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Effects of deficit irrigation on two cherry tomato cultivars in hilly areas

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Abstract. In the last years the cultivation of cherry tomato significantly increased in the hilly areas of Campania region. Generally in the Campania hilly areas the species is cultivated under rainfed conditions to improve some quality parameters. The cultivation without irrigation is feasible thanks to the resistance to abiotic stress of cherry tomato and because climatic conditions of hilly areas of the region are characterized by erratic rainfall during the summer. The aim of the present work was to evaluate the response to deficit irrigation scheduling based on critical plant growth stages to ensure good productivity of two cultivars of cherry tomato (Altavilla cv. standard and Mignon hybrid). The trial was carried out in 2005 and 2006 at the experimental station of the CNR-ISAFoM, in Piano Cappelle (BN). The two cultivars were subjected to four irrigation regimes: T0 (rainfed), T1 (one irrigation at beginning of flowering), T2 (one irrigation at beginning of flowering and another at 50% of fruit set) and T3 (at beginning of flowering, at 50% of fruit setting and, after, every 15 days). Results showed that, in the area of the experiment, a limited water supply is useful to increase yield depending on the climate of the year and that it is possible to obtain high quality cherry tomatoes yield also with a limited irrigation water supply.

Keywords. Cherry tomato – Deficit irrigation – Hilly areas – Critical phonological stages – Productivity.

Effets de l'irrigation déficitaire sur deux cultivars de tomate cerise dans les zones collinaires

Résumé. *Dans les années récentes, la culture de la tomate cerise a remarquablement augmenté dans les zones caires de la Région Campania. En général, dans les zones collinaires de la Campania ces espèces sont cultivées sans irrigation afin d'en améliorer les paramètres qualitatifs. La culture sèche est faisable grâce à la résistance de la tomate cerise au stress abiotique et aux conditions climatiques des collines de la région, caractérisées par des pluies estivales inconstantes. Le but de cette étude est d'évaluer la réponse à un schéma d'irrigation déficitaire se basant sur les stades critiques du développement de la plante pour assurer une bonne productivité de deux cultivars de tomate cerise (Altavilla cv. standard et Mignon hybrid). L'étude a été menée en 2005 et 2006 dans la station expérimentale du CNR-ISAFoM, située à Piano Cappelle (BN). Quatre régimes d'irrigation ont été administrés aux deux cultivars: T0 (sans irrigation), T1 (une irrigation en début de floraison), T2 (une irrigation en début de floraison et une autre à 50% de la nouaison) et T3 (en début de floraison, à 50% de la nouaison et, ensuite, tous les 15 jours). Les résultats ont montré que, suivant le climat de l'année dans la zone de l'expérimentation, un apport d'eau limité fait augmenter la production tout en permettant d'obtenir des tomates cerises de haute qualité.*

Mots-clés. *Tomate cerise – Irrigation déficitaire – Zones de colline – Stades phénologiques critiques – productivité.*

I – Introduction

Tomato (Lycopersicon esculentum Mill.) is important worldwide, both for fresh and processing markets (Opiyo and Ying, 2005). It is grown wherever climatic conditions are favorable. In 2005, the world production of tomato reached about 126,090.74 (10^3) Mg, 18,227.53 (10^3) Mg of which in the European Union (EU). In Italy, 7,187 (10^3) Mg of tomato were produced, that is roughly 40% of the entire EU tomato production (Mori *et al.*, 2008).

Italy is the greatest European tomato producer for processing market: approximately 70,000 hectares are cultivated and about 4 million tons are intended for processing. The tomato production is mainly located in Puglia, Emilia-Romagna, Campania and Sicily (Tei *et al.,* Spigno *et al.,* 2003).

In Campania about 5,000 farms produce tomatoes for the processing industry, on an area covering 2,832 hectares (35.8% of the total area planted with tomatoes). In the last years the cultivation of cherry tomato significantly increased in the hilly areas of Campania region since the favorable climatic conditions allow a high-quality product. Generally in the Campania hilly areas, the species is cultivated under rainfed conditions that improve fruit sugar and soluble solids content and other quality parameters (Pentangelo *et al*., 2003).

The cultivation without irrigation is possible due to the species resistance to abiotic stress (high temperatures and water deficit) and to climatic conditions of hilly areas, characterized by erratic rainfall during the summer. Nevertheless this practice is very risky for farmer's income, because it becomes strictly dependent on the occurrence of useful rainfall during the most important phenological stages of the crop (fruit set and fruit growth). Furthermore, climate global change models forecast a decrease of about 10 to 15% of summer precipitation that makes crucial the study of sustainable irrigation scheduling in the area of the experiment.

The aim of the present work was to evaluate the response to deficit irrigation scheduling based on critical plant growth stages to ensure good productivity and quality.

II – Material and methods

The field trial was carried out in 2005 and 2006 at the CNR - Institute for Agricultural and Forest Mediterranean Systems (ISAFoM) research station located in Piano Cappelle, Benevento (41°06' Nord, 14°43' East; 250 m a.s.l.), an hilly areas of southern Italy.

The experiment involved two cultivars of cherry tomato (Altavilla cv. standard and Mignon hybrid) in a factorial combination with four irrigation regimes to partially satisfy the crop water consumption: T0 (rainfed), T1 (one irrigation at beginning of flowering), T2 (one irrigation at beginning of flowering and another at 50% of fruit set) and T3 (at beginning of flowering, at 50% of fruit setting and every 15 days onwards).

Watering volume was estimated as to replenish the soil profile to 50% of field capacity for a soil layer of 0-0.60 m. The irrigation water was distributed using a localized system with on-line drip nozzles delivering 2 L h^{-1} set in line equally spaced between the twin rows. Table 1 reports the amount of waterings along with the seasonal water volumes for all irrigation regimes for both experimental years.

Table 1. Irrigation volumes, useful precipitation (> 5 mm) and seasonal water of the two experimental years.

Irrigation date	Water volume			
	mm			
	T0	**T1**	**T2**	**T3**
2005				
Irrigation volume	0.0	37.0	81.2	154.9
Rainfall > 5mm	29.8	29.8	29.8	29.8
Seasonal volume	29.8	66.8	111.0	184.7
2006				
Irrigation volume	0.0	20.0	50.9	95.8
Rainfall > 5mm	186.8	186.8	186.8	186.8
* Seasonal volume	186.8	206.8	237.7	282.6

*A relevant rainfall of 70,2 mm occurred in the first decade of June 2006

During the crop cycle the soil water content of each treatment was gravimetrically measured for a soil layer of 0-0.60 m with 0.20 m increments; this was monitored before and 24-h after each watering and at the beginning and at the end of the growing season.

The experimental design consisted in a randomized complete block with four replicates where the irrigation variable was in the main plots and cultivars in the sub-plots.

Tomato plants, grown in greenhouse in plastic cellular containers, were transplanted on May 17th and May 10th in 2005 and 2006, respectively. In the conventionally tilled plots of 30 m^2 (5 by 6 m) plants were placed on twin rows to reach a density of 40.000 plants ha^{-1} (1.20 m row spacing and 0.30 m between the twin rows). The crop was cultivated adopting the traditional agronomic management for the area. At planting, all plots were equally supplementary irrigated to guarantee uniform plant development, thereafter irrigation level differentiation started. The harvest was made manually when the plants reached 90% of fruits ripening on the 18th and the 25th of August for cultivars Mignon and Altavilla in the first year and on 23 August for both cultivars in the second year. At harvest, in a sampling area of 20 m^2 per plot, marketable yield components (fruit mean weight, biomass yield and waste yield) as well as main quality characteristics were determined.

Data were analyzed by analysis of variance (ANOVA) using the SAS (SAS Institute inc., Cary, N.C.) statistical package, and means were compared using Least Significant Difference (LSD).

III – Results and discussion

Environmental conditions were typical of a sub-humid Mediterranean area characterized by a mean precipitation of about 740 mm, a potential evapotranspiration of 1,240 mm (23-year mean data) and scarce summer precipitation. In the experimental area the daily mean temperature increased from 10.7°C in April to 22.4°C in July, decreasing to 18.2°C in September, while the reference evapotranspiration increased from about 3 mm day^{-1} in April to about 8 mm day^{-1} in July, starting to decrease in August.

The climatic conditions during the two experimental years differed for the precipitation amount and distribution (Fig. 1).

The first year was dryer than the second one and, during the whole crop cycle, 29.8 mm rainfall occurred. In this year a rainfall event of 34 mm occurred during the harvest and it was not included in the seasonal water budget since it was not useful for yield formation. In the second year the seasonal amount of useful rainfall (> 5 mm in 24 hours) was 186.8 mm. In this year several precipitations occurred in the first decade of June when a total amount of 70.2 mm was monitored. Minimum and maximum air temperatures were generally lower than poli-annual mean value, while in the third decade of June values showed a peak of about 2.5°C higher than the poli-annual means in both years.

Evaporation pan showed values generally near to the poli-annual mean in both year, but for the first decade of June of the second year when it decreased as a consequence of a rainy period. In addition, the second decade of July 2006 was characterized by a daily evaporation of about 1 mm higher than the first year.

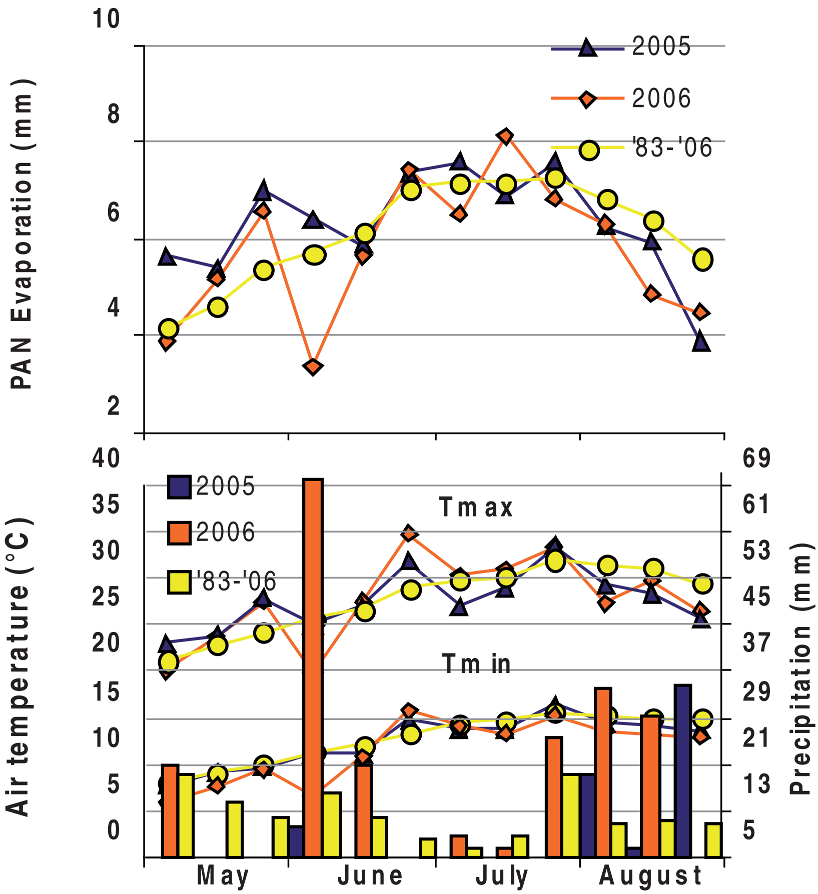

Figure 1. Time course of some climatic parameters in the two experimental years compared with the 23 - years mean values. PAN evaporation (10 days mean), minimum and maximum air temperatures (T min and T max - 10 days mean) and precipitations (10 days sum) are reported.

In 2005 the soil water content (Fig. 2) monitored before each watering showed a gradual reduction of soil water content during the crop cycle always showing values below wilting point for T0 treatment. Soil water content in irrigated treatments also reached a level near to the wilting point before each watering. This behavior points out that, in all treatments, both cultivars consumed the whole amount of the given water. In 2006 soil water content for T0 treatment showed values near to the wilting point and this trend increased during the plant growing. Only in the first decade of June 2006 soil water content reached a value near to field capacity because of a 70.2 mm rainfall.

After the beginning of watering the available soil water content clearly varied in different treatments. In the second year, the wetter year, irrigated treatments showed a soil water content higher than in 2005 and treatment T3 reached about 50% of available water content in the last two irrigation dates. In the 2006 watering volumes were lower than in 2005 (Tab. 1): as a consequence of the very rainy period occurred in the first decade of June soil water content during plant growing was higher.

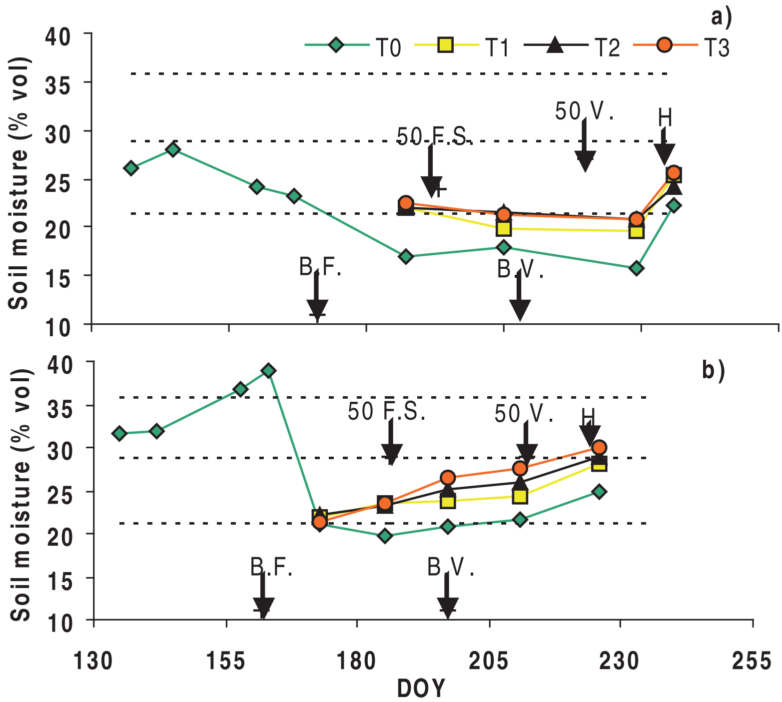

Figure 2. Volumetric soil water content of 2005 (a) and 2006 (b) in the top 0-0.60 m soil layer for the three irrigation levels. The main phenological stages are also reported: B.F.= beginning of flowering; 50 F.S. = 50% of fruit set; B.V. = beginning of fruit veraison; 50 V. = 50% of fruit veraied; H = harvest. F.C = field capacity; 50% A.W. = 50% of available water; W.P. = wilting point.

The statistical data analysis showed the significance of the three way interaction of cultivars x treatments x year for yield and vegetative parameters monitored (Fig. 3). As a general rule, for these two cultivars a higher water supply makes the yield to increase for both years although this was more evident in the first year.

Especially in 2005 - the drier year - the marketable yield obtained by T0 and T1 treatments was significantly lower than the one obtained by the two more irrigated treatments for both cultivars. Moreover, treatment T3, that received an irrigation volume of about 155 mm during the crop cycle, performed significant higher yield than T2 in cv. Mignon. If we compare cultivars, the most irrigated treatment (T3) of Mignon yielded a higher marketable yield than the same treatment for Altavilla (Fig. 3a) thanks to a more efficient use of irrigation water.

In the wet year (2006), due to rainfalls occurred from June to August (186.8 mm), the yields of the two cultivars receiving same treatments did not differ. Furthermore, climatic conditions determined a reduction of yield differences between treatments in both cultivars and significant differences were detected only between treatment T0 and T2.

The marketable yield enhancement of the two cultivars, as a consequence of irrigation volumes, was mainly determined by the increase of mean fruit weight that showed similar behavior described for marketable yield. The trend showed by waste yield and vegetative biomass (Fig. 3 c,d) was similar to marketable yield, but the waste yield was higher in 2005 Mignon because of a 34 mm rainfall occurred during the harvest.

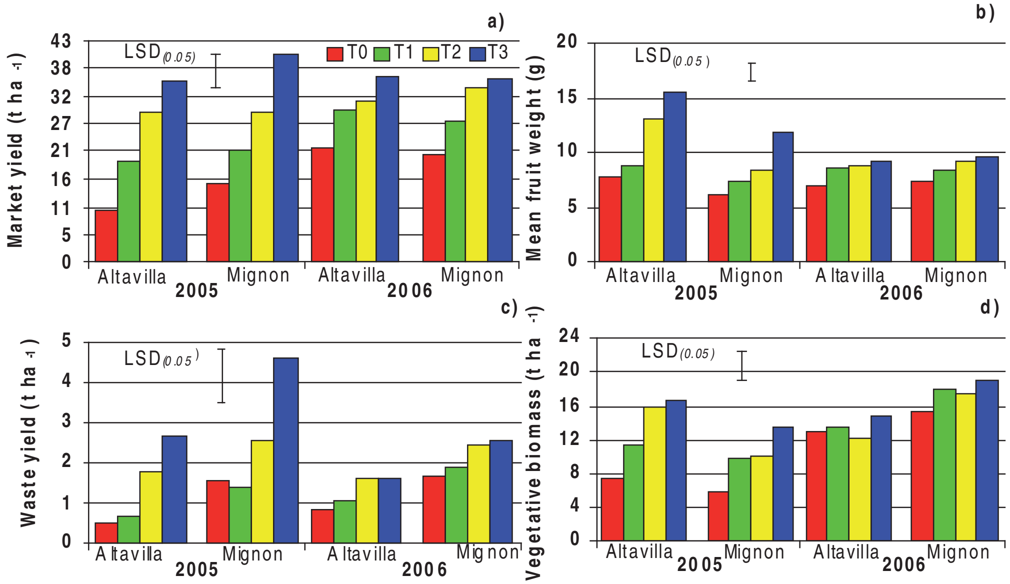

Figure 3. Marketable yield (a), mean fruit weight (b), waste yield (c) and vegetative biomass (d): interaction cultivars x irrigation level x year. Last Significant Difference (LSD) at 0.05 level is also reported.

Table 3 lists the fruits biometric parameters showing that in both years water supply influenced in the same way the polar and equatorial diameter so the fruits shape was not modified.

The harvest index (HI), calculated as marketable yield to vegetative biomass ratio, showed higher values for irrigated treatments against the control (T0). In the first year, Altavilla showed a significant increase of harvesting index between T0 and the irrigated treatments, while only a trend was evident among irrigation levels. In the second year this cultivar showed a significant increase of this parameter between T0 and T2 and similar values were monitored for the two most irrigated treatments. Similar response to irrigation was observed for Mignon. In the drier year, Altavilla recorded lower values respect to Mignon, while in 2006 the differences were less evident.

Quality parameters (Tab. 4) like high solid soluble (optical residue) and high sugar content, pH and fruits color (values> 2.1 Hunter Color) underlined a good yield quality.

According to previous experience (Giordano *et al*., 2005) irrigation influenced some chemical and technological parameters of tomato. Water, especially, administered at the end of the growing cycle may lead to a significant reduction of solid soluble and sugars content and total acidity. In this trial the decrease in soluble solids was evident among the non-irrigated and irrigated treatments. Instead fruits color and pH were not influenced by irrigation schedule.

Mignon showed good quality parameters and was suitable for industrial processing while Altavilla had some negative aspects, such as the low level of acidity (<0.4 g%) and a pH value slightly higher than the limit for industrial processing. However, a pH value of 4.5 is critical in food processing because pH pathogenic microorganisms are unable to growth below this level. Processed tomato with ph>4.5 can be adjusted by adding acidifying products - i.e. citric acid - that reduce pH to below 4.5 with obvious negative impact on the product quality. This trial emphasized the different response of two varieties in response to irrigation scheduling. In particular the optical residue and sugar content recorded a higher reduction with irrigation for Altavilla than for Mignon.

Table 3. Longitudinal and equatorial diameter and Harvest Index (HI) for both cultivars as a function of irrigation treatments. Last significant difference (LSD) at 0.05 level and Standard Deviation (Std. Dev.) are also reported.

	Longitudinal diameter		Equatorial diameter		HI
	Mean	*Std Dev.*	*Mean*	*Std. Dev*	
			cm		
2005			**Altavilla**		
T0	24.8	±1.6	22.4	± 2.2	55.7
T1	25.7	± 2.1	23.3	± 2.7	61.8
T2	29.5	± 2.9	26.9	± 3.1	61.5
T3	31.6	± 3.1	28.8	± 3.7	63.5
2006					
T0	24.9	± 1.9	20.4	± 2.2	68.8
T1	25.8	± 2.2	22.4	± 2.3	72.4
T2	26.2	± 3.1	22.3	± 2.0	76.1
T3	26.9	± 2.5	22.4	± 3.2	76.3
2005			**Mignon**		
T0	22.7	± 2.3	21.6	± 1.2	67.1
T1	24.1	± 2.5	22.8	± 1.8	65.4
T2	25.3	± 2.6	24.3	± 2.2	69.4
T3	28.2	± 2.8	26.6	± 2.9	67.1
2006					
T0	22.5	± 1.8	22.0	± 1.6	64.9
T1	23.8	± 1.7	23.0	± 1.8	66.1
T2	23.9	± 1.5	23.8	± 1.6	72.7
T3	24.7	± 1.8	24.0	± 1.5	72.2
LSD *(0.05)*	1.17		1.08		5.36

Table 4. Main quality parameters. OR=optical residue, Ac.=acidity (citric acid), Gluc=glucose, Fruct=fructose, Treat=irrigation treatment.

	OR	Ac.	Sugar			Ratio		pH	Hunter Color		
			Gluc.	Fruct.	Total	Ac.	Sugar		a	b	a/b
	%	*g %*	*g %*	*g %*	*g%*	*%*	*%*				
Year											
2005	7.65 a	0.54 b	2.30 a	2.42 a	4.72 a	7.1 b	61.8 a	4.33 a	24.9 b	10.9 b	2.28 a
2006	7.07 b	0.66 a	1.86 b	2.03 b	3.89 b	9.4 a	54.9 b	4.24 b	29.5 a	12.7 a	2.34 a
Cv											
Mignon	7.49 a	0.71 a	2.09 a	2.25 a	4.34 a	9.4 a	57.8 a	4.18 b	28.6 a	11.8 a	2.42 a
Altavilla	7.23 a	0.50 b	2.07 a	2.20 a	4.27 a	7.0 b	58.9 a	4.39 a	25.8 b	11.8 a	2.20 b
Treat.											
T0	8.16 a	0.68 a	2.30 a	2.46 a	4.76 a	8.4 a	58.1 a	4.28 a	27.7 a	11.9 a	2.32 a
T1	7.40 ab	0.63 a	2.12 a	2.27 a	4.39 a	8.6 a	59.0 a	4.29 a	27.2 a	11.7 a	2.33 a
T2	7.13 b	0.57 a	1.99 a	2.10 a	4.09 a	8.0 a	57.0 a	4.30 a	27.6 a	11.9 a	2.33 a
T3	6.74 b	0.53 a	1.91 a	2.08 a	3.99 a	7.9 a	59.1 a	4.26 a	26.3 a	11.7 a	2.25 a
Mean	7.36	0.60	2.08	2.23	4.31	8.20	58.3	4.28	27.2	11.8	2.3

IV – Conclusions

Results showed that, in the area of the experiment, a limited water supply is useful to increase yield depending on the climate of the year. In both cultivars marketable yield values showed a significant yield increase by T3 against T1, while T2 and T3 did not differ. Moreover, in the wet year cultivars responded similarly to irrigation levels.

The quality parameters showed that in the experimental area it is possible to obtain high quality cherry tomato yield also with a limited irrigation water supply.

In conclusion, in the year characterized by little or no rainfall during the growing cycle two (T2) or four (T3) waterings were necessary to ensure good yield and quality, depending of water cost, while in the years with useful precipitations during critical phenological stages one watering at the beginning of flowering may be sufficient to achieve good yield for Mignon, the less sensitive cultivar to drought. The tolerance to water stress of cultivars must be considered to optimize the water management.

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References

Giordano, I. et al., 2005. Colture industriali alternative al tabacco nelle aree interne della Campania. In: *Progetto Co.Al.Ta 1 – Risultati del 1° anno di attività*, pp. 51-66.

Mori, M. et al., 2008. Productive behaviour of "cherry"-type tomato irrigated with saline water in relation to nitrogen fertilisation. *Eur J Agron*, 29. pp. 135–143.

Opiyo, A. M., Ying, T-J., 2005. The effects of 1-methylcyclopropene treatment on the shelf life and quality of cherry tomato (*Lycopersicon esculentum* var. *cerasiforme*) fruit. *Int J Food Sci Techn*, 40. pp. 665–673.

Pentangelo, A. et al., 2003. Pomodorino da industria, varietà a confronto. *Campania Agricoltura*, dossier pomodoro, 4. pp. 8-15.

Spigno, P., Riccardi, R., D'Uva, A., 2003. Produzione integrata per il rilancio del pomodoro da industria campano. *Campania Agricoltura*, dossier pomodoro, 3. pp. 14-20.

Tei, F., Natalini, G., Bruni, R., 2002. Manuale di corretta prassi per la produzione integrata del pomodorino da industria. In: *Progetto per la valorizzazione delle produzioni agroalimentari umbre.* pp. 1-29.