



Growing banana under shade screens as a mean of saving irrigation water: preliminary results

El cultivo del banano bajo red de sombra a fin de ahorrar agua de irrigación: resultados preliminares

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ABSTRACT

Grand Nain (AAA) banana plantation in the Jordan Valley, Israel, was covered with two different types of transparent shade screens that reduced light intensity by 17%-28% as compared to the uncovered control. Quantity of irrigation water applied to the shaded bananas during the season was reduced to 65% (1373mm) of the unshaded control (2115mm). The overhead shade screens increased relative humidity in the plantation, decreased temperature during the hot summer days, reduced vapor pressure deficiency and provided significant wind protection. The bananas in the shade house grew faster, shot 13 days earlier and were harvested 18 days earlier than the unshaded control. Reducing the irrigation water in the shade house by 35% did not have negative effect on production. Bunch weight was 4kg heavier than the control, yield was similar (about 89 ton fresh fruits per ha) and finger size was bigger. We conclude that protecting banana plantation with overhead transparent shade screens is very effective in saving irrigation water in the hot and arid climate of the Jordan Valley.

RESUMEN

Una plantación experimental de banano Gran Enano (AAA) en el Valle del Jordán, Israel, fue cubierta con dos tipos de redes diferentes. Estas redes dan sombra y reducen la radiación solar entre 17-28% comparado con el testigo. La cantidad de agua de irrigación que fue necesaria aplicar durante la estación de riego se redujo a 65% (1373mm) comparado con el plantío descubierto (2115mm). La sombra que da la red aumentó la humedad relativa en la plantación, disminuyó la temperatura durante los calurosos días del verano, redujo la deficiencia de presión de vapor y dio una protección significativa contra vientos. El banano bajo la red creció más rápidamente, floreció 13 días antes, y fue cosechado 18 días antes en comparación al testigo no sombreado. La disminución de la irrigación en el plantío sombreado en un 35% no trajo efectos negativos sobre la producción. El peso del racimo fue de 4kg más que el testigo, el rendimiento fue semejante (aproximadamente 89 toneladas de fruta fresca por hectárea) y el tamaño de los dedos fue mayor. Se concluye de estas observaciones que la plantación de banano protegido con una red de sombra es muy efectiva para ahorrar agua de irrigación en climas calurosos y áridos como de la zona del Valle del Jordán.

INTRODUCTION

Growing banana in greenhouses is a common practice in the Mediterranean zone and in the Canary Islands (Cevik et al., 1984, Janick and Ait-Oubahou, 1989, Chouk-Allah, 1990, Galan-Sauco et al., 1992, Eckstein et al., 1998). The main purpose is to protect the banana against winter low temperatures and wind damage. Protected bananas usually gave higher yields and better fruit quality. In Israel, however, plastic-covered greenhouses failed to give positive results. The

reason is that during the very hot and dry summer (average maximum temperatures 37^o-38^oC during July and August; absolute maximum more than 45^oC) the greenhouse air is excessively hot, especially at the leaf level, close to the plastic cover. The high temperatures cause marginal leaf desiccation, leaf deformations and bunch and fruit malformations. In addition, dust accumulation on the plastic sheet during the summer reduced light transmission and limited photosynthetic activity.

Our next step was, therefore, to try to replace the greenhouse with a shade house. The negative

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effect of shade on banana was already documented (Israeli et al., 1995). We assumed, however, that banana grown under light, white-colored or transparent screens, will benefit the protection against wind damage and against excessive irradiation and thus overcome the damage of reduced photosynthetic activity.

Our main purpose in growing banana under shade screens is the reduction in water consumption. During the recent four years the region has suffered unusual low rainfall. Water reserves are now extremely low, and saving water is of utmost priority. We therefore tested the hypothesis that protecting banana with light, transparent shade screens will allow a significant reduction of the quantity of irrigation water, without (or with just a slight) negative effects on growth and production.

MATERIALS AND METHODS

A 6m high flat top shadehouse covering one ha was constructed using a combination of 3" and 2" galvanized poles connected and anchored to the ground with 5-6mm steel cables. The cables run over each banana row while perpendicular supporting cables were installed every 20m. Overhead guying cables were fixed along the rows at 4m height on the same poles. The shading net was stretched over the cables, covering the top and also all sides of the shade house, in order to give maximum wind protection. Two types of shading nets (=screens) were used, named 'Crystal' and 'Anti hail', each covering half of the shade house (0.5ha). Both nets had 12% initial shading rate, but the 'Hail' net is made of flate milky-white filament while the 'Crystal' is made of transparent round monofilament. The nets may differ in rate of dust adherence and in their behavior with regard to light transmission.

Grand Nain (AAA) tissue culture plants grown in 1.2L pots were planted in the shade house and in a neighboring open control plantation in 10 Aug. 2000. Planting distances in the shadehouse were 4.2m between the rows and 2.65m between the mats along the rows, three plants per mat (and a total of 2700 plants/ha). The control plantation had an intra-row distance of 2.5m and therefore 2860 plants/ha. The difference is based on the initial difference in light intensity.

The plantation was irrigated and fertigated with a drip system, two laterals for every banana row. Two different irrigation treatments were applied: "Normal" water supply (about 90% of the control) and "Reduced" water supply (65% of the control). The irrigation treatments were applied in randomized blocks with 8 replications, 12 banana mats (=36 plants) in each replication. Full information on growth and production was recorded. Automatic weather stations recording temperature and relative humidity were installed in each treatment. Soil water tension at a distance of 15 and 30cm from the drip lines, to a depth of 15 and 30cm, was periodically measured. The photosynthetically active radiation (PAR) was measured periodically with a Licor Li-190SZ quantum sensor, placed in the level of the banana plants canopy.

The results were analysed statistically using SAS application (SAS Institute Inc, Cary, NC, USA). The differences between the means of the replicated water quantity treatments were analysed using the General Linear Model and the Duncan multiple range test. The differences between the shadehouse and uncovered control bananas, and between the two types of shading screens, where no replications were used, the Students t statistic were used in order to evaluate the differences between the populations.

RESULTS

Light transmission

Shortly after planting, light transmission through the screens was slightly reduced, from the initial 88% to 83% light transmitted. One year later, light transmission was the same for the 'Hail' net but reduced to 72% with the 'Crystal' net (Table 1).

Irrigation and soil water tension

The control plants were irrigated according to the common practice of the Jordan Valley: daily irrigation based on pan A evaporation using a crop factor of 1 to 1.4. The lower factor used during the spring and autumn, the higher during the hot and dry summer. During the early 4 months after planting, the rate of water application in the shadehouse was only slightly different from the control in order to get optimal conditions for initial

Table 1: Photosynthetically Active Radiation (PAR, in $\text{mmol quanta m}^{-2}\text{s}^{-1}$) measured at noontime at canopy level with a Licor 190SZ quanta sensor, ten days after planting and one year later. Each data value is the average of 6 measurements ($\pm\text{SE}$).

PAR			
Date	Control	'Hail' net	'Crystal' net
20/8/00	1870 $\pm$ 13	1546 $\pm$ 7	1550 $\pm$ 8
	(100%)	(83%)	(83%)
21/8/01	1544 $\pm$ 10	1283 $\pm$ 10	1115 $\pm$ 27
	(100%)	(83%)	(72%)

establishment for all treatments (Table 2). Later, we significantly differentiated the water application: the 'Normal' irrigated bananas in the shade house received 91% of the water of the control, the 'Reduced' treatment received only 65% (Table 2).

The quantity of irrigation water divided by pan A evaporation for the main growth period was 1.18 for the control, 1.08 for the 'Normal' irrigation in the shadehouse, and only 0.77 for the 'Reduced' irrigation treatment. Despite the very significant reduction in water application, soil water tension was kept lower than 10 kPa, except during the spring and early summer, May-June (Table 3).

The effect on microclimate

The shading nets reduced air temperature, especially during the hot hours of the summer days,

and increased relative humidity. Consequently, the Vapour Pressure Deficiency (VPD), which represents the degree of environmental stress, was reduced up to 1 kPa (Table 4). These changes may explain why shadehouse bananas may perform well under lower irrigation rate.

Another important factor involved is the wind protection effect. It is not easy to precisely quantify this effect, but the difference was clearly evident. Very little wind damage was observed on the leaves of the shadehouse grown bananas while considerable damage was evident on the control leaves that were torn and sometimes even shredded.

Effect on growth and development

Planting banana in August is a common practice in the Jordan Valley. These plants usually grow

Table 2: Irrigation water quantity application (in mm) during the initial establishment and early growth period and during the following main growth, shooting and production period.

	Evap. (mm)	Irrigation Water application (mm)		
		Control	Shadehouse	
Period			'Normal'	'Reduced'
10/8/00 to 31/12/00	658	791 (100%)	771 (97%)	696 (88%)
1/1/01 to 20/11/01	1787	2115 (100%)	1935 (91%)	1373 (65%)

Table 3: The effect of reduced irrigation water application in the shadehouse on soil water tension (in kPa). Tensiometers readings were taken at a distance of 30cm from the dripper and the banana corm, at 30cm depth. Each data value is the average of six readings ($\pm\text{SE}$).

	Soil water tension, kPa			
	May	June	July	August
Control	11.6 $\pm$ 0.6	9.1 $\pm$ 0.3	4.3 $\pm$ 0.6	8.6 $\pm$ 0.7
Shadehouse, 'Normal'	10.9 $\pm$ 0.3	9.4 $\pm$ 0.3	6.9 $\pm$ 1.4	7.1 $\pm$ 0.6
Shadehouse, 'Reduced'	31.8 $\pm$ 2.8	15.5 $\pm$ 2.2	8 $\pm$ 0.3	8.7 $\pm$ 0.4

Table 4: The effect of shading nets on microclimate during the hot and dry summer months of year 2001. Temperature (Temp.) and relative humidity (RH) were recorded inside the plantation, 2m above ground, in the shadehouse (=Shade H.), in the control (=Cont.) and in a nearby standard meteorological station (=Met. Sta.). The vapor pressure deficiency (=VPD, kPa) was calculated from the readings. Data presented are monthly mean or monthly absolute readings of daily observations.

Month	Daily maximum temp. (°C)			Daily minimum RH (%)			Daily maximum VPD (kPa)		
	Shade H	Control	Met Sta	Shade H	Control	Met Sta	Shade H	Control	Met Sta
	Means			Means			Means		
Aug	36.6	37.5	38.4	46.6	45.1	42.2	3.3	3.6	4.0
Sep	34.9	35.5	36.2	47.5	46.4	43.4	3.0	3.2	3.5
Oct	31.2	33.0	32.6	48.7	47.3	43.6	2.5	2.8	2.9
	Absolute values			Absolute values			Absolute values		
Aug	38.2	39.2	40.8	37.4	36.1	26.0	4.18	4.50	5.79
Sep	37.8	39.0	39.4	32.7	31.8	31.8	4.16	4.41	4.88
Oct	37.0	38.6	39.3	29.0	26.7	24.2	4.14	5.08	5.30

rapidly until temperatures drop in early January. Growth almost stops during January and February, and resumes in March. Rate of leaf emission increases between March to June. Floral differentiation takes place during February-March, and shooting starts in late June. Peak shooting is normally through July, and harvest during September-November. Number of plants per ha is normally high, 2700-2900, and bunch fresh weight 30 to 40kg. Potential production is therefore relatively high, 80 to 120 ton of fresh fruits per ha, but time from planting to harvest is long, about 14 months. In this experiment, the plants grew fast, especially in the shadehouse (Table 5). This resulted in early shooting: average shooting date for the shadehouse plants was in 13 days earlier than the unshaded control and percent of May shot plants was 35 in the shadehouse and only 12% in the control. Shadehouse bananas shot earlier, had bigger bunches, and bigger pseudostems (Table 5). Reducing the quantity of water in the shadehouse in 35% had no effect on rate of shooting or bunch size, but slightly reduced pseudostem size (Table 5). No difference was recorded between the two types of nets.

Effect on production

Shadehouse protected bananas produced bunches heavier than the control. We distinguish between all harvested bunches, including also very early bunches which were differentiated in the

winter and are of poor quality and low weight, and main harvests bunches which are of the best size. The shadehouse bunches in the main harvest period were heavier by 4kg than the control (Table 6), but very little difference was noted in the overall seasonal average. This is explained by the earliness of floral differentiation, shooting and harvesting under the shadehouse. High percentage of very early (and therefore lower in weight) bunches result in reduced average bunch weight. The total yield of the shadehouse bananas was, however, similar to the control and single fruit size - weight and length - was significantly higher (Table 6). Reducing quantity of irrigation water did not have negative effects on bunch weight and on yield. Minor effect on finger length was noted (Table 6). The 'Crystal' net had an advantage in bunch weight and in finger size over the 'Hail' net.

DISCUSSION

Water requirement of Jordan Valley banana is high. In a recent 8 years long irrigation experiment a clear linear response of growth and production to irrigation water quantity was noted. When annual irrigation water quantity was experimentally reduced from 2682 mm/gear to 1087 mm/gear annual production dropped from 61.21 ton/ha to 44.25 ton/ha. The effect was linear, with the formula $\text{Yield (ton)} = 0.0011 Q + 32.69$, $R^2=0.9756$ where Q is the annual quantity of irrigation water (mm) (Israeli et al., unpublished).

Table 5: The effect of protecting shade net, the quantity of irrigation water applied to banana under the shade net and the effect of two different net types on growth, shooting rate and plants characteristics at shooting. Analysis of variance and F test using SAS general linear model procedure were used to evaluate the significance (signif.) of differences between the replicated irrigation water quantity treatments, and Student's t-test for comparing the two populations of the other two treatments.

Parameter	Effect of shadehouse			Effect of water quantity			Effect of net type		
	Control	Shaded	Signif.	Normal	Reduced	Signif.	'Hail'	'Crystal'	Signif.
Plants height in									
12/2/01 (cm)	155	175	0.0001	175	175	N.S.	174	176	N.S.
Mean shooting date	27/6/01	14/6/01	0.0102	14/6/01	16/6/01	N.S.	17/6/01	13/6/01	N.S.
Percent pants shot until:									
31/5/01	12	35	0.0069	35	32	N.S.	31	36	N.S.
30/6/01	68	82	0.0521	82	82	N.S.	78	86	N.S.
31/7/01	99	100	N.S.	100	99	N.S.	99	100	N.S.
Number bunches/ha	2700	2590	N.S.	2590	2640	N.S.	2600	2620	N.S.
Number hands/bunch	12.7	13.2	0.0110	13.2	13.4	N.S.	13.3	13.3	N.S.
Plant height shooting (cm)	271	283	0.0100	283	277	0.0242	277	279	N.S.
Pseudostem girth at 1m (cm)	62.4	64.2	0.05	64.2	62.2	0.0128	63	63	N.S.

Table 6: The effect of protecting shade net, the quantity of irrigation water applied to banana grown under the shade net and the effect of two different types of net on the production and fruit characteristics. Analysis of variance and F-test using SAS general linear model were used to evaluate the significance (signify.) of differences between the replicated irrigation water quantity treatments, and Student's t-test for comparing the two populations of the other two treatments.

Parameter	Effect of shadehouse			Effect of water quantity			Effect of net type		
	Control	Shaded	Signif.	Normal	Reduced	Signif.	'Hail'	'Crystal'	Signif.
Bunch weight (kg)									
All bunches	34.8	35.6	N.S.	35.6	35.1	N.S.	35.0	35.7	N.S.
Main harvests bunches	35.7	39.6	0.0002	39.6	39.7	N.S.	38.7	40.6	0.0580
Yield (Ton/ha)	89.0	88.6	N.S.	88.6	89.7	N.S.	87.7	90.6	N.S.
Number bunches									
Harvested/ha	2600	2490	N.S.	2490	2560	N.S.	251	254	N.S.
Mean harvest date	11/10/01	23/9/01	0.0011	23/9/01	23/9/01	N.S.	26/9/01	19/9/01	N.S.
Finger sample (3 rd hand)									
Weight (gr)	151	174	0.0005	174	167	N.S.	166	175	0.0086
Length (cm)	20.4	21.3	0.0054	21.3	20.8	0.0217	20.7	21.3	0.0017
Girth (cm)	12.0	12.4	0.0010	12.4	12.4	N.S.	12.3	12.5	N.S.

The reasons for the high water consumption are the dry, hot and windy weather and the calcareous, partially saline soils. Irrigation water salinity (EC ~ 1.2dSm⁻¹) is also a problem. Efforts to reduce water consumption concentrated on improving the irrigation system and gaining better technical control. Another approach was to save water by correlating the daily application to the environmental stress (temperature, VPD) and the

use of pulse-irrigation. These efforts resulted in reducing the rate of irrigation to about 2200mm per year (without a drop in production). But this is not enough. Under the pressure of a four years drought, we are looking for a more substantial saving of water.

In his early physiological studies in the Jordan Valley Shmueli (1953) has already shown the significant increase in transpiration with increased

wind. The common Mediterranean breeze blows almost daily in the Jordan Valley during the summer, causing substantial transpiration. Our assumption was that protecting the bananas from the wind would reduce water consumption. Although shading banana may cause reduced photosynthesis and drop in production (Israeli et al., 1995), the benefit of wind protection may overcome the negative effect of shading.

The actual results are very satisfactory: water consumption was reduced by 35%, to 1373 mm/Y, without negative effects on yields or bunch weight. Fruit production per volume of water used improved significantly: from 42kg/mm/ha in the control, to 65.3kg/mm/ha in the shadehouse. We do see some initial negative effect on finger length. We therefore aiming, at this moment, at only 30% water saving.

This preliminary study is now continuing on a wider scale, in purpose do increase our understanding of the physiological basis and to further improve the practical results.

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