

WATER RELATIONS IN LETTUCE (*Lactuca sativa* L. Var *longifolia*)

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ABSTRACT

Four experiments were conducted to investigate sowing rates (1, 2, 3, or 4g. seeds.m⁻²) effects on lettuce transplant performance, to improve growth and yield of lettuce by populations, plot and furrow cultivations under rainfalls and supplementary irrigation, to boost drought resistance by using either GA3 or NAA rates of 0, 50, 75 or 100 mg.l⁻¹. Results of experiment 1 showed that 2 g seeds.m⁻² was the most suitable rate for the high performance transplant productions. It gave transplant numbers of 738.3 in which large, medium and small size transplants constituted 18, 36, and 46%, respectively. Results of experiment 2 revealed that the possibility of producing lettuce under rainfalls only and supplementary irrigation is not required, furrow cultivation was superior to that of plot. It exceeded the latter by 15.4% in term of yield, high population (28 plants.m⁻²) yielded (109.1%) more than that of (14 plnt.m⁻²), however it tended to reduce the weight of individual head. The highest yield (8.08 kg.m⁻²) was obtained from furrow high population interactions with either rainfalls or supplementary irrigation. Experiment 3 results confirmed that GA3 highly improved the heading process, particularly 100mg.l⁻¹ treatment which resulted in the highest yield(5.9 kg.m⁻²), bulk density (0.2 g.cm⁻³), head size(2150 cm³) and individual head weight (423.3 g). The final experiment 4 results showed that NAA rate of 50 mg.l⁻¹ was the most effective treatment as it gave the highest yield (3.12 kg.m⁻²), and weight of single head (403.3 g). However NAA rates were inferior to these of GA3.

INTRODUCTION

Lettuce is a very popular vegetable crop grown in Iraq and its production facing many problems commencing with its seed germination and their inhibition by extremes temperature and light intensity (Gray, 1977; Cantliffe *et al.*, 1984 and Wein,1997). Lettuce heading highly influence by ambient environments and cultural practices as their negative effects display on plant stature and performance which reduce the marketable yield owing to physiological disorders and deformed heads(Wurr *et al.*,1987; Wurr and Fellows,1991; Quaile and Presnell,1991 and Misaghi *et al.*,1992).

Irrigation is one of the most effective cultural practice in vegetable production especially in lettuce owing to their shallow effective root system (30 cm) depth (Jackson, 1995; Schwarz *et al.*, 1995 and Gallardo *et al.*, 1996). Mosul city is located on 36° 42" latitude and Altitude of 230m , it receives an actual rainfalls (381 mm.year⁻¹), however, there are uneven yearly rain distribution and also among raining months in the season which is usually commence on November and ends on May(Guest,1966). Mosul suffer from

water shortages owing to the topography which makes water conduction be very difficult and cost much besides its scarcity ,

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and therefore four experiments were included to investigate lettuce productions through attempts to produce transplants and grow lettuce under rainfalls and complementary irrigation to find if there are any possibilities to produce this crop under rainfalls by manipulating some cultural practices.

MATERIALS AND METHODS

Four experiments was carried out in Mosul City which is located on north latitude of 36°42" and Altitude of 230m to investigate the possibility of producing lettuce under the available rainfalls during fall growing seasons of 2001-2002 and 2003-2004 through simulating cultural practices and use of some growth regulators, and thus we have conducted the following experiments .

Experiment 1: Production of lettuce (*Lactuca sativa* var *longifolia* Local cv.) transplants under rainfalls: This experiment was carried out during 2001-2002 fall growing season at Yarimja vegetable growing farms, Yarimja, Mosul city, IRAQ. Largest headed plants of good stature were selected from the previous fall season (200-2001) and cut off 5 cm above soil surface at harvesting , while other undesired plants were pulled with their roots out of the soil. Shoots were sprouted at nodes on the remained stem cuts and new small plants were formed, they were fertilized by NPK (27, 27,0) and weeds were manually eradicated .Finally seeds were collected and then kept at dry place to use them in the next season.

A randomized Complete Block Design (RCBD) was used to include four sowing rates(1, 2, 3 or 4 g. seeds. m⁻²) replicated four times, each replicate was represented by a plot of 1m². The given seeds of each plot were equally distributed on 9 lines 10cm apart , and therefore this experiments had 16 plots.

A laboratory seed germination at 20C° showed a germination percentage of (95%). Soil was dissected in to 16 plots . A sheep manure (0.1 m.m⁻²) and nitrogen fertilizer urea (25g.m⁻²) were applied before sowing on November,1st ,2000 .Seedlings were harvested on December, 20th , 2001. The harvested transplants were put into three size categories (large, medium and small) then for each category seedling numbers, seedling lengths, root length, stem lengths, leaf numbers , leaf fresh weights, root fresh weights, stem fresh weighs and weight of fresh transplants were measured . Leaves , roots and stems were oven dried at 60 C° for 72 h and the weighed to calculate their dry matter percentages. Soil analysis (table 1, 2) was carried out in agricultural college, soil department. Were as meteorological data (figure 1, 2) was obtained from Al-Rashidia station, Mosul, Iraq.

Table (1): Physical analysis for loam soil of Yarimja field.

Soil separation	Particle sizes (%)	Soil bulk density	Soil field
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(g.Kg ⁻¹)		(g.cm ⁻³)	capacity (%)
Clay	159.8	1.58	0.21
Silt	556		
Sand	294.2		

Experiment 2: The influence of supplemental irrigation , plant population and cultivation methods on growth and yield of lettuce (*Lactuca sativa* var

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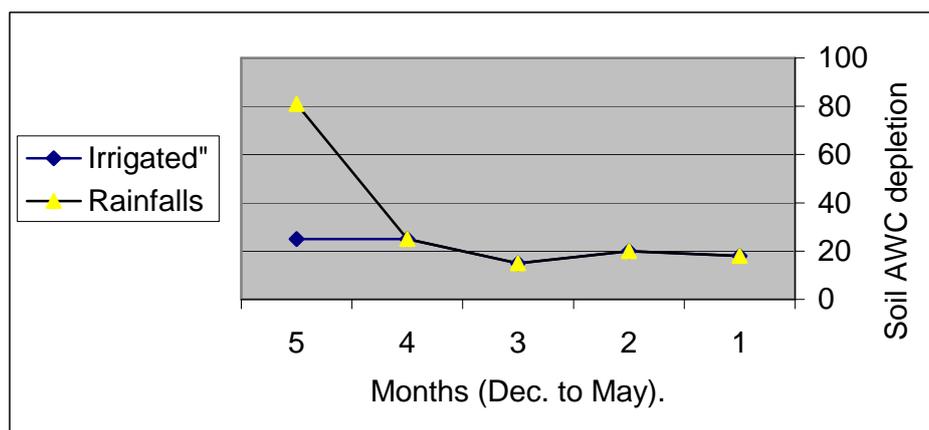
longifolia Local cv). Seedlings obtained from Experiment 1 were used in this trail at the same season and location, and therefore a split-split plot with in Factorial Randomized Complete Block Design (split-split F-RCBD) was used to include supplementary irrigation and rainfalls as main plots , Furrow and plot cultivations as sub-plots and two plant populations as sub sub-plots. Each of the 8 treatments was replicated 4 times and each replicate was represented either by a plot of (3 m²) or a furrow of (0.75x4 m). Furrows of population 1 of (14 plant.m⁻²) had one line at the upper third on both sides, while population 11 of (28 plants. M⁻²) had two lines one at the lower and the other at the upper thirds of each furrow side. Furrow lines were planted with (20 cm) apart, while lines in plots were planted with plant intra spaces of (20 cm) or (40 cm) for populations 1 and 11, respectively .

Weeds were eradicated manually on 29th., January and on 2nd ., March. NPK (27,27,0) was mixed with urea at rate of (20 g.m-2 of each) broadcasted immediately after the first weed eradication and a mixture rate of (30g.m⁻² urea + 20 g.m⁻² NPK) were applied after the second manual weed control. Supplemental watering was applied whenever a depletion of 25% of available water capacity at a soil depth of 30cm, determined by gypsum blocks.

On 5-7th , April plants were harvested and data on plant heights ,leaf numbers, weight of marketable head and yields were recorded, finally leaf and stem samples were oven-dried at 80C° for 72 h. to calculate their dry matter percentages.

Table (2): Meteorological data during 2001-2002 lettuce growing season.

Parameters	Months			
	December	January	February	March
Months				
Maximum Temperature (C°)	11.7	11.7	14.8	19.6
Minimum Temperature (C°)	3.1	1.3	2.3	4.9
Maximum RH (%)	95.3	99.2	99.3	95.9
Minimum RH (%)	62.5	44.6	37.9	25
ET0 Blany Cridle (mm.day-1	1.13	1.12	1.15	2.29
Rainfalls (mm)	107.2	44.7	104	24.2
Applied water (cm)	0.0	0.0	0.0	10.07
Irrigation frequency	0.0	0.0	0.0	1.0



Figurer (1): Depletion of AWC during the growing season.

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Experiment 3: The possibility of improving lettuce (*Lactuca sativa* var *longifolia* Paris Island cv) production under rainfalls by the application of gibberellic acid (GA3) in Mosul city: This experiment was conducted during lettuce growing season of 2003-2004 at Research field, Danadan, Mosul city. Seeds of lettuce (*Lactuca sativa* var *longifolia*, Paris Island cv) produced by Niagara Seed company USA , under Lot no. 18729rxt-2xv-143419015 and a germination percentage of 99%, tested on May, 2003.

Four GA3 rate treatments (0, 50, 75 or 100 mg.l⁻¹) were replicated five times and they were included in Randomized Complete Block Design (RCBD) , each replicate was represented by a furrow of (4X0.75m).

Seeds were sown on September, 20th , 2003 in previously prepared seed bed of (2X1m) , fertilized with (20g) urea, Benomyl fungicide was sprayed at rate of (1 g.l⁻¹) . On November, 20th , 2003, medium size seedlings of (4-5g , 4-5 leaves and 13-15cm in lengths) were planted on both furrow sides at a plant space of (25cm) on November, 27th , 2003 after considerable rainfalls . GA3 was sprayed two times with in 2 weeks interval commenced on March,1st 2004. 25 g.m⁻² Diameno phosphate (DAP) was broadcasted on December, 10th , 2003 and 40 g.m⁻² urea was broadcasted on March,1st ,2004, Other cultural practices were manually made (Table 3 and 4).

Plants were harvested on April, 4th , 2004 and data on plant heights, head sizes , number of unfolded leaves, number of folded leaves , stem lengths, weight of single folded head, weight of single unfolded plant, head bulk density, unmarketable yields and marketable yields were recorded. Leaf samples were weighed and then oven-dried at 80 C° for 72 h, to calculate the leaf dry matter percentages.

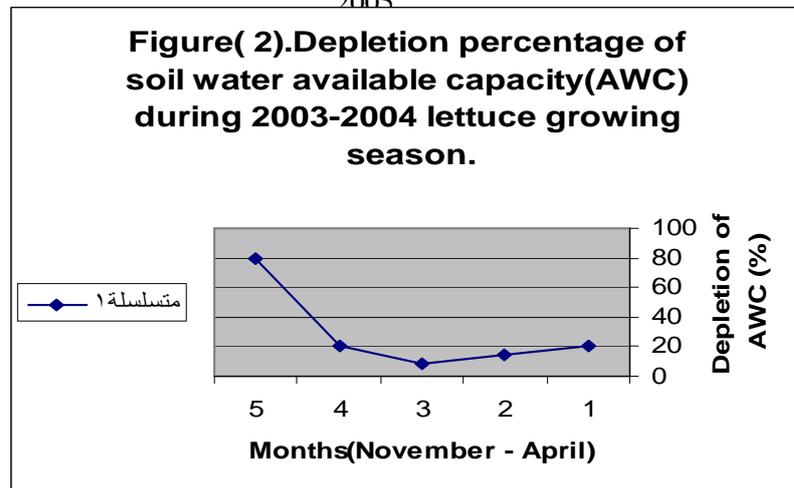
Experiment 4: The possibility of improving lettuce (*Lactuca sativa* var *longifolia* , Paris Island Cv.) yield under rainfalls by the application of naphthalene acetic acid (NAA) in Mosul City: The materials and methods of this experiment were similar to these of experiment 3 except in that of altering naphthalene acetic acid (NAA) in stead of GA3 in which NAA rates (0, 50,75,or 100 mg.l⁻¹) were sprayed two times started on March, 1st , 2004 and repeated after two weeks

Table (3): Meteorological data for 2003-2004 lettuce growing season

Parameters	Months				
	November	December	January	February	March
Maximum temperature (C°)	21.2	14.1	13.5	14.2	22.4
Minimum temperature (C°)	7.8	5.5	5.1	5	7.7
Relative humidity (%)	62	79.8	79.7	75	62.1
Rainfalls (mm)	83.5	72.6	88	61	75.8

Table (4): Physical analysis for silty loam soil of Danadan field.

Soil separation (g.Kg ⁻¹)	Particle sizes (%)	Soil bulk density(g.cm ⁻³)	Soil field capacity (%)
Clay	143	1.55	0.20
Silt	563		
Sand	294		



RESULTS AND DISCUSSIONS

Experiment 1: Transplant production lasted for 50 days owing to the gradual decreases in temperature from November, 1st to December, 20th (table1). Low temperature adversely influenced seed germination , seedlings development and final transplant performances. Similar results were found by OH *et al.* (1987) and El-Sabary (2005). Low temperature had indirect effects on enzymes activities which participate in the hydrophobic and hydrophilic balance of cellular membrane since it alter the Sol-Gel transition state of membrane, and subsequently unequivocal discrepancies in plant responses to temperature were observed (Levitt, 1980 and Turner and Kramer, 1980). Total number of transplants obtained from sowing rates 1, 2, 3 and 4 g.m-2 were 324,738.3, 1062.5 and 110.9 transplants, respectively. The percentage of large size transplants were 46, 18, 9 and 8% which represent transplant numbers of 148.5, 129.5, 99.5 and 86.5 , respectively.

Transplants had length (22.6 cm), root length (6.1 cm), stem length (2.2 cm), leaf numbers (8.8), leaf fresh weight (5g), root fresh weight 0.4g, stem

fresh weight (0.19), leaves dry weight (0.39g), root dry weight (0.035g), stem dry weight (0.029g) and transplant fresh weight (5.8g) means were categorized as a large lettuce transplant (table 5). Large sized lettuce transplants of fresh weight (4-6g) were recommended for greenhouses and early spring season production of lettuce to shorten growth duration and consequently reduce cost, avoid bolting, extend marketing duration before critical day length for bolting are reached and ensure high competition ability of lettuce to weeds(Guzman, 1987; Mangal *et al.*, 1988; Wein, 1997 and El-Sabary, 2005). However, using transplant of large size in fall season to produce lettuce in the early following spring are not preferred owing to their low duration requirement of verbalization which resulted in high unfolded head percentages, more vulnerable to freezing and frost injuries of the ensuing winter and earlier bolting in relation to smaller and younger transplants of high biologically active cells(Xing and Rajashekar,2001 and David and Henson, 1998). These ambient environments disable plants to perform hearting process perfectly rendering the plant vegetative apical meristems expose to sunlight , altering them to flowering meristems synchronized with assimilate diversion to the reproductive

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sink on the account of high rate of leaf differentiations to ensure marketable yields (Kinet *et al.*, 1985, Wein, 1997 and Ryder ,1999).

The numbers of medium transplant size of 18.5 cm length, 6 cm root length,1.3 cm stem length, 6.6 leaf numbers, 1.8g leaf fresh weight,0.2g root fresh weight, 0.1g stem fresh weight, 2.1g fresh weight and 0.29g dry weight were 111.5, 266.8, 343 and 438 transplants obtained from 1, 2, 3 and 4g.m⁻² seed rates , respectively. Medium size transplants (2-4g fresh weight) are perfect for lettuce production in moderate zone areas above north latitude 40° where long spring season durations and summer day temperature of 25C°. These transplants are somehow have an ability of cold stress tolerance owing to their biological activity of cells. Medium size transplants also recommended for fall growing season in the middle east rejoin where moderate short freeze duration occurs in some years(El-Shal *et al.*, 1986, El-Sabary, 2005).

Transplants which posses the lowest values in term of length(14.2 cm), root length (5.5 cm), stem length (0.8 cm), leaf numbers (4.7), leaf fresh weight(0.5g), root fresh weight(0.04g), stem fresh weight(0.06g) and mean of total transplant fresh weight(0.6g) were classified as small transplant size. Vast numbers of these were confined the two higher sowing rates and gradual decreases were obtained as sowing rate decreased. Transplant numbers of small size were 529 at rate of 3g.m⁻² and 583.8 at rate of 4g.m⁻² which constitute 50 and 53% of the total produced transplants, respectively. These transplant size may be suitable for late production of lettuce in fall, spring and summer seasons where the growing season is so long that enable these transplants to ensure well establishment in the permanent field during their early stages of growth, particularly when the prevail ambient environments are in favor of perfect growth and heading. Small transplant size possesses small

cells of highly active condensed protoplasts which enable them to display high cold stress avoidance and cold acclimation to the ensuing winter (Abdel, 1997). The environmental factors, such as day length, temperature, nutrition, water availability, light intensity and physiological maturity of plant or plant part are known to play a role in cold acclimation , generally, plant growth ceases before cold acclimation begins, decreasing day length provide the primary stimulus or trigger for cold acclimation in many plants(Dewayne *et al.*, 2001).

Negative correlation were found among sowing rates in term of transplant length($r=-0.1$), root length($r=-0.49$), leaf numbers($r=-0.26$), leaf fresh weight($r=-0.81$),root fresh weight($r=-0.083$), root dry matter percentage($r=-0.064$), stem dry matter percentage($r=-0.07$), large transplant fresh weight($r=-0.08$),small transplant fresh weight($r=-0.09$) and large transplant dry weight ($r=-0.089$), however, positive correlations were found in stem length ($r=0.088$), stem fresh weight($r=0.049$), transplant numbers($r=0.55$), medium transplant fresh weight($r=0.092$) medium transplant dry weight($r=0.0031$)and small transplant dry weight($r=0.024$). From the obtained negative and positive correlations of most detected traits we may inferred that the higher the sowing rate was applied the weaker the transplant was produced. This weakness explains the degree of competition among germinating seeds, seedlings or transplants on nutrients and lights. It is well established that high plant populations create ambient condition of low light intensities in which far-red light is

prevailed over red light, such conditions force the plant to direct their assimilate for the favor of internodes elongation to enable them to intercept more photosynthesis active radiation(PAR) on the account of other competed plants(Levitt, 1980; Kinet *et al.*, 1985). Competition on light reinforces the apical dominance and increases endogenous IAA which causes the release of H⁺ ion from plasma lemma membrane, directed them to cell walls to weaken the glycosides and hydrogen bonds occur among cellulose microfibrils and other cell wall components through pH reductions to facilitate cell wall expansion by turgor pressure(Goodwin and Mercer, 1985). Low light intensity induce expansion in the cells of the intercalary meristems located at the internodes and therefore elongation of internodes are occurred (Wareing and Phillips, 1978 and Burgess, 1985).

Table (5): The effects of sowing rates on transplant performance.

Detected traits (Y)	Sowing rates g.m ⁻² (X)				Linear equations(Y=a+bX)		
	1	2	3	4	A	b	r
Transplant length(cm)	18.9	18.4	15.9	18.5	18.91	-0.29	-0.1
Root length(cm)	6.1	6.2	5.8	5.4	6.5	-0.25	-0.49*
Stem length(cm)	1.4	0.9	1.5	1.5	1.28	0.043	0.088
Numbers of leaves	7.4	6.7	6.4	6.2	7.7	-0.41	-0.26

Leaf fresh wt(g)	2.6	2.4	2.1	2.3	2.72	-0.14	-0.81
Root fresh wt(g)	0.3	0.2	0.2	0.2	0.25	-0.011	-0.083
stem fresh wt.(g)	0.2	0.2	0.2	0.2	0.185	0.0077	0.049
Leaves dry matter (%)	7.2	7.8	7.8	7.7	7.77	0.00001	0.00001
Root dry matter(%)	8.8	8.9	8.8	8.7	8.89	-0.018	-0.064
Stem dry matter.(%)	4.4	4.3	4.3	4.3	4.37	-0.01	-0.07
Transplant nos.m ⁻²	324	738.3	1062.5	1109.1	46.2	89.32	0.55*
Large trs.size.(cm)	46	18	9	8	51	-12.3	0.086
Large trans. fw(g)	6.7	6.2	5.1	5.6	7	-0.44	-0.08
Large trans.Dw (g)	0.5	0.5	0.4	0.4	0.55	-0.04	-0.089
Medium transt(%)	34	36	41	40	32	2.3	0.089
Medium trans fw(g)	1.8	1.8	1.9	2	1.7	0.07	0.092
Medium transDw (g)	0.141	0.21	0.16	0.16	0.166	0.0007	0.0031
Small trans.(%)	20	46	50	55	16.5	10.3	0.084
Small trans fw(g)	0.71	0.6	0.5	0.51	0.76	-0.07	-0.09
Small trans Dw(g)	0.045	0.041	0.035	0.037	0.04	0.0285	0.024

Experiment 2: Continuous reductions in both maximum and minimum temperatures from December to mid February , then temperature commence to increase gradually up to the harvesting date (table, 3). Plant metabolic activities slow during extended cold period and are usually resulted in significant differentiation rate reductions (Dewayne *et al.*, 2001). In Iraq, daily temperature fluctuations are greatest when clear skies exist, since solar radiation warms the earth surface during the day and air temperature of 10 to 15°C are common even though the temperature at night may be less than -5°C. This phenomenon highly affects lettuce growth, since the apical meristem of lettuce plants being very close to the soil and thus these

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meristems are more influenced by soil temperature than air temperature. Lettuce plants are more related to heat lost from soil surface by radiation cooling moves away from earth surface, as the soil continues to lose heat until it is colder than the air just above it (Wurr *e. al.* ,1981). Kimball *et al.* (1967) determined that lettuce production in areas that had at least 2 months temperature of 17 to 28° C day and 3 to 12° C night, at temperature higher than these ranges, the cultivar grown in these areas develop a high incidence of tipburn, bolting and formation of loose puffy heads. Air temperature considered optimum for growth of lettuce in Florida from December to April ranges from maximum 26°C to minimum 13°C (Quaile and Presnell, 1991). Rainfall data illustrate that rainfalls significantly exceeded water losses by evapotranspiration estimated by Blay-Cridle equation. Therefore supplemental watering was not required during the first three months of the growing season , however complementary irrigation of 10.07 cm was applied once late in March to bring up the soil to field capacity to a depth of 25cm. However, the obtained results confirmed the ability of producing lettuce under rain fed in Mosul and supplementary irrigation mostly is not required this conclusion is inferred from

our results and 30 years data of rainfalls (Guest, 1966). Evapotranspiration (ET_o) for irrigated lettuce between thinning and harvesting was 146 mm and maximum crop coefficient of 0.81 to 1.02 were obtained at maturity 55-53 days after planting and lettuce Etc was higher in Cos cultivars than in two crisp head cultivars, furthermore lettuce root length density and soil water extraction were greatest in the top 0 to 45cm and decreased rapidly below 45cm depths, however, soil water extraction by root increased at low depths when irrigation was reduced (Gallardo *et al.*, 1996), they also stated that soil water tension at 0.3m depth should be maintained at 6 to 7 kpa for optimum yield of trickle irrigated lettuce.

Furrow cultivation method significantly exceeded that of plot method in term of leaf numbers per plant (34.8%), single head weight (19.3%) and yield (15.4%). This superiority might be referred to the ability of furrow to sustain better soil physical properties at lettuce root system such as low soil bulk density which facilitate optimal gas exchange between air and root zone in relation to plot cultivation. Plot cultivation usually manifests gradual bulk density increases during the growing season. These increases are obviously resulted from the continuous rainfalls and labor movement to achieve demanded cultural practices. In furrow cultivation, labor movements are usually demonstrated at the furrow bottom rendering other parts loose and aerated. Root establish a critical link in the soil-plant-air continuum and this link has to be maintained in the most adverse environment or physiological conditions (Jackson *et al.*, 1994 and Steudle, 2001). Anoxia results in profound physiological disturbances including an increase in CO₂ content in the soil solution and a decrease in O₂ supply anaerobiosis (Dell Amico *et al.*, 2001). Root absorption of mineral and water as well depend on energy generated by root respiration which in term depend on soil aeration. Kamaluddin and Zwiazek, (2001) applied 0.5 mM NaN₃ sodium azide, a respiration inhibitor on red-osier roots they found a 35% decreases in both O₂ uptake and root hydraulic conductivity after 2 hours. Contrary results were reported by El-Sabary (2005) he obtained higher lettuce yield in plot cultivation than that of furrow cultivation. This

disagreement may be attributed to soil texture which reflects on aeration and gas exchange and therefore soils of prevail clay minerals may differ apparently from soils of prevail sand.

Dense plant population (p2) highly exceeded normal population (p1) in term of plant height (15.4%) and yield (109.1%), however, p1 significantly increased leaf number per plant, weight of single head and stem dry matter percentage as compared to p2. Our results are in agreement with Mangal *et al.* (1988), they found that spaces ranges 15 to 20 cm gave the highest yield. Plant population in lettuce is a very important factor in production. Subsequently growers have to pay intensive care to the optimal population in order to improve yield quantity and quality. Low populations resulted in high yield reductions because of the low number of plants per unit area , whereas high

populations resulted in weak etiolated plants of puffy, lose leaves, elongated internodes and low weight of single head. Several morphological conditions must be met for head formation to succeed, these are large individual leaves, slow rate of stem elongation short petioles and a high rate of leaf production (Dullforce, 1962). Jonson(1983) described the importance of leaf differentiation rate in the lettuce heading process, he reported that marketable head formation resulted from the accumulation of young leaves under the layer of leaves covering the growing point. High population usually suffers low light intensity which in term divert the assimilates for the benefit of stem elongation on the account of other part developments (Wareing and Phillips, 1978).

Results of irrigation and cultivation methods interactions showed that lettuce plant cultivated on furrows under irrigated or rainfalls significantly exceeded these of plots in leaf numbers per plant, weight of single head and yield. These results explain the occurrences of adequate rainfalls through out the growing season and therefore cultivation methods had the dominated effects on watering. Irrigation and populations interaction results showed prevalence of populations over both rainfalls and irrigation. Population 1 under either rainfalls or supplementary irrigation treatments significantly increased leaf numbers per plant, single head weight and stem dry matter percentages , whereas population 2 resulted in apparent yield and plant height increases under rainfalls and watering treatments. Plants of population 2 grown on furrow was the most effective treatment . It gave the highest yield (8.08 kg.m⁻²) and single head weight (317.4g), however, it resulted in significant leaf numbers per plant reductions. The obvious domination of population and furrow cultivation under either rainfalls and supplemental watering explained the moderate degree of inter and intra competition among lettuce plants grown at the rows of each furrow . Population 2 degree of competitions were ameliorated and withdrawn below their critical point by furrow cultivation. High light incidence in Mosul may be another interpretation for completion being under the critical point which highly exceeded that of lettuce requirement. Glenn (1984) measured continued growth increases up to 500cal.cm⁻².day⁻¹ incident radiation in his green house trail. Whereas, Wein (1997) found that lettuce dry matter production was maximum at 150cal.cm⁻².day⁻¹ in field plantings in Italy and United Kingdom (UK). Ryder (1999) reported lettuce light requirement of 15klux. In comparison to Mosul City located on 36° 42" N latitude and 230m altitude has a radiation incidence ranges from 520 to 610 klux during lettuce growing season(Wein, 1997).

Table (6): Effects of supplementary irrigation, cultivation methods and plant populations on growth and yield of lettuce.

Irrigation levels	Rainfalls				Supplementary irrigation			
	Furrow cult.		Plot cult.		Furrow cult.		Plot cult.	
Cultivation methods	Pop I	Pop II	Pop I	Pop II	Pop I	Pop II	Pop I	Pop II
Plant populations	Pop I	Pop II	Pop I	Pop II	Pop I	Pop II	Pop I	Pop II
Plant height (cm)	34.5b	38a	33b	39.3a	30.1b	38.2a	33b	40a
Leaf numbers/plant	48.2a	44.8ab	36.8bc	31.3d	47.8a	46.8a	37.3b	33.5cd
Single head fwt.(g)	343.1a	320.5b	288.8c	260d	342.8a	314.7b	292.8c	265d
Yield (kg.m ⁻²)	4.06b	8.03a	3.26b	7.05a	3.89b	8.13a	3.33b	7.23a

Leaf dry matter (%)	10.5a	10.5a	10a	8.8b	9.5a	10.3a	10.5a	9.5ab		
Stem dry matter (%)	6.1a	5.1b	6.2a	5.1b	6.3a	5.2b	6.3a	5.5ab		
A*C & B*C	Irrigation levels*Populations				Cultivations*Populations					
Interactions	R*PI	R*PII	S*PI	S*PII	F*PI	F*PII	Plot*PI	Plot*PII		
Plant height (cm)	33.8b	38.7a	31.6b	39.1a	34.8b	33b	38.1a	39a		
Leaf numbers/plant	42.5a	38.1b	42.6a	40.2ab	34.3b	38.1a	33b	39.9a		
Single head fwt.(g)	316a	290.3b	316.9a	289.9b	343a	303.1a	209b	262.5b		
Yield (kg.m ⁻²)	3.7b	7.6a	3.6b	7.7a	3.98b	8.08a	3.3b	7.14a		
Leaf dry matter (%)	10.2ab	9.7ab	10.8a	9.5b	10.8a	10a	10.3a	9.2a		
Stem dry matter (%)	6.15a	5.1b	6.3a	5.35ab	6.2a	5.2b	6.3a	5.3b		
A, B ,C & A*B	Irrigation		cultivations		Populations		Irr*cult (A*B) interactions			
Interactions	Rain	Sup	Furrow	Plot	P I	P II	R*F	R*p	S*F	S*P
Plant height (cm)	36.3a	35.3a	35.2	36.3	32.65	38.9	36.3a	36.2a	34.1a	36.5a
Leaf numbers/plant	37.8a	41.4a	46.9a	34.8b	42.6a	39.1b	46.5a	44.8a	47.3a	46.8a
Single head fwt.(g)	303.1a	303.9a	330.2a	276.7b	316.9a	290b	331.8a	274.4b	28.8ab	278.9b
Yield (kg.m ⁻²)	5.6a	5.65a	6.03a	5.22b	3.64b	7.61a	6.05a	5.16b	6.01a	5.28b
Leaf dry matter (%)	9.95a	10.15a	10.7a	9.7a	10.6a	9.8b	10.5a	9.4a	10.3a	10a
Stem dry matter (%)	5.65a	5.85a	5.7a	5.8a	6.25a	5.25b	10.5a	9.4b	10.3a	10.1ab

(P1,P2= P0pulations);(P=plot=furrow);(R=rainfall's=supplemental irrigation). Figure of shared characters are not significant at 0.05 level/Duncan tests.

Experiment 3:Table (7) results showed that gradual increases in the applied rates of GA3 were concomitant by gradual growth and yield improvement of lettuce, and therefore apparent increases were observed in plant height , stem length numbers of folded leaves, single head weight, head size bulk density of head and marketable yield. 100 ppm GA3 treatments appeared to be the most effective. It highly increased plant height(24.6%), stem length(75.5%), numbers of folded leaves(22.1%), weight of single head(51.2%), head bulk density(25%) and marketable yield(114.5%) in comparison to check. Furthermore it gave the lowest values in the number of unfolded leaves and non-marketable yield. However it slightly reduced dry matter percentage of leaves. Growth and yield increases gained from GA3 application explained the huge dry matter production in relation to control ,and thus we could ignore dry mater percentage reduction.

Positive linear correlation were found among GA3 rates in plant heights($r=0.44$), stem length($r=0.63$), weight of single head($r=0.76$), head size($r+0.44$), bulk density of head($r=0.69$) and marketable yield($r=0.78$). However, negative correlations were also detected in the numbers of unfolded leaves ($r=-0.81$), unmarketable yield($r=$

-0.85 and leaf dry matter percentages($r=-0.39$). Precise prediction may be achieved by using linear equations obtained from regression , for instance the demonstrated lettuce yield in this trail of 100 ppm GA3 treatment was (5.9 kg.m⁻²) which is very close to predicted when the established equations are applied(yield =2.92 + 0.029 X 100 =5.82 kg.m⁻²).

Plant height increases as a result of GA3 application were attributed to the ability of GA3 in enhancing higher rate of node differentiations. This

enhancement ability proved by the production of a huge number of folded and unfolded leaves , otherwise plant height increase should be caused by internodes elongation and hence significant reduction would be observed in head firmness , numbers of folded leaves and yield. Lettuce stem elongation usually occurs after exposing plants to cold temperature and critical long day periods. Bolting is the real problem facing lettuce growers in Mosul.

Lettuce maturation are usually synchronized with the commence of critical bolting photoperiods and thus growers have to harvest their crops with in few days and sell it very cheap. GA- stimulated stem elongation is due to cell elongation rather than increased cell division after exposure to the cold temperatures of the ensuing winter they flower in the second year(Goodwin and Mercer, 1985), they also found that the level of extractable GA-like materials in rosette plant is equal or greater than that in photo periodically induce bolting plant, the possible explanation of negative correlation between GA-like materials and stem elongation is that under short days GA is compartmentalized in the cell and no available for the stimulation of stem elongation until long days initiate it release.

GA3 application resulted in high differentiation rate of leaves which is reflected on head bulk density (firmness), head size head weight, hearting process, plant height, yield and on entire head performance. These improvements might be attributed to the influence of GA3 on cell metabolism through its ability to increase activities of hydrolytic enzymes which provide crude materials to facilitate cell wall expansions. Mapelli, *et al.*, (1984) demonstrated increase in activities of amylase (15.7%0, A phosphotase (46.2%), peroxidase (34.4%), lipase(37.7%), pectinase (37.7%), esterase(2.1%), Pytase(45.9%), invertase8%) glucosidase 11.7%) and nuclease(11.2%). Treatment with GA1 tended to induce the production of ethylene with begin 10h after application, showed a peak at about 24h and the declined , the yield of ethylene was proportional to the amount of GA1, ethylene production has a boosting effect on cell wall expansion (Garcia-Martinez, *et al.*, 1984 ; Goodwin and Mercer, 1985).

Experiment 4: Application of NAA rates (Table 8), resulted in positive correlations in plant height($r=0.021$), weight of single head($r=0.1$), unmarketable yield ($r=0.33$) and marketable yield($r=0.7$). However, they also showed negative correlations in stem length($r=-0.36$), numbers of unfolded leaves($r=-0.7$), weight of unfolded plant($r=-0.09$), bulk density of head($r=-0.04$) and leaf dry matter percentage ($r=-0.13$). 50 ppm NAA appeared to be the most effective treatment It highly increased the individual head weight(19.8%), head size(21.1%), unmarketable yield (19.5%) and marketable yield (44.6%), followed by 100 ppm NAA treatment which gave the highest plant height (30.7cm) and marketable

yield(3.12kg.m^{-2}) when it compared to untreated control. In general, NAA application tended to reduce stem length(9.8%) and numbers of unfolded leaves

(43.5) in relation to check treatment. Lettuce growth and yield increases confirmed the positive effects of NAA applications on lettuce at heading stage.

Table(7): The effects of GA3 rates on growth and yield of lettuce .

Traits (Y)	GA3 rates mg.l ⁻¹ (X)				Linear Equations (Y=a+bx)		
Rates / a,b & r values	0.0	50	75	100	a	b	r
Plant height (cm)	23.67	26.33	26	29.5	23.47	0.0516	0.44*
Stem length (cm)	11	15	14.5	19.3	10.79	0.074	0.63**
Number of unfolded leaves	31.1	30	23	19.3	32.7	-0.12	-0.81**
Number of folded leaves	33	33.7	38	40.3	32.02	0.075	0.74**
Weight of un-headed plant	340	330	350	400	325.43	0.53	0.39
Weight of headed plant	280	390	386.7	423.3	292	1.39	0.76**
Head size (cm ³)	1761.7	1986.7	1895	2150	1762.3	3.3	0.44*
Head bulk density (g.cm ⁻³)	0.16	0.2	0.21	0.2	0.168	0.0004	0.69**
Unmarketable yield (Kg.m ⁻²)	6.3	1.87	1.13	1.67	5.57	-0.05	-0.085
Marketable yield (kg.m ⁻²)	2.75	4.93	4.7	5.9	2.92	0.029	0.78**
Leaf dry matter (%)	6.4	6.43	6.37	6.03	6.48	-0.003	-0.39

Similar results were obtained by Gallardo *et al.* (1996) Ryder (1999) and El-Sabary (2005), They confirmed that 60 to 80% of lettuce growth occurs during the last month of the growing season, and therefore heading stage should be paid an intensive care in all cultural practices such as watering, fertilizing and pest eradications . Studies reported that the primary effect of auxin is to cause the cell to lower the pH of the aqueous phase of the cell wall, possibly by stimulating a membranes-bond H⁺ ion pump, increase in H⁺ ion concentration would then weaken hydrogen bonding between the cellulose microfibrils and xyloglucans and allow them to slide past each other under the pull of turgor pressure to keep cell wall expansion(Goodwin and Mercer, 1985). The indirect effects of auxin are fulfilled through ethylene actions which is its generation boosts by auxins . Pretreatment of leaves with IAA elicited a rapid ethylene production and in endogenous ACC 1-aminocyclopropane-1-carboxylic acid (Mackeon *et al.*, 1982 and Garcia-Martinez *et al.*, 1984).

Table (8): Effects of NAA rates on growth and yield of lettuce.

Traits (Y)	NAA rates mg.l ⁻¹ (X)				Linear Equations (Y=a+bx)		
Rates / a,b & r values	0.0	50	75	100	a	b	r
Plant height (cm)	29.7	29.7	27.8	30.7	29.36	0.0017	0.021
Stem length (cm)	12.7	9.8	10.3	10.3	12.11	-0.023	-0.36
Number of unfolded leaves	33	25.3	19	24.7	31.46	-0.11	-0.7**
Number of folded leaves	33.3	33	31.7	31.7	33.47	-0.019	-0.25
Weight of unheaded plant(g)	320	513.3	336.7	293.3	387.05	-0.038	-0.09
Weight of headed plant(g)	336.7	403.3	350	356.7	354.38	0.13	0.1
Head size (cm ³)	1563.3	1893	1700	1803.3	1626.86	2.01	0.24
Head bulk density (g.cm ⁻³)	0.22	0.22	0.23	0.21	0.22	-0.00001	-0.04
Unmarketable yield (Kg.m ⁻²)	1.28	1.53	1.73	1.67	1.31	0.0043	0.33
Marketable yield (kg.m ⁻²)	2.13	3.08	3.03	3.12	2.29	0.0099	0.7**
Leaf dry matter (%)	6.43	6.43	6.77	6.17	6.51	-0.001	-0.13

Ethylene investigation demonstrated a root growth inhibition, presumably this inhibition may tend to convert the photosynthetic assimilate to the vegetative sink. Exogenously applied IAA is usually inhibitor on the root elongation, suggesting that endogenous auxin content is as high as supraoptimal concentration which causes H⁺ influx and tend to reduce pH.

العلاقات المائية في الخس (*Lactuca sativa L. Var longifloia*)

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الخلاصة

أجريت أربع تجارب منفصلة لدراسة تأثير معدلات البذار (١ و٢ و٣ و٤ غم بذور/م^٢) على أداء الشتلات المنتجة، تحسين النمو الحاصل باستخدام الكثافات النباتية وطريقة الزراعة تحت الري التكميلي والأمطار، تحسين مقاومة الجفاف باستخدام حامض الجبر ليك GA3 ونفثال حامض ألكليك وبمعدلات صفر و٥٠ و٧٥ و١٠٠ ملغم/لتر لكليهما. تظهر نتائج تجربة ١ بأن معدل البذار ٢ غم بذور /م^٢ كانت أفضل المعدلات حيث أعطت ٧٣٨ شتلة واحتوت على شتلات ذات أحجام كبيرة ومتوسطة وصغيرة بنسب ١٨ و٣٦ و٤٦% على التوالي. تؤكد نتائج تجربة ٢ إمكانية إنتاج الخس تحت الأمطار المتاحة في الموصل ولا توجد حاجة إلى الري التكميلي وكانت الزراعة بالمرور متفوقة على الزراعة بالألواح بمقدار ١٥,٤% في الحاصل وإن الكثافة النباتية العالية ٢٨ نبات /م^٢ أعطت حصلاً متفوقاً بمقدار ١٠٩,١% على الكثافة النباتية الواطئة ١٤ نبات /م^٢ ويعاب عليها الانخفاض الطفيف في معدل وزن الرأس الواحد. تؤكد نتائج تجربة ٣ بأن رش حامض الجبر ليك أثناء عملية تكوين الرؤوس أدت إلى تحسين الحاصل معنوياً خاصة معاملة ١٠٠ ملغم /لتر حيث أعطت أعلى حاصل ٥,٩ كغم /م^٢ وبكثافة ظاهرية للرأس ٠,٢ غم /سم^٣ وحجم الرأس ٢١٥٠ سم^٣ ومعدل وزن الرأس الواحد ٤٢٣,٣ غم. تشير نتائج التجربة الأخيرة بأن رش نباتات الخس بمعدل ٥٠ ملغم /لتر من نفثال حامض ألكليك أكثر المعدلات فعالية حيث أعطت أعلى حاصل ٣,١٢ كغم /م^٢ ومتوسط وزن الرأس الواحد ٤٠٣,٣ غم ولكن كانت أقل فعالية من معدلات حامض الجبر ليك

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