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Effect of Sowing Depth and Plant Density on Yield and Water Use Efficiency of Safflower (*Carthamus Tinctorius* L.)

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Abstract: *Field experiment was carried out during autumn season of 2013 at the experimental farm, of Agricultural Collage- University of Baghdad /Abu-Graib- Baghdad, Iraq. The layout of the experiment was Randomize Complete Blok Design with three replications. The objective was to study the effect of sowing depth and plant density on some growth characteristics, yield and water use efficiency of Safflower (Carthamus tinctorius L.).The sowing depth (3, 6 and 9 cm) while plant density levels (53333.33 and 40000 plant h^{-1}) were sowing to the plant spacing on row 0.75 and 1 m, respectively. Results showed that sowing depth 6 cm and plant density (40000 plant h^{-1}) gave the best parameters 117 cm, 21.60 branch plant^{-1}, 28.95 cm and 20.92 gm, respectively. The crop water use efficiency (WUE_f) of all the treatment ranges from 0.36 to 0.58* kg m^{-3}*and in the 3, 6 and 9 cm sowing depth + 40000 plant h^{-1} gave the highest values in WUE_f recorded 0.49, 0.58 and 0.39 kg m^{-3}, respectively*
Keywords: *sowing depth, plant density, water use efficiency and safflower.*

I. Introduction

Safflower (*Carthamus tinctorius* L.) is one of the oldest crops, traditionally, grown for its seeds, and used for coloring and flavoring foods and for making red and yellow dyes (**Zohary and Hopf, 2000**), and is a member of the composites family, tolerant to severe drought and salinity and an important alternative oil sources (**Gecgel*et al.*, 2007**).**Omidi and Sharifmogadas** (2010) reported maximum seed yield in safflower happen at the highest plant density (40 plant m^2). Plant density (4000 plant h^{-1}) had highest heads per plants, seed per head and total seed yield (**Shada and Hanaa, 2013**). In study of **Misra et al. (2005),** optimum seeding rate (row spacing and on-row plant spacing) influenced yield and yield components thought changing density. In the Iraqi soils, safflower seed deep does not exceed 30 cm and the number days for emergence different according to cultivars and growth factors.

Due to the few studies in Iraq, the purpose of the present study was to evaluate optimum sowing depth and plant density in components, yield of safflower and field water use efficiency in Abu Graib, Iraq.

II. Material and Methods

This experiment was located in field of Agricultural Collage- University of Baghdad /Abu-Graib- Baghdad, Iraq (33°20'37" N, 44°12'30" E, and 34.1 m above sea level). Some soil properties (Table 1) were determined according to methods described in **Black (1965) and Page et al. (1980).**

Table 1: Some chemical and physical soil properties

Properties	Unit	Value
pH	---	7.20
EC(1:1)	dS. m^{-1}	2.76
Organic matter	gm kg^{-1}	12.10
Sand	gmkg^{-1}	180
Silt		520
Clay		300
Texture		Silt loam
Bulk density	Mg m^{-3}	1.33
Water content at FC	cm^{3}cm^{-3}	0.35
Water content at WP		0.15
Available water		0.20

The experiment was a Split Plot Design with Randomized Complete Block Design (RCBD) with three replications. The first factor was plant density (53333.33 and 40000 plant h^{-1}) were sowing to the plant spacing on row 0.75 and 1 m, respectively. The second factor was assigned to three sowing depth levels 3, 6 and 9 cm. Safflower plant (*Carthamus tinctorius* L.) were transplanted manually on 11/November/ 2012, and harvested on 17/April/2013.Experimental plots were 9 m^2 (3m × 3m) and plants spaced 0.25 m (0.75 and 1 m between rows). Irrigation treatments included full irrigation (traditional), irrigation was imposed at 50% depletion of available water. Nitrogen applied in the rates of 120 kg N ha^{-1}, using urea as a fertilizer. Phosphorus and potassium were applied in the rates of 100 P ha^{-1} and 50 kg K ha^{-1} respectively to all treatments according to recommended by Ministry of Agriculture/Iraq.

All plots were irrigated with river water (ECi = 0.85 dS m^{-1}). Irrigation was scheduled when soil water content in the root zone was 50% depleted by the crop of available water. The soil depth of the effective root zone increased from 0.20 m at planting to 0.40 m in flowering and grain formation stages. Weeds were frequently controlled manually during crop growth and development stages. The amount of water consumed from the root zone between two successive irrigations as a water depth in cm, was calculated from the following equation (**Allen et al., 1998):**

$$d = D \times P_b \times \frac{(Q_2 - Q_1)}{100} \ldots\ldots (1)$$

Where:
d = Depth of water added
D = irrigation root zone depth (cm)
P_b = Bulk density of soil (µg.m^{-3})
Q_2 = Percentage of soil moisture at field capacity
Q_1 = Percentage of soil moisture before irrigation

Plant samples of one square meter from each plot were harvested and ten plants were taken randomly to determine yield attributes (plant height, number of branch $plant^{-1}$,length and weight of root, heads $plant^{-1}$, and total seed yield).The obtained data were analyzed and the significant compared at p≤ 0.05 using GenStat software. Field Water Use Efficiency (WUE_f) or irrigation water use efficiency (IWUE) calculated as follows:

$$WUE_f = \frac{Yield}{Waterapplied} \ldots\ldots\ldots\ldots\ldots (2)$$

III. Result and Discussion

The results of Table 2 indicate significant differences of each sowing depth and plant density in each of the plant height, number of branch $plant^{-1}$, root length and root weight. The sowing depth6 cm and plant density (40000 plant h^{-1}) gave the best parameters 117 cm, 21.60branch $plant^{-1}$,28.95 cm and 20.92 gm, respectively. These results may be due the all parameters of growth components increased with depth mean and decrease levels of plant density.

The values of all the plant growth parameters were significant among the sowing depth; this means that increasing or decreasing the sowing depth (3 and 9 cm) decrease all plant parameters, this is due to the increase depth of planting leads to increased soil resistance to penetration because of the increased mass of soil which leads to decreased in the speed and movement of the water and availability of the plant. And the low ratio of air pores decrease the movement and penetration roots in the soil.

Results showed that plant density have a significant effect (P<0.05) on all the plant growth parameters (Table 2), this due that to increased root uptake through root development because the increased distance between the rows decreased the competition between plants on the growth requirements such as water, nutrients and light, this lead to availability on a regular and balanced with different growth stages.

Table 2: Effect of sowing depth and plant density on plant height, branch number, root length and root weight

a. Plant height

Plant densi (planth^{-1})	Depth (cm)			Mean
	3	6	9	
40000	97.00	117.80	98.40	10.4.40
53333	92.50	92.50	97.40	94.1
Mean	94.70	105.20	97.90	
LSD 0.05	Plant densit	Depth		Plant density × De
	9.44	11.56		16.35

b. Number of branch

Plant densi (planth^{-}	Depth (cm)			Mean
	3	6	9	
40000	19.93	21.60	17.93	18.67
53333	19.87	18.20	15.73	19.07
Mean	19.90	19.90	16.83	
LSD 0.05	Plant dens	Depth		Plant density Depth
	1.550	1.899		2.685

c. Root length

Plant density ($planth^{-1}$)	Depth (cm)			Mean
	3	6	9	
4000	25.33	28.95	24.83	26.37
5333	21.07	24.68	24.13	23.29
Mean	23.03	26.48	24.48	
LSD 0.05	Plant density	Depth		Plant density Depth
	2.935	3.595		5.084

d. Root weight

Plant density ($planth^{-1}$)	Depth (cm)			Mean
	3	6	9	
4000(	16.00	20.92	16.73	16.88
5333:	16.48	20.42	17.80	18.23
Mean	16.24	20.67	17.27	
LSD 0.05	Plant density	Depth		Plant density Depth
	2.039	2.498		3.5311

The crop water use efficiency (WUE_f) of all the treatment ranges from 0.36 to 0.58 kg m^{-3}. It can also be deduced from the results of the percentage difference in water use efficiency compared between plant densities, also in sowing depth levels. Water use efficiency in the plant density based on sowing depth was significant ($p<0.05$) (Table 3). In the 3, 6 and 9 cm sowing depth + 40000 plant h^{-1} gave the highest values in WUE_f recorded 0.49, 0.58 and 0.39 kg m^{-3}, respectively. From these results it could be concluded there is decline in field water use efficiency with increasing plant density and sowing depth. Those increases in field water use efficiency were mainly due to increase of available water resulted in an increase of total grain yield more than the increase of water applied. Data in Table (3) show that total yield significantly decreased as plant density increased. The highest yield of safflower was obtained by (40000 plant h^{-1}) plant density (1981 kg ha^{-1}). It is obvious the decreased plant density produced maximum values of total yield of safflower. The increased production with decreased plant density comes from increase the soil spaces exploiter by a single plant and that provide greater nutrients and water, and improve the exploitation solar energy that contribute to increase photosynthesis and increase seed production per plant (**Mohammed and Abde-Wahed, 2009; Shada and Hanaa, 2013**).

Table 3: Effect of sowing depth and plant density on heads plant^{-1}, total seed yield and field water use efficiency

a. Heads plant^{-1}

Plant density ($planth^{-1}$)	Depth (cm)			Mean
	3	6	9	
40000	52.00	57.80	46.30	52.00
53333	46.70	47.30	38.70	44.23
Mean	49.35	52.55	42.50	
LSD 0.05	Plant density	Depth		Plant density × Depth
	7.23	8.85		12.52

b. Yield (kg h^{-1})

Plant density ($planth^{-1}$)	Depth (cm)			Mean
	3	6	9	
40000	1988.86	2366.99	1587.52	1981.12
53333	1589.21	1593.65	1476.79	1553.21
Mean	1789.04	1980.32	1532.16	
LSD 0.05	Plant density	Depth		Plant density × Depth
	200.98	189.76		269.78

c. Water use efficiency (kg m^{-3})

Plant density ($planth^{-1}$)	Depth (cm)			Mean
	3	6	9	
40000	0.49	0.58	0.39	0.49
53333	0.40	0.39	0.36	0.38
Mean	0.45	0.49	0.38	
LSD 0.05	Plant density	Depth		Plant density × Depth
	0.09	0.08		0.14

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