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LIGHT DISTRIBUTION ON *CITRUS CANOPY* AFFECTS PHYSIOLOGICAL PARAMETERS AND FRUITING PATTERN [1]

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SUMMARY

Light interception by the orange tree canopy during flower bud differentiation and subsequent flowering and fruit setting has been monitored by continuous data recording from 48 silicon cells distributed in different canopy zones. Two experimental conditions have been tested: trees artificially shaded by a black nylon net cage, and non-shaded trees. Observations were made on the total radiation accumulated in the different canopy zones, and they were related to photosynthetic activity, stomatal conductance, flowering and fruiting pattern, and fruit quality. The different light distribution affected both photosyntesis and stomatal conductance: in fact, they were both drastically reduced in shaded trees, and a significant decrease was also found in both shaded and unshaded trees in relation to different canopy zones. A significant decrease of flowering and fruit setting was found from the top of the canopy to the bottom and from outside to inside, in relation to the different amount of radiant energy availability. Finally significant differences were found on fruit quality.

Keywords: Radiation distribution, *Citrus sinensis* L., Net photosinthesis, Stomatal conductance.

RIASSUNTO

Distribuzione della radiazione all'interno della chioma nell'arancio e sua influenza su alcuni parametri fisiologici e sulla fruttificazione

La radiazione solare intercettata dalla chioma di piante di agrumi è stata misurata, nel periodo compreso tra l'induzione antogena e la fioritura, mediante l'impiego di 48 fotocellule al silicio collegate ad un data-logger e distribuite nelle diverse zone del "globo". Sono state considerate

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due condizioni sperimentali: piante non ombreggiate e piante ombreggiate con una rete di nylon nera. I rilievi sperimentali hanno riguardato la distribuzione dell'energia radiante nella struttura vegetale, l'attività fotosintetica, la conduttanza stomatica, l'enità della fioritura nonché la distribuzione e le caratteristiche qualitative della produzione. Le osservazioni hanno messo in evidenza che la distribuzione della radiazione nelle diverse zone della chioma influisce sull'attività fotosintetica e sulla conduttanza stomatica: infatti queste ultime hanno subito una drastica riduzione nelle piante ombreggiate ed è stata osservata una variazione significativa nelle diverse parti della chioma per entrambe le tesi. Sono state riscontrate differenze significative sull'entità della fioritura, e dell'allegagione, nonché sulla distribuzione dei frutti, in relazione alla quantità di energia radiante disponibile nelle diverse zone della chioma. Infine, sono state riscontrate differenze significative sulla qualità dei frutti.

Parole chiave: Distribuzione della radiazione, *Citrus sinensis* L., Fotosintesi netta, Conduttanza stomatica.

INTRODUCTION

Previous research has shown that the flowering and fruiting pattern in *Citrus* is greatly affected by the light distribution in the different canopy zones (1, 8, 9). In fact in the shaded zones inside the tree canopy low amounts of radiant energy should be assumed as responsible of the lower bearing ability of such zones (6, 7, 9). On the other hand, as stated elsewhere (2) it is difficult to explain this effect on the exclusive basis of the photosynthetic potential, since the wide range of responses due to phytochrome includes flower bud induction (13, 16), in addition to the complex light-gibberellins and light-auxins interactions. In this experiment further details on this topic are given, with particular reference to light distribution effects on photosynthesis, stomatal conductance and fruiting behaviour.

MATERIALS AND METHODS

The research has been made at the Institute Experimental Station, near Oristano (Sardinia), on a block of "Washington navel" orange trees, grafted on sour orange, planted in 1974 and spaced at 5.5 x 4 m.
Two experimental conditions have been tested: trees artificially shaded by a black nylon net cage, and non-shaded trees. During flower bud differentiation and subsequent flowering and fruit setting (from November 1, 1987 to May 23, 1988) light interception by the tree canopy was monitored by continuous data recording from 48 silicon cells distributed for each tree in different canopy zones (fig. 1). The cells were connected to a data logger (previously described by Benincasa, 4) and the radiation data were recorded at hourly intervals. Normally each cell was placed in the vicinity of a leaf, in order to have similar conditions of light interception. Total

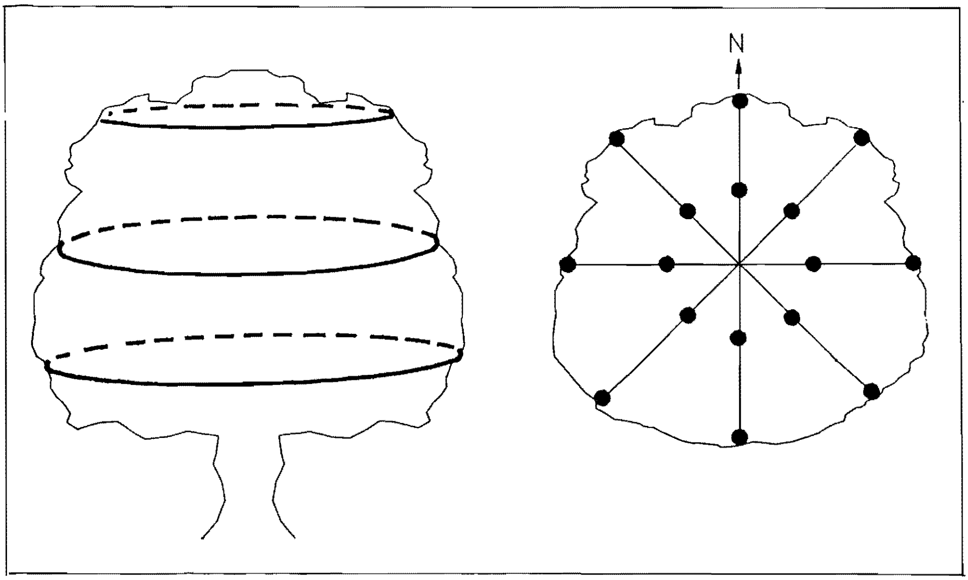

Fig. 1 - Cells location in different canopy zones.

sunlight radiation was also monitored from 8 cells distributed above the canopy in all the directions. During the experiment several observations (normally once a month) were made on phosynthesis and stomatal conductance; such determinations were made during sunny days, using a CO_2 analyser (I.R.G.A.-ADC) and a Autoporometer Li 1600. Flowering rate, fruit setting and fruit quality were also recorded. All data were subjected to statistical analysis.

RESULTS

The total radiation accumulated in different canopy zones in relation to the treatments is shown in table 1. It is rather evident that artificial shading drastically reduced the total radiation available by the canopy. It is also evident that the light intercepted by the foliage decreased from the canopy top to the bottom, and from the external to the internal canopy zones. Furthermore the table 1 evidences that only a fraction of total available radiation reached the tree canopy. In fact in non-shaded tree the light intercepted by the canopy changed from 47% to 24% of total available radiation, depending on the different canopy zones, while in shaded trees this condition changed from 12% to only 3.8% (fig.2). This situation is also evidenced in figure 3 where are represented the diurnal changes of radiation in shaded and unshaded trees during two typically sunny days of December and May. Of course this different light distribution affected both photosynthesis and stomatal

Table 1 - Radiant energy accumulation in different canopy zones from flower bud differentiation to fruit-setting, in shaded and unshaded trees (MJ m^{-2}).

	11-01-1987 01-31-1988		11-01-1987 05-23-1988	
	TOTAL	AV./DAY	TOTAL	AV./DAY
Top	129.6 c	1.4 c	486.4 c	2.4 c
Middle	101.0 b	1.1 b	368.4 b	1.8 b
Bottom	74.0 a	0.8 a	304.8 a	1.5 a
Sign.	**	**	**	**
Extern.	114.0	1.2	473.8	2.3
Intern.	89.0	0.9	299.3	1.5
Sign.	**	**	**	**
Shad.	32.6	0.4	154.3	0.8
Unsh.	171.0	1.9	618.8	3.0
Sign.	**	**	**	**
Tot. avail. radiat.	427.3	4.6	2224.0	10.8

Table 2 - Net photosyntesis and stomatal conductance in relation to light distribution (as percentage of total available radiation)

	Light distr. %		Net phot. µmol m^{-2} s^{-1}		Stom. conduct. cm s^{-1}	
CANOPY ZONE	S	NS	S	NS	S	NS
Top	9.6 b	34.2 c	1.7 b	7.9 c	0.25 c	0.53 c
Middle	5.9 a	27.2 b	1.4 a	6.1 b	0.20 b	0.39 b
Bottom	5.3 a	22.0 a	1.3 a	2.8 a	0.15 a	0.29 a
Sign.	**	**	*	**	**	**
Ext.	8.2	34.4	1.7	7.1	0.23	0.47
Int.	5.7	21.2	1.2	4.1	0.17	0.33
Sign.	**	**	*	**	**	**

conductance (table 2). In fact, they were both drastically reduced in shaded trees and a significant decrease was also found in both shaded (S) and unshaded (NS) trees in relation to different canopy zones. The flowering rate and fruiting setting were also strongly influenced by the availability of solar radiation. In shaded trees (table 3) the flowering rate was about 25% of that of the control trees, while the amount of fruits

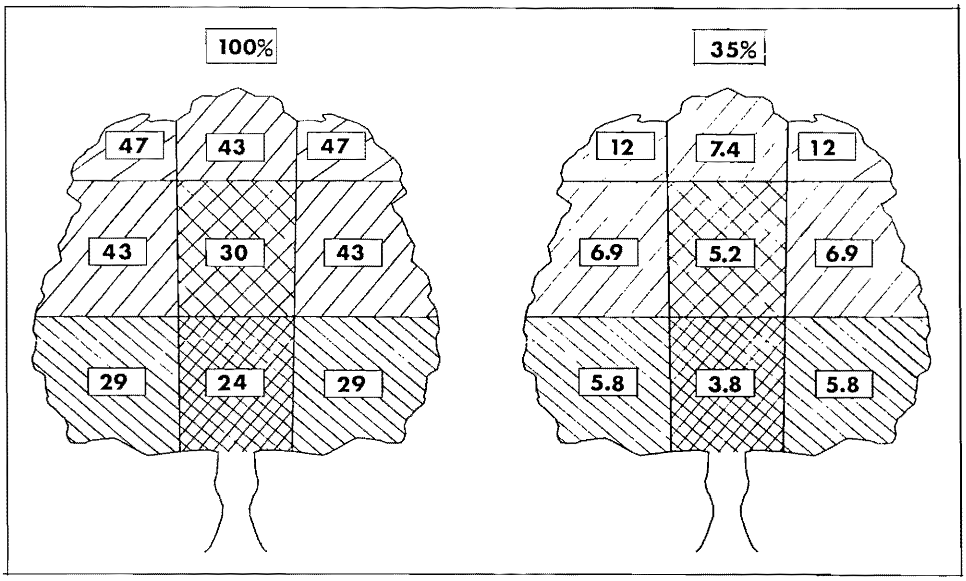

Fig. 2 - Intercepted radiant energy (as percentage of total available radiation) in different canopy zones of shaded and unshaded trees.

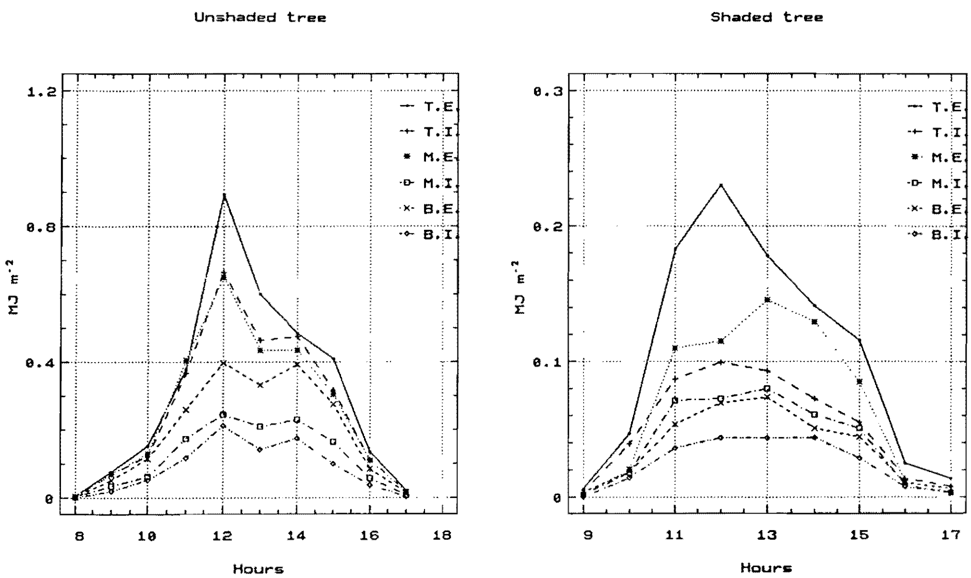

Fig. 3 - Diurnal radiant energy interception by different canopy zones in December, 5, 1987. (T=Top; M=Middle; B=Bottom; E=Ext.; I=Int.)

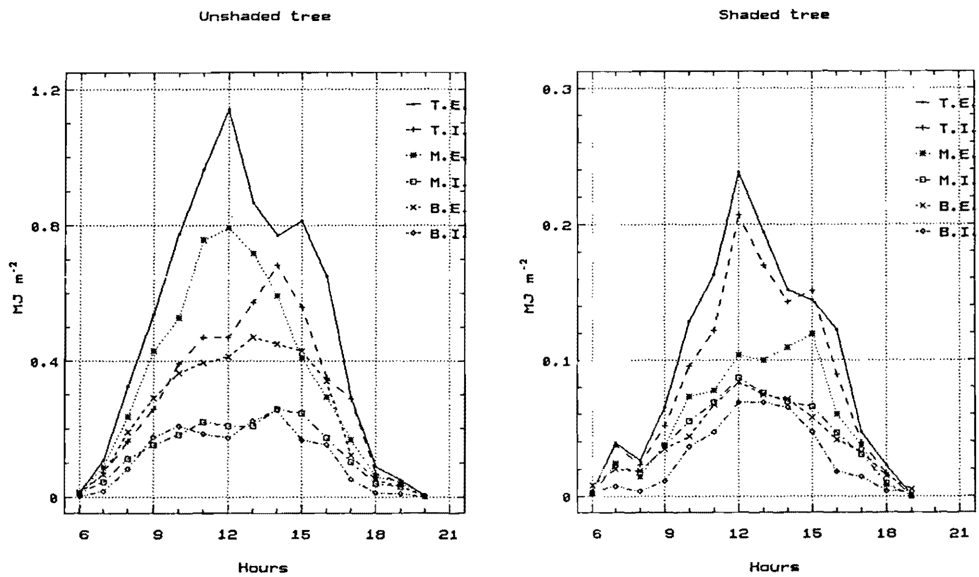

Fig. 4 - Diurnal radiant energy interception by different canopy zones in May, 30, 1988. (T=Top; M=Middle; B=Bottom; E=Ext.; I=Int.)

Table 3 - Flowering and fruit setting in different canopy zones.

CANOPY ZONE	FLOW. RATE (*) S	FLOW. RATE (*) NS	FRUIT NUMBER S	FRUIT NUMBER NS
Top	2.0 c	7.0 b	40 c	192 c
Middle	1.5 b	6.2 b	24 b	126 b
Bottom	1.0 a	3.5 a	14 a	108 a
Sign.	**	**	**	**
Ext.	2.6	6.3	44	262
Int.	0.4	4.8	34	164
Sign	**	**	**	**

(*) Rating from 0 (no fl.) to 10 (max. fl.)

harvested was about 18%. Moreover in both shaded and non-shaded trees there was a reduction of flowering and fruit setting from the canopy top to the bottom, and from the outside to the inside canopy. This decrease, which in unshaded trees averaged 47% in the bottom of the canopy and about 30% in the internal canopy zones, is clearly related to the reduction of light interception to a less than 30% of

Table 4 - Fruit quality in relation to different canopy zones in shaded and unshaded trees.

	FRUIT WEIGHT G	RIND TEXTURE (1)	RIND COLOR (2)	RIND TICK. mm	JUICE %	TSS %	TA %	TSS/TA
Top	301 a	7.2 b	10.3 b	5.9	47.1 b	10.7 b	1.04	10.3
Middle	322 b	6.5 a	10.2 b	6.0	46.7 b	10.5ab	1.05	10.0
Bottom	324 b	6.5 a	9.5 a	5.8	44.7 a	10.2 a	1.01	10.1
Sign.	*	**	**	NS	**	*	NS	NS
Int.	320	6.7	9.7	5.4	46.9	10.3	1.08	9.5
Ext.	312	6.8	10.3	6.4	45.3	10.7	0.98	10.9
Sign.	NS	NS	**	**	**	**	*	**
Shad.	370	6.8	9.2	5.7	47.5	10.1	1.06	9.5
Unsh.	262	6.7	10.8	6.1	44.7	10.9	1.00	10.9
Sign.	**	NS	**	*	**	**	NS	**

(1) Visually determined on a scale ranking 1 to 8

(2) Visually determined with the aid of a colour table on a scale ranking from 3 (dark green) to 13 (deep orange).

the total available radiation (see also table 2). Significant differences were finally found on the fruit quality (table 4). Particularly the shaded trees produced bigger, paler fruit, with a thinner rind, more juice, and less TSS and TSS/TA ratio. Naturally similar differences were found between inside and outside fruit in both shaded and unshaded trees. On the other hand, fruit at the top of the canopy were smaller, with a finer and more brightly coloured rind and a higher juice and TSS content.

CONCLUSIONS

First of all this experiment confirmed that under normal cultural conditions the radiant energy intercepted by the *Citrus* canopy is progressively reduced from the canopy top to the bottom, and from outside to inside. This condition mostly when the reduction of light availability is less than 30% of total available radiation, may results in a significant decrease of flowering and fruit setting, so confirming previous experiments on *Citrus* (1, 5, 8, 9, 10, 11, 12, 15). Therefore all the cultural factors (i.e. planting distances, row orientation and pruning) that induce abnormal shading, mainly during flower bud differentiation, negatively affect flowering and yield. Of course the different fruit distribution in the tree canopy in relation to the light availability implies also several differences in fruit quality, such as weight (due to different fruit number per unit of canopy volume), rind colour and thickness, juice and TSS content. Finally this research has evidenced that the shortage of radiant energy negatively affects some physiological processes, like photosynthesis and stomatal conductance. Nevertheless, on the basis of the typical saturation curves of photosynthesis reported by Barden (3) and Proctor (14) it is difficult to explain the yield reduction on the exclusive basis of the photosynthetic potential. Therefore the shortage of light availability becomes critical mainly during flower bud induction and it is likely that other factors, such as light-photoreceptive pigments and light hormone relationship, could be involved.

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