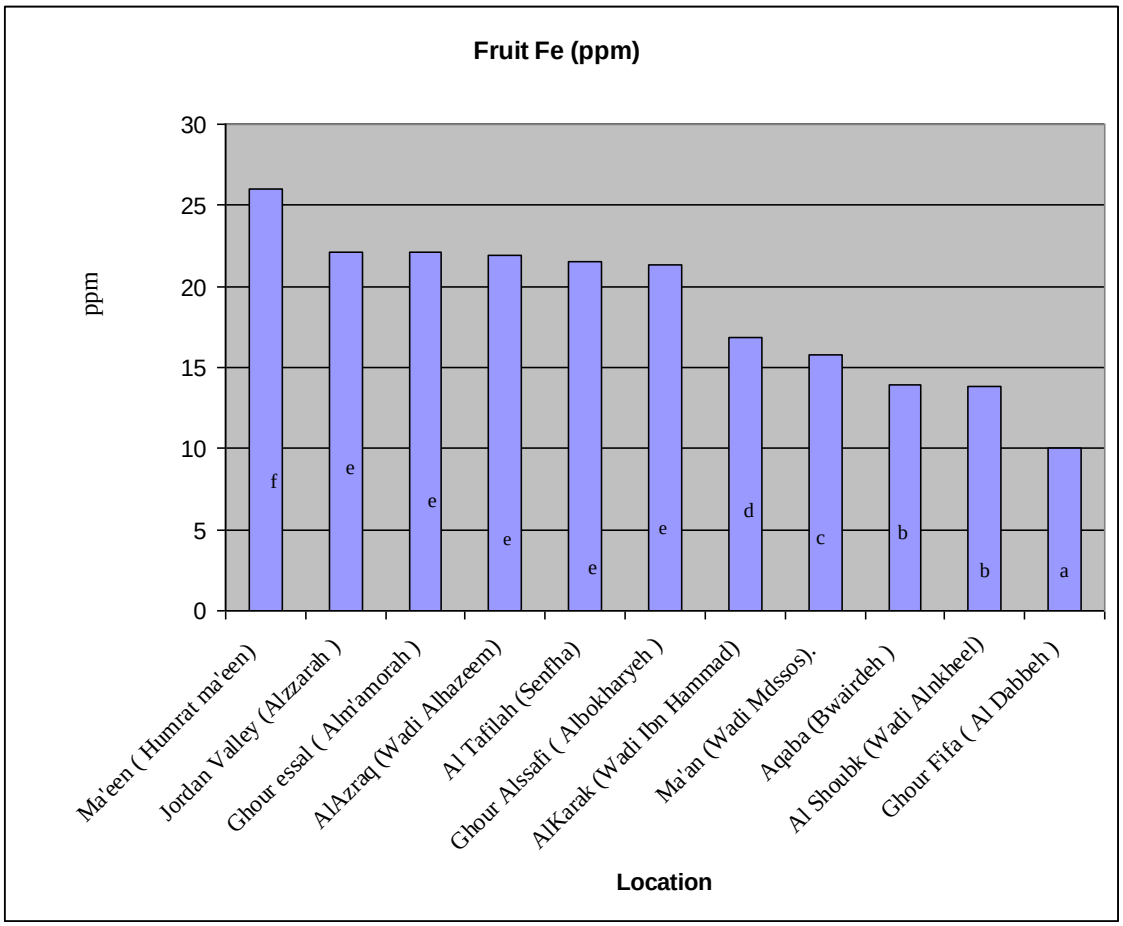


Fig (35). The average means and significantly differences of fruit content of Ferrous among locations under 0.05 LSD.

		Population 1	7.63	c	13	b
		Population 2	29.33	l	14.13	bcd
1	Aqaba (Bwairdeh)	Population 3	23.3	j	14.67	cd
2	Al Shoubk (Wadi Alnkheel)	Population 4	10	de	13.87	bc
		Population 5	10.4	ef	10.33	a
3	Ma'an (Wadi Mdssos).	Population 6	5.23	b	21.2	hi
4	Ghour Alssafi (Albokharyeh)	Population 7	9.53	d	21.33	hi
5	Ghour Fifa (Al Dabbeh)	Population 8	4.7	b	10	a
6	Ghour essal (Alm'amorah)	Population 9	10.93	f	22.07	ij
		Population 10	9.53	d	20.7	ghi
7	Al Tafilah (Senfha)	Population 11	3.73	a	22.27	ij
		Population 12	8.47	c	18.13	ef
		Population 13	12.33	g	31.3	l
		Population 14	8	c	19.8	gh
8	Jordan Valley (Alzzarah)	Population 15	17.7	i	19.3	fg
		Population 16	17.93	i	17.57	e
		Population 17	9.87	de	26.2	k
		Population 18	15.47	h	29.93	l
9	Ma'een (Humrat ma'een)	Population 19	8.3	c	30.5	l
		Population 20	14.93	h	23.13	j
10	AlAzraq (Wadi Alhazeem)	Population 21	10	de	10.53	a
		Population 22	26.2	k	15.63	d
		Population 23	9.5	d	25	k
11	AlKarak (Wadi Ibn Hammad)	Population 24	9.5	d	25.23	k

Table 4.12 Manganese and Ferrous content in fruit among the 24 studied populations.

4.2.2 Soil characteristics (Experiment II):

4.2.2.1 Soil moisture %:

Data analysis for the soil moisture percent showed significant differences within and among populations (Table 4.13). The population number eight had the highest percent mean (50.67 %) among all populations and population number twenty one was been the lowest percent mean (1.33 %).

On the other hand, when the locations had a comparison, Al Dabbeh recorded the highest average mean (50.67 %) while the lowest average percent was been at Wadi Al Hazeem (1.83 %) (Fig. 36).

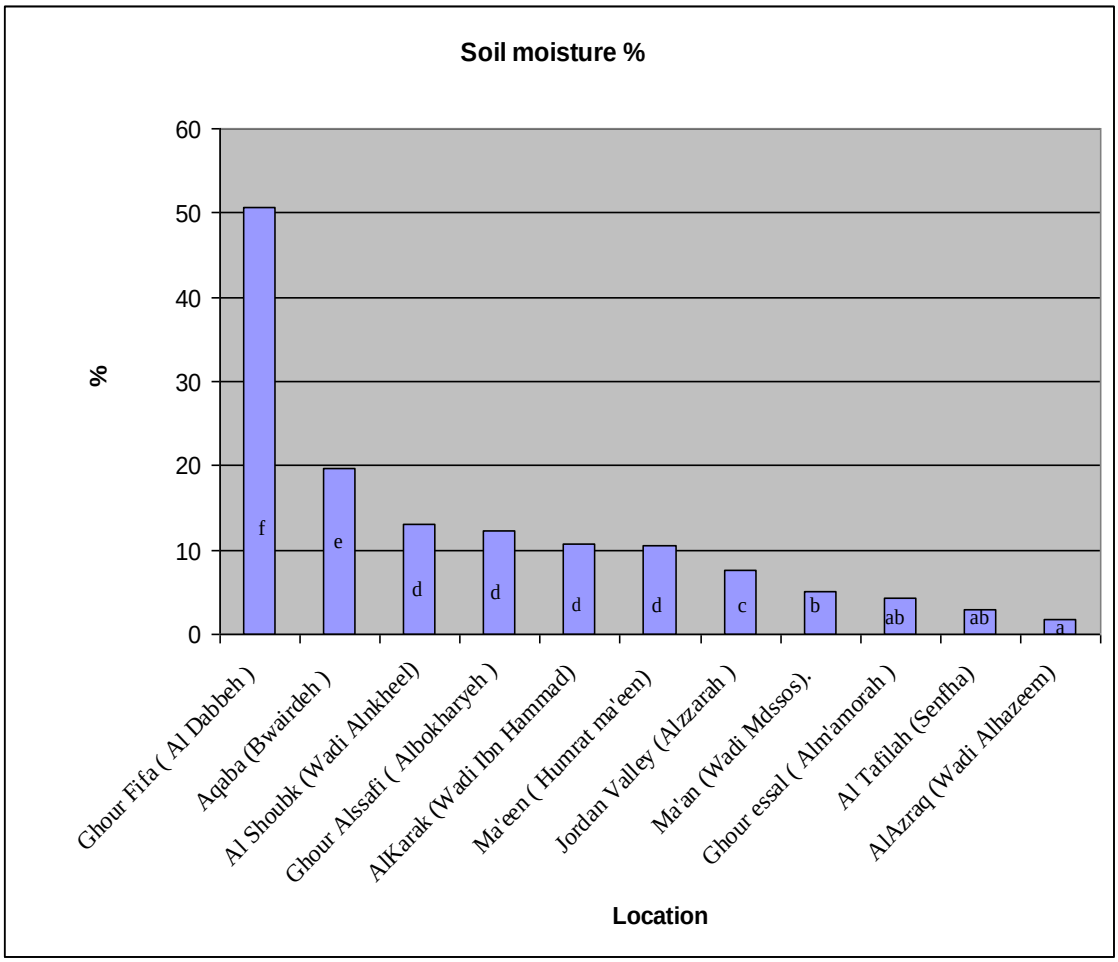


Fig (36). The average means and significantly differences of soil moisture content among locations under 0.05 LSD.

4.2.2.2 [Na+] in the soil:

Statistical analysis for Sodium concentration in the soil showed significant differences within and among populations (Table 4.13). Population number three had the highest concentration mean (542.4 meq/L), while the lowest concentration mean was recorded at number nine (2.8 meq/L).

Among the locations, Bwairdeh and Al M'amorah had the highest (295.4 meq/L) and lowest (2.8 meq/L) average mean respectively (Fig. 36).

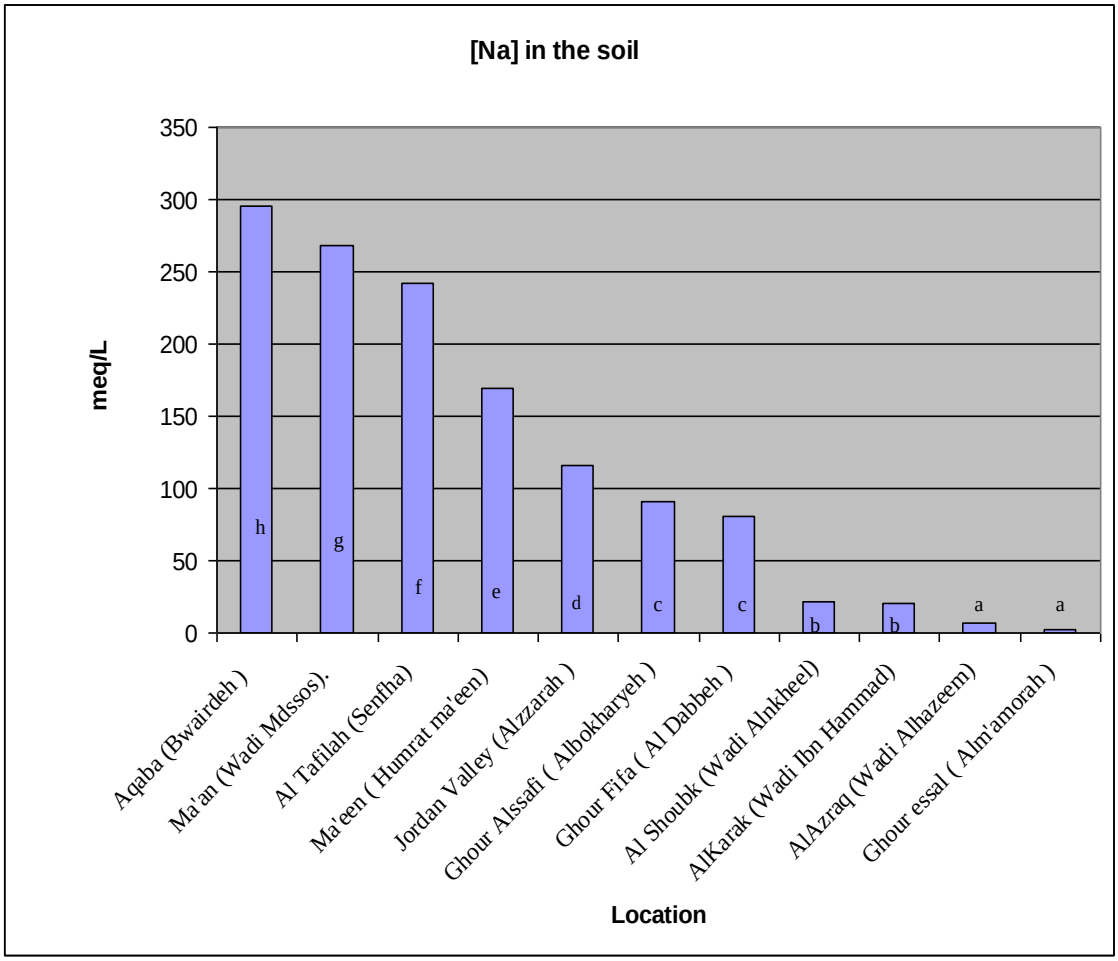


Fig (37). The average means and significantly differences of Sodium concentration in the soil among locations under 0.05 LSD.

4.2.2.3 [Cl-] in the soil:

There were large significant differences in Chlorine concentration in the soil within and among populations. Table 4.13 showed that the highest (747.5 meq/L) and lowest (2.7 meq/L) mean of concentration were recorded at population number three and nine respectively.

Bwairdeh and Al M'amorah were scored the highest (564.7 meq/L) and lowest (2.8 meq/L) average mean among the locations.(Fig. 38)

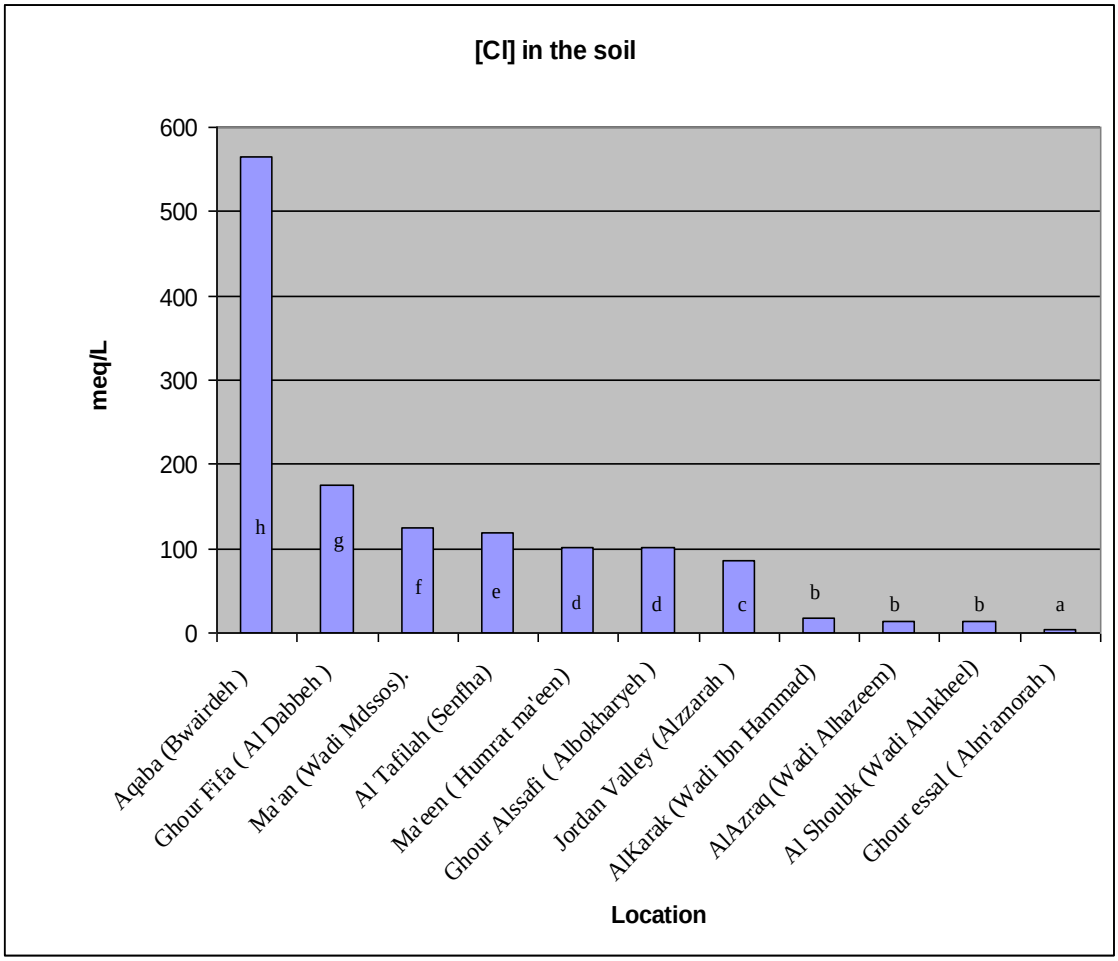


Fig (38). The average means and significantly differences of Chlorine concentration in the soil among locations under 0.05 LSD.

4.2.2.4 [CaCo3] in the soil:

Data analysis showed significant differences in Calcium carbonate concentration in the soil within and among the populations (Table 4.13). The highest mean percent (37.87 %) was recorded at population number six, while population number nineteen had the lowest mean (1.7 %).

At locations level, Al Bokharyeh got the highest percent mean (36.53 %) and the lowest average percent (3.9 %) was recorded at Senfha (Fig. 39).

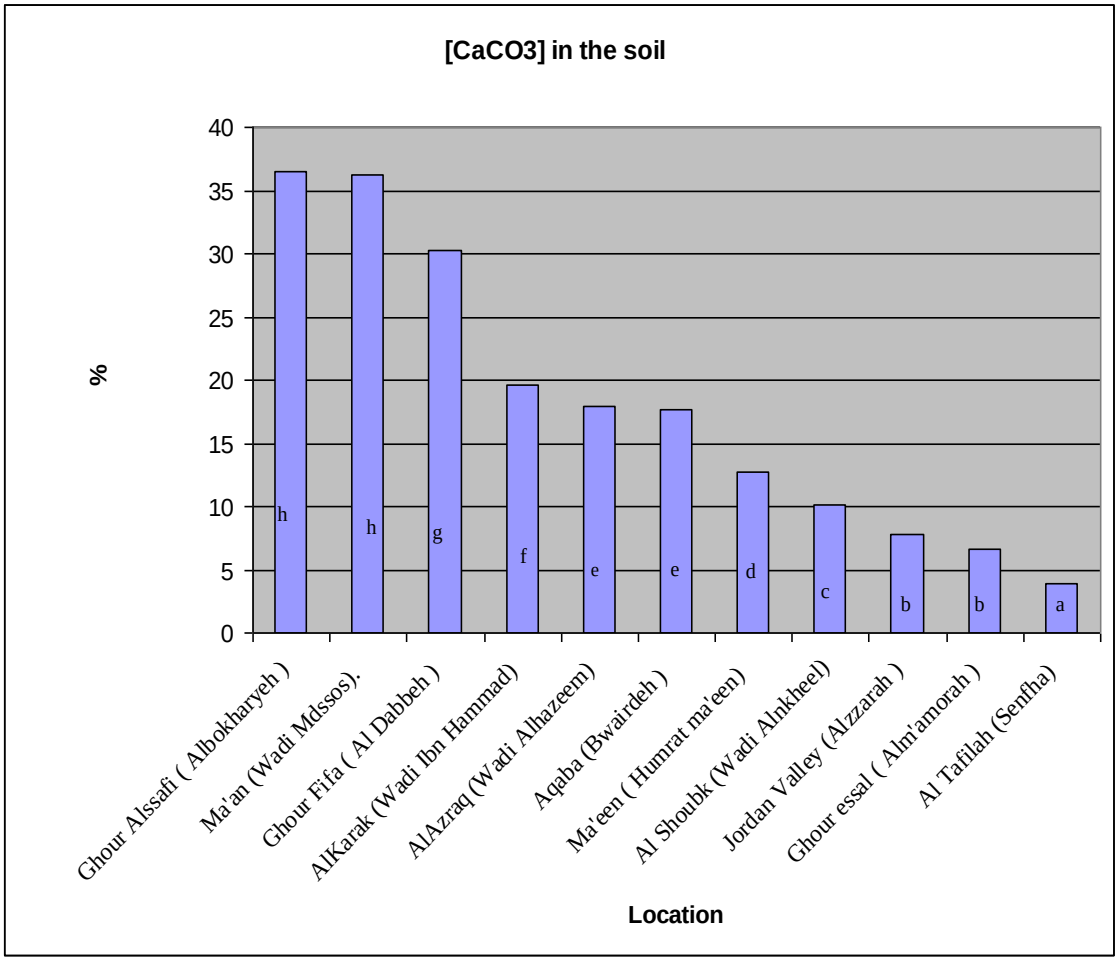


Fig (39). The average means and significantly differences of Calcium carbonate concentration in the soil among locations under 0.05 LSD.

Table 4.13 Moisture content, Sodium concentration, Chlorine concentration and total Calcium carbonate in soil samples among the 24 studied populations.

No.	Location	Population #	Soil Moist%		Soil Na		Soil Cl		Soil CaCo3	
		Population 1	10.67	def	127.1	g	249.2	n	19.57	fg
		Population 2	16.67	gh	216.6	i	697.5	o	18.3	f
1	Aqaba (Bwairdeh)	Population 3	31.67	i	542.4	m	747.5	p	15.3	e
2	Al Shoubk (Wadi Al Nkheel)	Population 4	13	efg	22	b	14.2	bc	10.07	d
		Population 5	4.67	abc	462.7	kl	151.7	j	34.47	jk
3	Ma'an (Wadi Mdssos).	Population 6	5.33	abc	74.4	de	97.5	h	37.87	l
4	Ghour Alssafi (Al Bokharyeh)	Population 7	12.33	defg	90.4	f	100.8	h	36.53	kl
5	Ghour Fifa (Al Dabbeh)	Population 8	50.67	j	80.9	ef	175.8	k	30.27	i
6	Ghour essal (Al M'amorah)	Population 9	4.33	abc	2.8	a	4.2	a	6.57	c
		Population 10	2.33	a	8.2	a	42.5	ef	4.17	b
7	Al Tafilah (Senfha)	Population 11	3.67	ab	474.7	l	194.2	l	3.63	ab
		Population 12	10.33	def	29.5	bc	48.3	f	7.03	c
		Population 13	12	def	22.5	b	47.5	f	6.53	c
		Population 14	4.67	abc	152.5	h	75.8	g	13.8	e
8	Jordan Valley (Alzzarah)	Population 15	3.67	ab	258.9	j	170.8	k	3.67	ab
		Population 16	5.33	abc	37.8	c	19.2	cd	6.57	c
		Population 17	18	h	122	g	119.2	i	13.53	e
		Population 18	8	bcd	67.4	d	37.5	e	29.33	i
9	Ma'een (Humrat ma'een)	Population 19	11	def	452.1	k	229.2	m	1.7	a
	AlAzraq	Population 20	2.33	a	6.9	a	20.8	cd	21.27	gh
10	(Wadi Alhazeem)	Population 21	1.33	a	7.5	a	8.3	ab	14.7	e
		Population 22	10	def	27.1	bc	22.5	cd	33	j
	AlKarak	Population 23	8.67	cde	31.6	bc	27.5	d	22.3	h
11	(Wadi Ibn Hammad)	Population 24	13.67	fgh	3.7	a	2.7	a	3.4	ab

4.2.2.5 Organic matter percent in the soil:

There were large significant differences in organic matter percent in the soil within and among populations. Table 4.14 showed that the highest (4.977 %) and lowest (0.033) mean of concentration were recorded at population number thirteen and fourteen respectively.

Among the locations, Al Dabbeh and Al M'amorah had the highest (4.1 %) and lowest (0.17%) average mean respectively (Fig. 40).

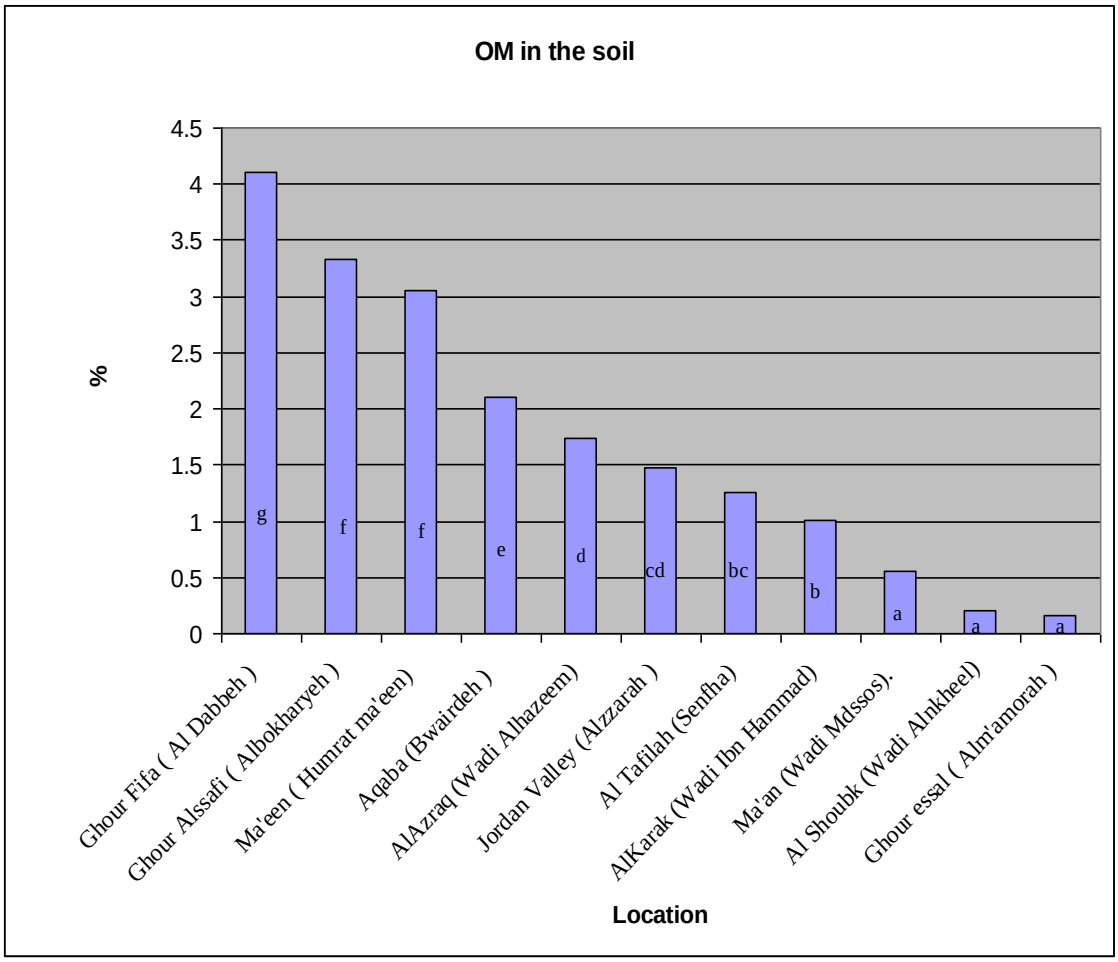


Fig (40). The average means and significantly differences of organic matter content in the soil among locations under 0.05 LSD.

4.2.2.6 Soil pH:

Statistical analysis for soil pH showed significant differences within and among populations. Table 4.14 illustrated that the highest mean value of pH (8.167) were recorded at population number nineteen while lowest mean (7.6) was scored at populations numbers seven and twenty.

According to the locations comparison; Wadi Al Nkheel was had the highest average mean (7.967) while Al Bokharyeh gave the lowest average mean (7.6) (Fig. 41).

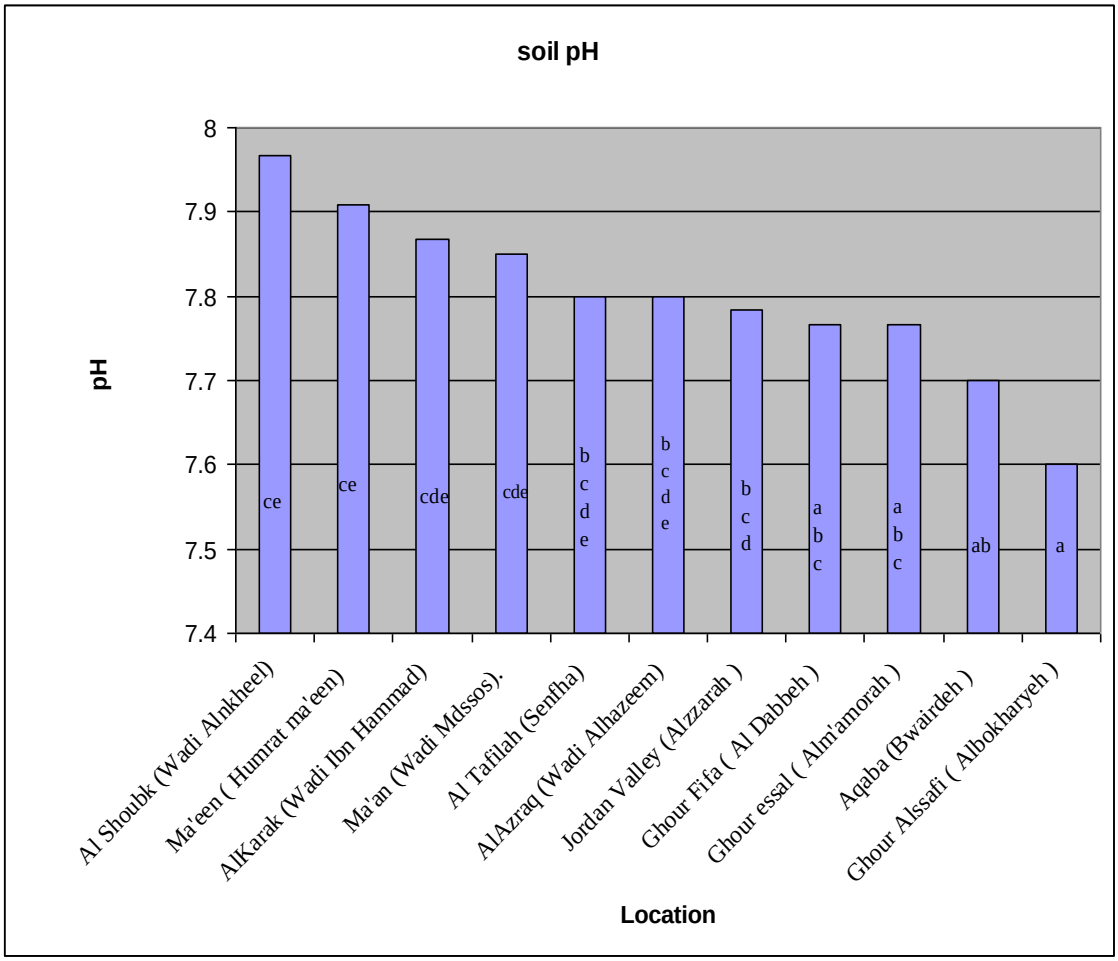


Fig (41). The average means and significantly differences of pH value in the soil among locations under 0.05 LSD.

4.2.2.7 Soil Electrical conductivity (EC):

Data analysis showed significant differences for soil electrical conductivity within and among populations. Table 4.14 showed that the highest mean value (121.6 ds/m) was been at population number three, while the shortest mean value(2.14 ds/m) was recorded at population number ten.

Bwairdeh had the highest average mean among the locations (96.82 ds/m) while AlM'amorah scored the lowest average mean of EC (2.88) (Fig.42).

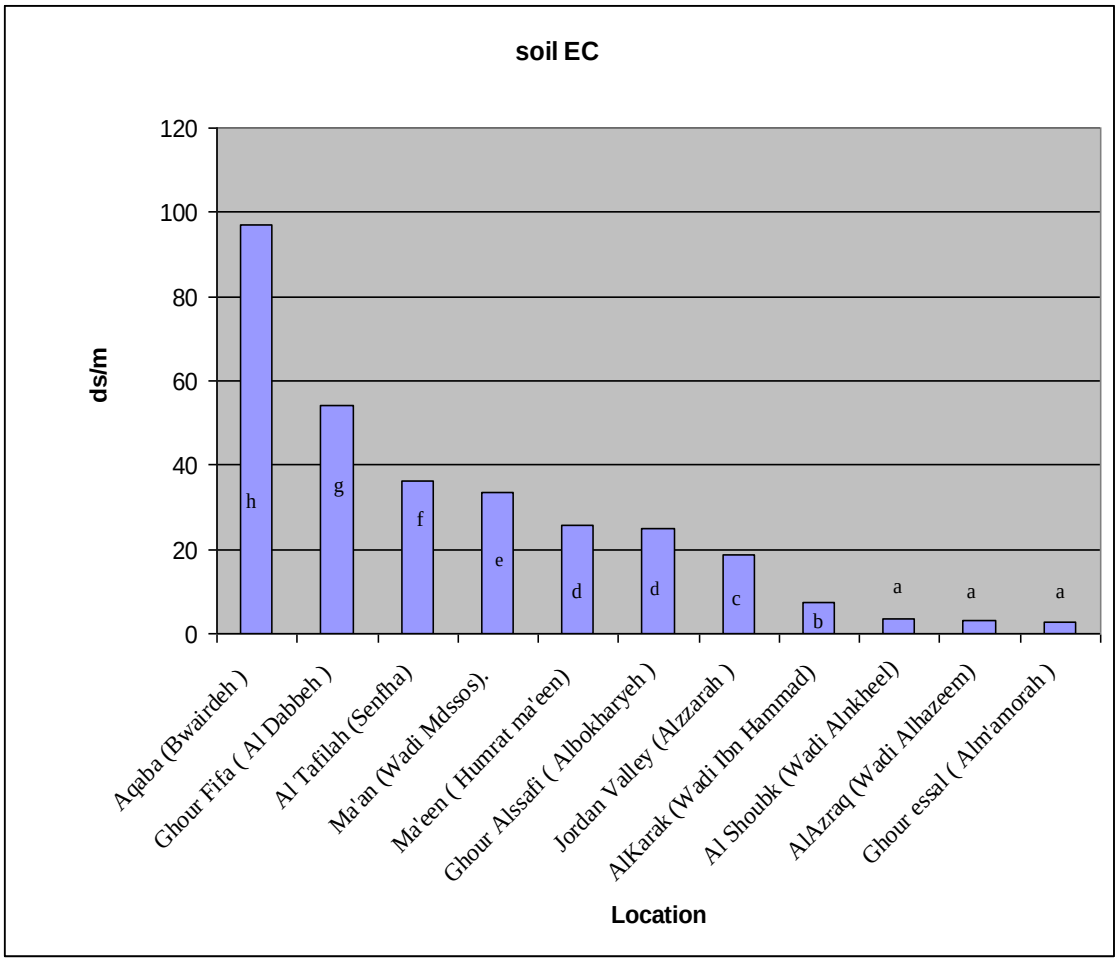


Fig (42). The average means and significantly differences of soil electrical conductivity among locations under 0.05 LSD.

Table 4.14 Organic matter percent, pH value and electrical conductivity in soil samples among the 24 studied populations.

No.	Location	Population #	Soil OM%		Soil Ph		Soil EC	
		Population 1	3.467	gh	7.633	ab	66.83	n
		Population 2	1.067	de	7.7	abc	102.03	p
1	Aqaba (Bwairdeh)	Population 3	1.8	f	7.767	abcde	121.6	q
2	Al Shoubk (Wadi Al Nkheel)	Population 4	0.2	a	7.967	defg	3.67	abcd
		Population 5	0.567	abcd	7.767	abcde	50.47	k
3	Ma'an (Wadi Mdssos).	Population 6	0.533	abcd	7.933	cdefg	16.3	h
4	Ghour Alssafi (Al Bokharyeh)	Population 7	3.333	gh	7.6	a	25	i
5	Ghour Fifa (Al Dabbeh)	Population 8	4.1	i	7.767	abcde	54.3	l
6	Ghour essal (Al M'amorah)	Population 9	0.167	a	7.767	abcde	2.88	ab
		Population 10	0.467	abc	7.833	abcdef	2.14	a
7	Al Tafilah (Senfha)	Population 11	2.033	f	7.767	abcde	70.37	o
		Population 12	0.3	ab	7.733	abcd	6.57	e
		Population 13	0.033	a	7.767	abcde	5.01	bcde
		Population 14	4.977	j	7.867	bcdef	25.7	i
8	Jordan Valley (Al Zzarah)	Population 15	6.9	k	7.767	abcde	38.3	j
		Population 16	0.8	bcd	7.933	cdefg	5.27	cde
		Population 17	3.733	hi	7.733	abcd	26.2	i
		Population 18	0.567	abcd	7.8	abcdef	8.97	f
9	Ma'een (Humrat Ma'een)	Population 19	0.8	bcd	8.167	g	62.4	m
		Population 20	2.9	g	7.6	a	3.33	abcd
10	AlAzraq (Wadi Al Hazeem)	Population 21	0.567	abcd	8	efg	3.07	abc
		Population 22	1.033	cd	7.767	abcde	5.57	de
		Population 23	1.633	ef	7.8	abcdef	12.43	g
11	AlKarak (Wadi Ibn Hammad)	Population 24	0.367	ab	8.033	fg	4.7	bcde

4.3 Phenotypic parameters correlations:

The correlation coefficients among the phenotypic parameters were conducted and presented in Table (5). The correlation revealed a three significantly level among the phenotypic parameters; highly significantly correlation (at less than 0.001level), low significantly correlations (at 0.05) and no significant correlation.

Tree height had low significantly correlation with spine width at the mid, fruit weight, flesh weight, fruit length and K% in the fruit, while it had no significant correlation with other phenotypic parameters.

Most of the morphological characters had highly correlation among them; also it had high significant correlation with TSS % in fruit, while the other physical and chemical properties of the fruit were not shown any correlation with the morphological parameters.

Fruit weight observed a strong correlation with flesh weigh, fruit length and fruit diameter, while it had low significant correlation with seed weight and K%. Flesh and seed weight appeared significant correlation with fruit length and diameter. The other physical and chemical parameters of the fruit not had shown any correlations among each other.

Table 5. Significantly correlations among the phenotypic parameters.

Trunk girth	--			
Leaf L.	--	--		
Midrib L.	--	--	**	
P. part L.	--	--	**	**
S. part L.	--	--	**	**
% of spine at midrib	--	--	**	**
% of spine at whole	--	--	**	**
Petiole W.	--	--	**	**
Spine No.	--	--	**	**
S. density/cm	--	--	**	**
S. L. at mid	--	--	**	**
S. W. at mid	*	--	--	--
Pinnaes No.	--	--	**	**
P. density/cm	--	--	--	*
P.L. at mid	--	--	**	**
P.L. at top	--	--	*	*
Fruit wt	*	--	--	--
Flesh wt	*	--	--	--
Seed wt	--	--	--	--
Fruit L.	*	--	--	--
Fruit D.	--	--	--	--
Fruit pH	--	--	--	--
Fruit moisture%	--	--	--	--
TSS %	--	--	**	**
K %	*	--	--	--
Mg %	--	--	--	--
Mn	--	--	--	--
Fe	--	--	--	--
	Tree height	Trunk girth	Leaf L.	Midrib L.

- * : Correlated significantly under 0.05 level.
- ** : Correlated significantly under 0.001 level.
- --: No correlation

Table 5. Continued.

S. part L.	**			
% of spine at midrib	**	**		
% of spine at whole	**	**	**	
Petiole W.	**	**	**	**
Spine No.	**	**	**	**
S. density/cm	**	**	**	**
S. L. at mid	**	**	**	**
S. W. at mid	--	--	--	--
Pinnaes No.	**	**	**	**
P. density/cm	--	**	**	**
P.L. at mid	**	**	**	**
P.L. at top	--	**	**	**
Fruit wt	--	--	--	--
Flesh wt	--	--	--	--
Seed wt	--	--	--	--
Fruit L.	--	--	--	--
Fruit D.	--	--	--	--
Fruit pH	--	--	--	--
Fruit moisture%	--	--	--	--
TSS %	**	**	**	**
K %	--	--	--	--
Mg %	--	--	--	--
Mn	--	--	--	--
Fe	--	--	--	--
	P. part L.	S. part L.	% of spine at midrib	% of spine at whole

- * : Correlated significantly under 0.05 level.
- ** : Correlated significantly under 0.001 level.
- --: No correlation

Table 5. Continued.

Spine No.	**			
S. density/cm	**	**		
S. L. at mid	**	**	**	
S. W. at mid	--	--	--	--
Pinnaes No.	**	**	**	**
P. density/cm	**	**	*	**
P.L. at mid	**	**	**	**
P.L. at top	**	**	*	**
Fruit wt	--	--	--	--
Flesh wt	--	--	--	--
Seed wt	--	--	--	--
Fruit L.	--	--	--	--
Fruit D.	--	--	--	--
Fruit pH	--	--	--	--
Fruit moisture%	--	--	--	--
TSS %	**	**	**	**
K %	--	--	--	--
Mg %	--	--	--	--
Mn	--	--	--	--
Fe	--	--	--	--
	Petiole W.	Spine No.	S. density /cm	S. L. at mid

- * : Correlated significantly under 0.05 level.
- ** : Correlated significantly under 0.001 level.
- --: No correlation

Table 5. Continued.

Pinnaes No.	--			
P. density/cm	--	**		
P.L. at mid	--	**	*	
P.L. at top	--	**	**	*
Fruit wt	--	--	--	--
Flesh wt	--	--	--	--
Seed wt	--	--	--	--
Fruit L.	--	--	--	--
Fruit D.	--	--	--	--
Fruit pH	--	--	--	--
Fruit moisture%	--	--	--	--
TSS %	--	**	--	**
K %	--	--	--	--
Mg %	--	--	--	--
Mn	--	--	--	--
Fe	--	--	--	--
	S. W. at mid	Pinnaes No.	P. density /cm	P.L. at mid

Fruit wt	--			
Flesh wt	--	**		
Seed wt	--	*	*	
Fruit L.	--	**	**	*
Fruit D.	--	**	**	**
Fruit pH	--	--	--	*
Fruit moisture%	--	--	--	--
TSS %	--	--	--	--
K %	--	*	*	--
Mg %	--	--	--	--
Mn	--	--	--	--
Fe	--	--	--	--
	P.L. at top	Fruit wt	Flesh wt	Seed wt

- * : Correlated significantly under 0.05 level.
- ** : Correlated significantly under 0.001 level.
- --: No correlation

Table 5. Continued.

Fruit D.	**			
Fruit pH	--	--		
Fruit moisture%	--	--	--	
TSS %	--	--	--	--
K %	*	*	--	--
Mg %	--	--	--	--
Mn	--	--	--	--
Fe	--	--	--	--
	Fruit L.	Fruit D.	Fruit pH	Fruit moisture %

K %	--			
Mg %	--	--		
Mn	--	--	--	
Fe	--	*	--	--
	TSS %	K %	Mg %	Mn

- * : Correlated significantly under 0.05 level.
- ** : Correlated significantly under 0.001 level.
- --: No correlation

4.4 Clustering analysis according to phenotypic traits:

Means of thirty three phenotypic parameters (qualitative and quantitative) were used as markers under Genstat version (16.1) to cluster the population. Cluster analysis was used to generate a dendogram based (Nei, 1978) genetic distance by using: Unweighted Pair Group Method with Arithmetic Mean (UPGMA) (Fig. 43). The cluster divided the populations into four groups under coefficient 80 %. Group one composed of two populations of Senfha locations (pop 10 and pop 11). Group two included ten populations distributed at six locations ; populations number two and three at Bwairdeh, population number five at Wadi Mdssos, populations fourteen and fifteen at Al Zzarah , population eighteen at Humrat Ma'een, population number twenty one at Al Azraq and finally population numbers twenty two , twenty three and twenty four at Wadi Ibn Hammad locations. Group three contained two populations at AlZzarah location (Population number twelve and thirteen). Group four included ten populations distributed at eight locations; population number one at Bwairdeh, population number four at Wadi Al Nakheel, population number six at Wadi Mdssos, population seven at Al Bokharyeh, population eight at Al Dabbeh, population nine at Al M'amorah , populations number sixteen, seventeen and ninteen at Humrat Ma'een and finally population number twenty at Al Azraq location.

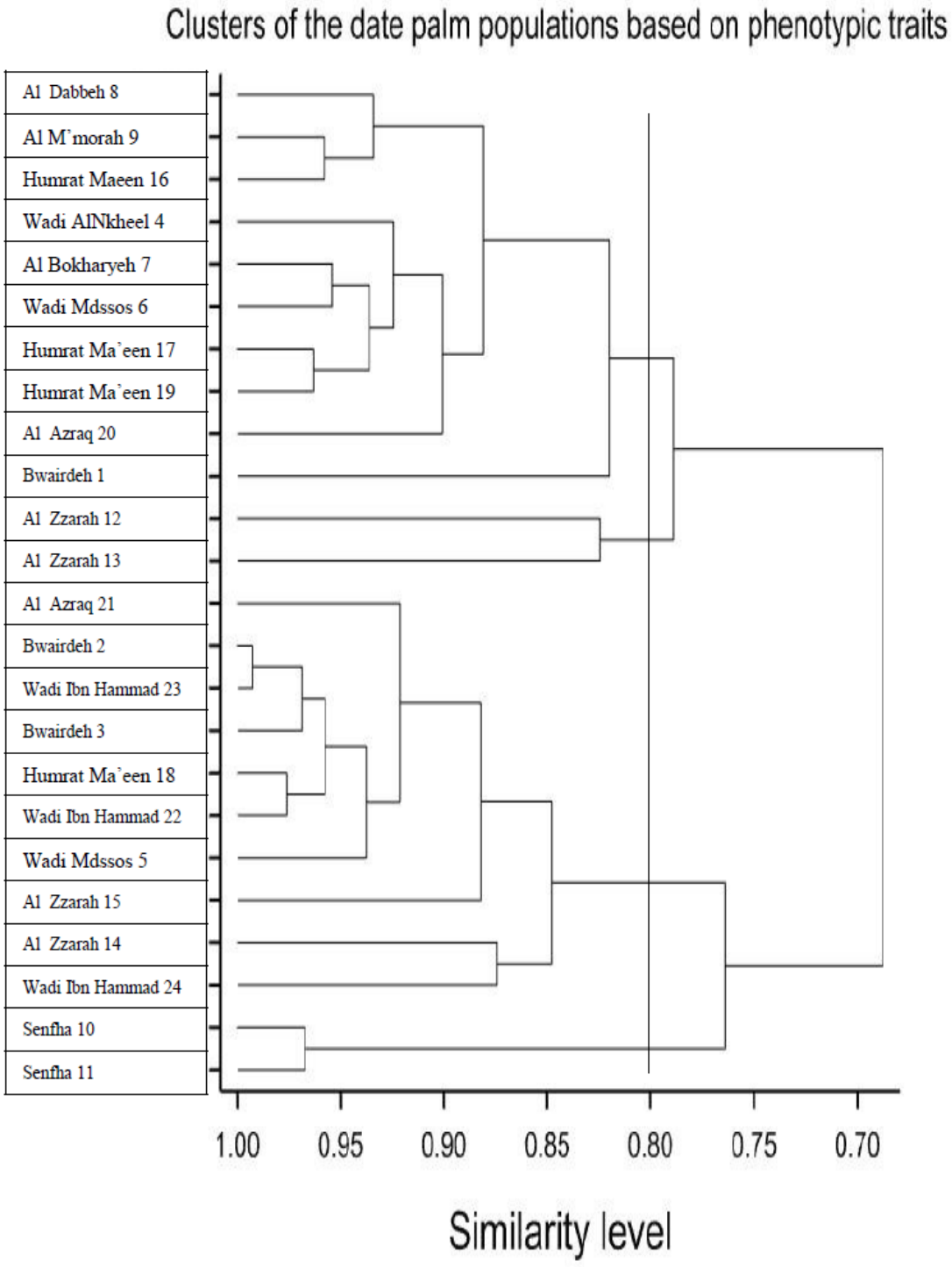


Fig. 43. Dendogram for 24 populations based on thirty three phenotypic parameters.

4.5 Interaction among phenotypic parameters, soil characteristics and climatic data (Models):

Correlation coefficient of phenotypic parameters with geographic site information and climatic data were conducted for the twenty four populations and presented in Table 6. The correlation coefficient revealed positive or negative significant association among the studied parameters.

Fruit weight, flesh weight, seed weight and fruit length were negatively correlated with the maximum temperature at February. The percent of spine at midrib part was affected negatively with minimum temperature at February, maximum temperature at March and Sodium concentration in the soil, while the percent of spine at whole leaf was had a negative correlation with minimum temperature at February and Sodium concentration in the soil.

Potassium and ferrous concentration in the fruit were negatively affected by precipitation at February. Also the spine part length was correlated negatively with maximum temperature at April and Sodium concentration in the soils.

The Sodium concentration in the soil was had the majority correlation with the other parameters, it had negative effect on Fruit TSS, leaf length, midrib length, pinnae part length, petiole width, pinnae number and pinnae length at mid, while it had a positive effect on the spine number, spine density per cm and spine length at mid.

Chlorine concentration in the soil was affected positively on the concentration of Manganese in the fruit. Organic matter percent had negatively correlation with Magnesium concentration in the fruit, pinnae number, pinnae density per cm, pinnae length at the top, while it had a positive correlation with spine length at the mid. Soil electrical conductivity wad had positively affect on the spine number.

Table 6. Significantly correlation among phenotypic parameters with soil characteristics and climatic data

	Maximum Temp Feb	Minimum Temp Feb	Precipitation Feb	Maximum Temp Mar	Maximum Temp Apr	[Na] in Soil	[Cl] in Soil	OM% in Soil	Soil EC
Fruit Wt	- ve**	-	-	-	-	-	-	-	-
Flesh Wt	- ve**	-	-	-	-	-	-	-	-
Seed Wt	- ve**	-	-	-	-	-	-	-	-
Fruit Length	- ve**	-	-	-	-	-	-	-	-
Fruit Diameter	- ve**	-	-	-	-	-	-	-	-
Fruit TSS%	-	-	-	-	-	- ve**	-	-	-
Fruit K%	-	-	- ve**	-	-	-	-	-	-
Fruit Mg%	-	-	-	-	-	-	-	- ve**	-
Fruit Mn	-	-	-	-	-	-	+ ve*	-	-
Fruit Fe	-	-	- ve**	-	-	-	-	-	-
Leaf Length	-	-	-	-	-	- ve**	-	-	-
Midrib length	-	-	-	-	-	- ve**	-	-	-
Pinnae part length	-	-	-	-	-	- ve**	-	-	-
Spine part length	-	-	-	-	- ve**	- ve**	-	-	-
% of spine midrib	-	- ve**	-	-ve*	-	- ve**	-	-	-
% of spine leaf	-	- ve**	-	-	-	- ve**	-	-	-
leaf width at base	-	-	-	-	-	- ve**	-	-	-
Spine number	-	-	-	-	-	+ ve*	-	-	+ ve*
Spine Density/Cm	-	-	-	-	-	+ ve*	-	-	-
Spine length at mid	-	-	-	-	-	+ ve*	-	+ ve*	-
Pinnae number	-	-	-	-	-	- ve**	-	- ve**	-
Pinnae Density/Cm	-	-	-	-	- ve**	-	-	- ve**	-
Pinnae length at mid	-	-	-	-	-	- ve**	-	-	-
Pinnae length at top	-	-	-	-	-	-	-	- ve**	-

- * : Correlated significantly under 0.05 level.
- ** : Correlated significantly under 0.001 level.
- - ve: negative correlation.
- + ve: positive correlation.
- - : No correlation

4.6 Genetic assessment (Experiment III).

Twelve primer pairs of genomic DNA markers were used to assess the genetic diversity of seventy three genotypes (seventy two for the collected wild date palm and one for Medjool cultivar). The primers name, sequence information, repeat motifs, allele size and status of amplification are shown in Table 7.

The results indicate that eleven of twelve markers generate polymorphic banding pattern at expected size and the other was showed amplified monomorphic banding patterns (Fig. 44). The microsatellite examined thirty four polymorphic alleles with a mean of 3.09 alleles per locus were scored, however, the number of alleles varied between two in primers DP 159, DP168 and DP172 and four in primers DP 151, DP 157, DP171 and DP175. (Table 8). The eleven polymorphic primers produced SSR band sizes ranging from 140 bp (marker DP157) to 324 bp (marker 151).

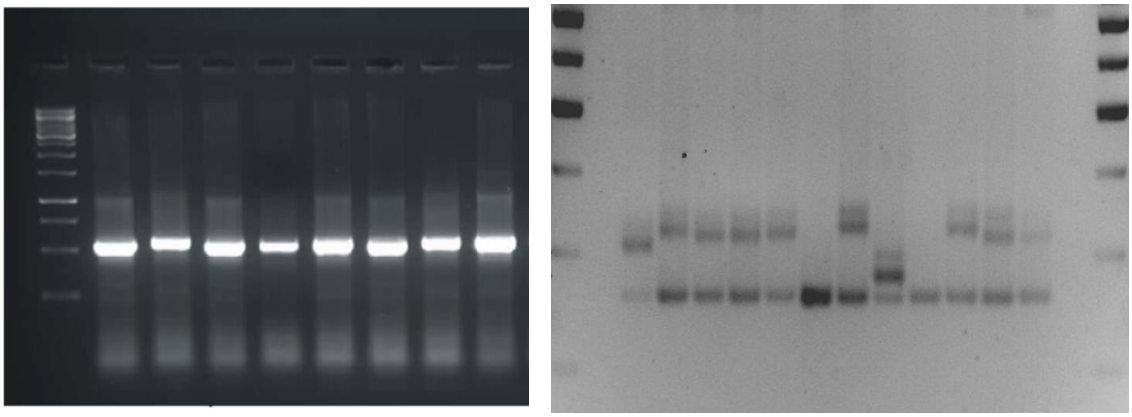
The eleven SSR markers tested in this study formed mean of 30.27 genotypes numbers, however, the highest were fifty six of seventy three genotypes scored in marker DP 151, on the other hand, only nineteen different genotypes was renewed in marker DP 168. The mean of gene diversity was ranging from 0.24 (for DP 168 marker) to high diversity 0.5 (for DP 151marker). The heterozygosity was 0.52 % and the average allele frequency was 0.24 ranging from 0.14 in marker DP 168 to 0.52 in marker DP 151. Similarly, the polymorphism information content PIC value which is commonly used in genetics as measure of polymorphism for marker locus used in linkage analysis, ranged between 0.21 in DP 168 to 0.68 in DP151 and DP157.

Table 7. Forward and reverse primer sequences, repeat motifs and expected sizes of microsatellite loci and its status of amplification of SSR loci of date palm.

No.	Primer name		Primer's sequence	Expected size	Motif repeat	Status of amplification
1.	DP 151	F	TTGCTGGTTGAAATGGTGTT	267-324	(AC) 37	Polymorphic
		R	GCAACAGATGCTCTTGCTCA			
2.	DP 157	F	TGGACAATGACACCCCTTTT	140-175	(TC) 19	Polymorphic
		R	GCCCACACAACAACCTCTCT			
3.	DP 159	F	AGCTCCAATTTGCTGCAGAG	140-150	(TC) 27	Polymorphic
		R	GCTGACCTGGAGTCCAAAAC			
4.	DP 160	F	AAGAGCGACAATCATGACCA	209-212	(GAAA) 5	Monomorphic
		R	GGAAATTGAAGGGCATCTTG			
5.	DP 168	F	GCAGCAAAGCCCTTAGGC	220-226	(CAT) 8	Polymorphic
		R	GGTGTTATGTGCAGCCAATG			
6.	DP 169	F	GCATGGACTTAATGCTGGGTA	209-216	(ATT) 12	Polymorphic
		R	GGTTTTCCTGCCAACAACAT			
7.	DP 170	F	TCTTTGGGCTTACGACAACC	221-226	(AGGG) 5	Polymorphic
		R	GTATGGCCCAAGATGCAGAT			
8.	DP 171	F	GTGGGAGTAGCGAGGTATGG	206-239	(TTC) 10	Polymorphic
		R	GTCCGGCACTTTAGGAAGTT			
9.	DP 172	F	GGTGTTTGGGCCTATTTCCT	223-228	(AGG) 11	Polymorphic
		R	GTCCTCCTCCTCCTCTGTCC			
10.	DP 175	F	ACACACACACACACACACCC	213-224	(CA) 19	Polymorphic
		R	GTGGCTTCTTTTTGGCTGTC			
11.	DP 176	F	GCCATTAACGAAATGGCTTG	227-237	(CAA) 9	Polymorphic
		R	GTTTGCACATAGCGTTCAA			
12.	DP 177	F	TTCCTTGGGCTCACTTCAAC	227-241	(AGGC) 6	Polymorphic
		R	TAACATGCCAGCAAAGGTGA			

Table 8. Genetic biodiversity information of wild date palm using SSR markers

Marker	Gene frequency	Genotype No.	Allele frequency		Allele No.	intralocus gene diversity	Heterozygosity	PIC
DP 151	0.77	56	0.48	0.52	4	0.50	0.73	0.68
DP 157	0.63	46	0.61	0.39	4	0.48	0.73	0.68
DP 159	0.27	20	0.85	0.15	2	0.26	0.38	0.3
DP 168	0.26	19	0.86	0.14	2	0.24	0.24	0.21
DP 169	0.38	28	0.79	0.21	3	0.33	0.57	0.5
DP 170	0.27	20	0.85	0.15	3	0.26	0.49	0.42
DP 171	0.48	35	0.72	0.28	4	0.40	0.67	0.62
DP 172	0.41	30	0.77	0.23	2	0.35	0.5	0.38
DP 175	0.45	33	0.74	0.26	4	0.38	0.64	0.58
DP 176	0.29	21	0.84	0.16	3	0.27	0.27	0.24
DP 177	0.35	25	0.81	0.19	3	0.31	0.53	0.47
Mean	**0.41**	**30.27**	**0.76**	**0.24**	**3.09**	**0.34**	**0.52**	**0.46**
SD	**0.16**	**11.27**	**0.11**	**0.11**	**0.79**	**0.09**	**0.16**	**0.16**



Primer DP 160 Primer DP 151

Fig.44. Markers amplified monomorphic and polymorphic banding patterns at expected size

4.6.1 Clustering analysis according to the genotypes:

In order to represent the relationships among populations, cluster analysis was used to generate a dendogram based on Nei (1978), by using UPGMA. A similarity matrix among the wild date palm showed an average similarity coefficient ranging from 0.60 to 1.00. The highest similarity coefficient value was observed among Ma'een populations also at Al Zzarah populations (1.0) (Fig.45).

Each collected accession was named according to the location name, population number and tree number, the name of location that sampled in it, the first number represent the population number that collected and the another number was for number of the tree that collected. (Table 9)

Table 9. Each sampled tree had name according to their location and population

1	Ma'een16.47	20	Alzzarah12.36	39	Mdsoos5.17	58	Bwairdeh2.6
2	Ma'een17.50	21	Alzzarah13.38	40	Mdsoos5.18	59	Mdsoos5.13
3	Alzzarah15.43	22	Ibnhammad22.65	41	Aldabbeh8.22	60	Mdsoos5.14
4	Alzzarah15.44	23	Ma'een16.46	42	Alzzarah13.37	61	Aldabbeh8.24
5	Alzzarah15.45	24	Ibnhammad22.64	43	Alzzarah12.34	62	Mdsoos5.16
6	Ma'een17.51	25	Bwairdeh2.4	44	Alzzarah12.35	63	Aldabbeh8.23
7	Ma'een18.53	26	Alnkheel4.12	45	Alzzarah13.39	64	Albokharyeh7.19
8	Alzzarah14.41	27	Alnkheel4.10	46	Ibnhammad23.67	65	Albokharyeh7.21
9	Ma'een17.49	28	Alma'morah9.25	47	Ibnhammad24.71	66	Albokharyeh7.20
10	Ma'een18.52	29	Alma'morah9.26	48	Ibnhammad23.68	67	Alazraq20.58
11	Ma'een18.54	30	Alma'morah9.27	49	Ibnhammad24.70	68	Alazraq20.59
12	Alzzarah14.40	31	Senfha10.28	50	Ibnhammad23.69	69	Alazraq20.60
13	Ma'een16.48	32	Senfha11.32	51	Ibnhammad22.66	70	Alazraq20.61
14	Bwairdeh2.5	33	Senfha10.29	52	Bwairdeh1.1	71	Alazraq20.62
15	Ma'een19.57	34	Senfha10.30	53	Bwairdeh1.3	72	Alazraq20.63
16	Alzzarah14.42	35	Senfha11.31	54	Bwairdeh1.2	73	Medjool
17	Ibnhammad24.72	36	Senfha11.33	55	Bwairdeh3.7		
18	Ma'een19.55	37	Mdsoos5.15	56	Bwairdeh3.9		
19	Ma'een19.56	38	Alnkheel4.11	57	Bwairdeh3.8		

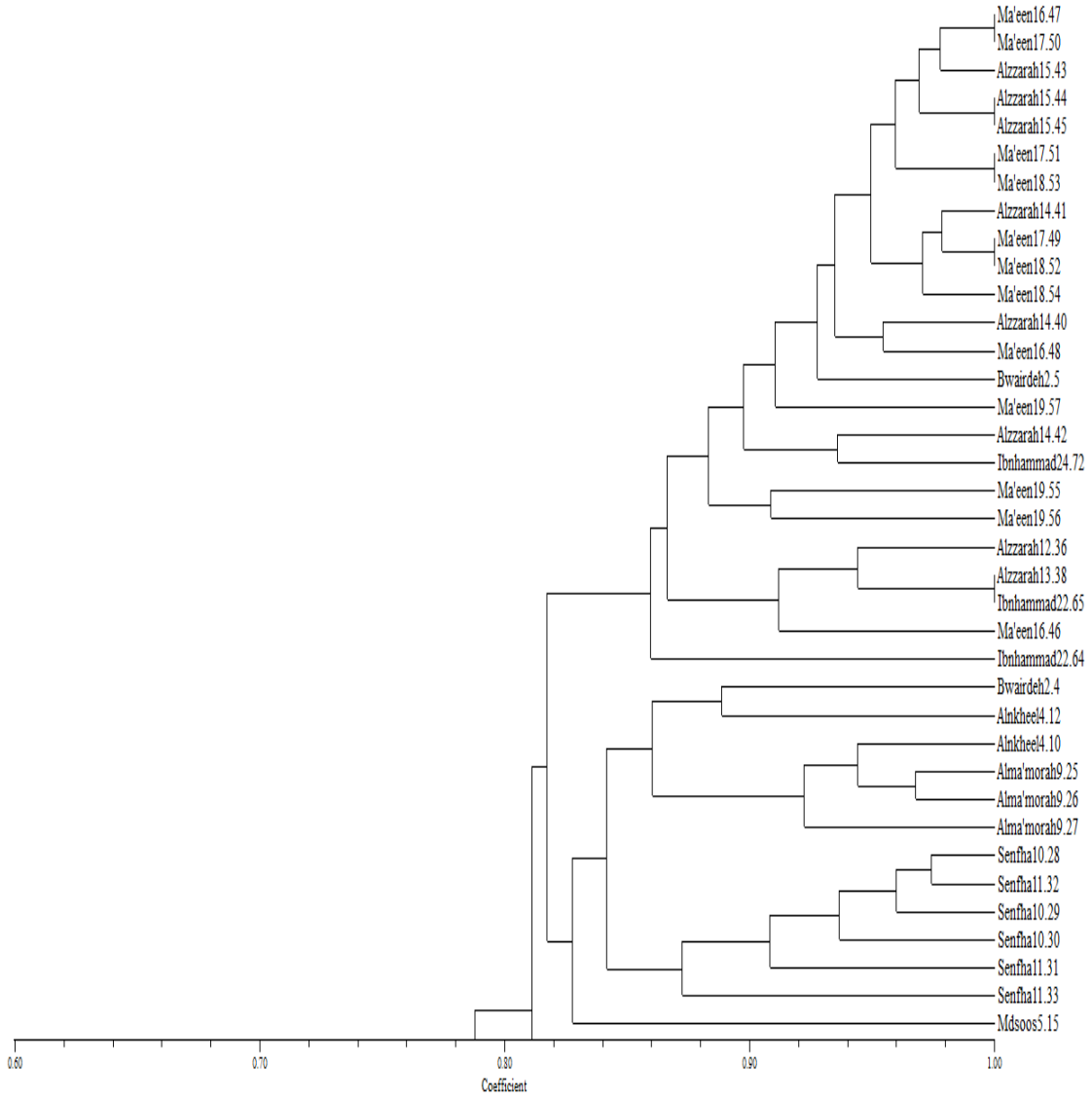


Fig.45. A dendogram showing the clustering of all wild date palm based on molecular aspect (SSR) markers.

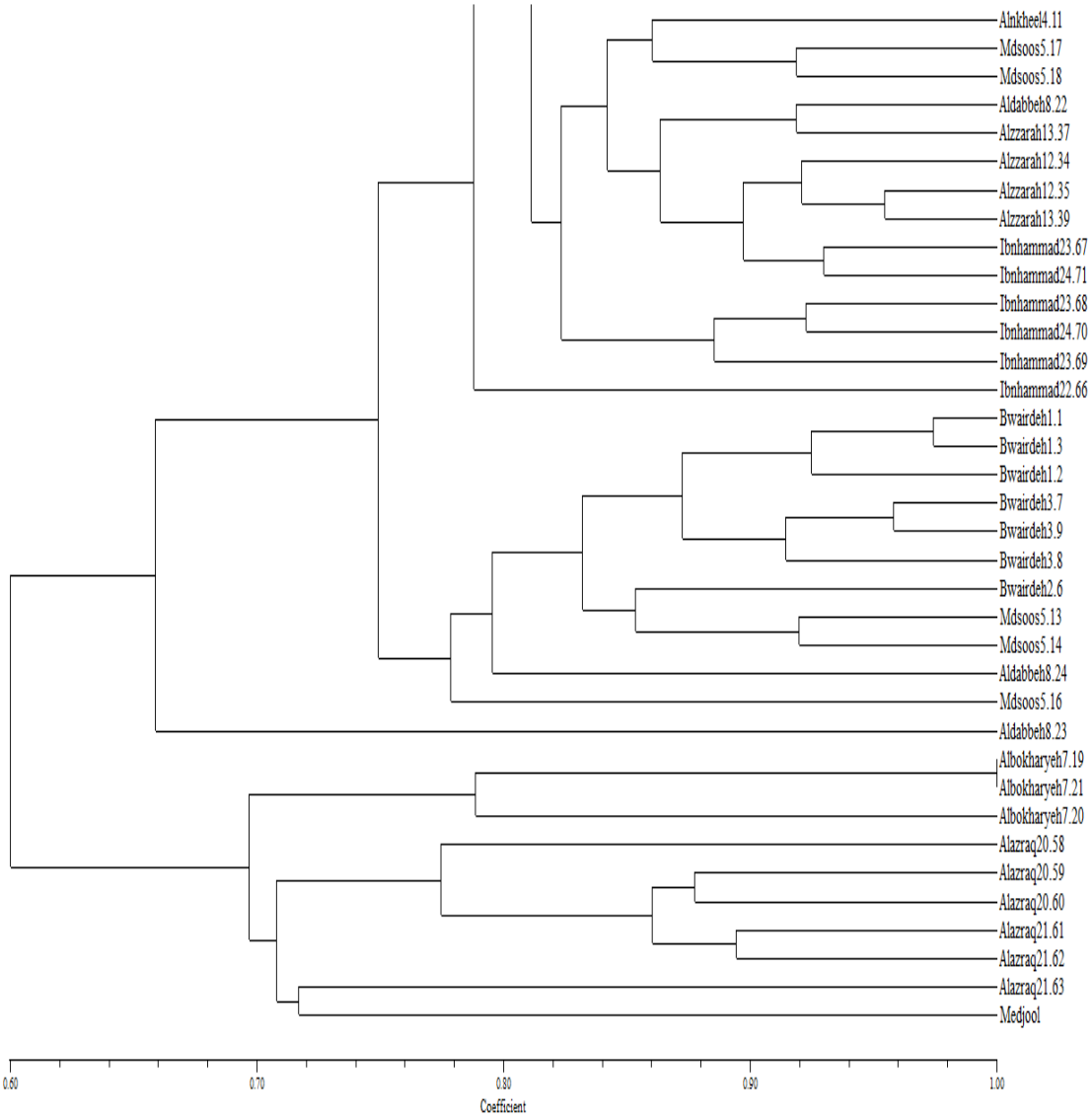


Fig.45. Continued.

4.6.2 Population structure:

The data of twelve markers were used to analyze the population structure of the wild date palm accessions by using the Structure software (Reference). The natural logarithm of the probability of the data, proportional to the posterior probability of Delta K was highest at K = 2 (Fig. 46). These results suggest that the analyzed of wild date palm in Jordan can be divided into two genetically distinct groups (Fig. 47 and 48). Medjool cultivar was classified with group number two that contain Bwairdeh, Wadi Mdssos, Al Dabbeh, Al Bokharyeh, and Al Azraq locations, while the other locations were grouped together with group number one.

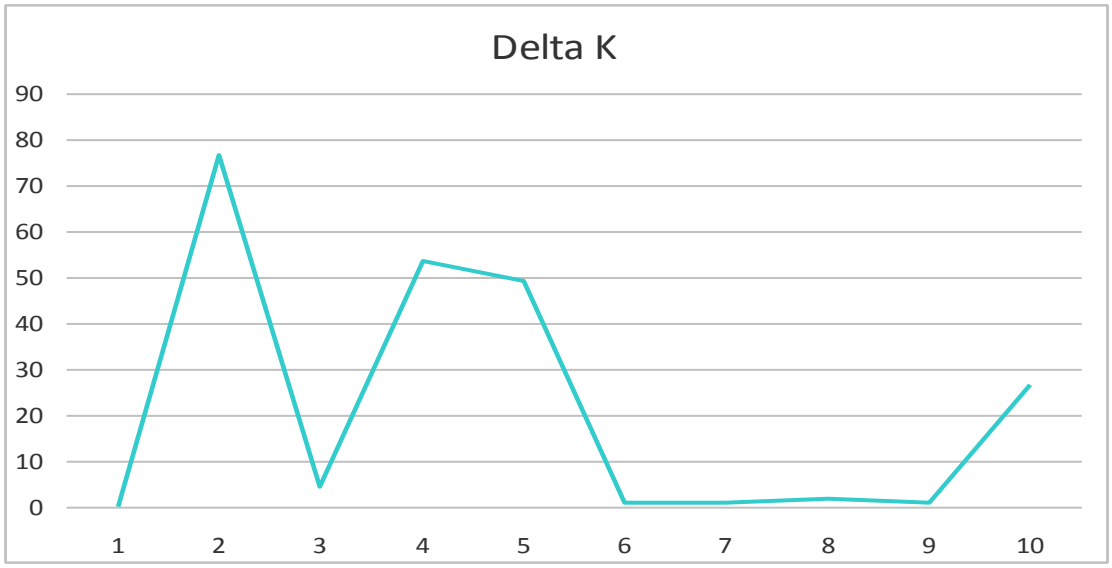


Fig.46. Estimation of the most probable number of clusters (K), based on 20 independent runs and K ranging from 1 to 10 by using magnitude of ΔK for each K value. Population structure assignment at K = 2 for (72 wild date palm + 1 date palm cultivar Medjool).

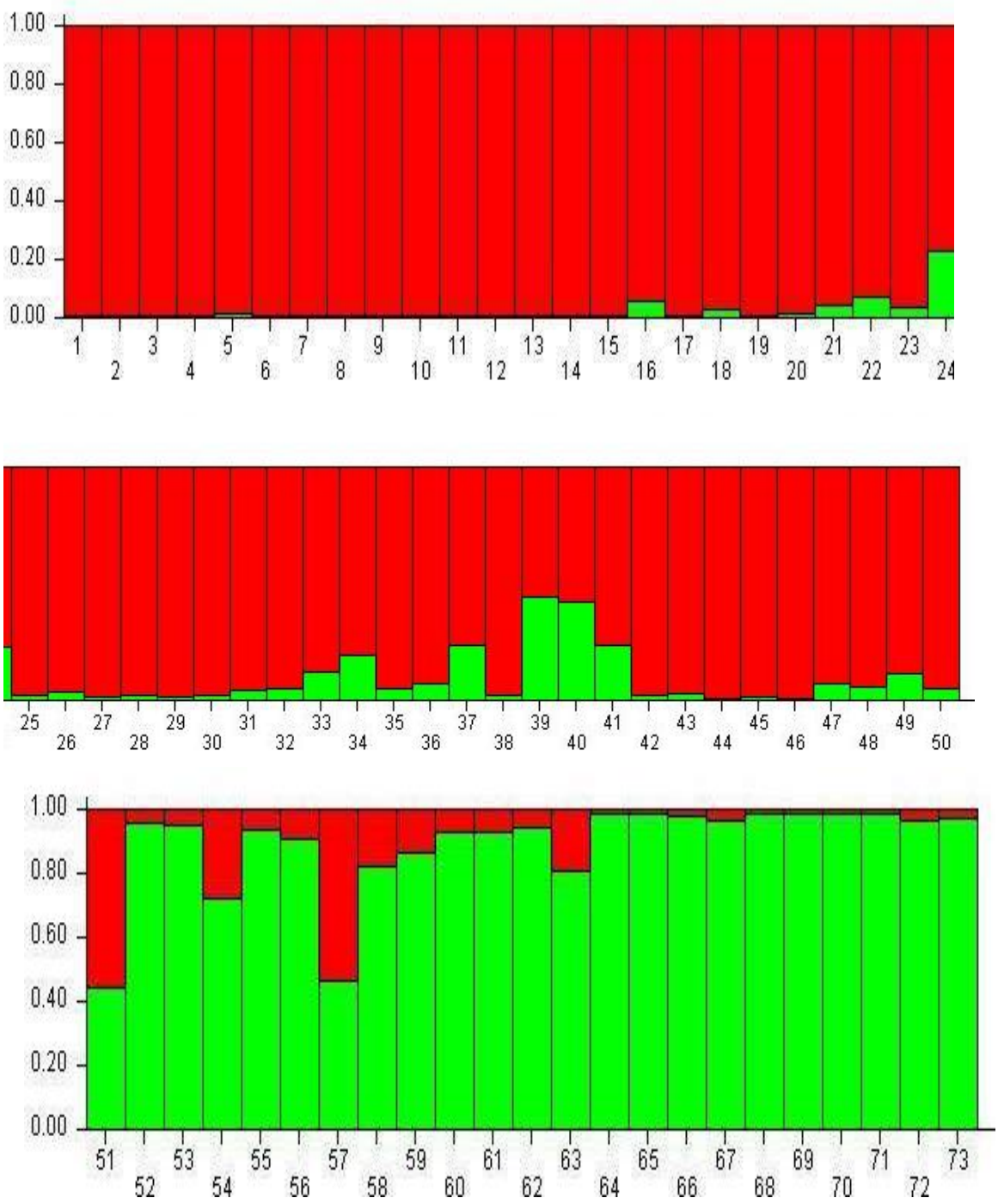


Fig. 47: Division and the frequency distribution of 72 wild date palm accessions and Medjool cultivar resulted from the K = 2. Each accession is shown by vertical line that is partitioned into two colored segments (Q1=red and Q2=green).

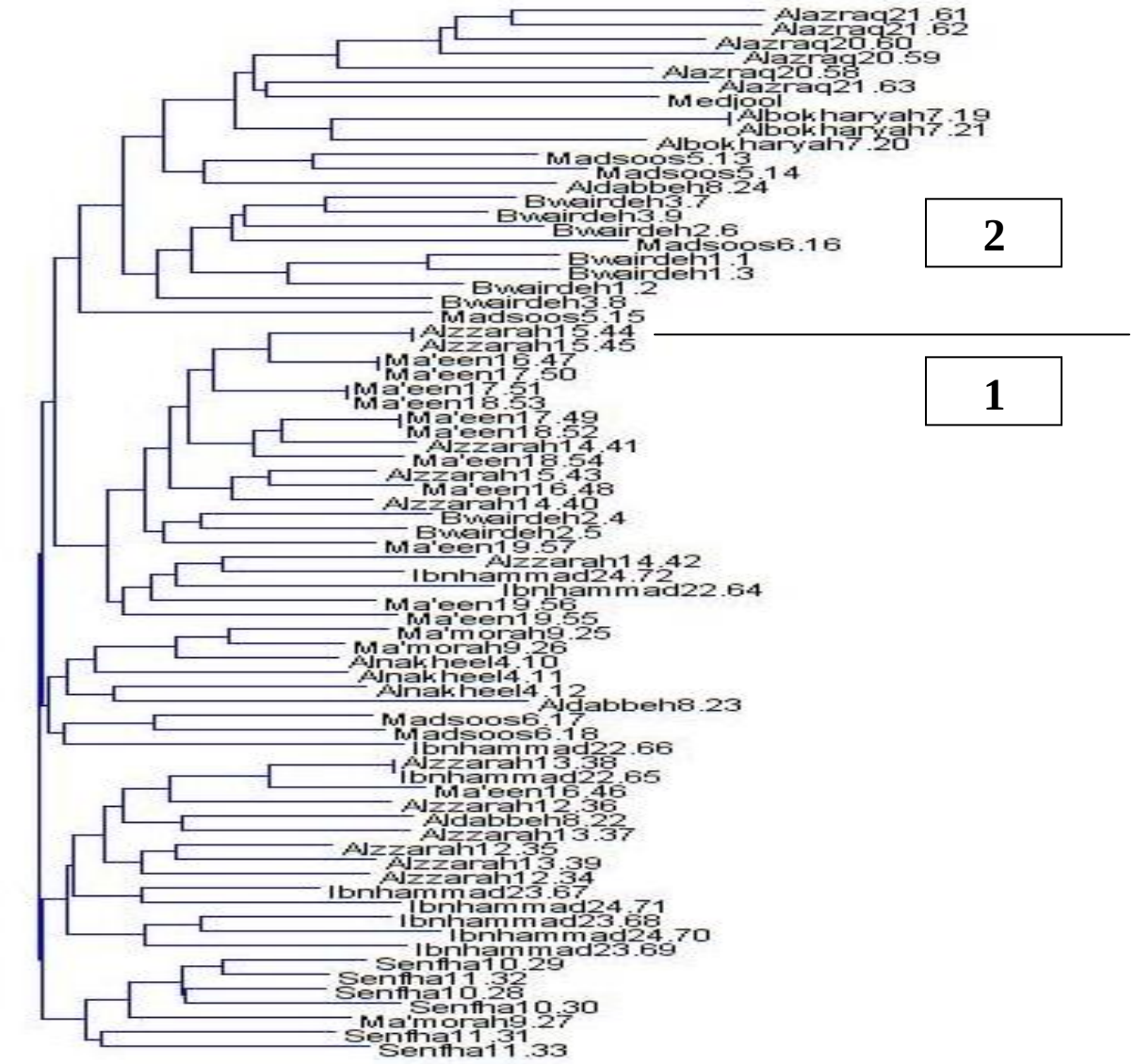


Fig.48. Dendogram showing the clustering of wild date palms based on molecular aspect according to population structure software.

4.7 Association between SSR markers and phenotypic traits:

The data analysis showed that there are some of the association between the used markers and the phenotypic traits (Table 10). The marker DP 151 had a correlation with Fruit weight, flesh weight, seed weight, fruit length and Mn concentration in fruit, while the primer DP 157 affected significantly on fruit pH, fruit moisture percent, TSS, Magnesium percent in fruit, leaf length, midrib length, pinnae part length and pinnae length at the mid.

DP 159 marker was significantly correlated with tree height, seed weight, percent of spine at whole leaf, percent of spine at midrib, pinnae length at the top, TSS, Potassium content in the fruit, leaf length, midrib length, pinnae part length, spine part length, petiole width, spine number, spine density per cm, spine length, pinnae number, pinnae length at the mid. Marker five was affected significantly on Potassium percent, petiole width and spine width at the mid, while marker six associated significantly with tree height, trunk girth, seed weight, fruit pH.

Tree height, seed weight fruit pH, Potassium content in the fruit, TSS, ferrous content in the fruit and most of the leaf morphology parameters that studied were correlated significantly with marker DP170. Marker eight was associated significantly with flesh weight, fruit length, Potassium percent in the fruit, ferrous content, and most of the leaf morphology characters, while DP 172 marker was correlated significantly with tree height, seed weight, Potassium and Magnesium percent in the fruit, fruit pH, ferrous content in the fruit, percent of spine at whole leaf and petiole width.

Marker number ten was significantly associated with tree height, seed weight, fruit diameter, Potassium and Magnesium percent in the fruit, fruit ph, fruit moisture percent, ferrous content in the fruit and most of leaf morphology parameters, while DP 176 affected significantly at tree height, seed weight and Potassium percent in the fruit.

Marker number twelve (DP 177) was associated significantly with most of fruit and leaf characteristics, while marker four (DP 160) was not had any associated correlation with the studied parameters.

Table 10. Association of molecular markers with the phenotypic traits.

Marker name	Tree height	Trunk Girth	Fruit Wt	Flesh Wt	Seed Wt	Fruit Length	Fruit Diameter
DP 151	NS	NS	**	**	*	*	NS
DP 157	NS	NS	NS	NS	NS	NS	NS
DP 159	*	NS	NS	NS	*	NS	NS
DP 160	--	--	--	--	--	--	--
DP 168	NS	NS	NS	NS	NS	NS	NS
DP 169	*	*	NS	NS	*	NS	NS
DP 170	**	NS	NS	NS	**	NS	NS
DP 171	NS	NS	NS	*	NS	*	NS
DP 172	**	NS	NS	NS	**	NS	NS
DP 175	**	NS	NS	NS	**	NS	**
DP 176	*	NS	NS	NS	*	NS	NS
DP 177	NS	NS	NS	NS	NS	NS	NS

Marker name	Fruit PH	Fruit Moist%	Fruit TSS%	Fruit K%	Fruit Mg%	Fruit Mn	Fruit Fe
DP 151	NS	NS	NS	NS	NS	*	NS
DP 157	*	*	*	NS	*	NS	NS
DP 159	NS	NS	**	**	NS	NS	*
DP 160	--	--	--	--	--	--	--
DP 168	NS	NS	NS	**	NS	NS	NS
DP 169	**	NS	NS	NS	NS	NS	NS
DP 170	**	NS	*	**	NS	NS	*
DP 171	NS	NS	NS	*	NS	NS	*
DP 172	*	NS	NS	**	**	NS	*
DP 175	*	*	*	**	**	NS	*
DP 176	NS	NS	NS	*	NS	NS	NS
DP 177	*	*	NS	**	NS	NS	*

- * : Correlated significantly under 0.05 level.
- ** : Correlated significantly under 0.001 level.
- -- : No correlation.
- NS : Non significant correlation

Table 10. Continued

Marker name	Leaf Length	midrib length	pinnated part length	Spine part length	% spine midrib	% spine leaf	Petiole width
DP 151	NS	NS	NS	NS	NS	NS	NS
DP 157	*	*	*	NS	NS	NS	NS
DP 159	**	**	**	**	*	*	**
DP 160	--	--	--	--	--	--	--
DP 168	NS	NS	NS	NS	NS	NS	*
DP 169	NS	NS	NS	NS	NS	NS	NS
DP 170	*	*	NS	*	*	*	*
DP 171	*	*	NS	**	**	*	**
DP 172	NS	NS	NS	NS	NS	*	*
DP 175	*	*	*	*	*	*	*
DP 176	NS	NS	NS	NS	NS	NS	NS
DP 177	*	NS	NS	**	**	*	*

Marker name	Spine #	Spine Density/Cm	Spine length at mid	Spine width at mid	Pinnae #	Pinnae Density/Cm	Pinnae length at mid	Pinnae length at top
DP 151	NS	NS	NS	NS	NS	NS	NS	NS
DP 157	NS	NS	NS	NS	NS	NS	*	NS
DP 159	**	**	**	NS	**	NS	**	*
DP 160	--	--	--	--	--	--	--	--
DP 168	NS	NS	NS	*	NS	NS	NS	NS
DP 169	NS	NS	NS	NS	NS	NS	NS	NS
DP 170	*	*	*	NS	*	*	*	NS
DP 171	**	*	*	*	**	**	*	NS
DP 172	NS	NS	NS	NS	NS	NS	NS	NS
DP 175	**	*	*	NS	*	*	*	*
DP 176	NS	NS	NS	NS	NS	NS	NS	NS
DP 177	**	*	*	NS	*	**	**	**

- * : Correlated significantly under 0.05 level.
- ** : Correlated significantly under 0.001 level.
- -- : No correlation.
- NS : Non significant correlation

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