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Effect of Irrigation Systems On: III-Productivity and Quality of Grape Crop

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Abstract: Field experiment was conducted on three years old grape vines (Thomposson variety) grown in clay loam soil to study the effect of irrigation systems: drip irrigation (DIS), low head bubbler (LHBIS) and gated pipe (GPIS) on grape yield, quality and on the net profit in two consecutive seasons. According to the parameter under irrigation (yield, juice volume /100 berries, total soluble solids, amount of sugar, crop load, and net profit, irrigation systems could be written in the following ascending order: GPIS< LHBIS < DIS. Concerning cluster density, the previous order took an opposite trend.

Key words: Irrigation system, drip, bubbler, gated pipe, grape yield and quality, and net profit.

INTRODUCTION

Grape is the second major fruit crops in Egypt and it is the fourth crop of a great potentiality for export to world markets. Total grapes area in Egypt reached 155743 feddans producing about 1.196 million ton. According to[1], 50 % of these areas concentrated in the old lands (Wadi and Delta). The water resources of Egypt are limited. The annual income from River Nile not exceeds 55.5 billion cubic meters, so we must rationalize irrigation water. We must also increase the cultivated lands via modern technology in developing farming irrigation systems in both the new lands and the old ones alike.

Hiler and Howell[2] compared trickle with subsurface, mist, and subsurface irrigation and evaluated the effects of reduced irrigation amounts on yields using trickle irrigation. They reported that the WUE were 198, 243, 234, and 171 Kg ha^{-1} cm^{-1} of grain sorghum with subsurface, trickle, mist, and surface flood irrigation methods, respectively.

Matthews[3] suggested that optimum growth, grape yield, and grape quality could be obtained by controlling irrigation during certain phenological stages of vine growth.

Kramer and Boyer[4] stated that if vines experience drought stress during ripening, leaf photosynthetic production would decrease. The vine stomatal is sensitive to water deficits and will close to prevent excessive loss of water through transpiration. Stomata closure during part of the day prevents carbon dioxide from entering the leaves and inhibits photosynthesis.

Brown[5] has proposed that the upcoming benchmark for expressing yield may be the amount of water required to produce a unit of crop yield, which is simply the long-used transpiration ratio, or the inverse of WUE. Tayel *et al*.,[6] studied the effect of irrigation systems on yield, water and fertilizers (N, P_2O_5; K_2O) use efficiency of grape grown on clay loam soil in Egypt. According to the values of the studied parameters, irrigation systems were arranged in the following: GPIS < LHBIS < DIS in two consecutive seasons. According to the infiltration rate and saturated hydraulic conductivity values, irrigation systems could be arranged in the following ascending order DIS< LHBIS < GPIS, while in the case of MWD and aggregation %, the order was: LHBIS <DIS < GPIS [7].

Nasharty and Ibrahim[8] found larger pulms (p. salicina) and soluble solid in the trees irrigated ever 16 days compared to a 24 days interval. They mentioned that neither irrigation treatment reached the wilting point at any time. Fruit from irrigated plot was generally lower in soluble solids and higher in water content than those from non irrigated ones in apples[9-11]. They added that irrigated apples were less firm and less acid but juicier and suffered more storage disorders. In experiment when soil water was kept above the wilting point,[12] found that soluble solid in peach fruits to be higher and the water content less when soil water suction approached 5.0 bars.

Saayman and Lambrechts[13] studied the response of Barlinka table grapes on greyish, sandy soil to irrigation-applied, N fertilization levels, patterns of N application, crop load and preplant P and K fertilization. Increased crop load had a marked negative effect on shoot growth and grape quality. They added that a crop load of 18-19 bunches per vine appeared to be the maximum that still ensured the best quality. Bravdo *et al.*[14] reviewed grapevine response to crop load and irrigation treatments.

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Three drip irrigation schedules were applied after veraison. Crop load (yield/pruning weight) was affected by irrigation due to a differential effect of irrigation on fruit bud differentiation and on vegetative growth.

Pire and Ojeda[15] determined minimum drip irrigation volumes for optimum grape quality. Different irrigation regimes affected overall fruit quality. Lower irrigation volumes consistently decreased fruit acidity and plant shoot growth. Azzazy *et al*.[16] found that irrigation systems significantly affected forage yield. The highest sucrose and purity percentages were obtained under drip irrigation system.

The paper aimed to study the possibility of applying modern irrigation systems in an old grapevine farm and increasing the grape vine, quality and net profit.

MATERIAL AND METHODS

Site Location: This study was conducted at the Experimental Farm of Agriculture Faculty, Ain Shams University. It is located at Shalaqan village 1km from El kanater El khairea, District (latitude 30.13^{O} north, altitude 31.25^{o} east, and 41.9m high above sea level), Qalubia Governorate, Egypt.

The Experiment: The field experiment was carried out through two growing seasons years 2002/2003 and 2003/2004 under three irrigation methods [drip, low head bubbler and the gated pipe, (control)]. Soil of the experimental field represents the (Nile alluvial) silty clay loam.

Ground water is the source of irrigation water. The vines were grown at distance of 2m X 3 m (700 tree fed^{-1}). The areas of the plots devoted for low head bubbler, drip, and gated pipe irrigation systems were 50 m X 27 m , 50 m X 27 m and 50 m X 54 m, respectively. Grapevines three years old were used in the present work. Grape yield was harvested in the last half of July (1st and 2nd season).

Irrigation systems: Irrigation networks include the following.

Control Head: It was located near the water source supply. It consists of centrifugal pump 4`` /4``, drived by diesel engine, sand media filter 48``(tow tanks), back flow prevention, device, pressure regulator, pressure gauges, flow meter, control valves and chemical injection equipment.

Main Line: Poly Venile Chloride (PVC) main line 125 mm in diameter was used to convey the water from the source to the main control points in the filed.

Sub-Main lines: (PVC) Sub-main lines 75mm in diameter were conducted with the main line through. a control unit consists of a 2`` ball water valve and pressure gauges.

Mainflod lines: (PVC) Mainflod lines 40mm in diameter were connected with the sub main line through control valves 1.5``.

2.3.5. Distributors:

- Emitters discharge 8 lph at 1.5 bar built on PE tube 16mm in diameter *?* and 50 cm in length. Tow emitters were allocated/vine.
- Low head bubbler (PE tube 8mm in diameter, with discharge of 40 lph at 1.5 m head). These tubes connected with PVC pipes 32mm in diameter and 50m in length. The head was adjusted by steel stand 180cm in height.
- PE gates fixed on aluminum pipes 160 mm in diameter. Gate discharge is 4.0 m^3h^{-1}. The lay out of different irrigation systems is shown in Fig. (1).

Irrigation water requirement calculation: Quantity of irrigation water requirements for grape trees were calculated after [17] using the following equation:

$$IR= [(ETo \times Kc \times Kr \times A/Ei)+l.R]\ I \qquad (1)$$

Where:
IR = Irrigation water requirements, L/vine/interval,
ETo = Reference evapotranspiration, mm/day,
Kc =Crop coefficient for grape crop,
Kr = Reduction factor due to ground cover.
A = Area m^2 /vine.
Ei = Irrigation system efficiency. %,
l.R = Leaching requirements, applied according to the relation between soil extract and irrigation water salinity.
Where L.R.= (ECiw / Ecdw)100
I = Irrigation interval, days.

Irrigation system efficiency (Ei) Was calculated from the flowing formula according to[18].

$$Ei = Ea \times Du \qquad (2)$$

Where:
Ea = Application efficiency, %
Du = Distribution efficiency, %

$$Ea = WDZ/ DT \times 100 \qquad (3)$$

Where:

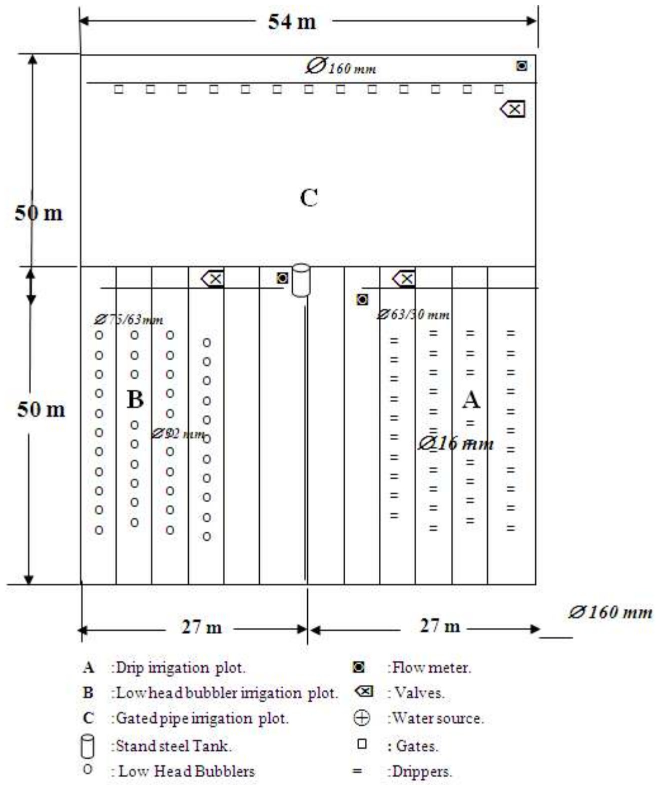

Fig. 1: Layout of different irrigation systems.

W *DZ* = Depth of water stored in the root zone, cm
DT = Gross depth of applied water, cm

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DT = Gross depth of applied water, cm

$$Du = (DLq / Dav) \times 100 \quad (4)$$

Where:
DLq =The depth infiltrated on the quarter of the area which receives the lowest amount of irrigation water, cm
Dav = The average depth of infiltrated of total area, cm.

Irrigation scheduling: Irrigation intervals of 4 days under both drip (DIS) and low head bubbler (LHBIS), while it was 7 days under gated pipes (GPIS) were used. According to the Central laboratory for Agricultural Climate, the available climatic data of Shalaqan weather Station , water requirement, vine grape was calculated.

Fertilizer program: Fertilizers recommended to be applied through season the 1st season were 300 kg.fed^{-1} ammonium sulphate (20.6 %N), 150 kg.fed^{-1} super phosphate (15.5 %P_2O_5), and 200 kg.fed^{-1} potassium sulphate (48.7 % K_2O). While through the 2nd one they were 400,200, and 250 kg.fed^{-1}in the same sequency.

Under DIS and LHBIS irrigation methods ammonium sulphate and potassium sulfate were applied using fertigation technique. But super phosphate was applied as top dressing for the three methods of irrigation used. Under GPIS all fertilizers were applied as top dressing also.

Yield and quality parameters: 2.7.1. Yield per vine was recorded in (kg) vine^{-1} at harvest time during July of each season. Yield in (kg fed^{-1}) was calculated by the following formula:

Yield product (kg fed^{-1}) = [Average No. Clusters $vine^{-1}$ X number of vine fed^{-1} X average weight yield $cluster^{-1}$

Juice Volume: Juice volume was determined by blending 100 berries per irrigation method and filtering through a fine muslin cloth. The biomass was pressed by hand until no more juice could be obtained. Juice volume in (cm^3) was then measured in a graduate cylinder and the average of three samples was calculated for each treatment.

The fresh extracted juice obtained from blending 100 berries samples was tested for total soluble solids content using a hand Refractometer[19]. The juice was thoroughly stirred and few drops were mounted on the clean stage of the Refractometer after which the readings were recorded.

Cluster Density: Cluster density (D) was determined by weighting a cluster (W) and immersing it in a graduated cylinder containing water at a fixed mark (V_1) , and measuring the 2nd volume (V_2). (D) was calculated by the following formula:

$$D = W / V_2 - V_1 \quad (gm\ cm^{-3})$$

Crop Load: Crop load (CL) was calculated using the following equation:

CL = Yield weight / Pruning weight

Economic Costs: Net profit of grape production (P) was calculated after[20] using the following equation:

$$P = T_y \times Y_p - T_{pc}$$

Where:
T_y = Total yield (ton/fed)
Y_p = Yield price (LE/ton)
T_{pc} = Total production costs LE/fed.

Statistical Analysis: All the collected data were subjected to the statistical analysis as the usual technique of analysis of variance (ANOVA) and the least significant difference (LSD) between treatments. The randomized complete block design according to[21].

RESULTS AND DISCUSSION

Soil Analysis: According to[6] soil texture varies from silty clay loam to clay at the depths of 0 – 30, 30-60 cm, respectively. There are an increase in both soil bulk density and its water content at WP and a decrease in both water content at FC and AW with depth. The soil pH and EC vary from 7.2-7.7 and 0.25-0.33 dSm^{-1}, respectively with depth.

Irrigation water: The values of pH, EC and SAR are 7.4, 0.66 dSm^{-1} and 1.51, respectively[6].

Yield: Table (2) illustrates the grape yield in ton/fed (fed = 4200 m^2) under the three studied irrigation systems. It can be noticed that the yield under DIS and LHBIS reached 136 and 125 % respectively, compared to that under GPIS.

Yield quality: The studied yield quality of grape included the following parameters:

Juice volume/100 berries: Juice volume/100 berries in cm^3 reached (94.7; 98.9), (89.0; 95.00 and (88.0; 94.0) under DIS, LHBIS and GPIS in the 1st and 2nd seasons, respectively (Fig. 2). Difference between any two irrigation systems was significant at the 5% level except that between LHBIS and GPIS in the 2nd season. It is obvious that juice of the 2nd season exceeded that of the 1st one.

Table 1: The annual costs of different irrigation systems.

	Irrigation systems		
Items	Drip	Low head bubbler	Gated pipe
Capital cost, LE/fed	2250	1660	1330
Fixed cost:			
Depreciation	199.2	156.0	78.6
Intersect	122.6	94.6	58.3
Taxes, etc. .(2% of capital costs	41.0	33.2	26.0
Subtotal	362.8	283.8	163.5
Operation cost:			
Labor	40.0	40.0	100.0
Fertilizer price	765.0	765.0	765.0
Fertilization (top dressing)	70.0	70.0	70.0
Power	80.0	60.0	30.0
Repair and Maintenance	61.5	33.2	6.65
Subtotal	181.0	417.0	136.6
Total costs, LE/fed.	544.3		300.1

Total soluble solids (TSS): TSS was the highest under DIS and the lowest under GPIS while, LHBIS occupied and intermediate position (Fig. 3). The differences in TSS between irrigation systems were significant at the 5% level in both seasons. TSS of the 2nd season overpassed that of the 1st one.

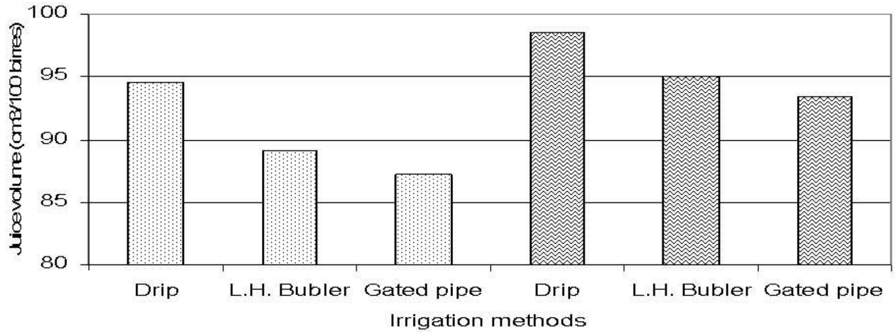


Fig. 2: Effect of irrigation systems on juice volume.

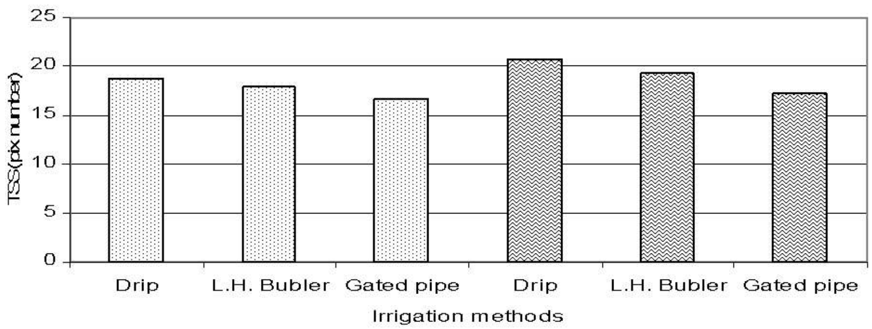


Fig. 3: Effect of irrigation systems on TSS.

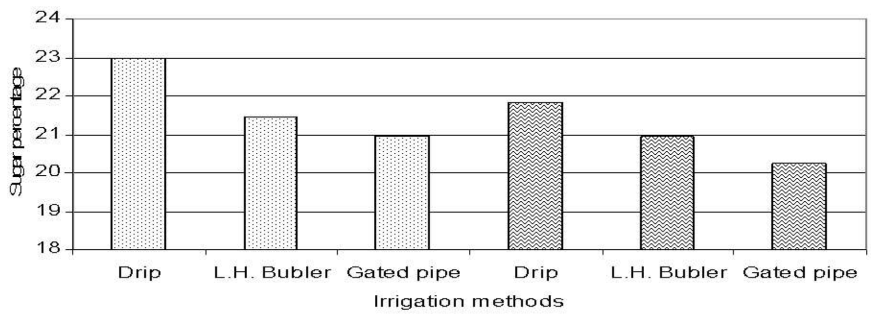


Fig. 4: Effect of irrigation systems on sugar percentage in grape yield.

Amount of sugar: According to the amount of sugar content of grape (Fig. 4), irrigation systems could be written in the following ascending order: GPIS < LHBIS < DIS in both seasons. Differences in sugar content between any irrigation systems were significant at the 5% level. Sugar content of the 2nd season was higher relative to that of the 1st one.

Cluster density: Fig. (5) indicates that according to increasing cluster density, irrigation systems could be arranged in the following ascending order DIS < LHBIS < GPIS. The difference in cluster density between DIS from one side, and both LHBIS and GPIS from the other side was significant at the 5% level. It is worthy, to state that according to grape shelf life, the order mentioned above would take an opposite trend. Cluster density under DIS and GPIS improved in the 2nd season, relative the 1st one. This finding agreed with those obtained by[22].

Crop load: Data on hand, (Fig. 6) illustrate the effect of irrigation systems on crop load. It is worthy to mention that the response of crop load to both irrigation systems and season was similar to the 1st three parameters mentioned above.

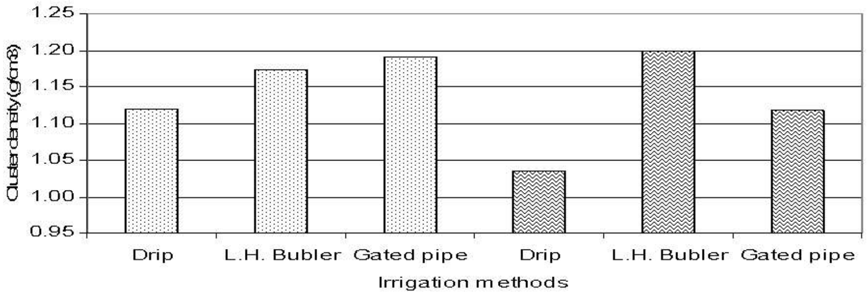


Fig. 5: Effect of irrigation systems on cluster density

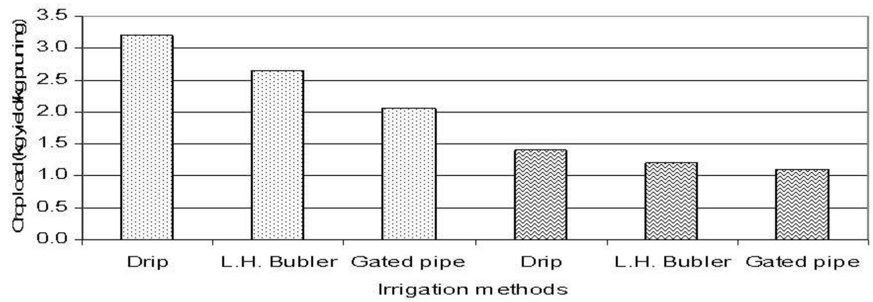


Fig. 6: Effect of irrigation systems on crop load of grapevines.

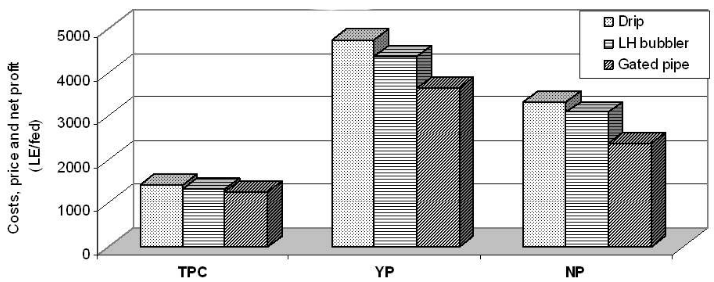
Table 2: Total production costs for grape under different irrigation systems.(LE/fed.)

Items	Irrigation systems		
	Drip	Low head bubbler	Gated pipe
Irrigation cost	544.3	417.0	300.1
Fertilization cost	710.0	710.0	710.0
Pest control cost	100.0	100.0	100.0
Weed control cost	60.0	90.0	150.0
Total production cost	1414.3	1317.0	1260.1
Yield price	4750.0	4375.0	3625.0
Net profit	3335.7	3058.0	2364.9
Grape yield (ton/fed)	3.8	3.5	2.9

Data in Table (1) show that the capital and annual costs in LE/ fed, were 1330; 300, 1660; 417 and 2050; 544 under GPIS, LHBIS and DIS, respectively. On the hand, Table (2) shows the total production costs, the total price of grape and the net profit under the three irrigation systems used. It is obvious that the total production costs were 1414, 1317 and 1260 LE/fed under DIS, LHBIS and GPIS, respectively, while the yield prices were 4750, 4735 and 3625 LE/fed in the same sequence. In other wards, the net profits were 3336, 3058 and 2365 LE/fed under DIS, LHBIS and GPIS, respectively (Fig. 7). The increase in the net profits under DIS and LHBIS, relative to GPIS could be due to sustaining soil structure under DIS [7].

Concerning the improving effect of grape quality (juice volume, sugar %, TSS, cluster density and crop load), irrigation systems could be arranged in the following ascending order GPIS < LHBIS < DIS. This arrangement could be due to one or more of the following reasons:

- Increasing both water and fertilizers use efficiency under DIS, relative to LHBIS and GPIS (Tayel *et al.* 2007),
- the seasonal amount of applied water in m^3/fed were (2019; 2016), (2110; 2227) and (3820; 3763) under DIS, LHBIS and GPIS in the 1st and the 2nd seasons, respectively led to more vegetative growth relative to the fruiting one under GPIS as indicated from crop load data,
- water, nutrients and aeration under DIS are in their optimum condition,
- the shorter irrigation intervals (4 days) and the slow wetting under both DIS and LHBIS relative to GPIS sustain soil structure,
- the longer irrigation intervals (7days) under GPIS and the hot summer create cracks in the surface soil layer which increase both IR to the soil and Ks, this may increase leaching of nutrients,
- the longer irrigation interval under GPIS reduces soil water content which lead to stomata closure during part of the day preventing the leaves and inhibiting photosynthesis process, and
- the increase in studied parameters in the 2nd season is due to the increase in vines age from 3 to 4 years.



TPC: Total Production Costs (LE/fed), YP: Yield Price (LE/fed); Net Profit (LE/fed)

Fig. 7: Total production, costs and yield price of grape.

Economic costs: The costs of grape yield production indicated that the yield of grape differs according to the irrigation system. Total irrigation costs are a major capital inputs for most farms. The capital and annual costs (fixed and operating) of different irrigation systems are presented in Table (1).

Data in Table (1) show that the gated pipes irrigation system is considerably low in both capital and annual costs (1000 and 327.1 LE/fed respectively), then cam the low head bubbler irrigation system (1720 and 389.4 LE/fed respectively), while the highest value of capital and annual irrigation costs was (2230 and 533.4 LE/fed respectively) when drip irrigation system was used.

Conclusion:
It could be concluded that:

- Irrigation could be arranged according to the values of juice volume/ 100 berries, TSS, sugar %, and crop load in the following ascending order: GPIS< LHBIS < DIS.
- Concerning cluster density the order mentioned above took an opposite trend and this it self is an improvement in quality.
- The values of the quality parameters were higher in the 2nd season relative to the 1st one, but the reverse was true in the case of cluster density.
- Irrigation systems and the season are important factors affecting grape quality.
- To improve the structure of the thoroughly dried clay soil and to save irrigation water in the same time, localized irrigation systems have to be used to prepare soil for the next crop.
- The net profits were 3307, 3046 and 1011 LE/fed under DIS, LHBIS and GPIS, respectively.

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