Strategic Water Management for Improved Tomato Yield and Quality in Greenhouse Environments with Different Water Quality

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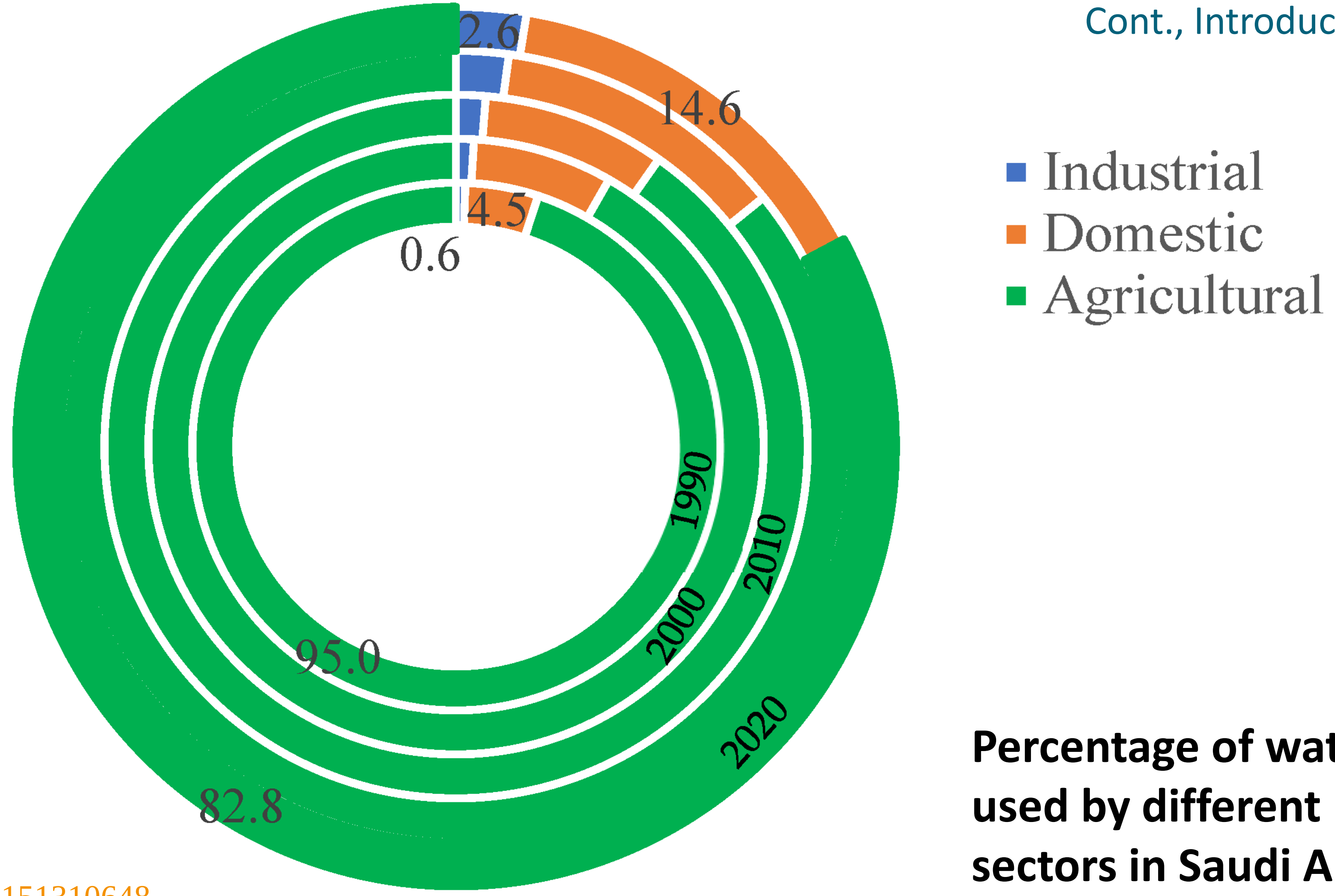
Overview

- Introduction
- Objectives
- Methodology
- Results
- Conclusion and Recommendations



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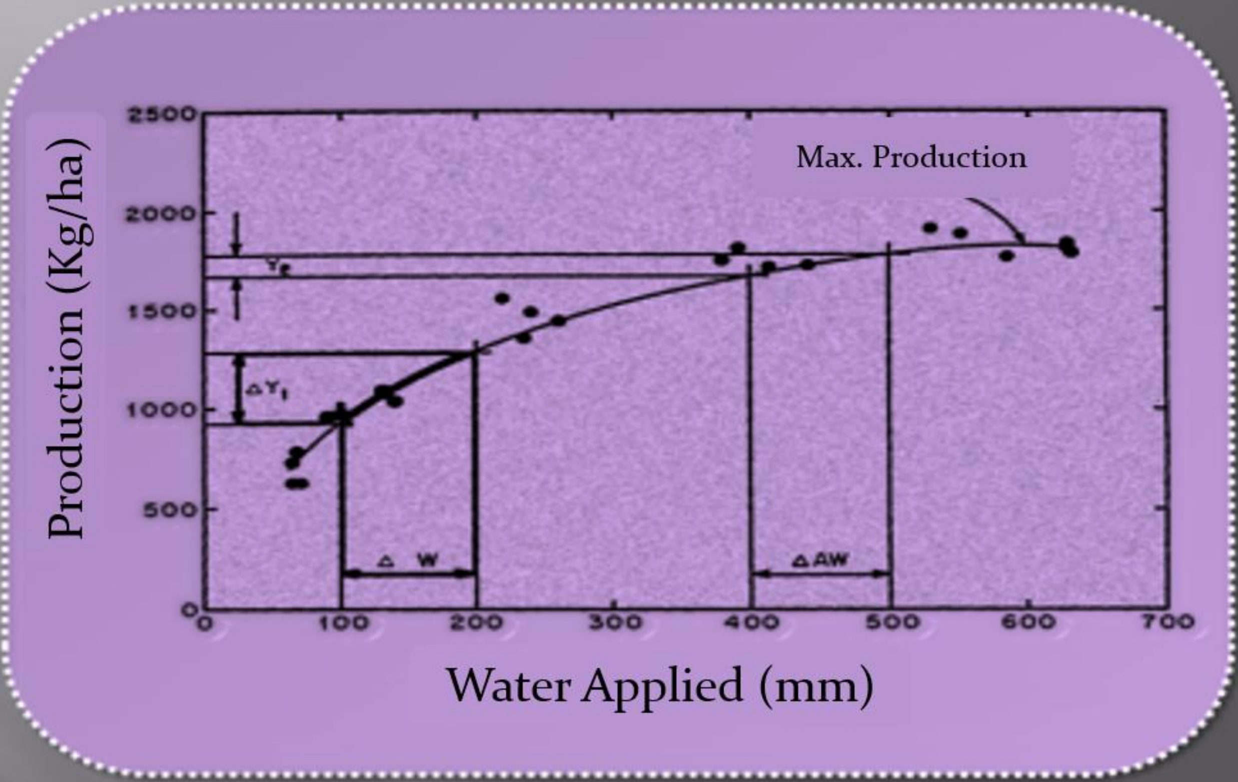
Percentage of water used by different sectors in Saudi Arabia (1990 to 2020)

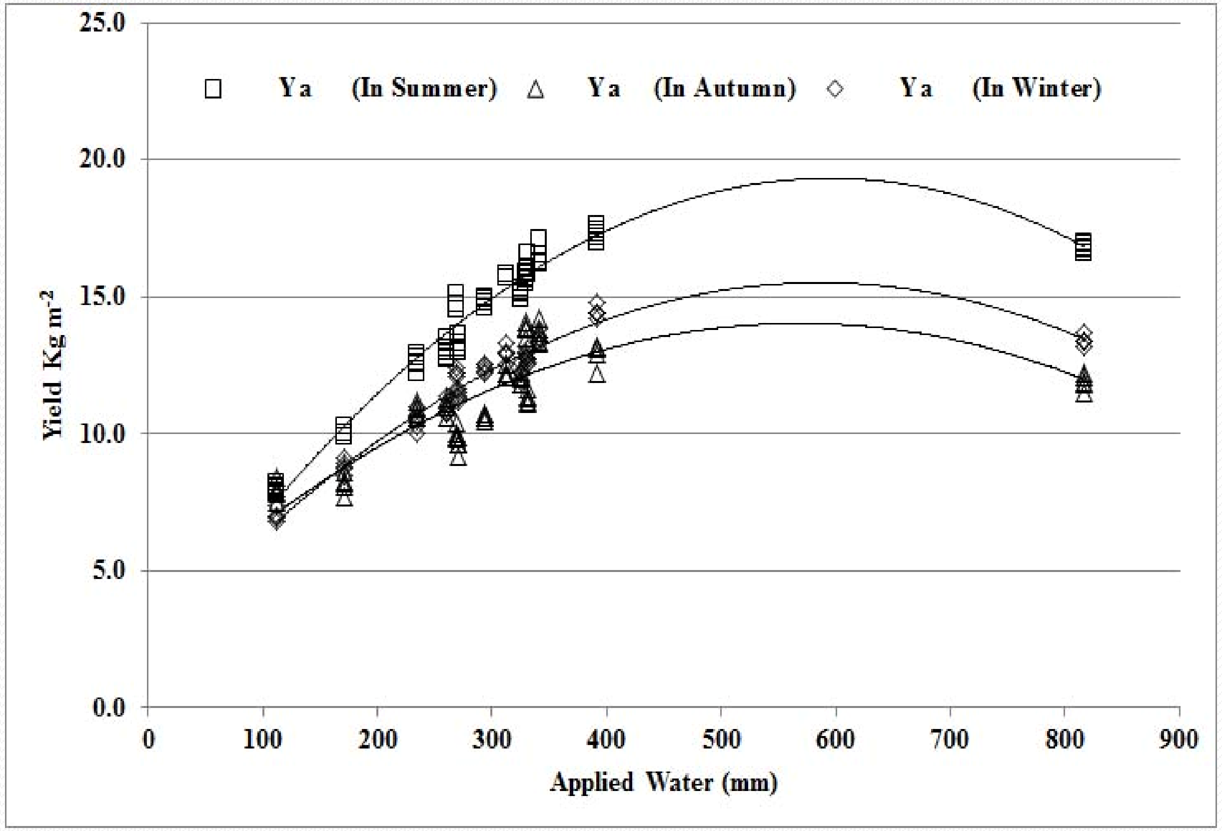
Deficit Irrigation:

Deficit irrigation or PRD practices differ from traditional water supply. It reduces irrigation during the whole season or stage of growth without a significant reduction in crop.

Crop water Production Function as the Basis for Deficit Irrigation



Water Production Function: implement any Irrigation Conservation program:
Water production function



Advantages of deficit irrigation application

- Deficit irrigation facilitates the optimization of water utilization, thereby conserving this essential resource for future generations.
- Reducing water consumption results in decreased irrigation expenditures, thereby conferring economic benefits to agricultural practitioners.
- The deliberate imposition of stress through deficit irrigation techniques has the potential to augment specific desirable attributes in crops, such as the concentration of flavor compounds in fruits.
- Plants subjected to deficit irrigation undergo adaptations that enable them to utilize water more efficiently, thereby maximizing crop yield relative to the volume of water consumed.
- Imposing limitations on water availability can mitigate the proliferation of certain plant pathogens that thrive in moist environments, consequently diminishing the necessity for chemical interventions.

Table: Irrigation treatment combination of each experiment.

Treatment	Initial St.[1]	Develop. St.	Mid. St.	Late. St.	Description
T_1-100	1[2]	1	1	1	Full irrigation during the season (100% of ET_m).
T_2-80-0	1	1	1	1	80% of ET_m irrigation during the season has been given.
T_3-80-1	0[3]	1	1	1	A full irrigation up to the end of 1st stage, then 80% of ET_m for the other stages.
T_4-80-2	1	0	1	1	A full irrigation at the development stage, then 80% of ET_m restoration for the other stages.
T_5-80-3	1	1	0	1	A full irrigation at the mid stage, then 80% of ET_m restoration for the other stages.
T_6-80-4	1	1	1	0	A full irrigation at the late stage, then 80% of ET_m restoration for the other stages.
T_7-60-0	1	1	1	1	60% of ET_m irrigation during the season.
T_8-60-1	0	1	1	1	A full irrigation up to the end of the 1st stage, then 60% of ET_m for the other stages.
T_9-60-2	1	0	1	1	A full irrigation at the development stage, then 60% of ET_m restoration for the remaining stages.
T_{10}-60-3	1	1	0	1	A full irrigation at the mid stage, then 60% of ET_m restoration for the other stages.
T_{11}-60-4	1	1	1	0	A full irrigation at the late stage, then 60% of ET_m restoration for the other stages.
T_{12}-40	1	1	1	1	40% of ET_m irrigation during the season has been given.
T_{13}-Trad.	1	1	1	1	The traditional drip irrigation in greenhouse. The farmer does not depend at scientific methods to calculate the amount of applied water and adds more than the required water (more than ET_m).

1= Growth stage

2= The growth stage took same amount of applied water as mentioned on the treatment

3= The growth stage took a 100% level of ET_m

Field testing of droppers during planting

Site # 2 a Open field Experiment

Objectives

The main objectives of the study were as follows:

- a comparison of the effects of fresh, saline, and mixed water on tomato growth, physiology, and yield.
- a comparison of full and deficit irrigation on tomato growth, physiology, and yield.
- an evaluation of the tomato growth stage in which deficit irrigation is not too harmful to the growth, physiology, and yield of tomato production.

Methodology

Physical characteristics of the soil										
Soil depth (cm)	ρ_b (g cm^{3-})	$CaCO_3$ (%)	Organic matter (%)	(%) Mechanical analysis				θ_S %	θF_C %	θW_P %
				sand	silt	clay	Soil texture			
0-25	1.57	15.8	0.4	88.8	5.0	6.8	Loamy sand	24.4	17.5	8.7
25-50	1.56	23.0	1.1	78.2	12.5	9.3	Sandy loam	26.0	19	11
50-70	1.50	18.25	1.0	79.8	8.95	11.3	Sandy loam	29.0	19.4	10.5

Chemical analysis										
Soil depth (cm)	pH	ECe (dS.m^{-1})	Cations (meq l^{-1})				Anions (meq l^{-1})			SAR
			Na^+	K^+	Ca^{++}	Mg^{++}	HCO_3^-	Cl^-	SO_4^{--}	
0-25	7.39	4.01	8.17	2.26	18.4	14	3.0	12.0	25.83	2.03
25-50	7.71	3.64	10.04	1.33	19.2	10.9	4.1	14.5	21.07	2.59
50-70	7.32	3.87	14.17	1.31	13.6	9.9	4.0	24.0	11.08	4.14

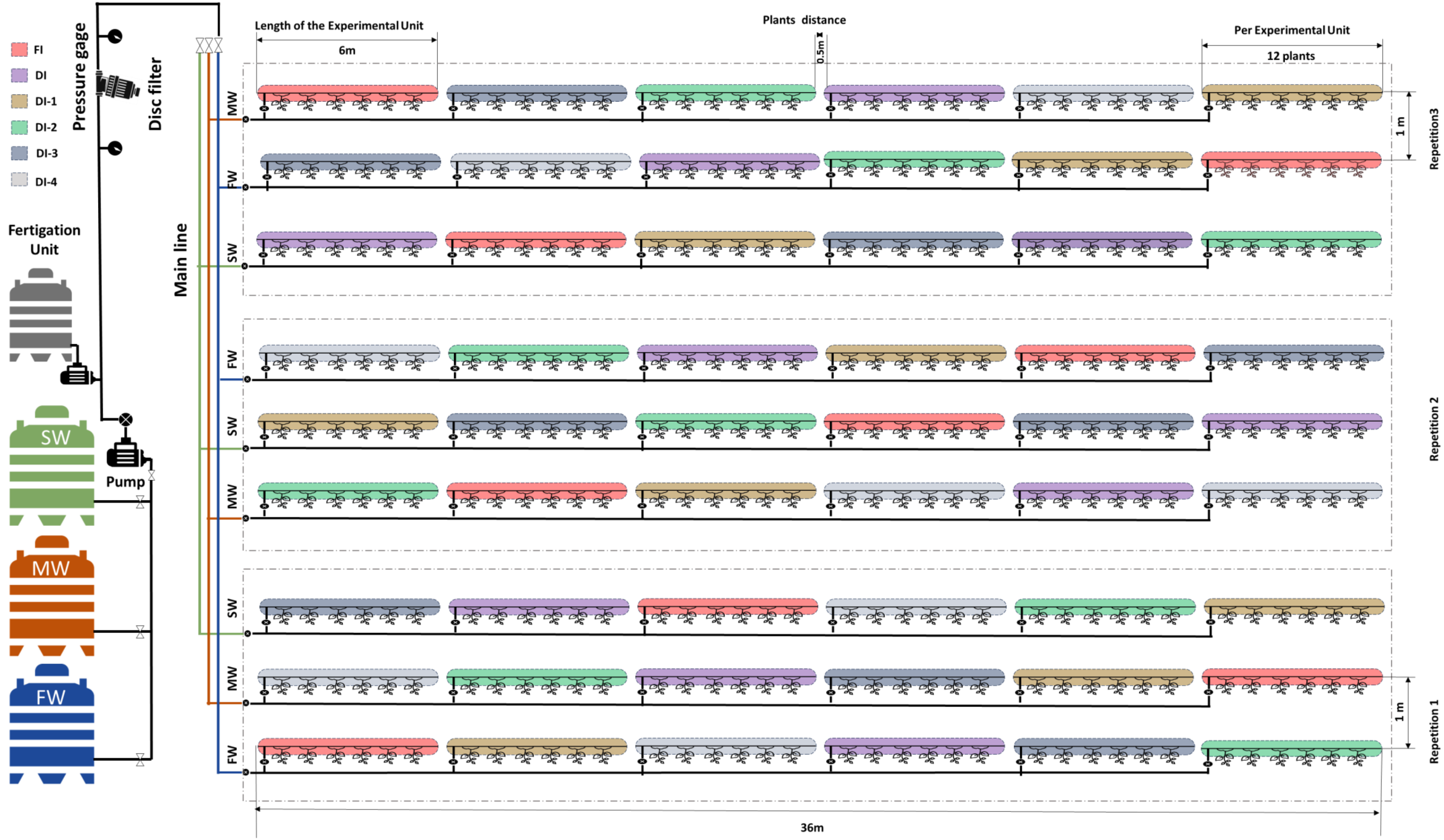
Water sample	pH	ECe (dS.m^{-1})	Cations (meq l^{-1})				Anions (meq l^{-1})			SAR
			Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	
Freshwater (FW)	7.20	0.92	5.70	0.12	3.69	2.5	0	2.10	7.21	3.24
Mixed water (MW)	7.36	2.27	18.63	0.21	3.25	2.35	0	2.48	19.25	11.6
Saline water (SW)	7.52	3.62	31.56	0.29	2.80	2.20	0	2.86	31.29	19.96

Bulk density (ρ_b), field capacity (θF_C), wilting point (θW_P), saturated moisture content (θ_s), soil electrical conductivity (ECe), organic matter (OM), acidity or basicity of water solution (pH), and sodium adsorption ratio (SAR). Fresh-Water (FW), Mixture-water (MW), Saline-Water (SW), water electrical conductivity (ECe).

Treatment / Irrigation quality	Description	Conductivity (dS.m-1)
FW	Fresh water (FW)	0.9
SW	Saline water (SW)	3.6
MW	1:1 mixture of fresh and saline water (MW)	2.25

Irrigation amount	Initial	Development	Mid-season Stage	Late-season	(mm)	% ET_c
*FI			Full irrigation with 100% ET_c (FI)		744.64	100
**DI			60% ET_c at all stages		446.79	60.0
DI-1	FI		60% ET_c		472.19	63.4
DI-2	60% ET_c	FI	60% ET_c		488.17	65.6
DI-3	60% ET_c		FI	60% ET_c	617.13	82.9
DI-4			60% ET_c	FI	507.51	68.2

*** Gray color refers to full irrigation; ** white color refers to 60% ETc deficit irrigation.**



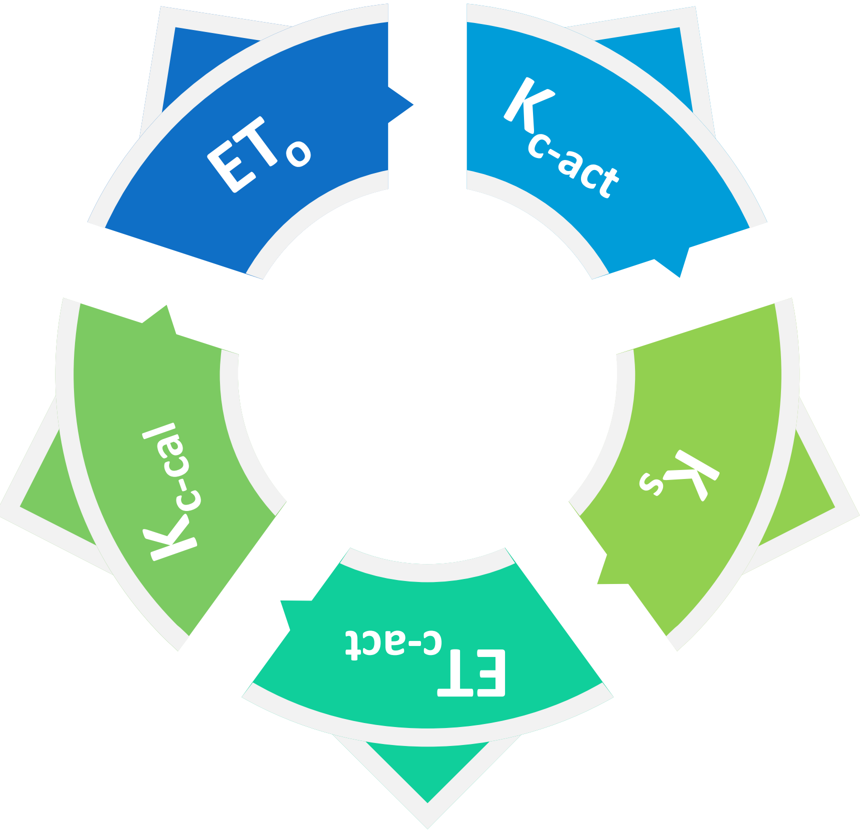
The experiment layout and the randomization of treatment conditions for salinity and combining deficit and full irrigation during tomato growth stages.

Reference Evapotranspiration

FAO Pan methodologies ($ET_{o\text{-}pan}$)

Adjusted Crop Coefficient

	Ini. sta.	Dev. Sta.	Mid-sea.	Late-sea.	Tot. days
$K_{c\text{-}tab}$	0.15	0.15-1.15	1.15	0.8	
$K_{c\text{-}cal}$	0.6	0.92	1.22	1.04	
Current observation	30	40	154	25	249



Actual Crop Coefficient

$$K_{c-act} = \frac{ET_c}{ET_o} = \frac{ET_{c-act(FI-FW)}}{ET_{o-pan}}$$

Water stress coefficient

$$K_s = \frac{ET_{c-act}}{ET_c} = \frac{ET_o K_c K_s}{ET_o K_c} = \frac{ET_{c-act}}{ET_{c-act(FI-FW)}}$$

Actual crop evapotranspiration

$$ET_{c-act} = P + I + U - R - D \pm \Delta W$$

devices and equipment used for the different measurements

Total Yield and Water Productivity

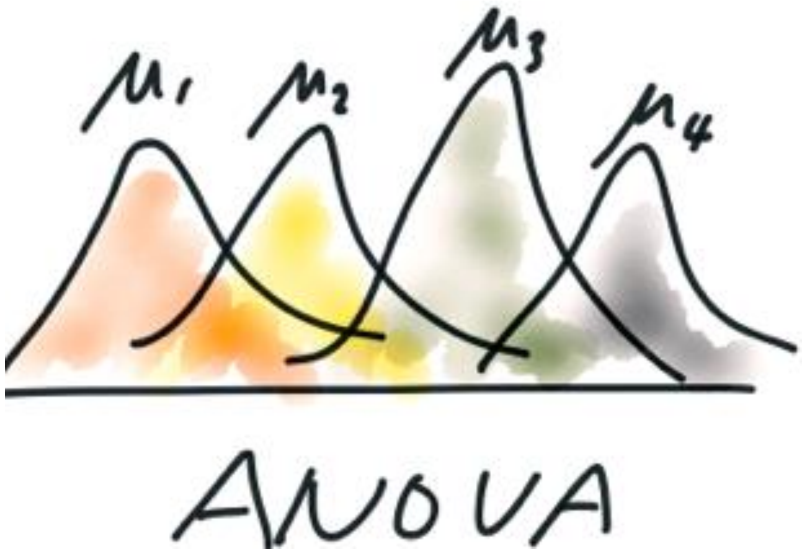
$$WP = \frac{Y}{W}$$

$$YR\ (\%) = \frac{Y_c - Y}{Y_c} \times 100$$

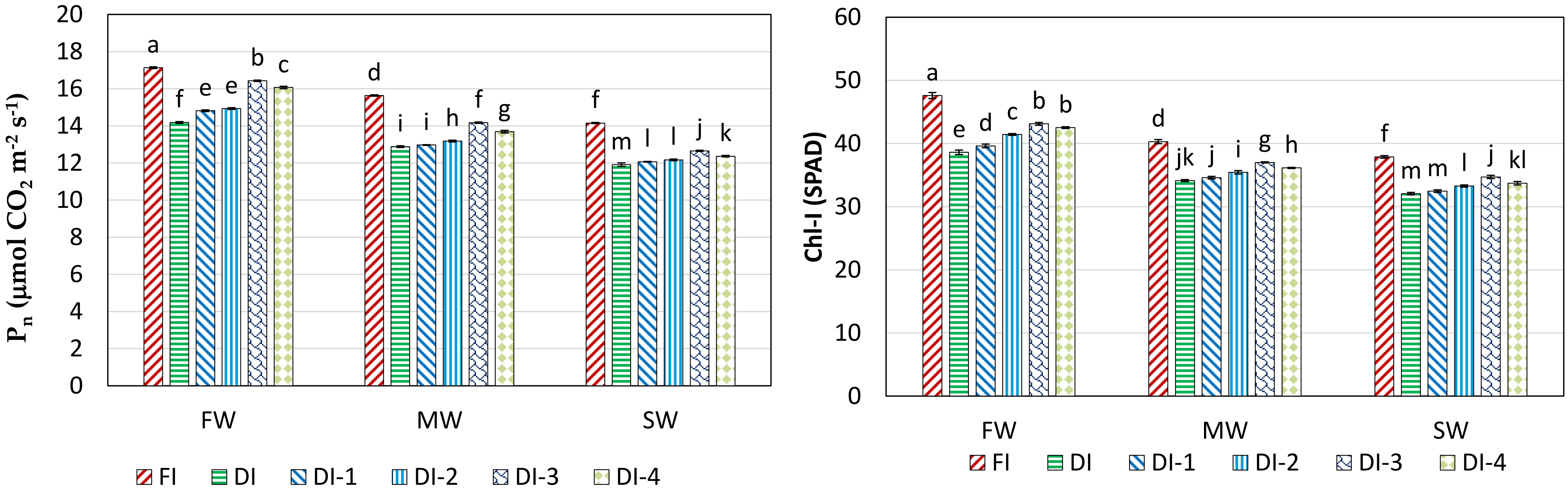
$$IWP\ (\%) = \frac{WP - WP_c}{WP_c} \times 100$$

where (WP) is water productivity, (Y) is total fresh tomato yields, (W) is the amount of applied water, (YR) is the yield reduction, (Y_c) is yield of a control treatment , (IWP) is the improve water productivity, (WP) is water productivity,and (WP_c) is water productivity of a control treatment.

Statistical Analysis of Water Productivity and Tomato Crop Responses

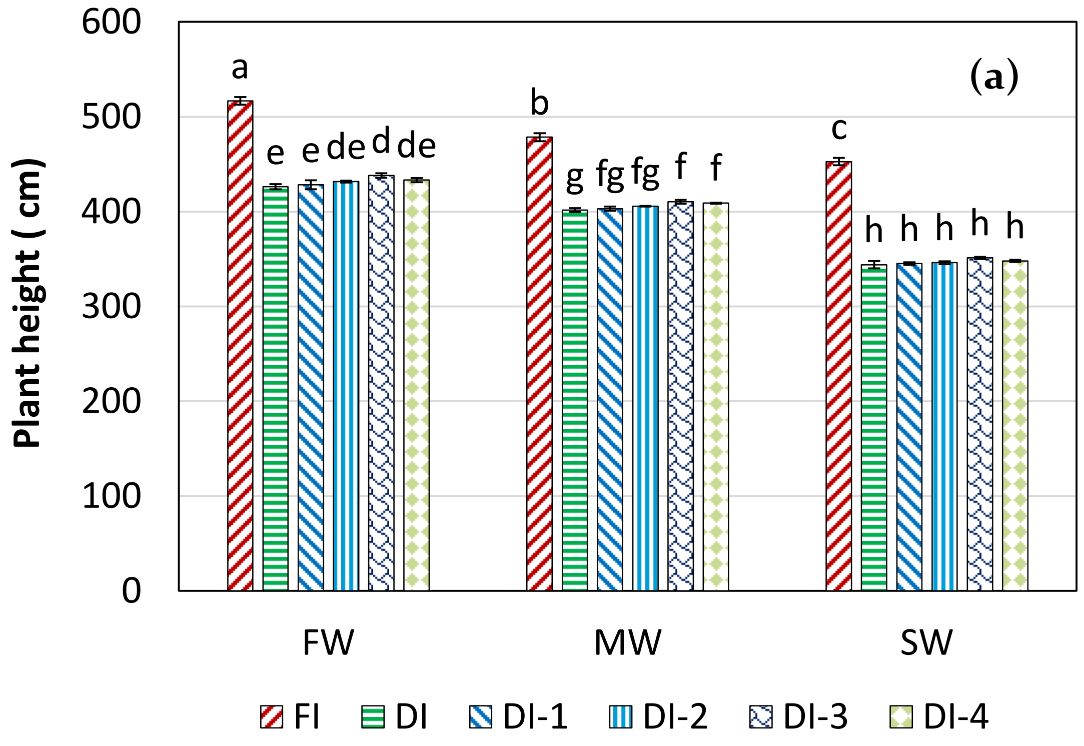


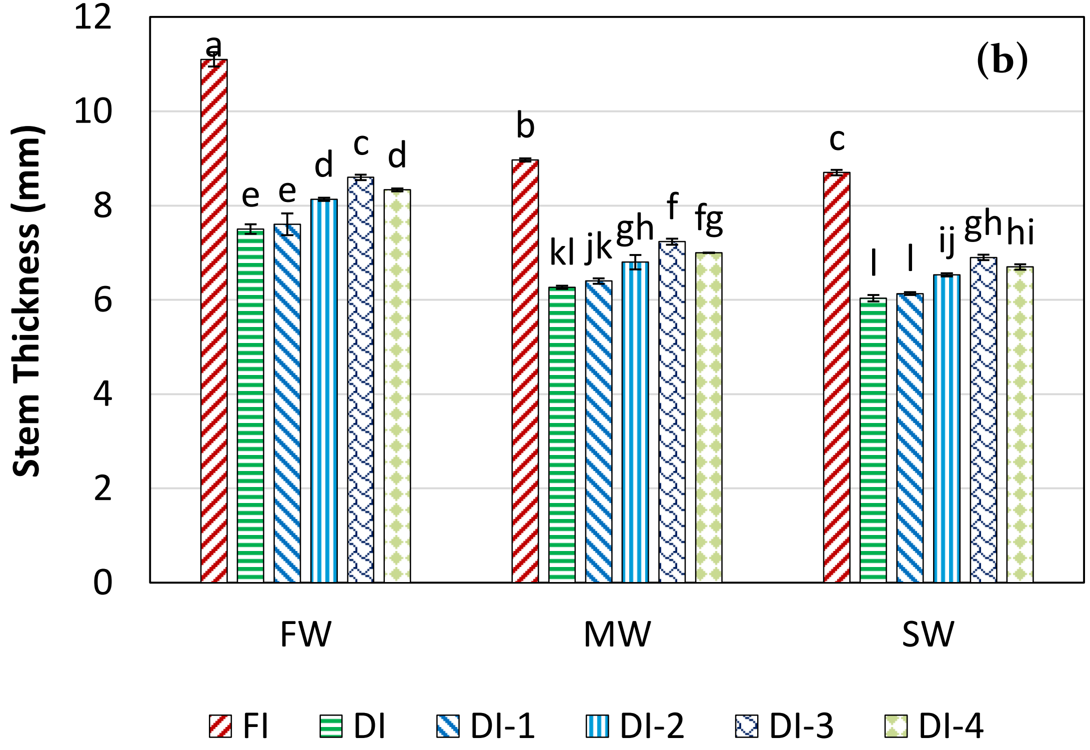
Physiological Responses of Tomato to Water Quality and Irrigation Levels



Interaction effects between water quality and irrigation water levels on (a) photosynthesis (Pn), and (b) chlorophyll index, for FW (Fresh-Water); MW (Mixed-Water); SW (Salinity-Water); full irrigation (FI), irrigation set at 60% ET_c (DI) level for all stages (DI), $ET_{c\text{-}100\%}$ in a single stage and irrigation at 60% ET_c in the remaining stages (DI-1, DI-2, DI-3, and DI-4) and distinct letters in the figure indicate significant differences within treatments.

Tomato Morphological Responses to Water Quality and Irrigation Levels





Interaction effects between water quality and irrigation water levels on (a) plant length and (b) stem diameter for FW (Fresh-Water); MW (Mixed-Water); SW (Salinity-Water); full irrigation (FI), irrigation set at 60% ET_c (DI) level for all stages (DI), $ET_{c\text{-}100\%}$ in a single stage and irrigation at 60% ET_c in the remaining stages (DI-1, DI-2, DI-3, and DI-4) and distinct letters in the figure indicate significant differences within treatments.

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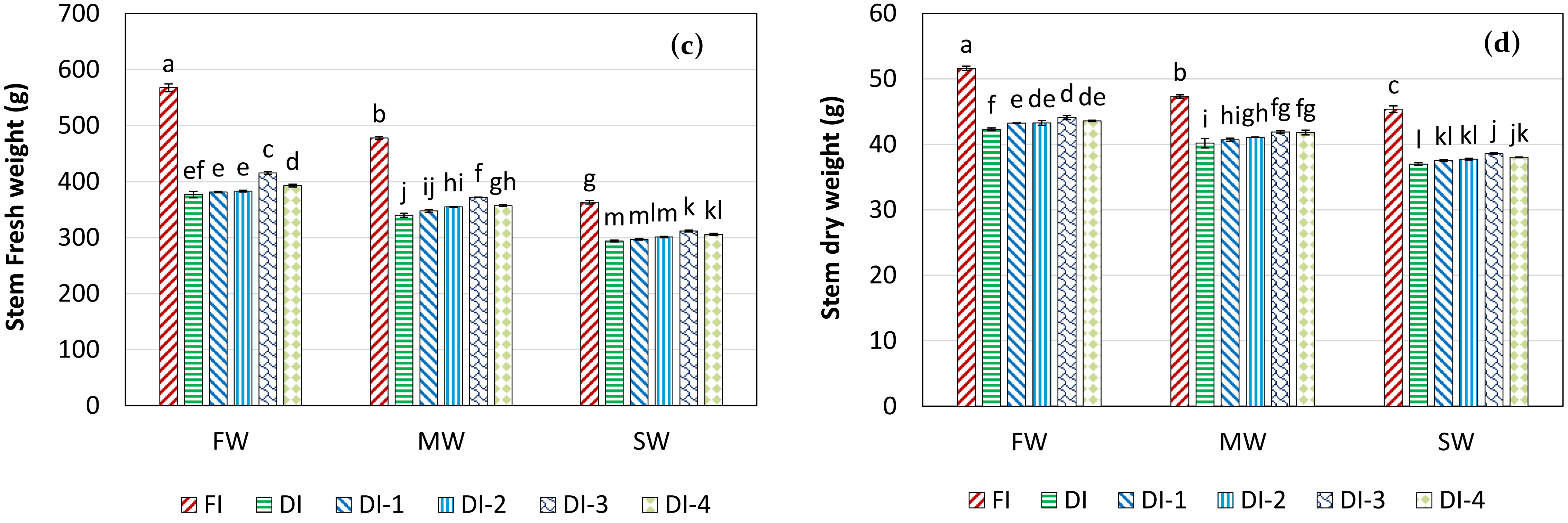

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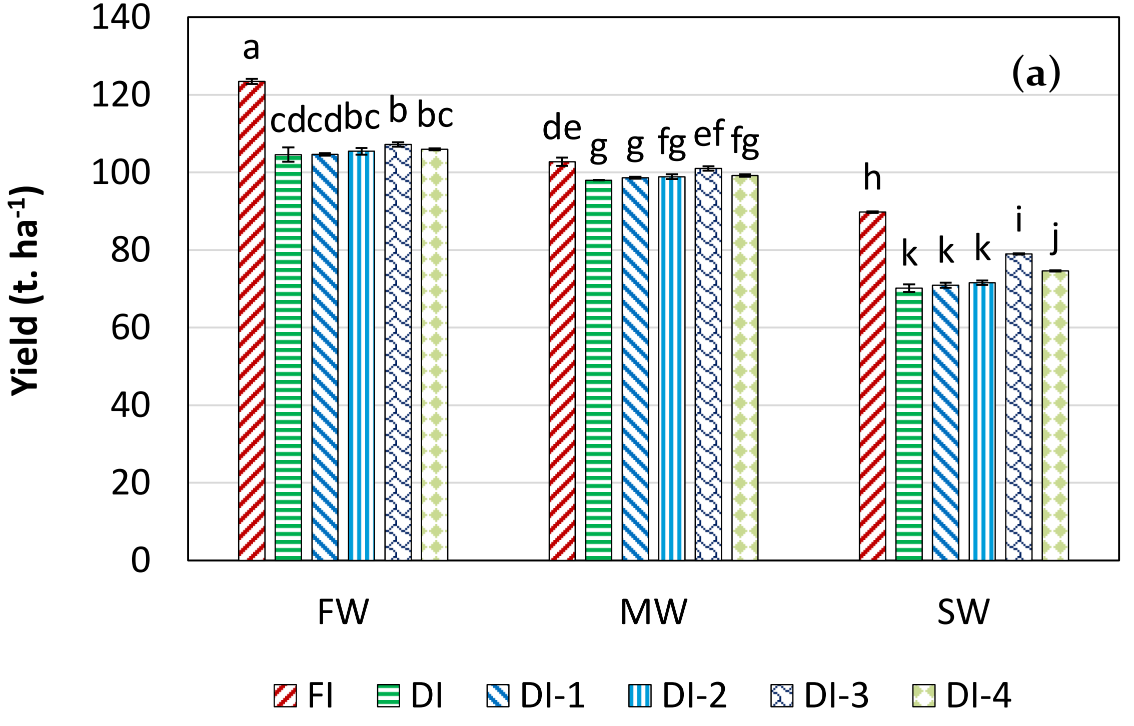
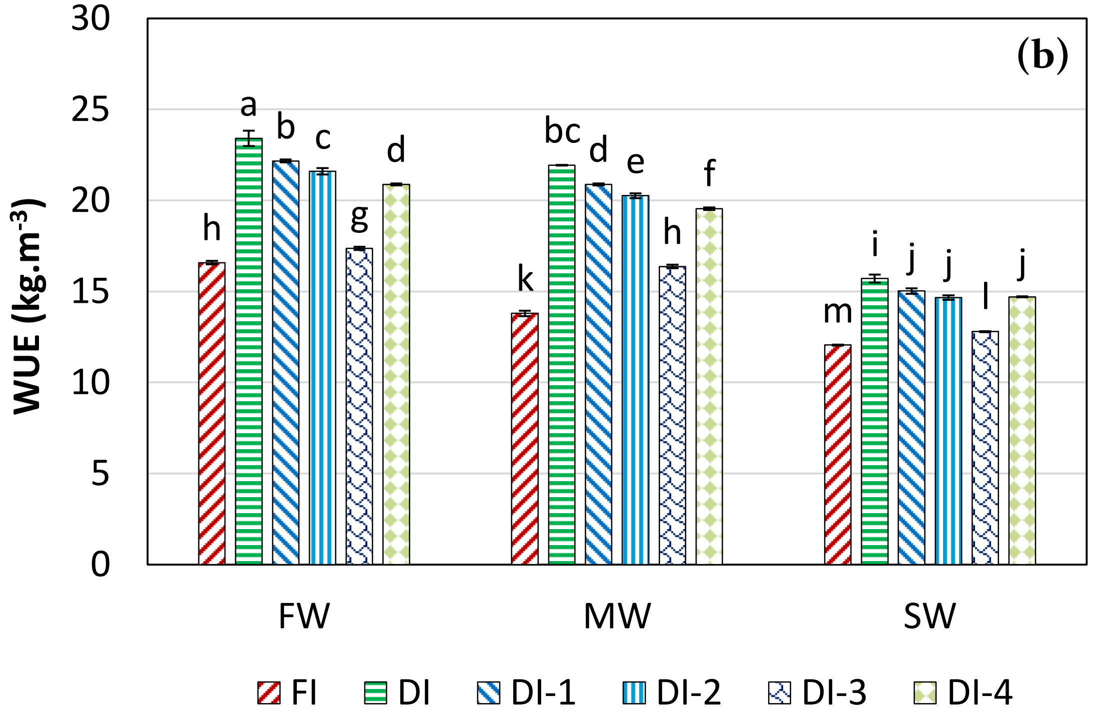
Irrigation quality	Y ($t\ ha^{-1}$)	WP ($kg\ m^{-3}$)	YR (%)	IWP(%)
FW	108.55 a	20.33 a	0.00	0.00
MW	99.75 b	18.8 b	8.11	-7.53
SW	76.02 c	14.16 c	29.97	-30.35
p-value	0.00	0.00	--	--
LSD	0.644	0.140	--	--
Variance:	0.485	0.023	--	--
Irrigation amount				
FI	105.34 a	14.15 f	0.00	0.00
DI	90.92 d	20.35 a	13.69	43.8
DI-1	91.4 d	19.36 b	13.23	36.8
DI-2	91.98 d	18.84 c	12.68	33.1
DI-3	95.73 b	15.51 e	9.12	9.6
DI-4	93.27 c	18.38 d	11.46	29.9
p-value	0.00	0.00	--	--
LSD	1.270	0.253	--	--
Variance:	1.739	0.069	--	--
Interaction of irrigation quality and amount				
p-value	0.00	0.00	--	--
LSD	2.199	0.438	--	--
Variance:	1.739	0.069	--	--

Impact of Combined Deficit and Full Irrigation on Yield and Water Management with Variable Water Quality in Tomato Growth Stages

The LSD test: values that share the same letter are not considered significantly different at the 0.05 probability level.

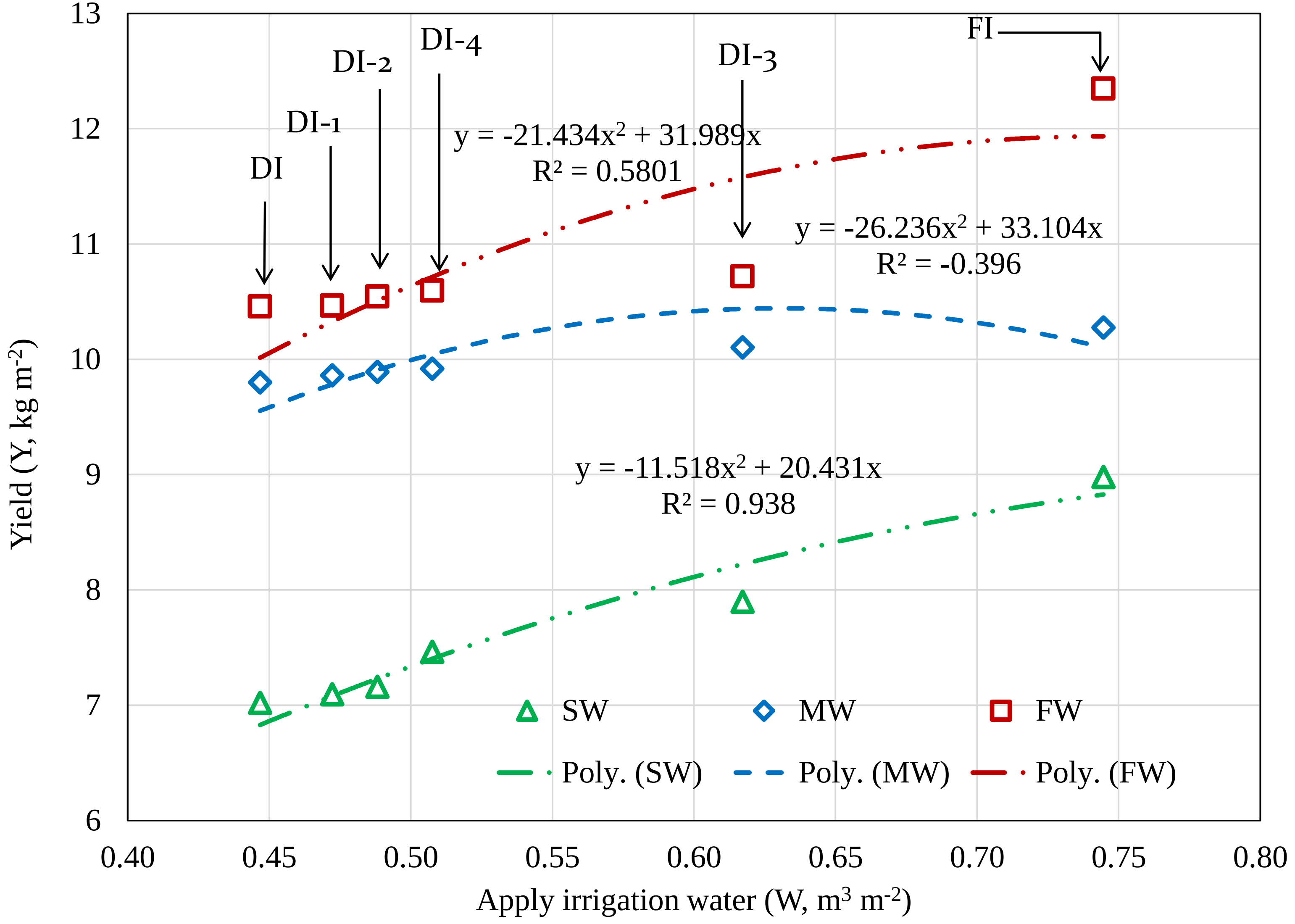
Impact of Salinity and Regulated Deficit Irrigation on Yield and Water Management during the Growth Stage





Water quality and irrigation water level interactions on (a) total fruit production (t ha^{-1}) and (b) water productivity (WP), for FW (Fresh-Water); MW (Mixed-Water); SW (Salinity-Water); full irrigation (FI), irrigation set at 60% ET_c (DI) level for all stages (DI), $ET_{c\text{-}100\%}$ in a single stage and irrigation at 60% ET_c in the remaining stages (DI-1, DI-2, DI-3, and DI-4) and distinct letters in the figure indicate significant differences within treatments

Impact of Combined Deficit and Full Irrigation on Yield and Water Management with Variable Water Quality in Tomato Growth Stages



The relationships between crop yield and applied water under different water quality: FW (Fresh-Water), MW (Mixed-Water), and SW (Salinity-Water). The data is the mean value ± standard error

Conclusion and Recommendations

- Saline water application can decrease growth, yield, and fruit quality of greenhouse tomato crops.
- Salinity and insufficient irrigation negatively impact photosynthetic rate, chlorophyll index, stomatal conductance, and transpiration, leading to reductions in morphological parameters such as plant height, stem weight, stem thickness, and leaf area.
- A mixed irrigation strategy involving both saline and freshwater (salinity of 2.25 $dS.m^{-1}$) is effective in achieving higher yields and improved tomato quality.
- Deficit irrigation at 60% of the crop evapotranspiration (ET_c) results in reduced ecophysiological and morphological parameters but increases water use efficiency by 44%.

- Full irrigation at the mid-season or late-season stage with a deficit of 60% ET_c for remaining growth stages slightly improves ecophysiological and morphological parameters and yields but significantly decreases water use efficiency.
- Regulated deficit irrigation at all stages outperforms other irrigation methods in terms of water use efficiency and crop performance, especially in water-scarce regions.
- Strategic implementation of a mixed water strategy (freshwater + saline water) with regulated deficit irrigation is recommended to reduce freshwater usage without significantly affecting greenhouse tomato crop growth, physiology, or yield.
- When freshwater is scarce, using saline water with a salinity of 2.25 $dS.m^{-1}$ along with 60% ET_c regulated deficit irrigation can produce acceptable yields while conserving water resources.


THANK YOU
FOR
Listening