Effects of Regulated Deficit Irrigation on Pear Trees cv. Conference under Temperate Zone Climate

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Abstract

To prevent drought stress, pear trees (*Pyrus Communis,* cv. 'Conference') in Belgium and the Netherlands, under temperate climate conditions are equipped with a drip irrigation system. To determine the optimal Soil Water Tension (SWT) threshold a field experiment was accomplished in a commercial orchard during two successive years (2007-2008). The objective was to test the impact of Regulated Deficit Irrigation (RDI) during the shoot growth period. The orchard was situated on a silt loam soil, and contained 11 year old pear trees cv.'Conference' on Quince Adams rootstock. The trees were trained in a free spindle system with a planting distance of 3.50 m x 1.25 m. One sided root pruning was preformed one month before full bloom. Each year two different irrigation regimes were accomplished. In the control treatment (T1) SWT was maintained above -45 kPa during the whole growing cycle. In the second treatment (T2) SWT reached -60 kPa up to -80 kPa during shoot growth. Each treatment consisted of minimaly three randomised blocks of 4 trees. Irrigation was scheduled with the aid of a soil water balance model calibrated by granular matrix sensors (Watermark) and gravimetric soil moisture determination. Based on the data of a nearby weather station, Reference Evapotranspiration (ET0) was calculated with the Penman-Monteith method. The tree water status was examined by Stem Water Potential (SWP) readings and sap flow measurements (Thermal Dissipation Probes). At harvest yield, fruit size and fruit quality of T2 did not differ from those of T1. Tree water status was not influenced by the depressed SWT. These findings illustrate the possibilities of RDI, on a silt loam soil under temperate climate conditions.

INTRODUCTION

Pear fruit (*Pyrus Communis* c.v. 'Conference') has become an important part of horticulture in Belgium and the Netherlands. Drip irrigation techniques are implemented to achieve maximal production results in high calibre grades. The financial return of fruits having a diameter of >60 mm is twice the return of smaller sized fruits (<55 mm). Especially in combination with growth control techniques such as root pruning, irrigation has gained importance (Maas, 2007). Besides root pruning RDI can be an additional valuable tool to control vegetative growth when applied during shoot growth (Asin *et al*., 2007).

Yield effects of RDI on *Pyrus Communis* were illustrated by Anconelli and Mannini (2002), a threshold of 20% available water after bloom to 60 days later has a significantly positive yield effect. However, O'Connel and Goodwin (2007) described negative effects on production when RDI (50% ETc) is applied in combination with Partial Root zone Drying (PRD) during the complete growth cycle.

Directly linking the amount of irrigation water applied to the production effects could lead to misinterpretation in silty and loamy soils given their high water storage capacities. Midday Stem Water Potential (SWP) measurements are a valuable water stress indicator in pear tree. (Naor, 2001; Marsal *et al*., 2002b). Measurements of SWT are often used to schedule irrigation in commercial orchards due to its practical benefits. However these readings should be accompanied with occasional determinations of SWP or pre-dawn leaf water potential. (Intrigliolo and Castel, 2006).

In Belgium, in the temperate climate zone with relative low average evapotranspiration (421 mm) en high rainfall (342 mm) from bloom (second decade of April) to harvest (first decade of September), pear trees are mainly grown on sand loam, loam and silt loam soils with a large water storage capacity and sometimes a water table present within a depth of 3 m. Given the capabilities of RDI to reduce vegetative growth and to enlarge the Water Use Efficiency (WUE) the objective of the present study is to examine the production effect of an elevated SWT during shoot growth. To evaluate the two different irrigation treatments yield is analysed and SWP is measured on a regular base. These observations are accompanied with sap flow measurements. Ma *et al.* (2007) demonstrates that a difference in transpiration can occur due to different irrigation treatments.

MATERIAL EN METHODS

During two successive years the research was conducted in a commercial orchard at Meensel-Kiezegem (Belgium). The orchard was composed of pear tree 'Conference' on a Quince Adams rootstock. The trees were planted in 1996 with a planting distance 3.5 m x 1.5 m and trained in a free spindle system. The soil texture was sandy loam and at the site there was a shallow ground water table present at 1.5 m. The orchard was situated on a small slope. One sided root pruning was carried out with a vertical knife at approximately 35 cm from the trunk one month before full bloom. A drip irrigation system was installed with drippers each 20 cm with a capacity of 2 L/h. In the orchards two irrigation treatments were applied. Treatment T1 maintained a SWT of minimal -45 kPa during the complete growing cycle. For treatment T2 SWT was maintained above -45 kPa during full bloom, the following six weeks, and the last four weeks before harvest. However for T2 during shoot growth, a SWT of -60 kPa up to -80 kPa was induced. RDI was not applied during the period of full bloom and the following six weeks to prevent yield decline due to water stress during this period of intensive cell division. Nor is RDI applied during the last four weeks before harvest to prevent a decline in fruit size. Each treatment consisted of four plots randomized in the orchard. Each plot consisted of four trees in a row. Between two plots there was a spacing of minimal two trees was provided in order to prevent side effects.

Scheduling of irrigation was based on a soil water balance, regularly checked by gravimetric water content measurements of the soil layers 0-30 cm and 30-60 cm. The water retention characteristics were determined on undisturbed soil samples. Water retention was 0.36 cm^3/cm^3 at pF 2, and 0.12 cm^3/cm^3 at pF 4.2. These measurements serve as input of the soil water balance. Rainfall was recorded on site, reference evapotranspiration was calculated using the Penman-Montheith equation (Allen et al., 1998). The data for the calculation were obtained from a weather station at approximately 20 km. For each plot one tree was equipped with six granular matrix sensors (Watermark); 3 sensors at 30 cm, 2 sensors at 60 cm and 1 sensor at 90 cm depth. The sensors were connected to a data logger who recorded SWT every four hours.

Due to the mild slope in the orchard and the shallow ground water table present at 1.5 m there was high variation in the evolution of moisture content was observed among the different plots. To assure an elevated SWT in T2 a part of the root zone of three plots was covered with rain repelling screens at soil surface during rainfall.

To monitor the effect of the different irrigation treatments at tree level, weekly SWP measurements were preformed. For each plot, from the tree equipped with Watermark sensors, tree leaves were selected from the inner part of the canopy; they were enclosed, while still attached, in plastic bags covered with aluminium foil. After 60 min the leaves were detached form the tree and SWP was immediately determined with a pressure chamber (Schollander et al., 1965).

Sap flow was measured based on the heat dissipation technique (Granier, 1985). Two trees were selected in the orchard, each in a different irrigation treatment. Two cylindrical probes of 2 mm diameter and 20 mm are inserted in the trunk 10 cm apart. The upper probe was heated with a constant power of 0.2 w. Based on the temperature difference between the two needles sap flow is calculated. To compare the results for the different parameters, statistical analysis was performed using the Mann-Whitney U test with the STATISTICA software

RESULTS AND DISCUSSION

SWP registrations were performed on a weekly basis (fig. 2). There was no difference in SWP during the growing season between T1 en T2, even if SWT averaged -60 kPa for T2 and -30 kPa for T1 during shoot growth. Naor (2001) reported a SWP of -1.3 MPa for well irrigated “Spadona” pear and a yield decline from -1.5 MPa and lower. During the growing season there was no SWP measured below -1.4 MPa. The relation between SWT and SWP has not yet been described extensively for pear. Intrigliolo and Castel (2004) describe a negative linear relationship between SWT and SWP for plum.

In addition to the SWP registrations, sap flow was monitored (fig. 1) on two similar trees: one in T1 and one in T2, during the period of elevated SWT. Although the difference in SWT measured by gravimetric moisture sampling, up to 75 kPa, there was no difference in diurnal pattern of sap flow. Only on 22/07 there was a difference in sap flow pattern. The registration of sap flow was higher at the plot with elevated SWT.

The lack of signals indicating water stress indicates that there is no physiological response of the tree measurable at 75 kPa. In the silt loam soil with a shallow groundwatertable there still is a sufficient flux of water between the deep soil layers and root zone. This suggestion is supported by Kang *et al*. (2004) who described an elevated ground water contribution to the root zone due to the effect of partial root zone drying without yield decline. Polak and Wallach (2001) discussed the importance of the hydraulic conductivity for water movement in the root zone. Hydraulic conductivity is closer related to the water uptake of the plant although it is difficult to measure.

Table 1 lists up all the plots where the maximum SWT did not exceeded -45 kPa during the whole growth cycle (T1) and the plots where a minimum of at least -60 kPa was reached during shoot growth (T2). During June and July 2007-2008 (period of shoot growth) the precipitation was approximately 160 mm. Reference evapotranspiration (ET0) was 182 mm in 2007 and 196 mm in 2008. For all the plots in the orchard SWT levels above -45 kPa during full bloom, the following 6 weeks and the last 4 weeks before harvest. RDI was only applied during the period of shoot growth.

Table 1 summarizes the main production results. In both 2007 and 2008 there was no fallback in production (kg/tree) due to elevated SWT (T2). Although the mean fruit weight was lower there were more fruits harvested from each tree in T2 though not significant. These results confirm previous findings of Marsal *et al.* (2002) who reported a fallback in the amount of fruits harvested in well irrigated plots compared to RDI plots. It seems logical that a lower amount of fruits in these well irrigated plots is accompanied with a higher individual fruit weight. Table 2 shows that there is no quality difference between the two treatments for the parameters fruit firmness and °Brix of the juice.

Figures 3 en 4 compare the distribution in the different calibre grades for the two treatments. Up to 60-65 mm T2 has a higher yield though not significant. In the big fruit sizes (65-70 mm, >70 mm), T1 has the highest yield. Due to more numerous amounts of fruits in T2, less fruits tend to grow to the highest calibre grades. RDI during shoot growth tends to grow more fruits per tree; therefore the average fruit weight is lower just as the amount of fruits in the highest diameter classes (not significant). The optimal balance between amount of fruits and the fruit sizes depends on the financial return of the different fruit sizes. In this case T2 has the highest financial return given the higher yield in the fruit size class >60 mm.

CONCLUSION

The RDI treatment received up to 20 mm less water compared to the control treatment in 2007 and up to 100 mm less water in 2008. RDI allows considerable water savings. This irrigation difference in irrigation amount in combination with the rain repelling screens constructed in the RDI treatment caused a depressed SWT up to -80 kPa in the RDI treatment. RDI had no negative effect on yield production nor on quality. The effect of the decreased SWT was not reflected in SWP measurements or sap flow measurements which can be explained by the high water storage capacity of the soil. It illustrates the possibilities of RDI on a silt loam soil under temperate climate conditions.

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Literature Cited

Scholander, P.F., H.T. Hammel, E.D. Bradstreet, and E.A. Hemmingsen. 1965. Sap pressure in vascular plants. Science 148:339-346.

Granier., A., 1985. Une nouvelle méthode pour la mesure du flux de sève brute dans le tronc des arbres. Ann. Sci. For. 42(2), 193-200.

Allen R.G., Pereira S.P., Raes, D. and Smith M. 1998. Crop evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and drainage paper nr.56. Rome.

Polak A. Wallach R. (2001) Analysis of soil moisture variations in an irrigated orchard root zone. Plant and Soil 233: 145-159.

Naor, A. (2001). Irrigation and crop load influence fruit size and water relations in fieldgrown 'Spadona' pear. J. of the Amer. society for Hort: science, 126: 252-255.

Anconelli, S. and Mannini P, 2002. Effects of regulated deficit irrigation on the performance of pear in an Italian sub-humid Area. Acta Hort. 596: 687-690

Marsal, J., Mata, M., Arbonés, A., Rufat, J. & Girona, J. (2002a). Regulated deficit irrigation and rectification of irrigation scheduling in young pear trees: an evaluation based on vegetative and productive response. European J. of Agron., 17: 111-122.

Marsal, J., Mata, M., Arbonès, A., Rufat, J. & Girona, J. (2002b). Water stress limits for vegetative and reproductive growth of 'Barlett' pears. Acta Hort., 596: 659-663.

Intrigliolo D.S. Castel J.R. (2004) Feasibility of using LVDT and Watermark sensor for irrigation scheduling in plum. Acta Hort. 664: 317-323.

Kang S., Xiaotao H., Jerie P. and Zhang J. (2003) The effects of partial rootzone drying on root, trunk sap flow and water balance in an irrigated pear (*pyrus communis* L.) orchard. J. of Hydrology 280 (2003) 192-206.

Intrigliolo D.S. Castel J.R. (2006) Performance of various water stress indicators for prediction of fruit size response to deficit irrigation in plum. Agri. Water Mgt. (2006) 83: 173-180.

Asín, L., Alegre, S. & Montserrat, R. (2007). Effect of paclobutrazol, prohexadione-Ca, deficit irrigation, summer pruning and root pruning on shoot growth, yield, and return bloom in a Blanquilla' pear orchard. Scientia horticulturae, 113: 142-148.

Maas, F.M 2007 Dynamics of fruit growth in «'Conference » pear as affected by root pruning, irrigation and climatic conditions. Acta Hort. 732: 555-563

Ma F., Kang S., Li F., Zhang J., Du T.., Hu X.., Wang M. (2007) Effect of water defecit in different growth stages on stem sap flux of greenhouse grown paer-jujube tree. Agri. Water Mgt. (2007) 90: 190-196.

O'Connell M., Goodwin I. (2007) Responses of 'Pink Lady' apple to deficit irrigation and partial rootzone drying: physiology, growth, yield, and fruit quality. Australian J. of Agri. Res. 58(11) 1068–1076.

Tables

Table 1: Comparison of yield two irrigation treatments; T1 a SWT of maximum 45 kPa during shoot growth, T2 a SWT of min 60 kPa during shoot growth.

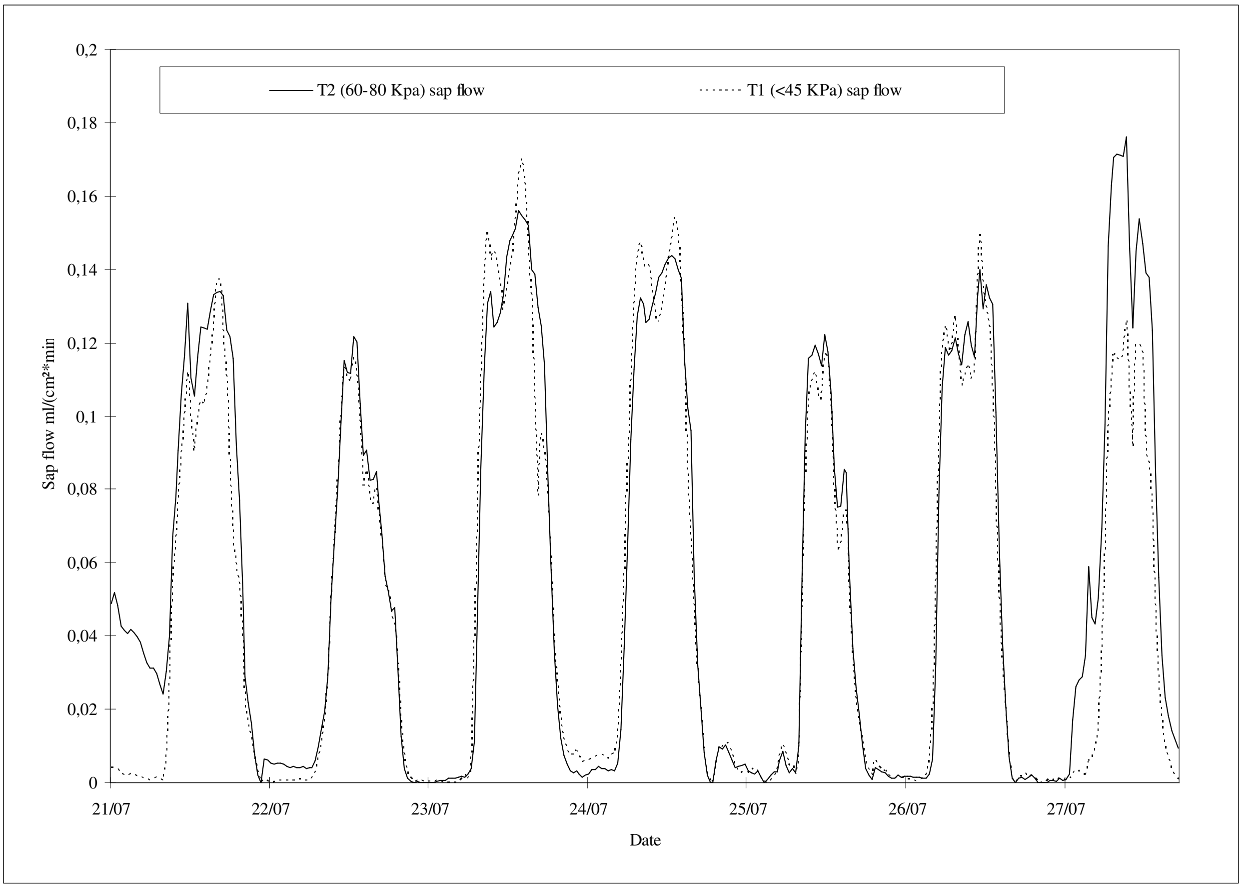
	2008	Rain (mm)	Irrigation (mm)	Average SWT (kPa)	Maximal SWT (30 cm) (kPa)	Yield (kg/tree)	Yield # fruit/ tree	Fruit weight (g/fruit)
T1	A10	160	108	24	45	26	142	183
	D6	160	30	18	30	24	137	177
	C4	160	108	23	38	23	134	170
	B8	160	108	5	24	19	121	159
	Mean			18*	34*	23	133	172
T2	A8	-	10	27	60	21	132	162
	A5	160	30	35	60	29	179	165
	B5	-	10	30	62	23	141	164
	D3	-	10	36	82	27	165	164
	Mean			32*	66*	25	154	164
	2007	Rain (mm)	Irrigation (mm)	Average SWT (kPa)	Maximal SWT (30 cm) (kPa)	Yield (kg/tree)	Yield # fruit/ tree	Average fruit weight (g/fruit)
T1	A10	162	42	24	34	39	280	139
	C8	162	28	25	33	40	274	146
	D6	162	28	28	34	30	181	166
	B8	162	42	6	20	27	184	149
	Mean			21*	30*	34	229	150
T2	A8	-	24	45	66	31	220	140
	B5	-	24	32	71	37	278	134
	C4	162	42	51	77	40	266	151
	A5	162	28	56	109	40	275	146
	Mean			46*	81*	37	260	143

* indicates a significant difference at $P < 0.05$ for the Mann-Whitney U test

Table 2: Fruit quality for two irrigation treatments; T1 a SWT of maximum 45 kPa during shoot growth, T2 a SWT of min 60 kPa during shoot growth.

	2008		2007	
	Firmness (kg/0.5 cm²)	Brix (%)	Firmness (kg/0.5 cm²)	Brix (%)
T1	6.00	13.21	3.54	11.54
T2	5.95	13.50	3.21	11.51

Figures



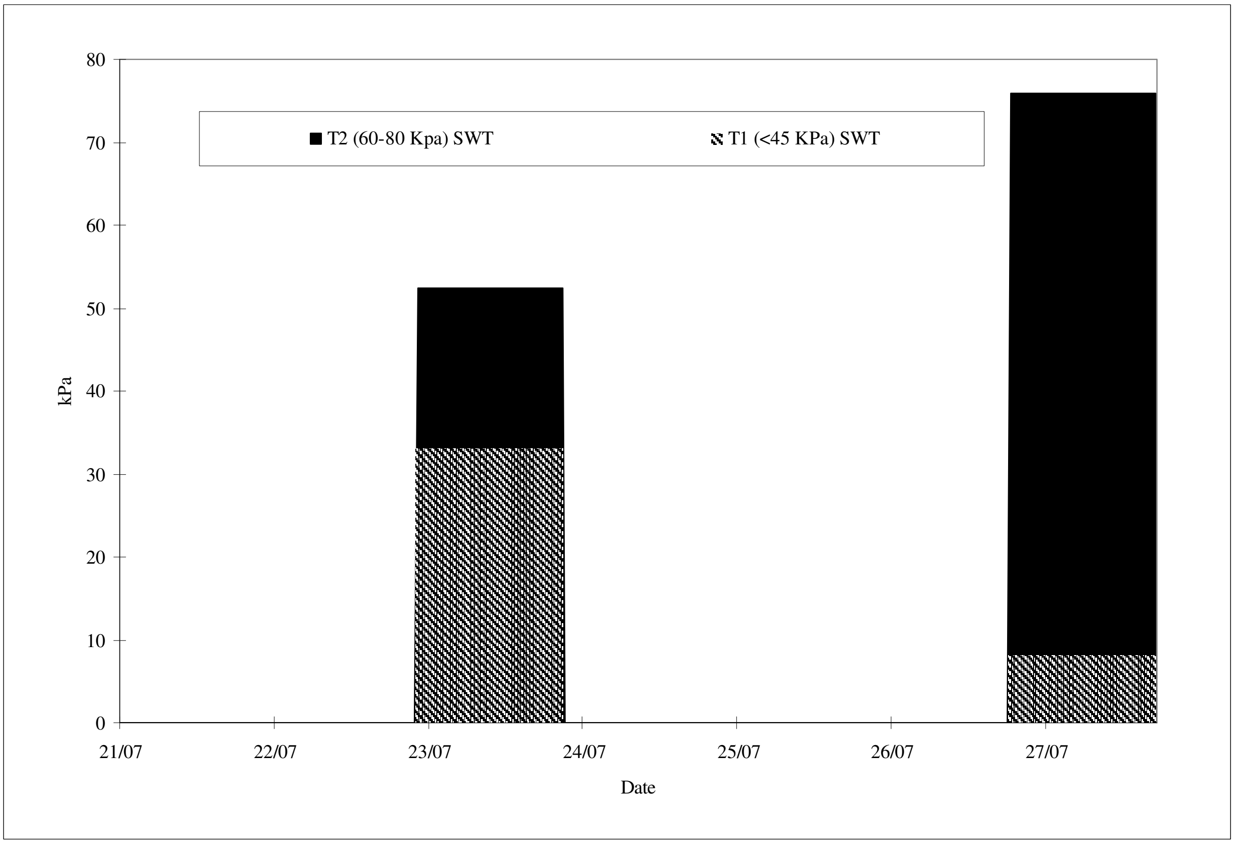


Fig.1.: Upper: Sap flow (Soil Water Tension) of two irrigation treatments. Lower: Soil Water Tension (SWT) measured by gravimetric moisture sampling of two irrigation treatments. T2: min 60 kPa during shoot growth, T1: max 45 kPa during shoot growth.

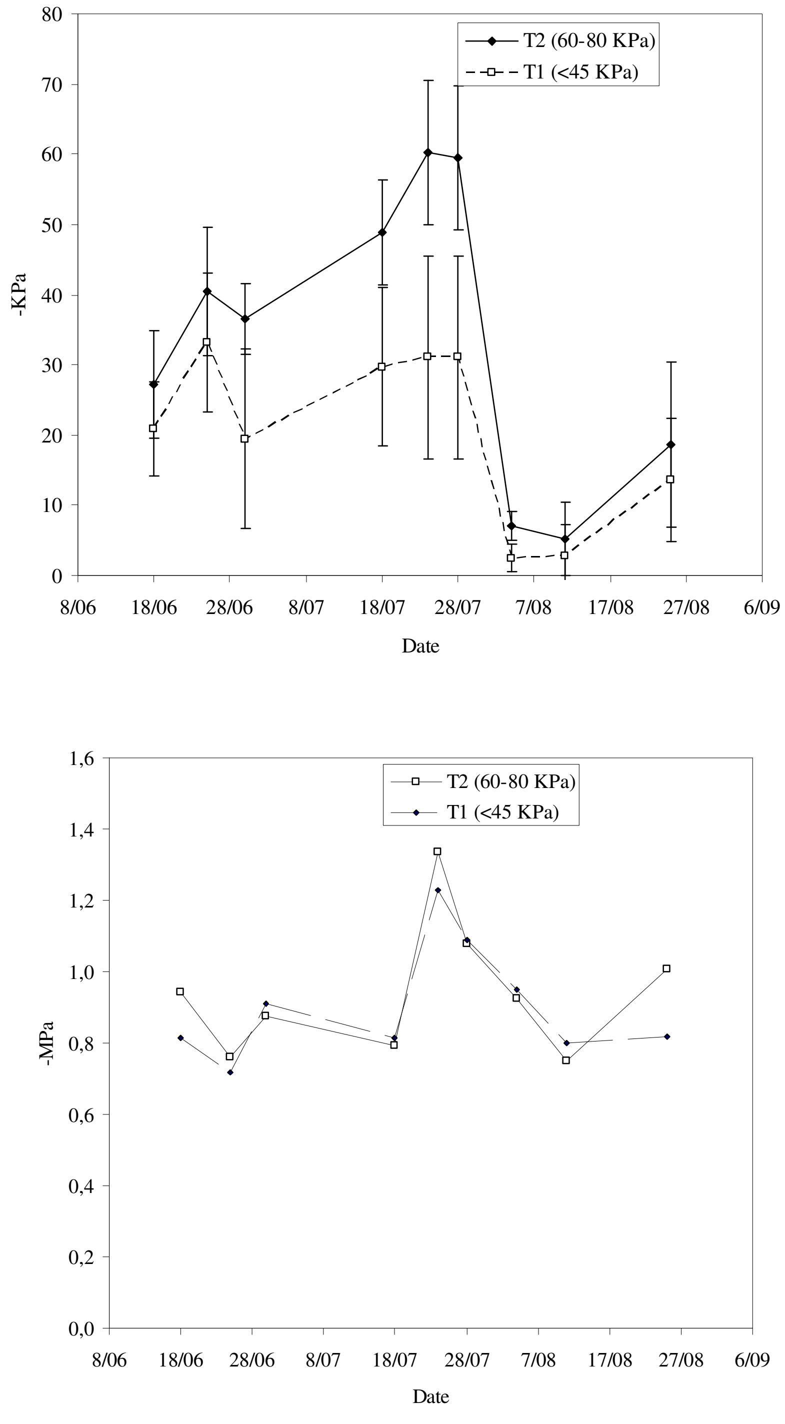


Fig 2.: (Upper) Soil Water Tension (SWT) measured by Watermark Sensors of two irrigation treatments (Lower) Stem Water Potential (SWP) of two irrigation treatments. T2: min 60 kPa during shoot growth, T1: max 45 kPa during shoot growth.

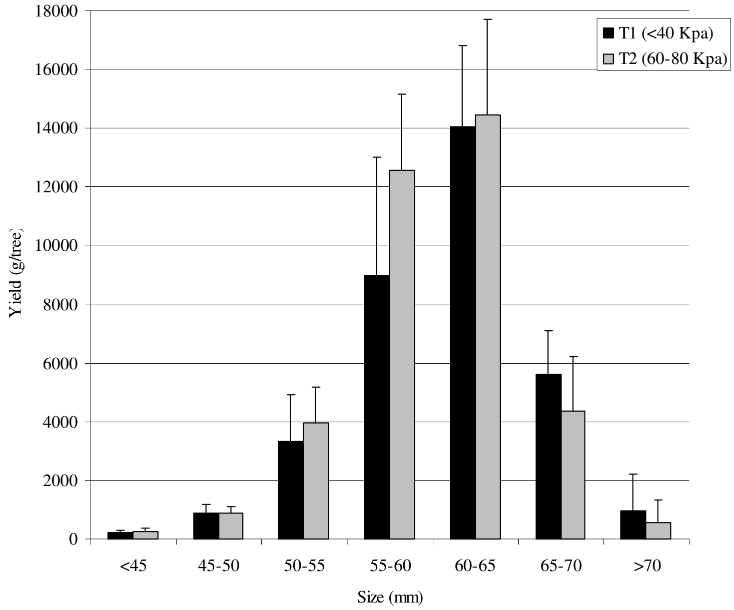


Fig. 3.: Size distribution yield 2007 for two irrigation treatments. T2: min 60 kPa during shoot growth, T1: max 45 kPa during shoot growth.

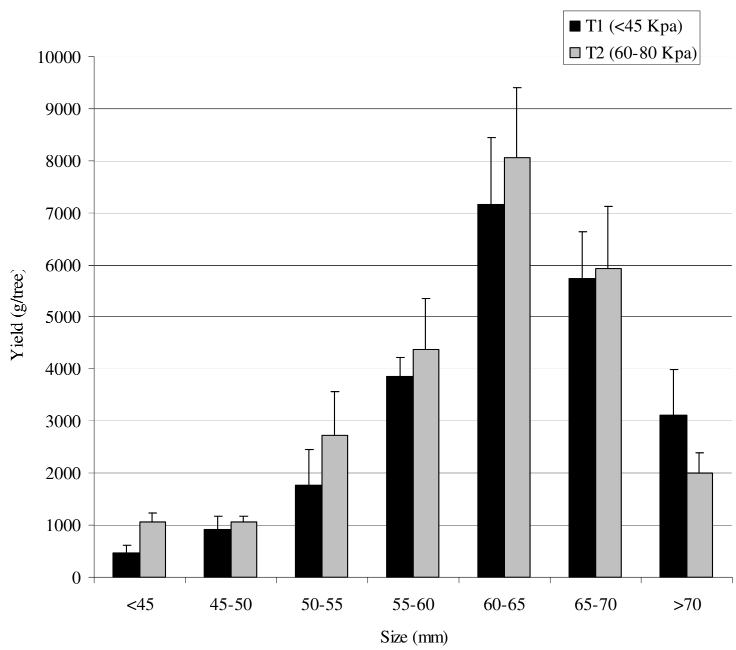


Fig. 4.: Size distribution yield 2008 for two irrigation treatments. T2: min 60 kPa during shoot growth, T1: max 45 kPa during shoot growth.