Evaluation of Local Safflower Landraces for Oil Production under Mediterranean Climatic Conditions in Palestine

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Abstract
Safflower is a Mediterranean-subtropical oil crop and has certain production potential in regions with Mediterranean climates. To assess the suitability of safflower cultivation under Palestinian climate, 56 safflower landraces were collected from different Palestinian geographical regions, and then grown in the field in two successive years (2014 and 2015) in the West Bank (Jenin). Growth parameters were monitored along the growing period of safflower; plant height (cm) at 50% flowering, days to 50% flowering. After harvesting three samples of each landrace were collected. Plant parts (stem, leaves, capitula, achenes) were separated, then the following parameters were monitored; total dry weight (g), stem weight (g), leaves weight (g), and capitula weight (g). Plant yield components parameters and yield parameters were monitored after harvesting; number of branches, number of capitula, number of achenes, number of achenes in main capitula, achenes weight, thous and achenes mass (TAM), number of capitula per plant, number of achenes per capitulum, oil percentage, oil yield, and seed yield. The oil was extracted from achenes using the solvent method. On the other hand, morphological characterization was monitored along the growing period of safflower; the color of petals, blade length (cm), blade width (cm), number of thistle in main capitula, main head width (cm) and main head length (cm). The nutrient status (N, P, K) of different landraces were tested including all part of plants (stems, leaves, achenes, capitula). The correlations between oil yield and previous parameters can be used as a base for selecting high oil yield landraces.
Keywords: *Safflower, Oil production, Palestinian safflower, Safflower cultivation, Oil yield*

1. Introduction

1.1 General

Safflower (*Carthamustinctorius* L.) is a member of the family called Asteraceae, cultivated mainly for its seeds, which is used as edible oil and as bird seeds. Traditionally, the crop is grown for its flowers, used for coloring and flavoring food and making dyes, especially before cheaper aniline dyes became available [1]. Safflower is an annual herbaceous, highly branched plant that can reach 0.3-1.5 m in height. It has an extensive root system with a strong fleshy taproot reaching 2-3 m in depth and thin lateral roots exploring the first 30 cm of the soil; the stems are glabrous, greenish-white, cylindrical and woody near the base. The leaves are sessile, arranged in a rosette from the base, 4-20 cm long × 1-5 cm broad, glossy dark green; the upper leaves bear many sharp spines. Each stem bears a terminal inflorescence. It is a globular capitulum, 1.3-3.5 cm in diameter, containing 20-80 tubular orange-red flowers becoming dark red during flowering. Each flower produces one fruit. Safflower fruits are achenes, usually called "seeds", surrounded by a thick fibrous hull [2].

1.2 Safflower is an oil crop

Globally, safflower represents a share of only 0.07% of the vegetable oil production compared to 7.3 % for sunflower as an example of oil crop from the same family and can grow in the same climatic conditions and regions. From 2000 to 2007, the areas harvested for safflower in the occupied Palestinian areas was fluctuated between 40-60 hectares only and produced around 6 tones seeds totally in an average yield of 1.5 tones /ha, while no data were detected before 2000 [3]. According to FAO statistics (2009-2014), Asia is the largest producer of safflower, then the United States. India is considered as one of the top ten producers of safflower seeds (147.500 tones), while the United Republic of Tanzania is in the bottom of the producers countries' list (12.349 tones).

2. Material and Method

2.1 Collection of safflower landraces

Searching for cultivated landraces of safflower was done by visiting many Palestinian villages and contacting the farmers in fields when safflower is in its physiological ripening stage. At least five whole plants were picked up from the field and put in separate bags. The areas of collection covered many Palestinian districts. The plants were dried without heat treatment and seeds were collected from each plant in each collection and preserved under optimal storage conditions.

2.2 Experimental design

2.2.1 Oil and silage production

Field experiments were conducted in Mediterranean climatic conditions in the West Bank-Palestine in 2014 and were repeated in 2015. The field experiments were done in the NARC station in the Jenin area (Mediterranean climate low latitude). Collected safflower landraces were planted in each experiment (three replicates for oil production) in a randomized complete block design (RCBD) (see Appendix), to access the suitability of the locations under investigation to cultivate different landraces of safflower (see Appendix).

2.3 Oil extraction

The capitula were separated, cleaned; the achenes were collected, and cleaned from hay. The oil was extracted using the solvent method [4] 0.5 g of achenes were ground, 30 ml of diethyl ether were added in closed bottles, samples were left on sonicator for 2 hours, and the mixture was filtered in beakers.
Oil percentage = [weight of oil (g)/ weight of seeds (g)] *100%

2.4Analytical procedures:

2.4.1Nutrient analysis

For determining the nutrient status of the plants, the plant parts were separated into stems, leaves, capitula and achenes. For P, and K contents, the ashing method was used for their determination [5]. For K determination parts of the plant was ground into homogenous mixture, 0.1g of homogenous plant parts (leaves, stems, flowers, and seeds) were weighted and placed in crucible into the furnace for ten hours at a temperature of 450℃ then 1 ml of diluted HCl was added, 49 ml of distilled water, and the K concentration was determined using a flame photometer.
For P determination, 0.8 ml of a solution (sample, HCl, deionized water) was taken in a test tube, 0.64 µl of reagent B (ascorbic acid solution) was added, 2.56 ml of distilled water were added to the mixture, and then the solution was recorded on a spectrophotometer at wavelength of 882 nm. For the preparation of 250 ml phenol reagent 7.5 g sodium phosphate ($Na_3PO_4.12H_2O$) (Sigma, catalog No. 5778), 7.5 g sodium citrate ($C_6H_5Na_3O_7.2H_2O$) (Sigma, catalog No. 54641), 0.75g EDTA, (Sigma. catalog no. E9884), 15.75 g phenol crystals (Sigma, catalog no. p5566), and 0.05 g sodium nitroprusside (Na_2FeCN_5NO). $2H_2O$ (Sigma, catalog no. 0501) were dissolved in 250ml deionized water, and mixed. The reagent was stored in dark bottles for only two weeks. Hypochlorite reagent: 100 ml of (1N NaOH) was added to 100 ml of deionized water, and then 6 ml of 11% sodium hypochlorite was added and mixed. The total volume obtained was 206 ml, and the mixture was stored in a dark of only two weeks.
For N determination, a wet acid digestion-sand bath was used. The plant parts (leaves, stems, flowers, and seeds) were ground into a homogenous mixture,0.1 g of homogenous weighted and transferred to test tube, 2 ml sulfuric acid was added for 2 hours on sand bath digester, after cooling, 1 ml of hydrogen peroxide was

added until discoloring, diluted with 50 ml of distilled water, then 50 µl of the solution was taken in a test tube,1 ml of phenol reagent was added, then 1.5 ml of sodium hypochlorite reagent was added to the solution. The resulted solution was left for 2 hours; the sample of the solution was recorded on a spectrophotometer at a wavelength of 640 nm [6].

2.5 Yield and nutrient efficiency parameters

The following relations were calculated: oil yield, oil harvest index, achenes harvest index, nitrogen harvest index (NHI), potassium harvest index (KHI), phosphorus harvest index (PHI), the nitrogen efficiency ratio (NER), the potassium efficiency ratio (KER), and phosphorus efficiency ratio (PER) [7].

Oil yield = [achenes weight (g)* oil percentage] /100
Oil harvest index = [oil yield /TDW(g)] *100
Achenes harvest index = [achenes weight (g) / TDW (g)] *100
NHI = [mg N of achenes / mg N of TDW]*100
KHI = [mg K of achenes /mg K of TDW]*100
PHI = [mg P of achenes / mg P of TDW] *100
NER = [TDW(g) / mg N of TDW]*100
KER= [TDW(g) / mg K of TDW]*100
PER = [TDW(g) / mg P of TDW]*100

3. Results

3.1 Oil percentage of safflower landraces

As indicated in Table 1, the oil percent of safflower landraces ranged from the lowest value of 9.7 in landrace number 5 to the highest value of 21.12 in landrace number 21. There is a large variation in the landrace of oil percentage. Landrace number 21 has the highest oil percentage.

Table 1. Percentage of safflower oil

Landrace Number	Oil percentage (%)	Landrace Number	Oil percentage (%)
1	15.66	44	12.65
2	16.90	45	18.26
2	17.29	52	16.83
4	16.98	53	10.23
5	9.70	54	11.90
6	16.70	56	18.20
8	15.84	57	15.32
9	10.70	58	16.90
11	18.10	59	12.99
12	12.90	65	13.38
13	20.99	66	14.20
14	15.23	68	18.76
15	11.30	69	15.30
16	16.03	71	11.00
17	16.97	72	11.66
20	12.85	73	11.81
21	21.12	74	14.35
22	16.00	76	12.15
25	15.75	80	15.00
26	13.20	84	13.28
27	10.34	85	13.49
28	13.24	86	15.46
29	18.50	87	17.20
31	12.55	88	9.91
33	15.60	89	13.59
34	12.02	100	13.52
35	14.04	81- 1	15.00
42	14.40	81 -2	15.78

3.2 Pearson correlation among oil yield parameter and growth parameter

As shown in Table 2, Pearson coefficient showing an overall correlation between oil yield, yield component (achenes weight (g)), HI (HI in term of oil, HI in terms of achenes) and some growth parameters (stem weight, leaves weight, TDW (g), and capitula weight (g)). The oil yield was significantly correlated with stem weight (0,332***), leaves weight (0.380***), and TDW (0.715***), and with achenes weight (0.886***), however, it was slightly correlated with capitula weight (0.021).On the other hand, the weight of leaves was negatively correlated with the weight of capitula but was significantly correlated with the weight of achenes and TDW but not correlated with HI in terms of achenes and HI in terms of oil.
The weight of stems was significantly correlated with the weight of leaves, weight of achenes, and TDW and negatively correlated with HI in terms of achenes. On the other hand, the weight of capitula was significantly correlated with TDW but was negatively correlated with the weight of achenes, HI in terms of achenes, and HI in terms of oil. The weight of achenes showed slight correlation with TDW and HI in term of achenes and HI in term of oil. On the other hand, the oil yield was significantly correlated with TDW, HI in term of achenes and HI in term of oil. The HI in term of achenes showed high correlation with HI in term of oil.

Table 2. Pearson coefficient among variable determining oil yield of landraces, growth parameters

	Stem wt. (g)	Leaves wt. (g)	Capitula wt. (g)	Achenes wt. (g)	Oilyield (g)	TDW (g)	HI Achenes	HI oil
Stem wt. (g)								
Leaves wt. (g)	0.312***							
Capitula wt. (g)	0.020	-0.217*						
Achenes wt. (g)	0.370***	0.438***	-0.062					
Oilyield (g)	0.332***	0.380***	0.021	0.886***				
TDW (g)	0.756***	0.67***	0.125***	0.803***	0.715***			
HI Achenes	-0.178	0.031	0.007	0.780***	0.676***	0.271		
HI oil	-0.178	0.041	0.032	0.642***	0.846***	0.262	0.767***	

*indicate significant at P<0.05,**indicate significant at p<0.01,***indicate significant at P<0.001, n=3

3.3. Pearson correlation among growth parameter and yield component

Table 3 shows the Pearson coefficient of overall correlation between growth parameter (plant height (cm), days to flowering, and capitula weight (g) and yield component (branch number, capitula number, and achenes number. The plant height was significantly correlated with days to flowering, however, no correlation was observed with some branches. On the other hand, the plant height showed a negative correlation with several capitula, the weight of capitula, and many achenes. The days to flowering were negatively correlated with the number of branches, number of capitula, and number of achenes, but were slightly correlated with the weight of capitula. The number of branches was significantly correlated with capitula, slightly correlated with achenes number, and negatively correlated with capitula number. While the capitula number was significantly correlated with the weight of capitula and number of achenes. The weight of capitula was significantly correlated with several achenes.

Table 3. Pearson coefficient among variable determining growth parameters of landraces and yield component

	Plant height (cm)	Days to flowering	Branches No.	Capitula No.	Capitulawt (g)	Achenes No.
Plant height (cm)						
Days to flowering	0.872***					
Branches No.	0.042	-0.056				
Capitula No.	-0.140	-0.023	-0.059			
Capitula wt. (g)	-.0.036	0.012	0.355***	0.760***		
Achenes No.	-0.153	-0.056	0.146	0.546***	0.582***	

*indicate significant at P<0.05,**indicate significant at P<0.01,***indicate significant at P<0.001,n=3

3.4. Pearson correlation between oil yield, yield component and growth parameters

Table 4 lists Pearson coefficient of overall correlation between oil yield (g), yield component (achenes weight, branch number, achenes number, and TAM), HI in term of oil, HI in term of achenes and growth parameters (stem weight, leaves weight, TDW (g) and capitula weight). The oil yield was negatively correlated with the plant height (-0.104), days to flowering (-0.095), some branches (-0.043), capitula number (-0.077), and capitula weight (-0.021). It shows a slight positive correlation with TAM (0.102), but a better correlation with achenes number (0.121). The plant height showed a negative correlation with weight of stems, the weight of leaves, the weight of capitula, the weight of achenes, TDW, HI in terms of achenes, and HI in terms of oil. Days to flowering was negatively correlated with the weight of stems, the weight of leaves, the weight of achenes, TDW, HI in terms of achenes, and HI in terms of oil, but slightly correlated with the weight of capitula. While the number of branches was significantly correlated with the weight of capitula, slightly correlated with the weight of stem and TDW, but was negatively correlated with the weight of leaves, HI in term achenes and HI in term oil.

The number of capitula showed good correlation with the weight of capitula, was negatively correlated with the weight of stems, weight of leaves, weight of achenes, TDW, HI in terms of achenes, and HI in terms oil. The weight of capitula was negatively correlated with the weight of leaves, weight of achenes, and TDW. However, it was slightly correlated with the weight of stem, HI in terms of oil, and HI in terms of achenes. The achenes number was significantly correlated with the weight of capitula, negatively correlation with the weight of leaves, and slightly correlated with weight of stem and weight of achenes, TDW, HI in term achenes, and HI in terms of oil. The TAM was slightly correlated with the plant height, leaves weight, capitula weight, TDW, HI in term of achenes, and HI in term of oil, but negatively correlated with stem weight, days to flowering, capitula number, and achenes number, while it was significantly correlated with some branches.

Table4. Pearson coefficient between yield component and morphological parameter determining oil yield of safflower landraces

	Stem wt. (g)	Leaves wt. (g)	Capitula weight (g)	Achenes wt. (g)	Oil Yield	g TDW	HI achenes	HI oil	TAM
Plant height (cm)	-0.138	-0.033	-0.036	-0.078	-0.104	-0.116	-0.018	-0.068	0.033
Days to flowering	-0.099	-0.010	0.012	-0.068	-0.095	-0.089	-0.025	-0.065	-0.103
Branches No.	0.111	-0.025	0.335***	-0.009	-0.043	0.026	-0.043	-0.083	0.407***
Capitula No.	-0.041	-0.174	0.760***	-0.119	-0.077	-0.157	-0.051	-0.015	-0.090
Capitula wt. (g)	0.020	-0.217		-0.062	-0.021	-0.125	0.007	0.032	0.099
Achenes No.	0.091	-0.082	0.582***	0.044	0.121	0.022	0.026	0.134	-0.130
TAM	-0.059	0.077	0.099	0.110	0.102	0.077	0.095	0.094	

*indicate significant at P<0.05,**indicate significant at P<0.01,***indicate significant at P<0.001,n=3.

3.5 Pearson correlation between oil yield, yield components, growth parameters, and nutrient HI

Table 5 depicts Pearson coefficient of overall correlation between oil yield, nutrient HI, growth parameter (stem weight (g), leaves weight (g), TDW (g), capitula weight (g)) and yield components ((achenes weight (g)) and achenes yield). The oil yield was significantly correlated with NHI (0.481***), PHI (0.316***) and accumulated nitrogen in TDW (0.507***), but was positively correlated with KHI (0.246). The NHI was highly correlated with, the weight of achenes, g TDW, HI in terms of achenes and HI in terms of oil, but was slightly correlated with the weight of leaves and the weight of capitula and negatively correlated with the weight of stem. The PHI was highly correlated with the weight of achenes, HI achenes, and HI in term oil, but was negatively correlated with the weight of leaves and showed a slight correlation with the weight of stem, the weight of capitula, and g TDW. The KHI showed high correlation with HI achenes, a slight correlation with the weight of stem, the weight of achenes, g TDW, and HI in terms of oil. Further, it was negatively correlated with the weight of leaves and the weight of capitula. The accumulated nitrogen in TDW was highly correlated with the weight of stem, the weight of leaves, the weight of achenes and TDW, but it was slightly correlated with HI in term achenes and HI in term of oil, while it showed a negative correlation with the weight of capitula.

Table 5. Pearson coefficient between nutrients HI, and concentration, yield component and growth parameter to determining oil yield of safflower landraces

	stem wt. (g)	Leaves wt. (g)	Capitula wt. (g)	Achenes wt. (g)	Oil Yield	g TDW	HI achenes	HI oil
NHI	-0.075	0.224	0.074	0.564***	0.481***	0.292***	0.612***	0.464***
PHI	0.176	-0.1544	0.216	0.345***	0.316***	0.161	0.397***	0.323***
KHI	0.137	-0.032	-0.072	0.233	0.246	0.161	0.213***	0.199
mg N TDW	0.442***	0.477***	-0.161	0.606***	0.507***	0.684***	0.262	0.193

*indicate significant at P<0.05,**indicate significant at P<0.01,***indicate significant at P<0.001,n=3.

3.6 Pearson correlation between yield component, oil yield, growth parameter and nutrient status in achenes

Table 6 lists the Pearson coefficient of overall correlation between nutrients status in achenes, oil yield, yield component (achenes weight (g)), growth parameters (TDW (g)), HI in terms of oil and HI in terms of achenes. The oil yield was significantly correlated with the potassium accumulated in achenes (0.326***), the phosphorus accumulated in achenes (0.383***) and the nitrogen accumulated in achenes (0.606***). The potassium accumulated in achenes was significantly correlated with the weight of achenes, but was positively correlated with HI in term of achenes and HI in term of oil. The phosphorus accumulated in achenes was highly correlated with the weight of achenes and g TDW, and positively correlated with HI in term of achenes and HI in term of oil. While the nitrogen accumulated in achenes showed a significant correlation with the weight of achenes, g TDW and HI in term of oil, but was positively correlated with HI in term of achenes.

Table 6. Pearson coefficient between oil yield and nutrients status in achenes determining oil yield of safflower landraces

	Achenes wt (g)	Oil yield (g)	g TDW	HI achenes	HI oil
mg K achenes	0.291 ***	0.326***	0.263	0.184	0.238
mg P achenes	0.396***	0.383***	0.342***	0.277	0.262
mg N achenes	0.700***	0.606***	0.586***	0.496	0.390***

*indicate significant at P<0.05,**indicate significant at P<0.01,***indicate significant at P<0.001,n=3.

4. Discussion

4.1 Oil and achenes yield

Achenes yield (weight) of safflower landraces ranged from 4.6 g in landrace number 8 to 18.3 g in landrace number 57. These results are in agreement with previous studies. On the other hand, the oil yield of safflower landraces were ranged from0.7 g in landraces number 8, 12 and 53 to 3.1 g in landrace number 21.This is in total agreement with the results of [8]. The achenes and oil yields are affected by the sowing date and environmental conditions. Sowing date is one of the most important factors affecting crop yield and other agronomic traits [9].

4.2 Oil percentage of safflower landraces

The oil percent of safflower landraces ranged from the lowest value of 9.7 % in landrace number 5 to the highest value of 21.12 % in landrace number 21.Similar results were reported by other investigators [7-8], while are not in agreement with that published in [10] where they were controlled by the genotype of landraces and sowing date in addition to the environmental conditions.

4.3 Pearson Correlations between Yield, and Growth and Yield Traits

Safflower yield was found not to be correlated with the plant height, which is not in agreement with previous investigations [11]. The yield was correlated with TDW [12], and consequently, large plants produced more number of capitula and TAM. In agreement with our findings, it was reported that both achene and oil yields are not correlated with several capitula. This is not in agreement with other reports [13-14]), but correlated with several achenes [14-15] and the TAM. The number of capitula was found to be negatively correlated with TAM are not in agreement with [15] and positively correlated with the oil yield is not in agreement with [13]. In contrary to our results, it was reported that the number of capitula plants and number of achenes are positively correlated with each other. As our findings, TAM and achenes capitulum were reported to be negatively correlated to each other and are not in agreement with [15]. It should be indicated that our study demonstrated a positive correlation between oil yield and TAM.

4.4 Pearson correlation between oil yield, yield components, growth parameters and nitrogen accumulated in TDW

The oil yield was significantly correlated with accumulated nitrogen in TDW, while nitrogen accumulated in TDW was significantly correlated with stem weight, leaves weight, achenes weight, and TDW. These results concur with results of [16]. Our results have concurred in that found by other researchers [17]; the accumulated nutrients (N and P) increase the yield of oil and seeds. These nutrients play an essential role in plant yield and growth through biochemical reactions. Although nutrient availability was the same for all landraces under study, the nutrient efficiency (efficiency ratio and utilization index) may differ among landraces indicating the differences in the efficiency between different landraces subjected to the same nutritional conditions [18].

4.5Yield component and their developmental as affected by climatic condition

Oil yield can be analyzed in terms of its yield components which are divided into several branches related to several capitula per plant, several achenes capitulum, mean achene mass, and the oil concentration [7]. These components develop sequentially, with later-developing components under the control of earlier-developing ones [19]. Branching is one of the first developmental processes; it occurs during early growth and mainly depends on sowing density and the availability of water and nitrogen [20]. Development of florets or capitula happens during rapid vegetative growth, then, competition for limiting recourses may take place between vegetative and floral organs [21]. Later, achene filling is maintained by a high contribution from assimilation before and immediately after anthesis and remobilization of vegetative reserves [22]. The compensation of yield components occurs as a result of competition for limited resources and environmental stresses [23].Therefore, there is a reduction in a certain yield component which is due to stresses during the time of development of that component. Accordingly, Pearson correlation of our data revealed that the oil yield of landraces number 57, 5, 16, 21, 27, 42, 52, 56, 68, and 80 produced significantly higher oil yield than other landraces.

Also, the yield component analysis showed influencing yield component on oil yield. Accordingly, it seems that the number of achene per capitulum may be the important yield component determining the yield of the landraces which compensates with the number of capitula per plant (number of branches)as reported by [7].

Seeds are influenced by many factors like genotype, environment, and agronomic practices. Environmental variables can be classified as predictable and/or unpredictable factors [24]. Planting date is among the predictable factors (i. e. those that occur in a systematic manner or under human control). Sowing time is a major agronomic factor affecting both seed and oil yield in safflower [25]. Therefore, determining optimum sowing time and selecting a suitable variety for growing regions are necessary to obtain safflower with high yield. Environmental factors can make the difference between a good and a bad season. Besides, it reveals the adaptive potentiality of genotypes. Temperature is a major environmental factor that determines the rate of plant growth and development.

5. Conclusions

Based on our results, we can conclude that the high oil yield of the studied safflower landraces was obtained from landraces number 5, 16, 21, 27, 42, 52, 56, 57, 68, and 80, while the lowest was in landraces number 15, 9, 31, 20, 29 and 71. The most striking parameters affecting the yield are the growth parameters (stem weight, leaves weight, capitula weight and total dry weight (TDW)), yield component (achenes number) and nutrients status (potassium accumulated in achenes, phosphorus accumulated in achenes, nitrogen accumulated in achenes) that may contribute to the high yield production according to the comparisons of means, Pearson correlation with oil yield, and previous growth parameters, yield component, and nutrient status analysis. Growth and yield components traits can be used as a base for selecting cultivars with the highest oil yield. According to the Pearson correlation, the oil yield was negatively correlated with the following growth parameter: plant height and days to flowering, and yield component (number of branches and number of capitula). Yield was positively correlated with the number of achenes per capitulum. Therefore, the number of achenes per capitulum can be used for selecting cultivars adaptive to Mediterranean climatic condition. The growth period which influences this yield component must be given attention to improved yield under these conditions. More field trials are needed to tune the date of sowing using the high yielding cultivars found in this investigation to improve their achenes quality and oil concentration. Finally, the seeds of these landraces were planted again and samples were taken from the fresh leaves to make a future genetic characterization.

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List of Abbreviations

Abbreviations	Description
BL	Blade Width
BW	Blade Length
CF	Crude Fiber
CP	Crude Protein
DM	Dry Matter
DMY	Dry Matter Yield
FA	Fatty Acid
HI	Harvest Index
HPFB	High Point First Branch
KER	Potassium Efficiency Ratio
KHI	Potassium Harvest Index
LMB	Length Main Branch
MH	Main Head
MHW	Main Head Width
NARC	National Agricultural Research Center
NER	Nitrogen Efficiency Ratio
NHI	Nitrogen Harvest Index

NPK	Nitrogen ,Phosphorus, Potassium
PER	Phosphorus Efficiency Ratio
PHI	Phosphorus Harvest Index
RCBD	Randomized Complete Block Design
SAM	Single Achene Mass
TAM	Thousand Achene Mass
TDW	Total Dry Weight
TMH	Thistle Main Head
YMB	Young Mature Blade

Appendix

: Metrological parameters In Jenin (place of Cultivating)

Latitude: 32 .28 N Longitude: 35 . 18 (2013-2015)

Month / Element	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Mean monthly max Temp	17.2	19.3	23.1	25.8	29.9	31.0	32.6	34.1	32.7	29.2	24.4	18.6
Mean Monthly Min Temp	8.4	9.6	12.5	14.5	18.7	20.9	23.3	24.4	23.0	18.8	14.8	9.4
Monthly Average Temp	12.4	13.9	17.3	19.7	23.9	25.7	27.5	28.8	27.3	23.3	19.0	13.5
Absolute Monthly MaxTemp	23.0	28.0	35.2	37.6	41.6	37.2	37.2	41.6	40.2	36.2	31.4	25.2
Absolute Monthly Min Temp	0.0	2.4	6.2	8.2	15.0	20.0	20.0	22.6	17.0	12.4	8.4	1.6
Absolute Monthly Min Temp	135.1	69.9	31.4	28.8	7.7	0.0	0.0	0.0	3.0	23.2	59.6	78.9
Max Monthly rainfall	258.7	185.6	75.9	57.8	22.5	0.0	0.0	0.0	3.0	46.3	142.1	167.2
Mean Monthly Relative Humidity	75.0	70.4	64.9	60.6	57.3	67.1	67.1	65.3	62.8	63.7	67.8	71.0

Mean Monthly Sunshine Duration	5.5	6.6	7.5	8.8	10.2	11.7	11.7	11.2	9.3	8.4	6.2	5.8
Mea n Monthly Pressure At Station Level	1000.6	998.0	998.3	993.8	995.2	992.5	992.5	992.0	995.9	997.4	998.7	1001.5
Mean Monthly Wind Speed	2.6	3.0	3.3	3.6	3.6	4.2	4.6	4.2	3.4	2.8	2.4	2.2
Total Number Of Rainy Days per month	8.7	8.7	4.7	5.0	1.7	0.0	0.0	0.0	0.5	4.3	7.0	8.7

	44	**26**	**89**	**16**	**11**	**59**	**58**	**72**	**7**	**9**	**69**	**25**	**12**
	22	**81**	**100**	**34**	**73**	**45**	**80**	**66**	**21**	**87**	**35**	**14**	**15**
31	**6**	**65**	**52**	**20**	**1**	**84**	**88**	**76**	**5**	**74**	**54**	**86**	**17**
27	**52**	**81**	**42**	**68**	**28**	**3**	**4**	**85**	**71**	**13**	**2**	**29**	**53**

Appendix A. Experimental Design In NARC

North –station border

Third replicate

First replicate

Second replicate

22	**34**	**58**	**29**	**57**	**81**	**33**	**25**	**68**	**28**	**2**	**65**	**20**	**1**
42	**54**	**89**	**72**	**12**	**53**	**31**	**11**	**14**	**100**	**8**	**69**	**73**	**6**
85	**59**	**66**	**84**	**17**	**76**	**56**	**88**	**27**	**26**	**86**	**4**	**71**	**13**
44	**22**	**35**	**16**	**9**	**87**	**52**	**21**	**15**	**74**	**45**	**5**	**3**	**81**

6	**85**	**71**	**7**	**3**	**73**	**13**	**100**	**4**	**26**	**76**	**81**	**12**	**20**
88	**14**	**81**	**53**	**42**	**44**	**16**	**1**	**68**	**69**	**29**	**80**	**2**	**45**
87	**11**	**66**	**84**	**5**	**85**	**17**	**58**	**59**	**65**	**25**	**21**	**15**	**28**
		31	**27**	**52**	**54**	**9**	**72**	**86**	**35**	**89**	**34**	**22**	**74**

Appendix B. Places of Safflower Landraces

Code	Source
1	yabad
2	al-lubban
3	Beit sahour
4	anabta
5	Ramallah
6	Abu Dis
7	Bethlehem
8	Hjja-Qalqiliyah
9	Ramallah
10	Ramallah
11	East of Nablus
12	Azmoot
13	Abu Dis
14	Ramallah
15	Ramallah
16	Bethlehem
17	Ramallah
18	Betoina
19	Jerusalem
20	Nablus
21	Azmoot
22	Alfaraa
23	Jerusalem
24	Jerusalem
25	Jerusalem
26	Jericho
27	Jerusalem
28	Alfaraa
29	Ramallah
30	Nablus
31	azmoot
32	BeitJala
33	Bethlehem
34	Ramallah
35	Alfaraa
36	Ramallah
37	Jerusalem
38	Tulkarm
39	Qabalan
40	Ramallah
41	Ramallah
42	Ain Alsultan
43	yabad
44	Hebron
45	Hebron
50	Tulkarm
51	Jerusalem
52	Ramallah
53	Al-lubban
54	Beit Rema

55	Nablus
56	Bethlehem
57	Hebron
58	Ramallah
59	Aqbat jabber
60	Ramallah
61	Jenin
62	Al-Sawahreh Al Shrqya
63	Ramallah
64	Ramallah
65	Azmoot
66	Jericho
67	Ramallah
68	Hebron
69	Ramallah
70	Ramallah
71	Bethlehem
72	Birzit
73	Nablus
74	Silwad
75	Tulkarm
76	Ramallah
77	Jerusalem
78	unknown
79	Ramallah
81	Hebron