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SALTMED MODEL TO SIMULATE YIELD AND DRY MATTER FOR QUINOA CROP AND SOIL MOISTURE CONTENT UNDER DIFFERENT IRRIGATION STRATEGIES IN SOUTH ITALY[Ψ]

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ABSTRACT

The aim of this research was to calibrate and validate the SALTMED model with soil moisture, total dry matter and yield data of Chenopodium quinoa Willd var. Titicaca grown in a Mediterranean environment of south Italy under different irrigation strategies. For this purpose the data used were obtained from a biannual field trial (2009-2010) performed at the experimental station of the CNR - Institute for Agricultural and Forest Mediterranean Systems (ISAFoM) on the Volturno river plain, an irrigated area of Southern Italy; a control irrigation treatment where water was given to restore the root zone layer (0.00 - 0.36 m) to 100% of its field capacity, and two other treatments where water given represented 50% and 25% of the water volume given for the control treatment. Two water qualities were used, saline and well water.

SALTMED model was calibrated using yield, total dry matter (including roots) and soil moisture data from 100% well water treatment in 2009. After the calibration, the model was validated using the same set of crop and soil parameters. The results indicated the model ability to simulate with good precision, soil moisture values, total dry matter and grain yield for quinoa under different irrigation strategies with saline and fresh water for a two years experiment.

KEY WORDS: irrigation strategies; quinoa; SALTMED; model validation; soil moisture.

[Ψ] Modèle SALTMED pour simuler la production de matière sèche et des cultures de quinoa et de l'humidité du sol sous différentes stratégies d'irrigation dans l'Italie du Sud

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RESUME

L'objectif de cette étude était de calibrer et de valider le modèle SALTMED, à l'aide des paramètres de l'humidité du sol, la biomasse et les données de rendement de Chenopodium quinoa Willd var. Titicaca cultivée dans un environnement méditerranéen du sud de l'Italie avec différentes stratégies d'irrigation. A cet effet, les données utilisées ont été obtenues a partir d'un essai de plein champs pour une période de deux ans (2009-2010) réalisé à la station expérimentale du CNR - Institut pour les Systèmes Agricoles et Forestiers dans la région Méditerranéenne (ISAFoM) dans la plaine du fleuve Volturno, un périmètre irrigué de l'Italie du Sud; un témoin irrigué recevant 100% de l'eau nécessaire pour maintenir à la capacité au champ, la tranche de sol explorée par les racines (0.00 à 0.36 m) et deux traitements avec restitution de 50% et 25% du volume d'eau utilisé pour le traitement témoin, ont été comparées en utilisant de l'eau saline et de l'eau fraiche. Le modèle SALTMED a été calibré en utilisant le rendement, la biomasse totale (y compris les racines) et les données d'humidité du sol du témoin en 2009. Après la calibration, le modèle a été validé en utilisant les mêmes paramètres liés à la culture et au sol. Les résultats ont montré la capacité du modèle à simuler avec une bonne précision les valeurs d'humidité du sol, la biomasse totale et le rendement en grains de quinoa en utilisant différentes stratégies d'irrigation avec l'eau saline et l'eau fraiche.

MOTS CLES: stratégies d'irrigation; quinoa; SALTMED; validation d'un modèle; humidité du sol.

INTRODUCTION

In recent years there has been a growing interest for introducing so-called alternative weather proof, drought and salt tolerant crops in Europe. One such crop is Quinoa (*Chenopodium quinoa* Willd) originating from the South America, where it has been cultivated by local farmers for several millennia (Jensen *et al.,* 2000).

Quinoa is well adapted to grow under unfavorable soil and climatic conditions (Garcia *et al.,* 2003) and the crop is also rapidly gaining interest throughout the world (Jacobsen, 2003) because of its robust character and its high nutritional value (Mujica *et al.,* 2006, Gómez-Caravaca *et al.,* 2012).

The plant is characterized by a high tolerance to the main abiotic stresses such as frost, salinity, and drought, as well as the ability to grow on marginal soils (Maughan *et al*., 2009;

Jacobsen *et al*., 2009, Pulvento *et al*., 2010).

Due to its remarkable adaptability, the cultivation of quinoa could be extended to those areas of the Mediterranean region affected by water scarcity, drought and salinity problems (Jacobsen *et al.*, 2003).

An accurate analysis of crop response to environmental stresses using alternative management practices is fundamental to optimize irrigation scheduling. Crop simulation models can be of great help toward this purpose.

Today's models represent important tools to assess the impact of the water resources management for irrigation purposes and to predict crop adaptation to different environments of different types of agricultural management.

In addition the crop simulation models can predict crop growth and yield as a result of the future climate changes so that they could be considered an important support to the farmer's decisions on how to accomplish sustainable agriculture. (Boote *et al.*, 1996).

As reviewed by Wu and Kersebaum (2008) there are many different root-water-uptake models described in literature that follow two main approaches: microscopic and macroscopic. Examples of microscopic approach are the approach implemented in Daisy model (Abrahamsen and Hansen, 2000) that considers cylindrical flow patterns towards individual roots; and those implemented in DSSAT (Jones *et al.,* 2003) and Ceres-Wheat (Ritchie *et al.,* 1988), based on the 'law of the limiting' approach. The macroscopic scale approach, generally applied in management-oriented holistic models that, consider the entire root system as a whole. In literature several macroscopic models of root water uptake have been described. They can be divided into two types: the first type, implemented in CropSyst (Stockle *et al.,* 2003) describe the root water uptake throughout root resistance and water potential inside and at the soil water interface, and the second approach is based on the reduction of the maximum water uptake (usually ET_0) in response to soil water availability and root depth. Two examples of second type of macroscopic approach, were described by Feddes *et al.,* (1976) and Cardon and Letey (1992) and are being implemented respectively in SWAP (van Dam *et al.,* 1997) and SALTMED (Ragab, 2002).

SALTMED is an integrated, physically based, model that simulates on a daily basis the main processes of the soil-water-plant continuum. This model describes the crop growth and development in generic terms appropriate for several crop species.

The early version of the SALTMED model has been successfully tested against field data of tomato grown in Syria and Egypt for five seasons 2000-2002 in both countries. The results are published in Ragab, (2005a, b). Since then, the model underwent several modification and improvements. The model has recently been applied successfully on sugar cane field experiment in Iran (Golabi *et al*., 2009) and on several field crops in north east of Brazil (Montenegro *et al*., 2010). The SALTMED model has also been tested against field data of tomato and potato from Italy, Crete and Serbia. Sub-surface drip irrigation, Furrow irrigation and sprinkler irrigation were applied as full or deficit irrigation including partial root drying (PRD) system using subsurface twin tubes drip-lines and alternate furrows. More recently, the model was applied on sweet corn, chickpea and Quinoa in Morocco (Hirich, *et al*. 2012), Denmark (Razzaghi *et al*. 2011) and Portugal (Silva *et al*. 2012) in Morocco, Denmark and Portugal. In all those tests, the model was successfully able to simulate, dry matter and final yield, soil moisture and nitrogen profiles.The aim of the work was to calibrate and validate SALTMED model using experimental data collected during a biannual field trial performed to evaluate quinoa tolerance to drought and salinity.

MATERIAL AND METHODS

Field trial

Site description

The field trial was carried out during the two-year period 2009-2010 at the CNR - Institute for Agricultural and Forest Mediterranean Systems (ISAFoM) research station located in the Volturno river plain (14°50' E, 40°07' N; 25 m above sea level), an area of southern Italy characterised by soil secondary salinization due to intrusion of seawater in the groundwater (Pagliuca, 2009).

The experimental site is characterized by a Mediterranean climate with annual average rainfall of 805 mm and annual reference evapotranspiration (ET_0 estimated by Penman–Monteith equation) of about 1160 mm, estimated using a historical data series of the period 1976–2010. The soil of the site has a clay-loam texture along the entire profile. The main physical and chemical properties were determined in situ and in laboratory at the beginning of the trial and are reported in Table I.

Experimental design

A Danish bred cultivar of quinoa, Titicaca, was tested. The experimental design was a completely randomized block with three replicates.

Three irrigation levels were compared: a control treatment with application of 100% of the water necessary to replenish to field capacity (FC) the root zone and two deficit irrigation levels with application of 25% and 50% of the water volume used for the control. For each irrigation level one treatment irrigated with saline (100S, 50S and 25S treatments) and one with fresh water (100, 50 and 25 treatments). For saline treatments water with an electrical conductivity (EC_w) value of about 22 dS m^{-1} was used. The irrigations started when the soil moisture decreased below the 50% of available water (AW) in the root zone. Water was supplied weekly using a surface drip irrigation system with self-compensating drippers (4 L h^{-1}) spaced 0.30 m on the line.

The sowing was performed to a theoretical density of 200,000 plants per hectare in plots of 6 x 6 m with 0.5 m row spacing.

Field data collection

Quinoa Titicaca was sown on 20 May 2009 and on 21 April 2010 and was harvested on 24 August and 29 July in the first and second year, respectively.

The soil water content, (SWC) was weekly determined 24 hours before and after the irrigations by thermo-gravimetric method at different depths (0.00-0.12 and 0.12-0.36) along the soil root zone using a soil auger with a length of 12 cm.

Daily meteorological data (minimum and maximum air temperature, humidity, wind speed and direction, global solar radiation and rainfall) were recorded by an automatic weather station (iMETOS ag) located close to the experimental field; the average annual value of the main meteorological data are reported in Table I.

The main physical and chemical properties were determined in situ and in laboratory at the beginning of the trial and are reported in Table II.

During the crop cycle, some vegetative parameters, such as plant height, stem diameter, maximum root depth and leaf area (LA) were measured biweekly; in addition at harvest grain yield, and total dry matter were determined,. The leaf area during the growth seasons was measured by the D*elta-T Image* Analysis System *Dias II.*

More details about the field experiment are reported by Pulvento *et al*., (2012).

SALTMED model

A detailed description of SALTMED model and the equations to reproduce the key processes of evapotranspiration, water and solute transport, and nitrogen cycle was provided by Ragab (2002, 2010) and Ragab *et al.* (2005 a and b), thus here only a brief overview of the main processes involved in the simulations, such as plant water uptake and biomass production, that distinguish SALTMED from other crop models is presented.

SALTMED calculates the crop daily transpiration as the sum of soil water extraction by the roots at different depths. The soil is divided into compartments (layers) and for each one the model determines the actual and potential water uptake; the daily water uptake at a certain depth *z*, in presence of salt is described by the Cardon and Letey (1992) equation.

To calculate reference evapotranspiration (ET_0) by SALTMED, one option among others (Ragab, 2002) based on FAO Penman–Monteith equation (Allen *et al.*, 1998) was selected.

SALTMED calculates the relative yield as the ratio between simulated total water uptake to the total potential water uptake, but the model also provides a more detailed plant growth routine for biomass calculation, based on the work of Eckersten and Jansson (1991).

The version of SALTMED used (Silva *et al.*, 2012) is able to produce soil moisture at a certain depth as well as for the soil layer (depth range). The latter is very important for the field trials where soil moisture content is measured by thermo-gravimetric and TDR methods where measurements are carried out over a certain depth range/layer.

Model parameterization

The main climatic parameters collected during the trial were quality controlled and organized on daily basis in a suitable excel file, imported into the climatic dialogue of SALTMED model.

Crop-specific input data were estimated on the basis of measurements (LAI, maximum plant height, maximum and minimum root depth, growth stage length).

Finally, the irrigation input values were those applied in the field at different levels (100%, 50% and 25% of full irrigation): during 2009 and 2010, 1295 (four irrigations) and 1286 m^3 ha^{-1} (five irrigations) were supplied to the control treatment respectively.

The soil profile, which has clay-loam properties, was divided into 4 layers of 0.00-0.20 m, 0.20-0.50 m, 0.50-0.65 m and 0.65-0.90 m depth, respectively; this allowed better simulation of soil water dynamics. The soil hydraulic properties for each horizons were obtained from field (parameters inverse method or instantaneous profile method), and from laboratory (tension table and pressure chamber) determinations.

Calibration procedure

SALTMED model was calibrated with data recorded under fully irrigated fresh water treatment (100%) by fine tuning soil and crop parameters to obtain a good agreement between simulated and observed values of yield, total dry matter and soil moisture. For the soil, the parameters subjected to calibration were those mainly related to the up-scaling between lab-scale measured and field-scale applied hydraulic properties (saturated hydraulic conductivity, saturated soil water content, SWC, lambda 'pore size distribution index', bubbling pressure/air entry value). The crop yield and total dry matter were calibrated using a step-wise procedure. The first step was to adjust the crop coefficient (K_c) (Table II), crop transpiration coefficient (K_{cb}), Fraction Cover (Fc) and π_{50} values by a 'trial and error' procedure; the second step was to fine tune the crop growth parameters like photosynthesis efficiency that affect the biomass production.

Validation

The validation was carried out by comparing simulated and observed yield, dry matter and soil moisture data, for both experimental years, of the irrigation treatments (50, 25, 100S, 50S, 25S%) different from 100% used in the calibration. The model performance was evaluated by quantitative (statistical) and qualitative (graphical) methods. In the graphical approach, the measured and simulated values of soil moisture were plotted against time. The response of the model can, therefore, be visually quantified. The statistical approach, involved the use of the goodness of fit test proposed by Loague and Green (1991) to compare observed data with results predicted by the model. The goodness of fit expressions are: the root mean square error (RMSE), coefficient of determination (R^2), and coefficient of residual mass (CRM).

The RMSE values show by how much the simulations under or over-estimate the measurements:

RMSE= (Eq. 1)

where

ys= predicted value

yo= observed value

N= total number of observations

The R^2 statistics demonstrate the ratio between the scatter of simulated values to the average value of measurements:

R^2= (Eq. 2)

where

= averaged observed value

= averaged simulated value

σyo= observed data standard deviation

σys= simulated data standard deviation

The coefficient of residual mass (CRM) is defined by:

CRM= ———— [Eq 3]

The CRM is a measure of the tendency of the model to overestimate or underestimate the measurements. Positive values for CRM indicate that the model underestimates the measurements and negative values for CRM indicate a tendency to overestimate. For a perfect fit between observed and simulated data, values of RMSE, CRM, R^2, should be equal 0.0, 0.0, and 1.0, respectively. All the analyses were made in Excel (Microsoft Inc.)

RESULTS AND DISCUSSION

Calibration

The calibrated crop parameters for quinoa in south Italy are presented in Table III. During the calibration, particular attention was paid to the π_{50} value (no published data were available); it was set to values of 20, 80 and 80 dS m^{-1} respectively for the initial, middle and final development stage. This was due to the fact that during the trial were no significant differences between harvested yields between saline and not saline irrigation treatments.

During the calibration, the simulated SWC for soil layers 0.00-0.12 and 0.12-0.36 m for the 100 treatment was compared with the values measured in 2009. In the validation procedure, SWC of the other irrigated treatments (100% (2010 only), 50%, 25%, 100S%, 50S%, 25S%) in the two years. As shown in Figures 1 and 2, after the model calibration there was a good agreement between simulated and observed soil moisture data for each soil layer. The correlation coefficient of (R^2) reached values of 0.98 and 0.97, respectively for soil layers 0.00-0.12 m, 0.12-0.36 m (Figures 3 and 4). Especially for the top soil layer (0-0.12 m) SALTMED proved its high sensitivity to simulate sudden soil moisture changes due to irrigation and rainfall events. The good results, obtained comparing simulated SWC content versus observed SWC are in agreement with those reported by Silva *et al.* (2012) and Hirich *et al.* (2012) who calibrated

SALTMED model using SWC data at certain depths, detected using soil moisture probe(TDR and AquaCheck). In the calibration phase, the simulated yield and total dry matter values were equals to the measured ones (Tables III and IV).

3.1 Validation

After the calibration, the model was able to simulate soil moisture of each irrigation treatment applied in both years of simulation; a good agreement between simulated and observed soil moisture data is shown in Figures 5 and 6 for the different simulated treatments in 2009-2010. Figure 7 shows the linear relationship between observed and simulated soil moisture content (SMC) for the root soil layer (0.00-0.36 m) for all irrigation treatments and for the two years of experimentation. The observed versus simulated SMC data showed a good correlation with R^2 of 0.84, and a slope of 0.87 that confirmed the ability of the version of SALTMED utilized to simulate SWC for a layer/range of soil after an adequate parameterization and calibration.

During validation the average observed data of total dry matter and yield were compared with those simulated for each treatment used, though the differences observed in field were not significantly different among treatments. SALTMED showed good performances in the simulation of yield and total dry matter; Even though there were differences between times of simulations due to the fact that quinoa during 2010 was sown earlier (one month) than 2009, the differences between observed and simulated yield and dry matter were in general lower than 5.4%; only for the 50S there was a difference of 7.67% The relation between observed and simulated final yield during 2009-2010 produced R^2 of 0.95 (Figure 8), RMSE of 0.19 (Table IV) and CRM value of -0.02.

For the total dry matter the statistical indices were satisfactory during the biannual field trial with R^2 of 0.96 (Figure 9), RMSE of 0.35 (Table V) and CRM value of -0.01.

The results obtained for total dry matter are in agreement with Hirich *et al.* (2012) who predicted dry matter of quinoa grown in south Morocco with SALTMED model obtaining a R^2 of 0.98. Similarly, Silva *et al.* (2012) reported R 2 of 0.99 simulating yield and biomass of chickpea in Portugal under wet and dry year conditions.

Results from SALTMED model are also comparable to yield (0.82 R^2) and dry matter(0.87 R^2) simulations made on seven different quinoa varieties grown in the Bolivian Altipiano (Geerts et al 2009) using AquaCrop model;

CONCLUSIONS

In the current study, SALTMED model was calibrated and validated for soil moisture, yield and total dry matter of quinoa under saline and fresh water conditions using different irrigation strategies. SALTMED proved its ability to predict yield, total dry matter and soil moisture during two years of experimentation. The limited numbers of inputs required during the calibration and validation highlighted that SALTMED is a holistic model that simulates with good accuracy the cultivation of quinoa in south Italy. The model is a potential tool for optimal management of water resources to ensure high production in the Mediterranean environment and could be used to study the crop system adaptation to the future climate changes.

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Table I. Average growing season (sowing-harvest) meteorological data at experimental station of Vitulazio . PM-ET0 is the reference evapotranspiration calculated using P

Year	Ait temp	Solar radiation	Wind speed	Total PM-Eto	Total precipitation
	°C	*W* m^{-2}	*m* s^{-1}	*mm*	*mm*
2009	24.3	284	1.73	543	192
2010	21.1	257	1.50	443	209
1976-2010	21.2	NA	NA	634	155

Table II. Main physical and chemical characteristics of the soil of the experimental area.

	Physical			
Soil layer (*cm*)	**0-20**	**20-50**	**50-65**	**65-90**
Texture	Clay-loam	Clay-loam	Clay-loam	Clay-loam
Clay (*%*)	38.9	38.9	34.6	34.6
Silt (*%*)	38.5	38.5	32.6	32.6
Sand (*%*)	22.6	22.6	32.8	32.8
Field capacity	31.2	40.5	40.0	40.0
Wilting point	15.6	22.0	31.1	27.0
Bulk density (*t* m^{-3})	1.3	1.3	1.4	1.3
	Chemical			
ECe (*dS* m^{-1})	0.8	0.8	1.0	1.0
pH	8.0	8.0	8.0	8.0
CEC (*meq* $100g^{-1}$)	39.1	39.1	30.5	30.5
Mg^{2+} (*meq* $100g^{-1}$)	1.4	1.4	0.8	0.8
Na^{+} (*meq* $100g^{-1}$)	0.03	0.03	0.06	0.06
Ca^{2+} (*meq* $100g^{-1}$)	40.2	40.2	34.3	34.3
K^{+} (*meq* $100g^{-1}$)	0.64	0.64	0.31	0.31
Total $CaCO_3$ (%)	1.60	1.60	1.90	1.90
Organic matter(*%*)	1.70	0.68	0.35	0.35

Table III. Main calibrated and observed input parameter used in the study for quinoa Titicaca.

Symbol	Parameter	Dev. Stage	Observed	Calibrated
	Cultivation dates			
	Sowing (day)		20 May	
	Emergence (day after sowing)		3	
	Harvest (day after sowing)		96	
	Growth Stages			
	Initial (days)		14	
	Development (days)		22	
	Midle (days)		38	
	Late (days)		22	
	Crop inputs			
K_c	Crop coefficient	Initial		0.7
		Middle		1.15
		End		0.4
K_{cb}	Traspiration corp coefficient	Initial		0.15
		Middle		1
		End		0.2
Fc	Fraction cover	Initial	0.4	
		Middle	0.6	
		End	0.6	
h	Plant height (m)	Initial	0.35	
		Middle	0.8	
		End	1	
LAI	Leaf Area Index	Initial	0.4	
		Middle	0.2	
		End	0.3	
$\pi50$	Osmotic pressure at witch crop growth is reduced by 50%	Initial		20
		Middle		80
		End		80
	Minimum root depth (m)		0	
	Maximum root depth (m)		0.55	
	Unstressed crop yield (t ha^{-1})		3.1	

Table IV. Comparison of the observed and measured total dry matter in the validation.

Year	Irrigation Treatments	Observed dry matter	Simulated dry matter	Difference
		t ha^{-1}	*t ha^{-1}*	%
2009	25	6.10	6.17	-1.13
2009	50	8.10	7.70	5.19
2009	100	8.20	8.20	0.00
2009	25S	6.00	6.20	-3.23
2009	50S	7.10	7.69	-7.67
2009	100S	8.30	8.30	0.00
2010	25	4.68	4.68	0.01
2010	50	5.67	5.70	-0.57
2010	100	5.53	5.70	-2.98
2010	25S	6.50	6.49	0.17
2010	50S	6.38	6.70	-4.78
2010	100S	6.11	6.36	-3.95
RMSE		78.67	79.89	0.35
CRM				-0.01

Table V. Comparison of the observed and measured yield in the validation.

Year	Irrigation Treatments	Observed Yield	Simulated Yield	Difference
		t ha^{-1}	*t ha^{-1}*	%
2009	25	2.50	2.53	-1.19
2009	50	2.90	2.78	4.32
2009	100	3.10	3.10	0.00
2009	25S	2.40	2.48	-3.23
2009	50S	2.40	2.60	-7.69
2009	100S	3.00	3.00	0.00
2010	25	1.96	1.96	0.13
2010	50	2.10	2.22	-5.41
2010	100	2.33	2.40	-2.81
2010	25S	2.26	2.26	0.00
2010	50S	2.58	2.70	-4.37
2010	100S	2.36	2.46	-3.90
RMSE		29.90	30.49	0.17
CRM				-0.02

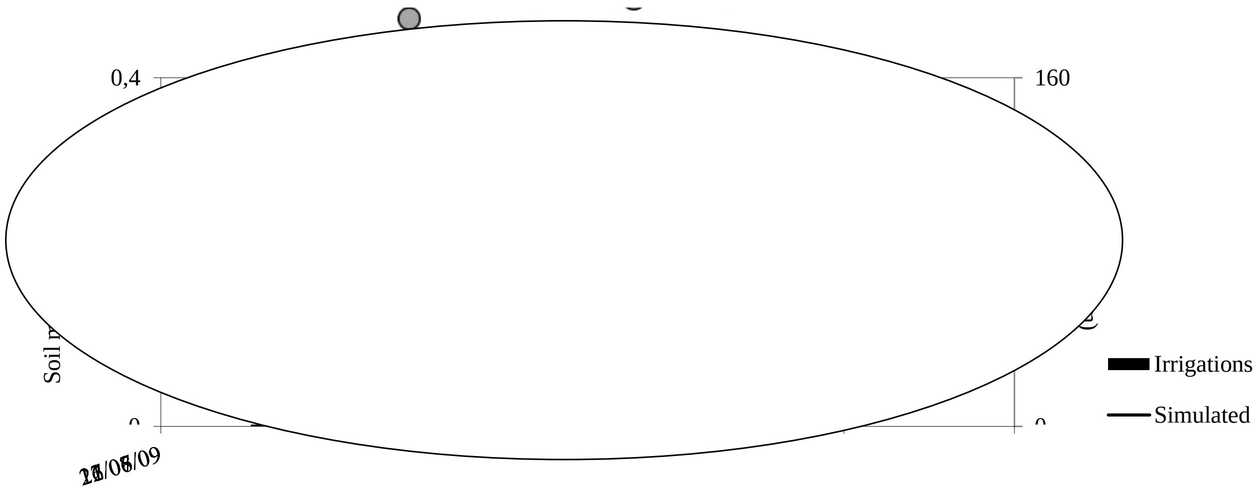

Figure 1. Observed (dots) versus simulated (line) soil moisture content in the 0.00-0.12 m soil layer for 100 treatment during 2009, modelled with SALTMED after calibration. Irrigations and rainfalls occurred are reported as histogram.

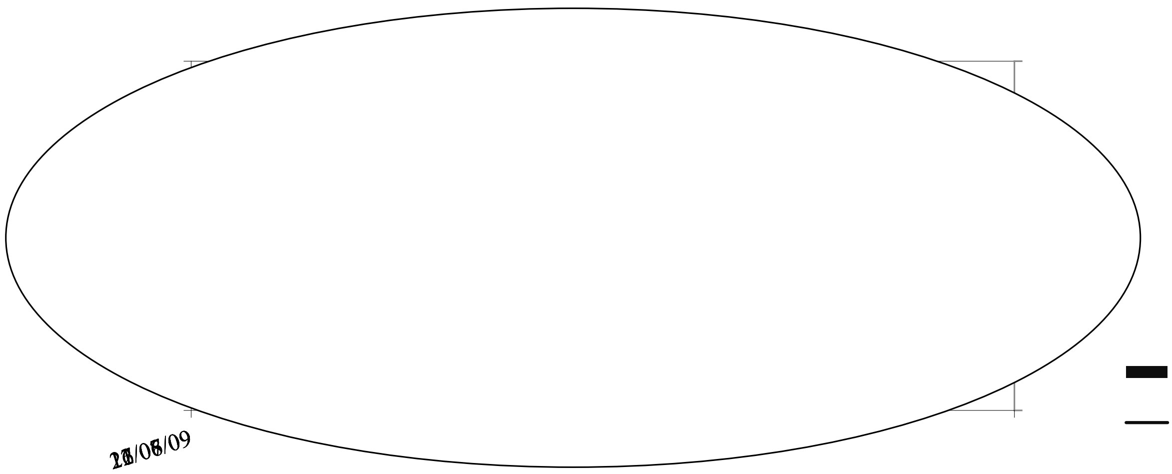

Figure 2. Observed (dots) versus simulated (line) soil moisture content in the 0.12-0.36 m soil layer for 100 treatment during 2009, modelled with SALTMED after calibration. Irrigations and rainfalls occurred are reported as histogram.

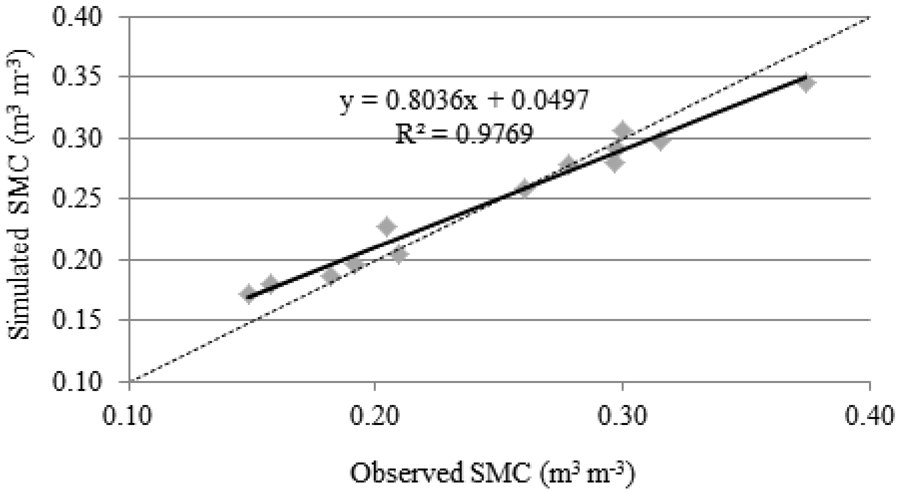

Figure 3. Relation between simulated and observed soil moisture content (SMC) in the 0.00-0.12 m soil layer for 100% treatment during 2009, modelled with SALTMED during the calibration. The dotted line represents the 1:1 line.

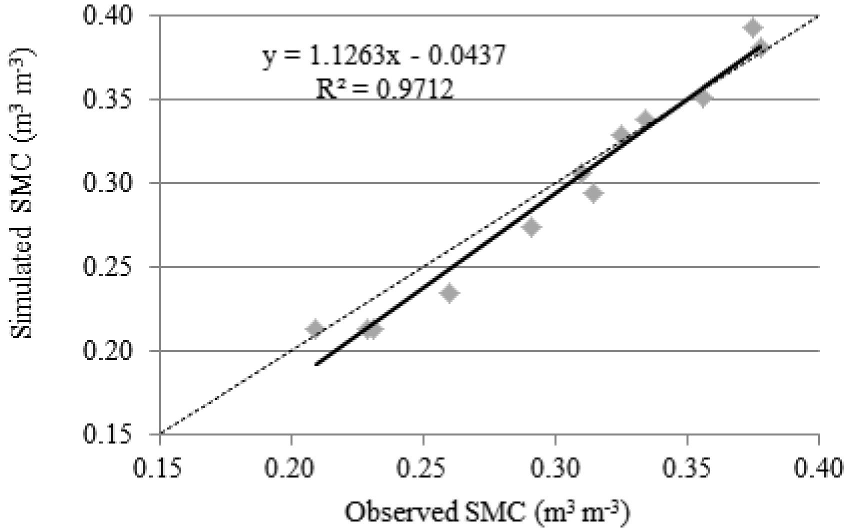

Figure 4. Relation between simulated and observed soil moisture content (SMC) in the 0.12-0.36 m soil layer for 100% treatment during 2009, modelled with SALTMED during the calibration. The dotted line represents the 1:1 line.

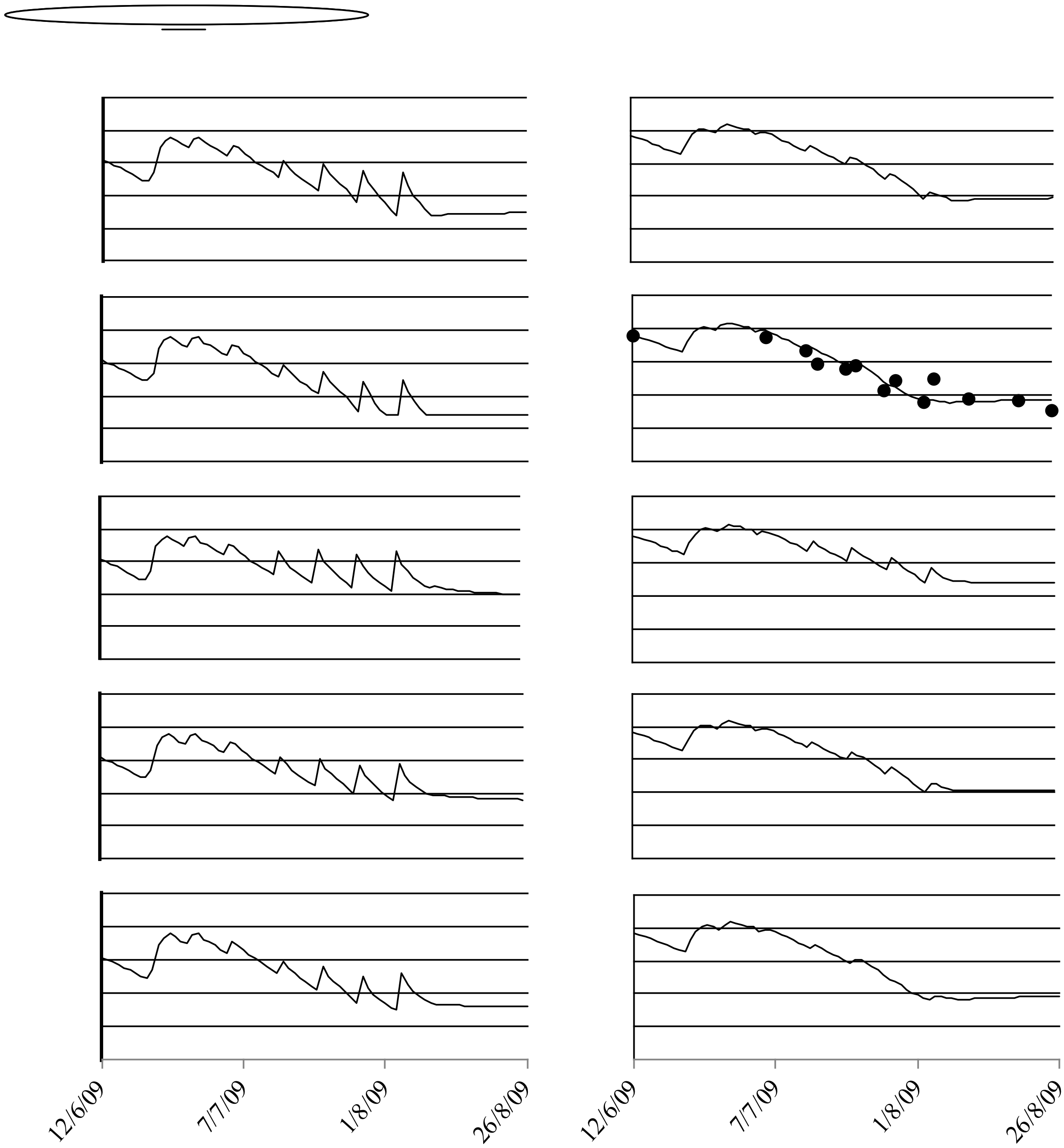

Figure 5 Observed (dots) versus simulated (line) soil moisture content in the 0.00-0.12 and 0.12-0.36 m soil layers for 50 (a, b), 25 (c, d) 100s (e, f) 50S (g, h) 25S (i, l) treatments during 2009, modeled with SALTMED during validation.

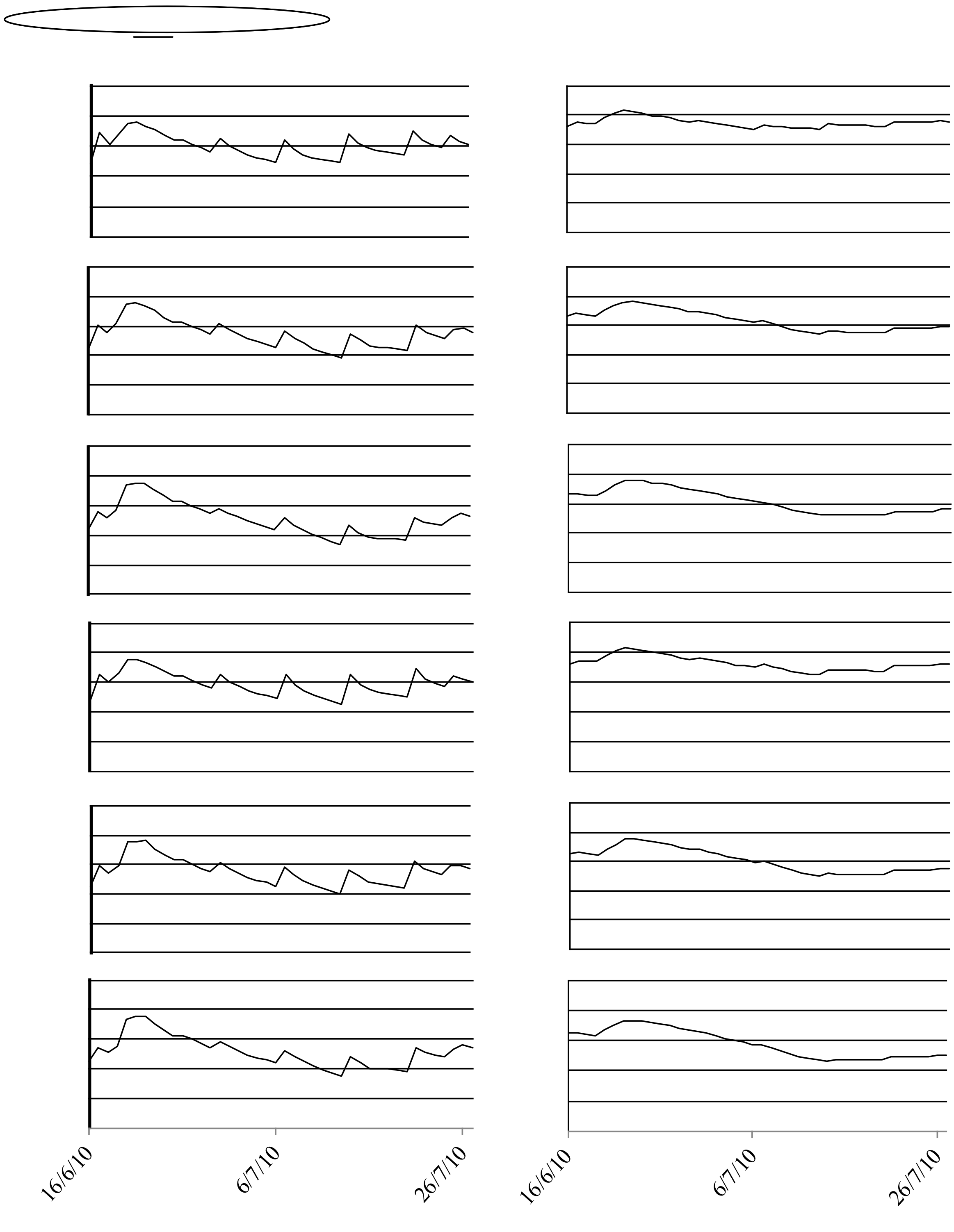

Figure 6. Observed (dots) versus simulated (line) soil moisture content in the 0.00-0.12 and 0.12-0.36 m soil layers for 100 (a, b), 50 (c, d) 25 (e, f) 100S (g, h) 50S (i, l), 25S (m, n) treatments during 2010, modelled with SALTMED during validation.

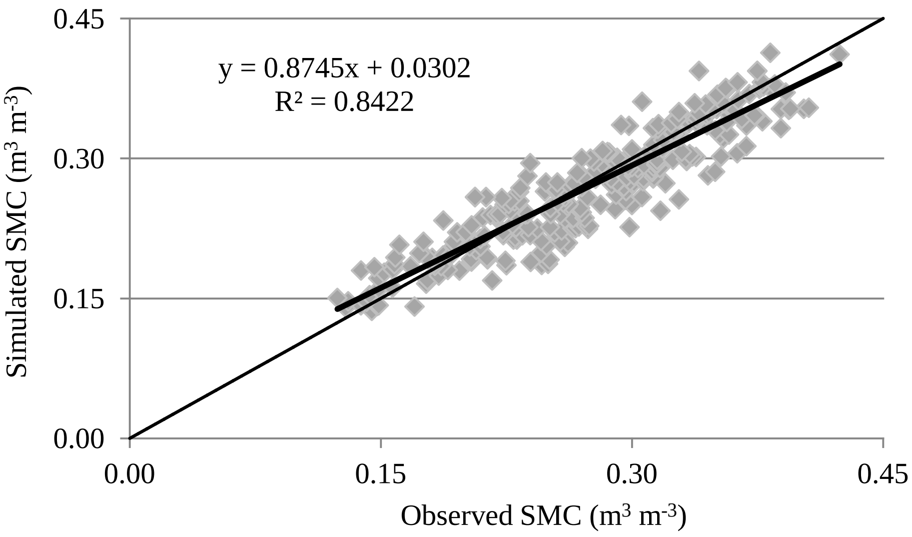

Figure 7. Relation between simulated and observed soil moisture content (SMC) in the 0.00-0.36 m soil layer of 50, 25, 100S, 50S, 25S treatments during 2009 and 100, 50, 25, 100S, 50S, 25S treatments during 2010, modelled with SALTMED during its validation. The dotted line represents the 1:1 line.

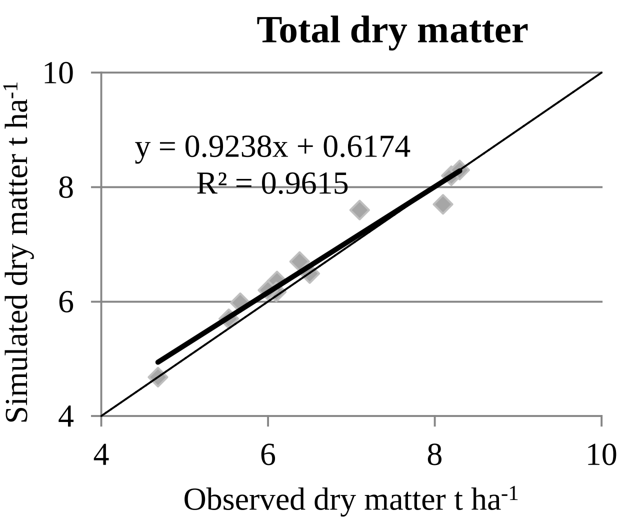

Figure 8. Relation between simulated and observed total dry matter during 2009-2010. The dotted line represents the 1:1 line.

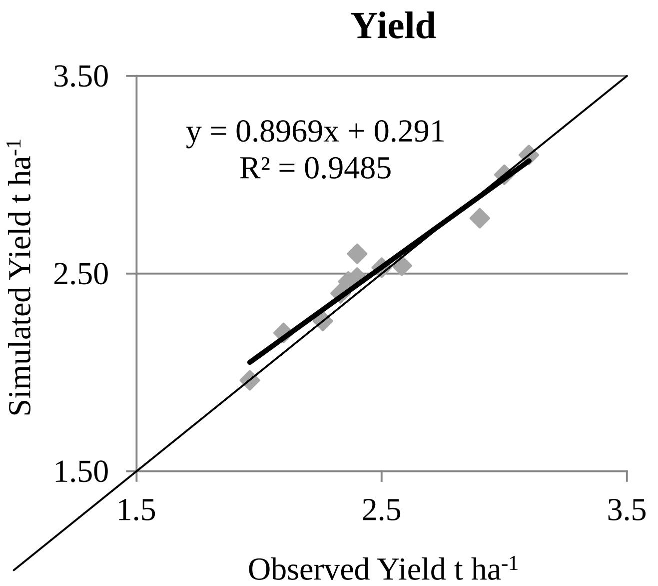

Figure 9. Relation between simulated and observed yield during 2009-2010. The dotted line represents the 1:1 line.