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EFFECT OF IRRIGATION SYSTEM AND PLANTING PATTERN, ON YIELD AND QUALITY OF SUGAR BEET UNDER NORTH DELTA CONDITIONS

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ABSTRACT

Two field experiments were carried out at Biyala region during 2004/05 and 2005/06 winter seasons to study the effect of two irrigation systems; i.e., improved and traditional mesqa, and, three sowing patterns, i.e., ridges, platforms and rows on yield and quality of sugar beet. The experimental design was a split-plot, with four replications, where the irrigation systems were allocated to the main plots and planting patterns were arranged in the sub-plots.

The results indicated that the improved mesqa irrigation system gave the highest values of root length and diameter, root and top yields, root/top ratio, gross and white sugar percentage and yields, while traditional mesqa obtained the lowest value. Also, the maximum optimum irrigation efficiency (Iopt) was recorded under improved mesqa method compared with traditional mesqa method during the two seasons of study.

Beet sowing in ridge or platform patterns produced the highest values of all studied traits, while the highest top yield was obtained by using row pattern.

It might be seen from data obtained that improved mesqa irrigation system saved water by 14.77 and 17.98%, whereas the platform pattern saved water by 18.82 and 19.87% in the first and the second seasons, respectively.

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is widely grown in many countries under very different climatic regimes, varying from hot semi-arid to cool humid conditions. In most places, it is grown as a summer crop, with irrigation if necessary, in dry climates. But, in some Mediterranean countries, it is grown as a winter crop and harvested in late spring (early summer). Sugar beet is a field crop with increasing importance in Egyptian agriculture. The expansion in its production helps to fill the gab in sugar requirements with less consumption of water as compared with sugarcane. Sugar beet is grown an area in Egypt reached 168,000 fed. in 2005 season with a total production of 449,418 tons of sugar (Sugar Crops Council Report, 2005).

Irrigation, fertilization, plant population, soil type, climate, previous cropping history and many other factors need to be taken into account to maximize sugar beet yield. Under semi-arid and arid climates, the agricultural production relies almost entirely on irrigation. It is a feature of traditional irrigation system that more water is added to the soil than is actually required to make up the deficiency in soil moisture which results from evapotranspiration. In addition to the excessive water, which drains through the root zone of the crop, water seeps from irrigation canals and water courses and, together, these can lead to a problem of water logging , especially when no adequate drainage system is for water table control. Realizing the significant included role of irrigation and drainage in Egyptian agriculture, which depends completely on irrigation water, the government has given a high priority to this sector. The improved management of water on the farm may conserve, either labor or soil and may increase yields of crops. In recent years, due to population pressures and demands for both increased quantity and better quality of food, Egypt must improve the agriculture efficiency to overcome the increasing population. Since water is the most riveting factor for plant production, it seems necessary to improve the irrigation management as a prerequisite to improve the water delivery system in the Nile Delta. Many investigators studied the effect of various methods of water delivery system on water relations and yield of field crops among of them [Ibrahim *et al.,* (2003) and Mahmoud (2005)]. They concluded that the supply of water delivery using improved mesqas under land levelling, markedly affected water relations, yields of field crops and soil properties than the traditional mesqa irrigation.

Also, results of many experiments on sugar beet and other field crops have been reported, which, either directly or indirectly suggested the importance of adequate light for optimum yield. Since sugar beet is usually produced under row culture, it seems reasonable to assume that variation in row and plant spacing will greatly influence solar radiation. Therefore, the objective of this study is to determine the effect of irrigation systems and planting patterns on yield and quality of sugar beet.

MATERIALS AND METHODS

Two field experiments were carried out at Biyala district, Kafr El-Sheikh Governorate, North Delta, on Farmer's fields, which were mainly different in irrigation systems during 2004/2005 and 2005/2006 growing seasons. These experiments were designed to study the effect of irrigation systems; i.e., improved and traditional methods, and sowing patterns; i.e., ridges, platforms and rows on yield and quality of sugar beet. Each experimental field included one irrigation system and three planting patterns. In both experiments sugar beets were growing in large field plots.

Soil physical and chemical analyses were done for samples taken from 0-30 cm depth in the experimental sites before seedbed preparation and their data are presented in Table (1), according to methods of Jackson (1967). The experimental field was fertilized with 30 kg P_2O_5/fed. in the form of calcium superphosphate (15.5% P_2O_5) and 24 kg K_2O/fed. in the form of potassium sulphate (48% K_2O) during soil preparation. Nitrogen, with the rate 100 kg/fed., in the form of urea (46.5% N), was applied in two equal doses; namely, the first one after thinning and the second at twenty days later. The previous crop was rice in both fields and seasons.

The two experiments were laid out in a split-plot design with four replications. The main plots were assigned to the two irrigation systems (improved and traditional mesqa), while, the sub-plot treatments were assigned to the three plant patterns (ridges, platforms and rows). The sub-plot area was 86.4 m^2 (6 x 14.4 m).

Each sub-plot included 24 and 36 ridges and 29 rows spaced at (60, 40 and 50 cm) and hills at (20, 30 and 24 cm), respectively. The optimum plant population (35000 plants/fed.) was used and it was distributed as given in Table (2).

Table (1):Some physical and chemical analyses of the experimental fields (average of two seasons) before planting.

Irrigation system	Physical analysis				Chemical analysis						
	Sandy (%)	Silt (%)	Clay (%)	Texture class	EC (mmohs/cm)	pH	O.M. (%)	CaO_3 (%)	F.C. (%)	W.P (%)	Soil saturation
Improved mesqa	21.60	25.17	53.23	Clay	3.89	8.25	1.27	1.48	40.81	23.41	81.79
Traditional mesqa	25.02	22.20	52.78	Clay	4.49	8.42	1.20	1.72	40.19	24.37	81.37

Table (2):Planting patterns in ridges, platforms and rows.

Plant spacing	Ridge spacing (cm)	Hill spacing (cm)	Plant distribution
60 x 20 cm	60	20	One side (ridges).
40 x 30 cm	120	30	Two sides and middle (platforms).
50 x 24 cm	50	24	One row (rows).

The commercial sugar beet cultivar Toro polygerm, was used in both seasons. Beet seeds were sown on 27/9/2004 and 30/9/2005 in hills at the rate of 3-4 seeds/hill. Hills were thinned at one plant/hill 35 days after sowing. Other cultural practices were done as recommended in sugar beet fields in the region.

Irrigation systems:

The field of irrigation method was either an improved pump station, connected to pipe line mesqa, or a traditional pump, connected to unimproved earthen mesqa. The amount of irrigation water applied was measured by using a cut-throat flume (20 x 90 cm) and was calculated in m^3/fed. (Early, 1975).

The collected data of the experiments involved the following criteria:

I. Amount of applied seasonal irrigation (m^3/fed.).

II. At maturity (210 days after sowing), a central area of 24 m^2 from each sub-plot was harvested at both experiments in the two seasons. Root and top yields per harvested area were transformed to metric tons/fed. They were estimated follows:

1. Number of plants/fed. at harvest.
2. Root length (cm).
3. Root diameter (cm).
4. Root weight (kg).
5. Root yield (t/fed.)
6. Top weight/plant (kg).
7. Top yield (t/fed.)
8. Root/top ratio.

III. Quality parameters:

All parameters were determined in the Delta Sugar Company Limited Laboratories at El-Hamoul, Kafr El-Sheikh Governorate according to the method of Le-Docte (1927), as described by McGinnus (1971). The parameters of quality included the following:

1. Gross sugar yield (t/fed.) = Root yield (t/fed.) x gross sugar percentage.
2. White sugar yield (t/fed.) = Root yield (t/fed.) x white sugar percentage.
3. Sugar losses yield (t/fed.) = Root yield (t/fed.) x loss sugar percentage.
4. Gross sugar (%):
   Juice sugar content was determined according to LeDocte (1927), as described by McGinnus (1971).
5. Extractable white sugar %:
   Corrected sugar content (white sugar) of beet was calculated according to Reinefeld *et al.* (1974), as described by Harvey and Dutton (1993).
6. Loss sugar (%) = Gross sugar (%) - White sugar (%).
7. Juice purity percentage.
8. Soluble non-sugars content:
   The soluble non-sugars (potassium, sodium and α-amino nitrogen in meq/100 of beet) in roots were determined by means of an automatic sugar polarimetric.

IV. Optimum irrigation efficiency (Iopt):
It was calculated, according to Michael (1978).

$$\text{Iopt} = \text{Max.}\left(\frac{Y}{Wa}\right) = (\text{kg/m}^3).$$

Where:
Y = Root or white sugar yields (kg/fed.)
Wa = Seasonal water applied (m^3/fed.).

Statistical analysis:

The analysis of variance was carried out according to Gomez and Gomes (1984). All means were compared by Duncan’s Multiple Range Test (Duncan, 1955). All statistical analyses were performed by using the analysis of variance technique by means of “IRRISTAT” computer software package L.S.D. test for interactions.

RESULTS AND DISCUSSION

Focusing light on the obtained results and tryins to explain them are the aim of this study. Effect of irrigation systems and planting patterns as well as their interactions on sugar beet yield and quality are discussed, as follows:

I. Amount of applied seasonal irrigation (m^3/fed.):

The seasonal applied water included the sowing irrigation. The total amount of irrigation water was measured and recorded, as shown in Table (3). It has been noticed that the plant distribution in rows under traditional mesqa irrigation system, received the highest amount of irrigation water, while the beet sowing in platform pattern, under improved mesqa irrigation, utilized the least amount of irrigation water in both seasons. It can be seen from data that the improved mesqa irrigation system saved water by 14.17 and 17.98% in the first and second seasons, respectively.

Table (3): Amount of water applied (m^3/fed.) for sugar beet as affected by irrigation systems and planting patterns in the two seasons.

Planting patter	Irrigation systems		Water saving (%)	Irrigation systems		Water saving (%)
	Improved mesqa	Traditional mesqa		Improved mesqa	Traditional mesqa	
	2004/05 season			2005/06 season		
Ridges	2346.46	2666.74	12.01	2325.19	2804.23	17.08
Platforms	2096.34	2582.55	18.82	2085.74	2603.07	19.87
Rows	2597.58	2941.78	11.70	2494.36	3005.00	16.99
Mean	2346.79	2730.35	14.17	2301.76	2804.10	17.98

II. Yield and its components:

1. Number of plants/fed. at harvest:

The theoretical number of plants/fed., at sowing, was 35000 plants/fed. Data in Table (4) showed the means of actual number of plants/fed. at harvest, as affected by irrigation systems, planting patterns and their interactions, in both seasons.

Data indicate that irrigation system did not significantly affect the actual number of plants/fed. in the first season. However, such effect was significant in the second one. Where, improved mesqa irrigation system gave the highest number of plants (31940.83), compared with traditional mesqa method (31136.66).

In both seasons, the number of harvested plants were significantly affected by plant spacing treatments. While, sowing sugar beet on rectangular spacing of 40 x 30 cm(platform) recorded the highest number (34125.00 and 32531.25 plants/fed.) and the lowest ones were obtained from sowing on rows spaced at 50 x 24 cm (33093.75 and 30751.87 plants/fed.) in the two seasons, respectively.

These results are in accordance with those obtained by Antoniani (1973), Kamel *et al.* (1981) and (1990), Smit *et al.* (1996) and Hilal (2000).

Table (4):Actual number of sugar beet plants/fed. at harvest as affected by irrigation systems, planting patterns and their interactions in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns			Mean
	Ridges (60 x 20 cm)	Platforms (40 x 30 cm)	Rows (50 x 24 cm)	
	2004/05 season			
Improved mesqa Traditional mesqa	32375.00 34000.001	33468.75 34781.25	35000.00 31187.50	33614.58 33322.91
Mean	331857.50 b	34125 a	33093.75 b	-
Interaction LSD (5%)	1349.46	-	-	-
	2005/06 season			
Improved mesqa Traditional mesqa	30187.50 32478.75	32156.25 32906.25	33478.75 28025.00	31940.83 a 31136.66 b
Mean	31333.12 b	32531.25 a	30751.87 c	-
Interaction LSD (5%)	917.16	-	-	-

Means designated by the same letter within the same row or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.

In general, the interaction between irrigation system and planting pattern affected significantly the actual number of plants/fed. at harvest in both seasons. The highest harvestable number of plants were obtained from planting on rows under improved mesqa and ridges or platforms under traditional mesqa (Table 4), in both seasons.

2. Root length (cm):

Data in Table (5) showed should be at 1% level of significant differences between the irrigation systems, concerning root length in both seasons. It is clear that improved mesqa system significantly increased root length (41.05 and 40.10 cm) in both seasons, respectively. Similar results were found by Sobhy (1994). He reported that increasing the applied irrigation decreased root length.

Concerning the effect of planting pattern on root length, data revealed significant effect in both seasons. Sowing sugar beet at rectangular plant spacing (60 x 20 cm) gave the longest root followed by the other planting patterns (platforms or rows). Such increases in root length might be attributed to more regular distribution of plants over the soil surface, which resulted in a more effective use of water and light available in the field. Similar observations were reported by El-Khatib (1991), Nemeat Alla (1997) and Hilal (2000).

Data in Table (5) farther showed that the longest roots were obtained from the sowing pattern in ridges and platform under improved mesqa irrigation, while the shortest one was recorded at traditional mesqa x row pattern in both seasons, according to the significant interaction the two studied factors.

Table (5):Effect of irrigation systems, planting pattern and their interactions on root length (cm) at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns			Mean
	Ridges (60 x 20 cm)	Platforms (40 x 30 cm)	Rows (50 x 24 cm)	
	2004/05 season			
Improved mesqa	40.65	41.00	41.50	41.05 a
Traditional mesqa	34.85	30.65	30.25	31.92 b
Mean	37.75 a	35.83 b	35.88 b	-
Interaction LSD (5%)	1.89	-	-	-
	2005/06 season			
Improved mesqa	41.25	40.65	38.40	40.10 a
Traditional mesqa	35.35	31.75	29.95	32.35 b
Mean	38.30 a	36.20 b	34.17 c	-
Interaction LSD (5%)	3.69	-	-	-

Means designated by the same letter within the same row or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.

3. Root diameter (cm):

The analysis of variance revealed that root diameter was significantly affected by irrigation system in both seasons. In general, the trend of these results are similar to that of root length (Table 6).

Table (6): Effect of irrigation systems, planting patterns and their interactions on root diameter at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns Ridges (60 x 20 cm)	Platforms (40 x 30 cm)	Rows (50 x 24 cm)	Mean
	2004/05 season			
Improved mesqa	13.70	13.60	13.50	13.60 a
Traditional mesqa	13.30	10.55	11.25	11.70 b
Mean	13.50 a	12.08 c	12.38 b	-
Interaction LSD (5%)	0.68	-	-	-
	2005/06 season			
Improved mesqa	13.30	13.90	13.30	13.50 a
Traditional mesqa	12.85	10.60	11.15	11.53 b
Mean	13.08 a	12.25 b	12.23 b	-
Interaction LSD (5%)	1.13	-	-	-

Means designated by the same letter within the same row or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.

It is clear that planting pattern had a slight effect on root diameter. The variation in root diameter, occurring at different plant spacings could be ascribed to different shares of utilized nutrients, water and other factors of growth (Table 6). Similar results were reported by Winter (1980), Zocca (1980), Lauer (1995) and Hilal (2000).

Data presented in Table (6), also, showed that the highest root diameter values were obtained from all planting patterns under improved mesqa irrigation in the two seasons. However, the thinnest diameter was obtained from traditional mesqa and 40 x 30 cm (platform) or 50 x 24 cm (row) plant spacings.

4. Root fresh weight and yield:

Root fresh weight (kg), as well as its yield (t/fed.) at harvest, as affected by irrigation systems, planting patterns and their interactions are shown in Tables (7 and 8).

Data in Tables (7 and 8) clearly revealed significant differences among the mean values of root weight and root yield, as affected by irrigation systems in both seasons. The heaviest root yields were obtained from improved mesqa irrigation. It was noticeable that root fresh weight was increased as plants advanced towards maturity due to increases in root length and diameter. Concerning the effect of irrigation system on root fresh weight/plant (in kg), the data, also, revealed that the average root fresh weight took the same trend as root yield (t/fed.). Meaningful, improved mesqa irrigation surpassed the traditional mesqa in increasing root fresh weight and yield. The difference, in root yield between irrigation systems could be largely attributed to the amount of irrigation water, which was enough to meet the crop water need and availability of soil water in the effective root zone. Therefore, from the viewpoint of water management, there were improved mesqa irrigation systems to get the maximum beet root yield in the area of study. These results are in agreement with those obtained by Azzazy (1998), Saied (2000), Abd El-Wahab *et al.* (2002) and Emara and Ibrahim (2004).

Data in Table (8), also, indicated that planting patterns had a significant effect on root yield/fed. in both seasons. Beet sowing in platform or ridge patterns produced the highest root yields/fed. compared with row pattern. Most workers mentioned that the range of 75000 to 100000 plants/ha (a spacing of 60 x 20 to 50 x 20 cm apart) was the most effective density for obtaining an optimum root yield. These findings agree with those obtained by Lauer (1995), Smit *et al.* (1996), Nemeat Alla (1997) and Hilal (2000).

The interactions effect were significant between planting patterns and irrigation systems on root yield/fed. The trend of root yield/fed. was similar to that of root weight (kg) (Tables 7 and 8). Generally, all planting pattern under improved mesqa, increased root yields more than traditional mesqa irrigation method.

Table (7): Effect of irrigation systems, planting patterns and their interactions on root weight (kg) at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns			Mean
	Ridges (60 x 20 cm)	Platforms (40 x 30 cm)	Rows (50 x 24 cm)	
	2004/05 season			
Improved mesqa	1.50	1.45	1.40	1.45 a
Traditional mesqa	1.33	1.21	1.25	1.26 b
Mean	1.41 a	1.33 ab	1.32 b	-
Interaction LSD (5%)	0.13	-	-	-
	2005/06 season			
Improved mesqa	1.51	1.50	1.40	1.47 a
Traditional mesqa	1.20	1.21	1.30	1.23 b
Mean	1.35	1.35	1.35	-
Interaction LSD (5%)	0.15	-	-	-

Means designated by the same letter within the same row or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.

Table (8): Effect of irrigation systems, planting patterns and their interactions on root yield (t/fed.) at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns			Mean
	Ridges (60 x 20 cm)	Platforms (40 x 30 cm)	Rows (50 x 24 cm)	
	2004/05 season			
Improved mesqa	48.56	48.52	49.00	48.69 a
Traditional mesqa	45.22	42.21	38.98	42.13 b
Mean	46.89 a	45.36 b	43.99 c	-
Interaction LSD (5%)	2.78	-	-	-
	2005/06 season			
Improved mesqa	45.50	48.23	46.87	46.86 a
Traditional mesqa	38.97	39.81	36.43	38.40 b
Mean	42.23 b	44.02 a	41.65 b	-
Interaction LSD (5%)	2.54	-	-	-

Means designated by the same letter within the same row or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.

5. Top yield:

Data in (Tables 9 and 10) showed that top weight in (kg) and top yield in (t/fed.) significantly responded to the tested irrigation systems; i.e., improved mesqa, and traditional mesqa in both seasons. The presented data showed that improved mesqa was favorable enough to produce higher top yields (27.00 and 26.54 t/fed.), compared with that obtained by traditional mesqa irrigation (24.25 and 22.83 t/fed.) in both seasons, respectively. Similar findings were recorded for the top weight in (kg).

Table (9): Effect of irrigation systems, planting patterns and their interactions on top weight (kg) at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns			Mean
	Ridges (60 x 20 cm)	Platforms (40 x 30 cm)	Rows (50 x 24 cm)	
	2004/05 season			
Improved mesqa	0.80	0.80	0.81	0.80 a
Traditional mesqa	0.70	0.70	0.79	0.73 b
Mean	0.75 b	0.75 b	0.80 a	-
Interaction LSD (5%)	0.10	-	-	-
	2005/06 season			
Improved mesqa	0.81	0.80	0.88	0.83 a
Traditional mesqa	0.71	0.70	0.89	0.76 b
Mean	0.76 b	0.75 b	0.88 a	-
Interaction LSD (5%)	0.13	-	-	-

Means designated by the same letter within the same row or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.

Table (10): Effect of irrigation systems, planting patterns and their interactions on top yield (t/fed.) at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns			Mean
	Ridges (60 x 20 cm)	Platforms (40 x 30 cm)	Rows (50 x 24 cm)	
	2004/05 season			
Improved mesqa	25.90	26.77	28.35	27.00 a
Traditional mesqa	23.80	24.34	24.63	24.25 b
Mean	24.85 b	25.55 ab	26.49 a	-
Interaction LSD (5%)	2.97	-	-	-
	2005/06 season			
Improved mesqa	24.45	25.72	29.46	26.54 a
Traditional mesqa	23.05	23.03	22.42	22.83 b
Mean	23.75 b	24.37 a	25.94 a	-
Interaction LSD (5%)	3.01	-	-	-

Means designated by the same letter within the same row or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.

There were substantial differences in top yields obtained among planting patterns in both seasons (Tables 9 and 10). Sowing beets on row or platform patterns produced the highest top yields, while, those of ridge pattern produced the lowest ones. Results of planting pattern effect on this criterion are conflicting. While, Kamel *et al.* (1981) noticed that top yield was lower with widening distances plants, Mohamed (1985) reported that narrowing distances among beet plants caused significant decreases in number of leaves per plant. Mahmoud *et al.* (1990) stated that top yield was maximized when plants were sown at wider spacings (60 x 30 cm). Also, Hilal (2000) found that top yield was the highest at platform pattern. Generally, the trend of top weight (kg) results were similar to those of top yield (t/fed.), as shown in Tables (9 and 10).

There was a significant interaction between irrigation systems and planting patterns for top yields in both seasons. It is clear from data in Table (10) that platform or row pattern, under improved mesqa, gave the highest top yields, while, the lowest ones were obtained with ridge pattern under traditional mesqa irrigation.

Finally, the results indicate that the yield of sugar beet (roots and top) was highly related not only to number of plants per unit area, but also to the process of contributing this number, amount of water applied and soil fertility.

6. Root/top ratio:

Concerning the effect of irrigation systems on root/top ratio, it is obvious from data collected in Table (11) that irrigation systems had a significant effect on root/top ratio in both seasons. Meanwhile, improved mesqa irrigation recorded the highest values of root/top ratio (1.80 and 1.76), compared with traditional mesqa type (1.73 and 1.62) in both seasons, respectively.

Table (11):Effect of irrigation systems, planting patterns and their interactions on root/top ratio at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns			Mean
	Ridges (60 x 20 cm)	Platforms (40 x 30 cm)	Rows (50 x 24 cm)	
	2004/05 season			
Improved mesqa	1.87	1.81	1.72	1.80 a
Traditional mesqa	1.90	1.72	1.58	1.73 b
Mean	1.88 a	1.76 b	1.65 c	-
Interaction LSD (5%)	0.92	-	-	-
	2005/06 season			
Improved mesqa	1.86	1.85	1.59	1.76 a
Traditional mesqa	1.70	1.70	1.46	1.62 b
Mean	1.78 a	1.77 a	1.52 b	-
Interaction LSD (5%)	0.35	-	-	-

Means designated by the same letter within the same row or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.

Results in Table (11) farther indicated that the highest values of root/top ratio (1.88 and 1.78) were obtained from ridge pattern (60 x 20 cm). On the contrary, the lowest root/top ratio (1.65 and 1.52) was recorded from plants sown in row pattern (50 x 24 cm) in both seasons, respectively. These results could be explained on the basis that plants grown at wide hill spacings, and with good orientation, resulted in low competition among them for nutrient, soil moisture and sunlight, so that translocation and, consequently, accumulation of metabolites through root was increased to form heavier roots. Similar observations were reported by Obead (1988), Badawi (1989), Mahmoud *et al.* (1990) and El-Khatib (1991).

The effect of interaction was significant between irrigation systems and planting patterns on root/top ratio in both seasons (Table 11). The highest values of root/top ratio resulted at improved mesqa and traditional systems with ridge pattern, while the lowest one resulted at traditional mesqa irrigation and row pattern, in the two seasons.

III.Quality parameters:

Beet quality is not a single character, which can be presented in a quantitative form by using a single numerical value. Instead, it is a combination of all the chemical and physical aspects of beet root, which influence its processing, or which affect sugar yield of its by-products.

1.Gross sugar percentage and yield (t/fed.):

The gross sugar yield is an important yield parameter of sugar beet. Gross sugar percentage showed a slight positive response to the irrigation systems in both seasons (Table 12), but, sugar yield was significantly increased. Improved mesqa irrigation gave the highest sugar yield (8.99 and 8.42 t/fed.) in both seasons, respectively. While, the lowest sugar yield (7.62 and 6.77 t/fed.) was recorded under traditional mesqa in both seasons, respectively (Table 13). These results agreed with those obtained by Shams El-Din (2000) and Meleha (2002).

Regarding the effect of planting patterns, data in Tables (12 and 13) showed that significant differences were recorded between treatments on gross sugar (%) and sugar yield. The highest gross sugar % values were obtained by ridge pattern, in both seasons, while the highest sugar yield was recorded by ridge in the first season and platform patterns in the second season. As gross sugar yield/fed. was expressed as the multiplication of root yield/fed. by gross sugar (%), the differences in root yield and gross sugar (%) between traits reflected the differences in sugar yield/fed. Similar results were found by Kamel *et al.* (1981), Ramadan (1986), Mahmoud *et al.* (1990), El-Khatib (1991) and Hilal (2000).

The effect of interaction was significant between irrigation systems and planting pattern on gross sugar (%) and sugar yield in both seasons Tables (12 and 13). The highest sugar yield (ton/fed.) resulted under improved mesqa irrigation with ridge and platform pattern, while the lowest one resulted under traditional mesqa irrigation and row patterns.

2. White sugar percentage and yield (t/fed.):

Quality, expressed as purity %, which is the percentage of sucrose in juice from roots as a percent of the total soluble solids in the juice. Purity is important to the processor as soluble solids other than sucrose in the expressed sugar juice. Particularly, soluble N compounds make it more difficult to recover sucrose in the refining process.

In general, the trend of the effect of irrigation systems, planting patterns and their interactions on white sugar percentage and yield was similar to that of gross sugar percentage and yield and similar discussions could be cited (Tables 12 and 13).

T12-13

3. Loss sugar percentage and yield (t/fed.):

The most sugar losses in sugar factories result from the sugar in molasses, which is not crystallized. It is estimated by the major non-sugar components in the beet.

Although the efficiency of sugar recovery depends, to a large extent, on the factory equipments, the beet quality is by far, the most important parameter affecting the process (Khalil *et al.,* 2003).

With respect to the effect of irrigation system, the results indicated that loss sugar % was significantly affected only in the second season, but planting patterns and the interaction had insignificant effect on these traits (Table 12). The obtained results showed that the lowest values of sugar loss yield were recorded by traditional mesqa (1.57 and 1.53 t/fed.) in both seasons, respectively. Whereas, improved mesqa gave the highest one (1.91 and 1.76 t/fed.) in both seasons, respectively. However, in the first season beet sown an ridge pattern had the highest sugar loss yield (1.89 t/fed.) as indicated in Table (13).

4.Juice purity percentage:

Concerning the effect of irrigation systems, planting patterns and their interaction on purity percentage, results in Table (14) indicated that such effect was not significant on these traits in the two seasons.

Table (14):Effect of irrigation systems, planting patterns and their interactions in juice purity percentage at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns			Mean
	Ridges (60 x 20 cm)	Platforms (40 x 30 cm)	Rows (50 x 24 cm)	
	2004/05 season			
Improved mesqa	78.02	78.27	79.68	78.66
Traditional mesqa	77.65	80.98	79.71	79.45
Mean	77.83	79.63	79.70	-
Interaction LSD (5%)	NS	-	-	-
	2005/06 season			
Improved mesqa	78.55	79.32	78.42	78.76
Traditional mesqa	78.18	76.71	78.71	77.87
Mean	78.36	78.02	78.57	-
Interaction LSD (5%)	NS	-	-	-

Means designated by the same letter within the same row or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.

5.Soluble non-sugars:

The soluble non-sugars; viz., potassium, sodium and α-amino nitrogen, alone or in root juice, are regarded as impurities because they interfere with sugar extraction. Also, sodium and potassium ions play an important role on physiological equilibrium conditions in cellular solution for sugar contents in sugar beet yield. The nitrogenous compounds in beet, especially those containing amino nitrogen has a significant effect on juice purification and sucrose crystallization (Jenson *et al.,* 1983; Dutton and Turner, 1984; Armstrong and Moliford, 1985 and Marcussen, 1985).

T15

The overall mean values of soluble non-sugar percentage for beets as affected by irrigation systems, planting patterns and their interaction, are presented in Table (15). With regard to the effect of all treatments on K, Na and α-amino N concentration, it could be shown that these traits were insignificantly affected in both seasons, except for Na (%) in the first season, whereas planting in ridges surpassed the other patterns in their Na content.

IV. Optimum irrigation efficiency (Iopt):

The optimum irrigation efficiency (Iopt) determines the capability of plants to convert the applied water in to crop yields. In case of sugar beet, this parameter of crop yield can be evaluated both by root and white sugar yield. Table (16) illustrates the (Iopt) values for root beet yield, as influenced by irrigation systems and planting patterns. The average values of (Iopt), in the two growing seasons were 20.89, 15.51, 20.49 and 13.76 (kg/m^3) for improved and traditional mesqa systems, respectively. The highest values were 20.89 and 20.49 (kg/m^3) of root yield for improved mesqa, while the lowest values were 15.51 and 13.76 (kg/m^3), resulted from traditional mesqa. These results could be due to the minimum water applied in case of improved mesqa system. It is obvious that pipe line mesqa (improved mesqa) had the highest efficiency and the earthen mesqa (traditional mesqa) had the lowest one (Table 16). That is, a very little loss of water occurred through improved mesqa, compared to traditional mesqa.

Table (16):Sugar beet optimum irrigation efficiency (Iopt) in kg/m^3 of root yield for irrigation systems and planting patterns in both seasons.

Irrigation systems	Planting patterns									Average kg/m^3
	Ridges			Platforms			Rows			
	Wa m^3	Y kg/fed.	Iopt, kg/m^3	Wa, m^3	Y, kg/fed.	Iopt kg/m^3	Wa m^3	Y, kg/fed.	Iopt, kg/m^3	
	2004/05 season									
Improved mesqa	2346.5	48560	20.69	2096.3	48520	23.14	2597.5	49000	18.86	20.89
Traditional mesqa	2666.7	45220	16.95	2582.5	42210	16.34	2941.8	38980	13.25	15.51
Average (kg/m^3)	2506.6	46890	18.82	2339.4	45365	19.74	2769.65	43990	16.05	-
	2005/06 season									
Improved mesqa	2325.2	45500	19.56	2085.7	48230	23.12	2494.4	46870	18.79	20.49
Traditional mesqa	2804.2	38970	13.89	2603.1	39810	15.29	3005.0	36430	12.12	13.76
Average (kg/m^3)	2564.7	42235	16.72	2344.4	44020	19.20	2749.7	41650	15.45	-

Wa = Seasonal water applied. Y = Root yield.

The optimum irrigation efficiency was completely affected by each of irrigation systems and planting patterns. Concerning planting pattern, the platform pattern exhibited the highest effect on (Iopt) 19.74 and 19.20 (kg m^3) followed by ridge one 18.82 and 16.72 (kg m^3), whereas, row pattern was at the end values being 16.05 and 15.45 (kg m^3) in both seasons, respectively (Table 16).

Optimum irrigation, in relation to white sugar yield, (Table 17) illustrates that over the two averages in the both seasons, were 3.01, 2.17, 2.92 and 1.87 (kg m^3) for improved and traditional mesqa irrigation systems, respectively.

The highest value of (Iopt) was 3.01 (kg m³) resulted from improved mesqa system, while, the lowest value 1.87 (kg m³) resulted form traditional mesqa one.

In the present study, (Iopt) values indicated that, proportionately, higher yield of white sugar might be possible by the application of relatively low amounts of irrigation water.

Table (17):Sugar beet optimum irrigation efficiency (Iopt) in kg/m³ of white sugar yield for irrigation systems and planting patterns in both seasons.

Irrigation systems	Planting patterns									Average kg/m³
	Ridges			Platforms			Rows			
	Wa m³	Y kg/fed.	Iopt, kg/m³	Wa, m³	Y, kg/fed.	Iopt kg/m³	Wa m³	Y, kg/fed.	Iopt, kg/m³	
	2004/05 season									
Improved mesqa	2346.5	7130	3.03	2096.3	6920	3.30	2597.5	7080	2.72	3.01
Traditional mesqa	2666.7	6230	2.33	2582.5	6050	2.34	2941.8	5420	1.84	2.17
Average (kg/m³)	2506.6	6680	2.68	2339.4	6480	2.82	2769.65	6250	2.28	-
	2005/06 season									
Improved mesqa	2325.2	6520	2.80	2085.7	6910	3.31	2494.4	6640	2.66	2.92
Traditional mesqa	2804.2	5440	1.93	2603.1	5330	2.04	3005.00	5000	1.66	1.87
Average (kg/m³)	2564.7	5980	2.36	2344.4	6120	2.67	2749.7	5820	2.16	-

Wa = Seasonal water applied. Y = White sugar yield.

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تأثير نظام الرى وتوزيع النباتات على محصول وجودة بنجر السكر تحت ظروف منطقة شمال الدلتا

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أجريت تجربتان حقليتان فى منطقة بيلا خلال موسمى شتاء ٢٠٠٤/٢٠٠٥م و ٢٠٠٥/٢٠٠٦م وذلك لدراسة تأثير نظامين للرى (الرى المتطور والرى التقليدى) وثلاث طرق لتوزيع النباتات (الزراعة على خطوط وعلى مصاطب وفى صفوف).

استخدم فى هذه الدراسة تصميم القطع المنشقة مرة واحدة فى أربع مكررات حيث اشتملت القطع الرئيسية على معاملات نظم الرى والقطع المنشقة على طرق توزيع النباتات بالحقل.

وقد أوضحت النتائج الآتى:

- أعطى نظام الرى المتطور أعلى القيم لكل من الصفات الآتية: طول وقطر الجذر ـ محصول الجذور والعرش ـ نسبة الجذور إلى العرش ـ نسبة السكر الكلية ـ نسبة السكر الأبيض ـ محصول السكر الكلى والأبيض. فى حين أعطى الرى التقليدى أقل القيم لهذه للصفات.
- حقق نظام الرى المتطور أعلى قيمة لكفاءة الرى المثلى (I_{OPT}) وذلك مقارنة بالرى التقليدى.
- أدت طرق توزيع النباتات على خطوط أو مصاطب الى الحصول على أعلى القيم لكل من الصفات تحت الدراسة. بينما أعطى توزيع النباتات فى صفوف أكبر محصول من العرش.
- تشير البيانات الى أن استخدام نظام الرى المتطور قد أدى إلى توفير ماء الرى بنسبتى ١٤,٧٧ و ١٧,٩٨% ، بينما أدى توزيع النباتات على مصاطب إلى توفير ماء الرى بنسبتى ١٨,٨٢ و ١٩,٨٧% فى الموسمين الأول والثانى على التوالى.

Table (12):Effect of irrigation systems, planting patterns and their interactions on gross, white and loss sugar percentage at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns											
	Ridges	Platforms	Rows	Mean	Ridges	Platforms	Rows	Mean	Ridges	Platforms	Rows	Mean
	Gross sugar yield (t/fed.)				White sugar yield (t/fed.)				Loss sugar yield (t/fed.)			
	2004/05 season											
Improved mesqa	18.85	18.23	18.37	18.48 a	14.70	14.28	14.45	14.47 a	4.14	3.96	3.74	3.93
Traditional mesqa	18.07	18.26	17.96	18.10 b	13.78	14.41	13.93	14.04 b	3.94	3.60	3.67	3.73
Mean	18.46 a	18.24 b	18.16 b	-	14.24	14.34	14.19	-	4.04	3.78	3.68	-
Interaction LSD (5%)	0.13	-	-	-	NS	-	-	-	NS	-	-	-
	2005/06 season											
Improved mesqa	18.03	18.07	17.84	17.98 a	14.35	14.33	14.18	14.29 a	3.87	3.65	3.79	3.77 b
Traditional mesqa	17.87	17.47	17.64	17.66 b	13.96	13.41	13.73	13.07 b	3.80	4.19	4.05	4.01 a
Mean	17.95 a	17.77 b	17.74 b	-	14.16	13.87	13.96	-	3.83	3.92	3.92	-
Interaction LSD (5%)	0.43	-	-	-	NS	-	-	-	NS	-	-	-

Table (13):Effect of irrigation systems, planting patterns and their interactions on gross, white and loss sugar yields (t/fed.) at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns											
	Ridges	Platforms	Rows	Mean	Ridges	Platforms	Rows	Mean	Ridges	Platforms	Rows	Mean
	Gross sugar yield (t/fed.)				White sugar yield (t/fed.)				Loss sugar yield (t/fed.)			
	2004/05 season											
Improved mesqa	9.15	8.84	9.00	8.99 a	7.13	6.92	7.08	7.04 a	2.01	1.92	1.81	1.91 a
Traditional mesqa	8.17	7.70	7.00	7.62 b	6.23	6.05	5.42	5.90 b	1.78	1.51	1.43	1.57 b
Mean	8.66 a	8.27 b	8.00 c	-	6.68 a	6.48 ab	6.25 b	-	1.89 a	1.71 ab	1.62 b	-
Interaction LSD (5%)	0.58	-	-	-	0.71	-	-	-	0.41	-	-	-
	2005/06 season											
Improved mesqa	8.20	8.71	8.36	8.42 a	6.52	6.91	6.64	6.69 a	1.76	1.70	1.74	1.76 a
Traditional mesqa	6.96	6.95	6.42	6.77 b	5.44	5.33	5.00	5.25 b	1.48	1.60	1.45	1.53 b
Mean	7.58 b	7.83 a	7.39 b	-	5.98 b	6.12 a	5.82 b	-	1.62	1.65	1.60	-
Interaction LSD (5%)	0.56	-	-	-	0.33	-	-	-	NS	-	-	-

Means designated by the same letter within the same Rows or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.

Table (15):Effect of irrigation systems, planting patterns and their interactions on K, Na and α-amino-N contents in fresh root (meq/100 g beet) at harvest in 2004/05 and 2005/06 seasons.

Irrigation systems	Planting patterns											
	Ridges	Platforms	Rows	Mean	Ridges	Platforms	Rows	Mean	Ridges	Platforms	Rows	Mean
	K meq/100 g				Na meq/100 g				α-N meq/100 g			
	2004/05 season											
Improved mesqa	7.70	7.30	7.10	7.37	1.88	1.80	1.69	1.79	4.77	4.41	4.21	4.46
Traditional mesqa	7.61	6.73	6.98	7.11	2.39	1.54	1.66	1.86	4.21	3.94	4.14	4.09
Mean	7.66	7.01	7.04	-	2.13 a	1.67 b	1.67 b	-	4.49	4.18	4.17	-
Interaction LSD (5%)	NS	-	-	-	0.52	-	-	-	NS	-	-	-
	2005/06 season											
Improved mesqa	7.38	7.25	7.19	7.27	1.81	1.72	1.70	1.74	4.50	3.91	4.24	4.21
Traditional mesqa	7.39	7.83	7.30	7.51	1.83	1.93	1.72	1.83	4.58	4.48	4.51	4.52
Mean	7.39	7.54	7.24	1.82	1.82	1.71	1.71	-	4.54	4.19	4.37	-
Interaction LSD (5%)	NS	-	-	-	NS	-	-	-	NS	-	-	-

Means designated by the same letter within the same Rows or column for each season are not significantly different at 5% level, according to Duncan's multiple range test and L.S.D. test for interactions.