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Validation of SALTMED Model under Different Water Regimes and N Fertilizer Rates for Snap Bean

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Abstract: This study aims to validate SALTMED model under the experimental treatments to prove that it is a useful tool for the decision makers in the farm. A field experiment in Egyptian delta (clay loam soil) on snap bean (*Phaseolus vulgaris*) for two successive growing seasons. The statistical design of the field experiment comprised three water regimes and three N fertilizer rates under drip irrigation system to test the validity of SALTMED model (version 2011), which has been developed for generic applications. The model employs solute transport, Evapotranspiration and crop water uptake equations. The results indicated that the model provided acceptable predictions of salt and water distributions in the soil profile under the drippers by using fertigation technique. Correlation between the observed and simulated data of salt and water distributions in the soil profiles were strong or showed good agreements (higher than 0.8 for all experimental treatments). The highest significant values of snap bean yield 14.9 and 15.2 ton/fed. were obtained by using 150 kg N/fed. followed by 112.5 kg N/fed. (100% and 75% of the suggested N amount from the Agricultural and Land Reclamation Ministry), under the irrigation of 100% Etc water regime (1542 m3/fed.), in the second season.

Keywords: Validation, SALTMED, Drip Irrigation, N Fertilizer rates, Water regimes, Simulation Model.

Introduction

Drip irrigation have been considered to be one of the most important obligatory irrigation systems, which has to be applied in newly reclaimed desert areas as well as old Delta soils, to irrigate vegetable and fruit crops. It was found that surface drip and subsurface drip irrigation increased vegetable and fruit crop production and saved water which is usually lost by deep percolation and run-off when using the traditional methods of irrigation [1]. Recently, there is a trend to use drip irrigation method more and more for saving much irrigation water especially for using under the old Delta conditions (clay soil) instead the traditional surface irrigation system, which could be used to reclaim and cultivate more desert land areas or to avoid the shortage of water resources in Egypt. Water is a very limited resource and most of Egypt’s water uses are within the agriculture sector that consumes about 84% [2]. The demand for irrigation water will continue to increase in the next decade and beyond which implies that the agriculture sector will have to adjust to a smaller amount of available water than before. Therefore, improving the efficiency of irrigation water practices is critical. This action could be made by using of simulation models which help the farmers to make their decision for the suitable and economical practices in the field.

The surface drip and/or subsurface drip systems exhibited the highest values of vegetative growth (plant height, No. branches, No. leaves, No. pods, leaves area and dry weight of stem, leaves, pods and total plant); pods yield (kg/fed.) and WUE followed by gated pipes meanwhile furrow irrigation recorded the lowest values in the same concern for snap bean. Increasing irrigation treatment up to 100% ETo exhibited the highest values of vegetative growth. However, the highest values of pods yield/fed and WUE were achieved by 80% Eto treatment [3].

Ragab *et al.* (2001) indicated that there is a shortage in models of a generic nature models that can be used for a variety of irrigation systems, soil types, soil stratifications, crops and trees, water management strategies; i.e. blending (apply mixed saline and fresh water with different ratios) or cyclic (apply fresh and saline water), leaching requirements and water quality. They developed SALTMED model for such generic applications. The model employs established water and solute transport, evapotranspiration and crop water uptake equations. The model has been run with five examples of applications for one growing season using data from the literature. The model successfully illustrated the effect of the irrigation system, the soil type, irrigation and irrigation salinity level on soil moisture and salinity distribution, leaching requirements, and crop yield. The model successfully predicted the impact of salinity on yield, water uptake, and soil moisture and salinity distribution with reasonable degree of accuracy. The model provides the academics with a research tool and field managers with a powerful tool to manage their water, crop and soil in effective way to save water and protect the environment. They also indicated that the careful management of irrigation water is the key to success; proper crop selection taking into consideration rainfall and climate, leaching to control soil salinity, drainage, and amendment applications, if necessary to control sodicity [4]. On the other hand, they emphasized the fact that, it was not their intention to study the impact of nutrients on yield and in fact none of the experiments focused on impacts of increased levels of plant nutrients on yields. Consequently, the ''added nutrient'' impact needs to be further assessed. Moreover, the effect of nutrient load on yield goes beyond the SALTMED model capability. Future development of the SALTMED model could take into account the impact of both salinity of irrigation water and nutrients (e.g. fertigation) on yield [5].

Validation is the process of determining that the system actually fulfills the purpose for which it was intended in such a way that it answers the question "is it the right system?", "is the knowledge base correct?" or :is the program doing the job it was intended to do?" [6]. For the same purpose, Models adequately calibrated for semi-arid conditions and for typical crops are useful tools for analysis of on-farm strategies to improve water use efficiency [7].

This work aimed to validate the SALTMED model under the impact of nutrients (fertigation) on the yield of snap bean.

Materials and Methods

To validate the SALTMED model, observed data was undertaken at delta, Egypt) to represent the old alluvial soil of the Nile Delta. Snap bean crop under drip irrigation system was selected during two successive growing seasons. Soil and irrigation water analysis were conducted according to standard procedures and represented in Tables (1, 2 and 3) [8].

The field was plowed with a chisel plow to 30 cm depth, three passes and leveled with the conventional technique. The experimental area was divided into three main plots (11 m x 25 m) with 2 m free between plots. Each plot was divided into three subplots (3 m x 25 m) with 1 m spacing between subplots. Snap bean crop was sown on the 11^{th} of March, and harvested on the 10th of June, on both growing seasons. The distance between hills was 20 cm apart in each row, on one side cultivation. Crop coefficient (kc) for snap bean crop was used to calculate the Etc values according to FAO (1998) [9]. The irrigation process was applied every three days and the fertilization processes under surface drip irrigation system (GR 4 l/h, with 40 cm between drippers) as well as the other cultural practices were applied according to the recommendations of the Egyptian Ministry of Agriculture, except for adding of N fertilizer.

The experimental design was split plot with three replications. The studied experimental treatments were three water regimes (100%, 75% and 50% of the Etc or 1542, 1156.5 and 771 m3/fed./season, respectively), which were assigned in the main plots, and three N fertilizer amounts (100%, 75% and 50% of the recommended N fertilizer amount or 150, 112.5 and 75 kg N/fed., respectively), which were distributed in the sub main plots. The green pods yield as an average of the two growing seasons (ton/ha) was measured to compare it with that obtained from the model run under the same field practices of irrigation water and N fertilizer (fertigation process).

Table (1): Some soil physical properties at the experimental site.

Sample depth, cm	Particle Size Distribution, %				θ_w (w/w)			B.D. (g/cm^3)	Texture class
	Coarse Sand	Fine Sand	Silt	Clay	F.C.	W.P.	A.W.		
0-15	5.2	9.20	27.3	58.3	34.84	19.59	15.25	1.19	C.L
15-30	2.1	9.2	28.2	60.5	34.57	19.87	14.70	1.12	C.L
30-45	3.0	2.05	28.85	66.10	33.6	19.0	14.6	1.08	C.L

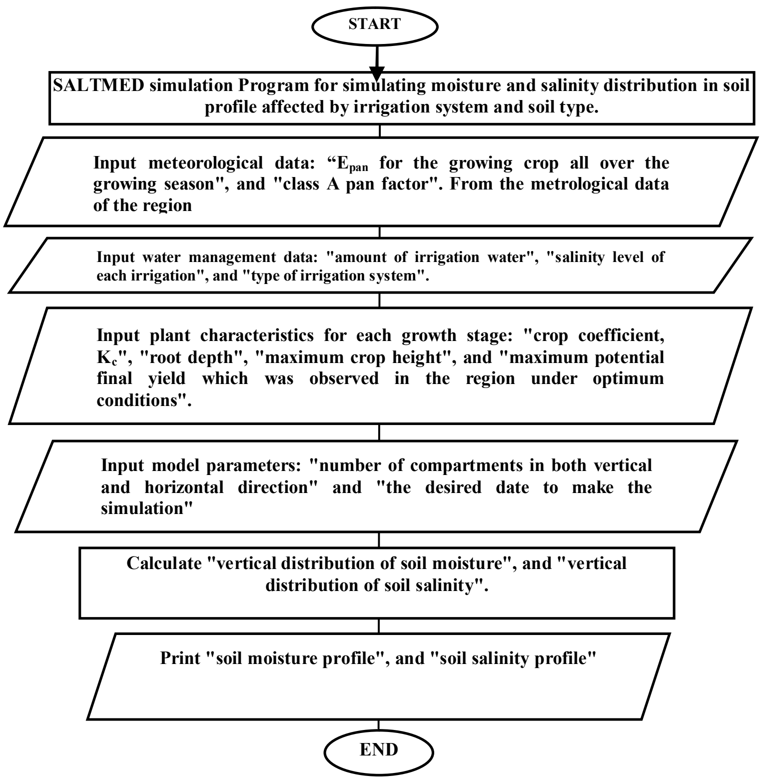
F. C : Field capacity **W. P** : Welting point **A.W** : Available water
B.D : Bulk density **C. L** : Clay loam

Table (2) : Some chemical properties of soil profile at the experimental site.

Sample depth, cm	pH 1:2.5	Ec dS/m	Soluble Cations, meq/L				Soluble Anions, meq/L			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	CL^{-}
0-15	7.7	0..2	0.40	0.48	0.41	0.19	0	0.63	0.36	0.49
15-30	7.6	0.20	0.46	0.35	0.51	0.18	0	0.76	0.23	0.51
30-45	7.4	0.20	0.57	0.55	0.62	0.20	0	0.79	0.40	0.75
45-60	7.2	0.21	0.48	0.66	0.67	0.16	0	0.86	0.45	0.66

Table (3): Some chemical data of the irrigation water.

pH	EC dS/m	Soluble Cations, meq/L				Soluble Anions, meq/L			SAR
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{--}	Cl^{-}	
7.1	0.83	1.72	0.85	4.78	0.85	2.18	0.14	5.88	4.22



Flowchart 1. Flow chart components of SALTMED simulation model program for simulating moisture and salinity distributions in soil profile affected by irrigation system and soil type.

Validation of SALTMED model was done during the last growing season of snap bean. Soil moisture profiles were drawn by determining moisture content of soil samples under and around the dripper [(at 0, and 0.25 m in the horizontal direction) x (0.6 m depth, with 0.15 m vertical step)] at one day after the middle irrigation of the growing season (irrigation with nitrogen fertilizer, ammonium sulphate 21.5%). Soil moisture percentage in the soil layer samples were measured gravimetrically on a dry weight basis (oven dry basis). Moisture content (MC%) was calculated according to the following equation:

MC% = [(wet soil weight – oven dry weight) / oven dry weight] *100

Salt content (EC, ds/m) of soil solutions were measured in 1:2.5 soil water extract ratio. Finally, the correlation was made between the measured data and the predicted by using SALTMED model to validate it under Egyptian clay loam soil conditions with the effect of three water regimes and three levels of N fertilizer. The inputs of SALTMED simulation model (necessary to run the simulation process) and outputs of the program were described in Flowchart (1).

Results and Discussion

The model has been calibrated by using 100% Etc water regime (1542 m^3/fed.) and 100% of recommended N fertilizer (150 kg N/fed.) Photos (from 1 to 4). The meteorological data of the experiment site were obtained from El-Gharbya Governorate Weather Station. The irrigation files contained field measurements of the irrigation water flow rate for every irrigation every 3 days all over the two growing seasons as a duration of irrigating process or pump operating and the salinity of irrigation water which was affected by the fertigation process (nitrogen fertilizer), added every 10 days. These circumstances were input to the simulation model for the different experimental treatments which were 100%, 75% and 50% of Etc water regimes (1542, 1156.5 and 771 m3/fed), and 100%, 75% and 50% of the recommended N fertilizer (150, 112.5 and 75 of Ammonium sulphate 21.5% as N). Plant parameters such as maximum plant height and rooting depth, planting date and harvesting date were based on the field measurements and records (Photo, 5). Crop coefficients kc, Kcb, Fc were based on FAO- Irrigation and Drainage paper No. 56 (1998) which forms a part in the database of the SALTMED model (version 2011). The initial soil moisture and salinity in the different soil depths are shown in Photo (2). Photo (3) shows the Evapotranspiration as Class A pan (Etp). Photos (4 and 5) show the irrigation and Nitrogen inputs in the model, respectively.

Photo 1. Soil profile screen.

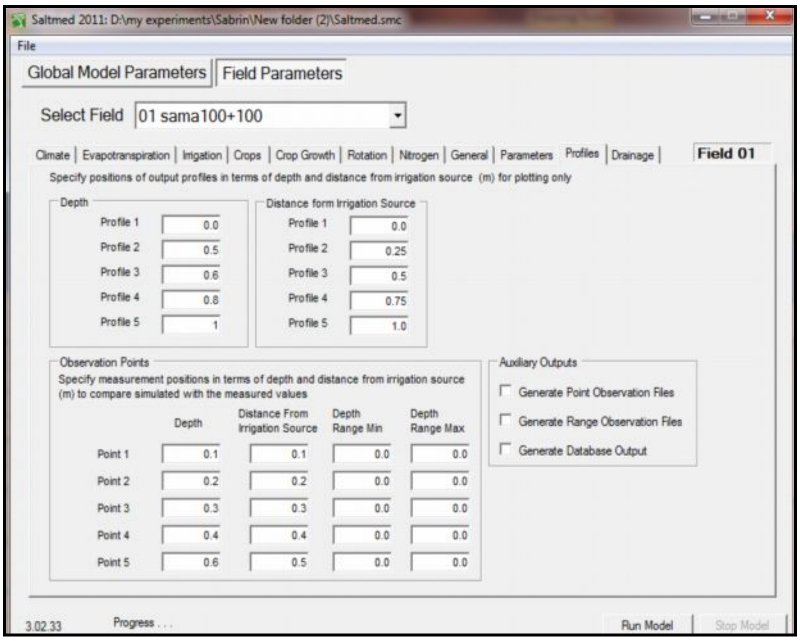


Photo 2. Evapotranspiration as Class A pan screen

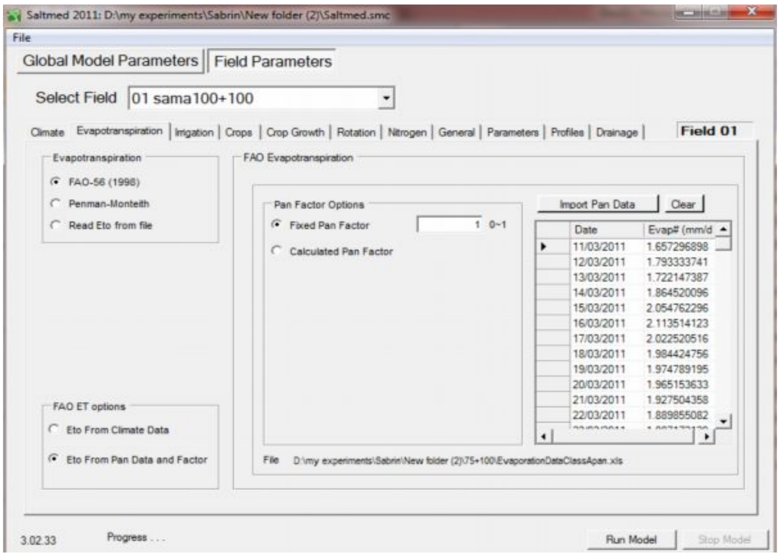


Photo 3. Irrigation inputs screen. Evapotranspiration as Class A pan screen

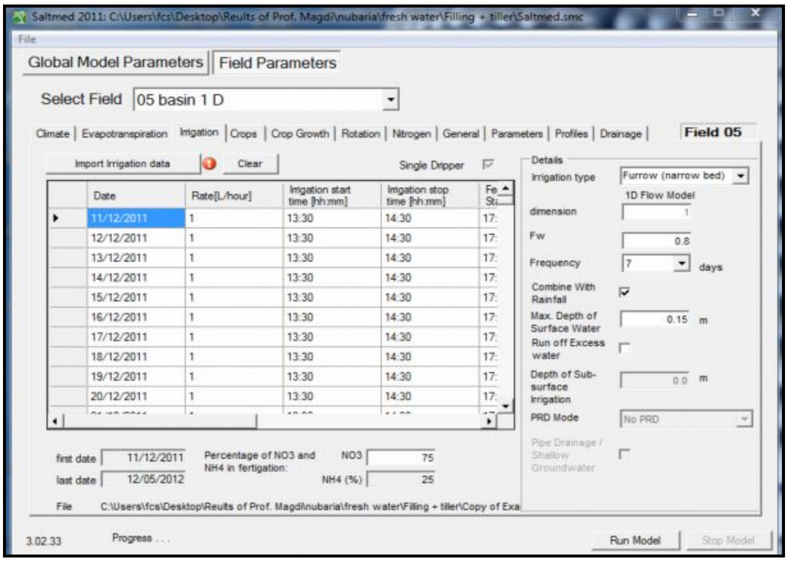


Photo 4. Nitrogen Fertilizer input screen.

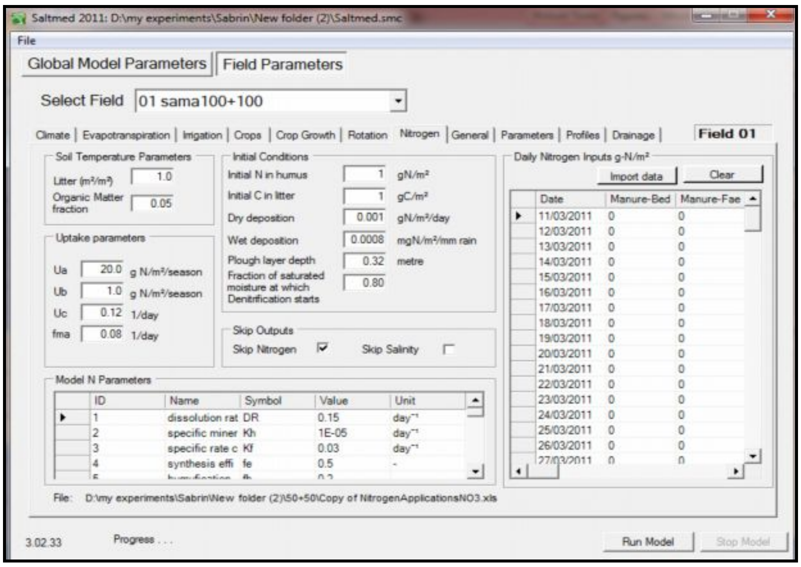
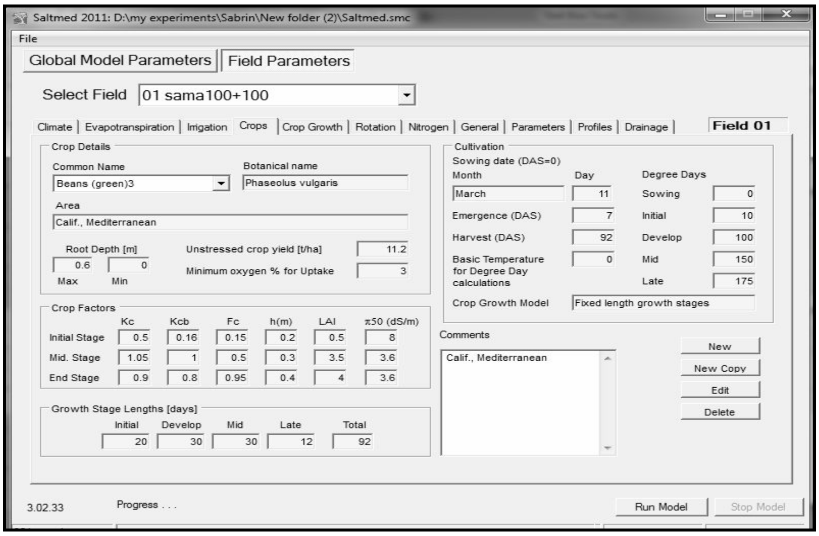


Photo 5. Crop type screen.



The observed soil moisture content data in the soil profile (0.25m x 0.6 m) were measured to compare them with the simulated soil moisture content data at the same soil profile points (0 and 0.25 m in the horizontal direction and 0.15, 0.30, 0.45 and 0.6 m vertically in the soil under the dripper) for the different experimental water regimes treatments (1542, 1156.5 and 771 m3/fed.) after 24 hours from the 15th irrigation process (in the middle of the growing season).

Figure (1) shows the comparison between the simulated and the observed soil moisture content (%) in the soil profile by using 100% Etc, 75% Etc and 50% Etc water regimes, respectively. The results indicated that there are high values of correlation coefficient (r, more than 0.9) and low values of standard deviation (σ, less than 10%), so these relations are strong. Moreover, the SLATMED model is a good and helpful tool to predict the soil moisture content in the soil profile under the different crop growing conditions (water regimes and N fertilizer regimes).

Figures (2, 3 and 4) show the comparison between the simulated and the observed salinity (Ec, ds/m) to validate the SALTMED model under different amounts of N fertilizer with the combination irrigation water regimes treatments. These amounts were 150, 112.5 and 75 kg N/fed. (100%, 75% and 50% of the recommended N fertilizer for snap bean crop, respectively). Generally, there are small differences between the simulated and observed soil salinity (Ec, ds/m) in the soil profile (0.25m x 0.6m) after 24 hours from the 15th irrigation (in the middle of the growing season) by using the experimental water regimes as well as N fertilizer treatments. The highest values of standard deviation (0.07) was obtained by using 100% Etc water regime and 100% of the recommended N fertilizer, on the contrary the lowest one was detected by using 50% Etc water regime and 50% of N fertilizer treatment. All of the standard deviation values were less than 0.1, and the correlation coefficient values were more than 0.8. These results indicated that the SALTMED model is a good tool to predict the salinity concentrations in the tested soil profile under the dripper for the different experimental treatments.

The simulated and observed yield (as an average of the two growing seasons of snap bean crop) were compared as illustrated in Figures (5 and 6). There are small differences between simulated and observed yield for all experimental treatments (Figure, 5). The highest measured yield was obtained by using 100% Etc water regime with 75% of N fertilizer, this value of yield is almost equal to that obtained by using 100% Etc water regime and 100% of N fertilizer, this result save 25% of the used N fertilizer which will reduce the impact on the environment and the costs of the production.

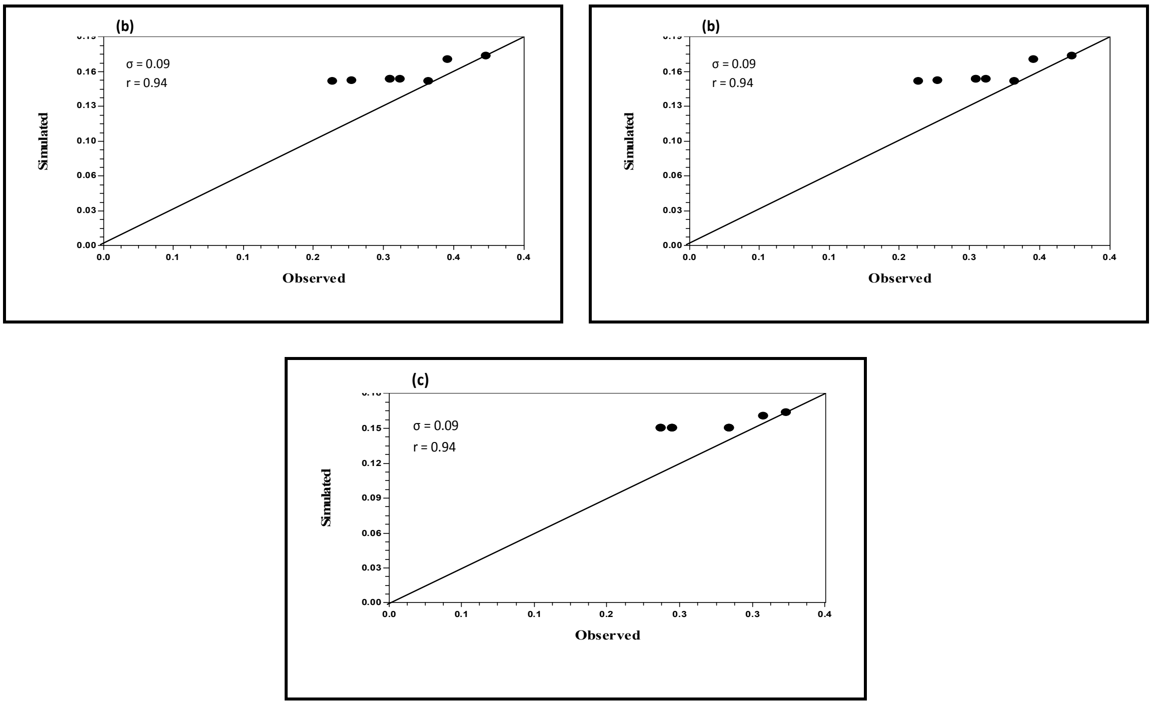


Figure 1. Comparison between simulated and observed moisture content in the soil profile for (a) 100% Etc, (b) 75% Etc, and (c) 50% Etc water regimes treatments.

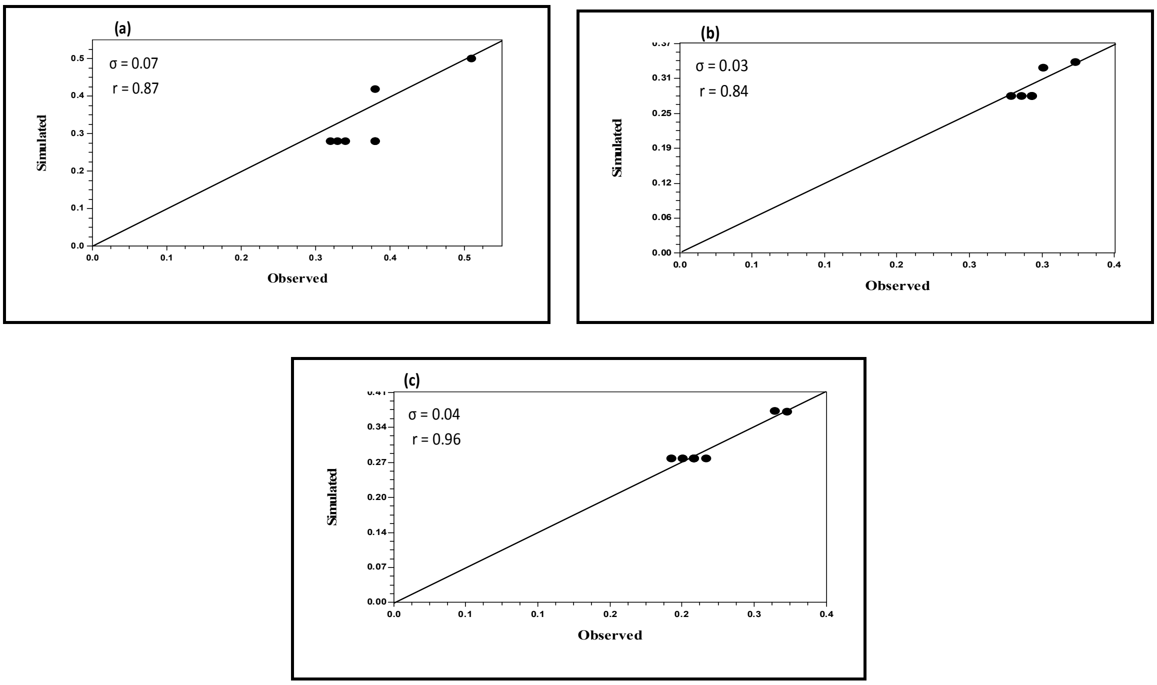


Figure 2. Comparison between simulated and observed salinity concentration in the soil profile of 100% Etc water regime with (a) 100% of the N fertilizer, (b) 75% of the N fertilizer, and (c) 50% of the N fertilizer treatments.

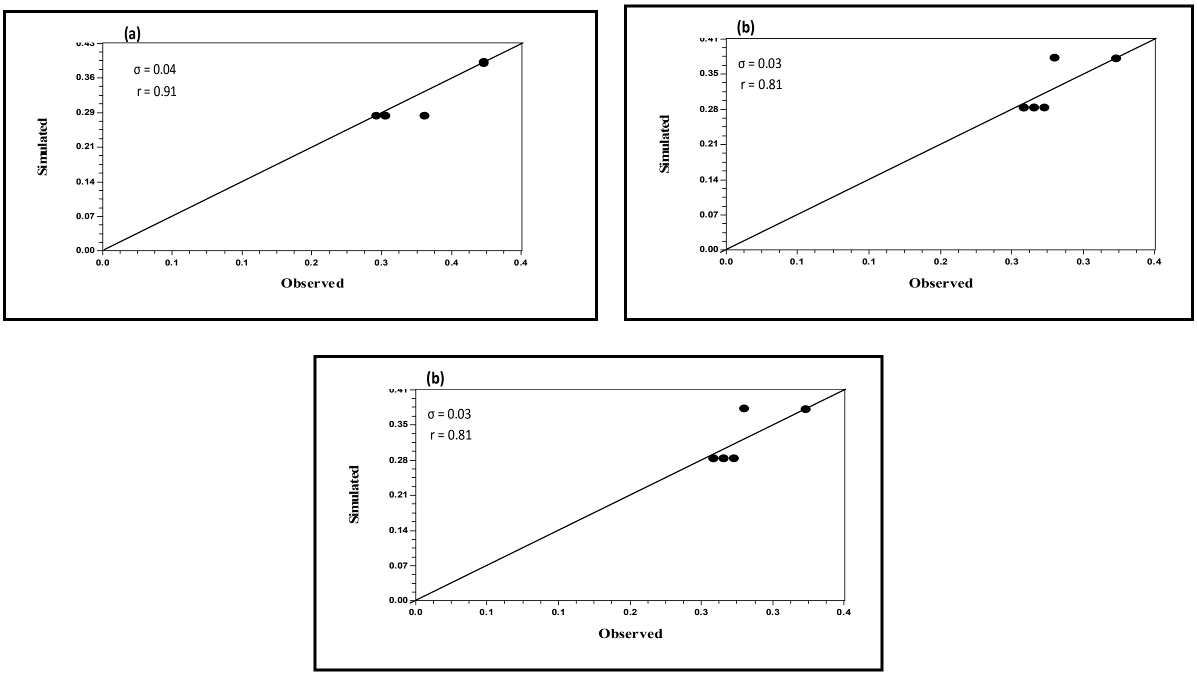


Figure 3. Comparison between simulated and observed salinity concentration in the soil profile of 75% Etc water regime with (a) 100% of the N fertilizer, (b) 75% of the N fertilizer, and (c) 50% of the N fertilizer treatments.

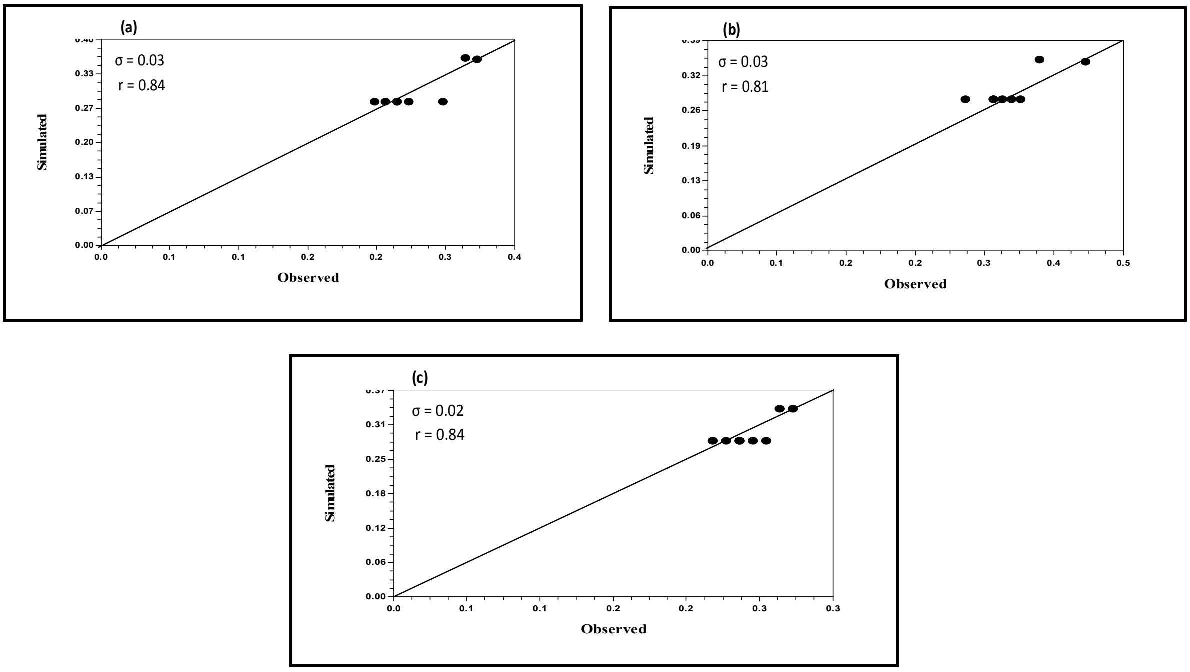


Figure 4. Comparison between simulated and observed salinity concentration in the soil profile of 50% Etc water regime uu5with (a) 100% of the N fertilizer, (b) 75% of the N fertilizer, and (c) 50% of the N fertilizer treatments.

On the other hand, there was a harmful effect on the measured yield by using 50% Etc and 50% N fertilizer, these results were predicted by using the SALTMED model also (the simulated yield). The same trend was detected for the comparison between the simulated and the observed yield of snap bean crop (Figure, 6), where the standard deviation is less than 0.10 and the correlation coefficient is more than 0.90 under the interaction between the experimental treatments.

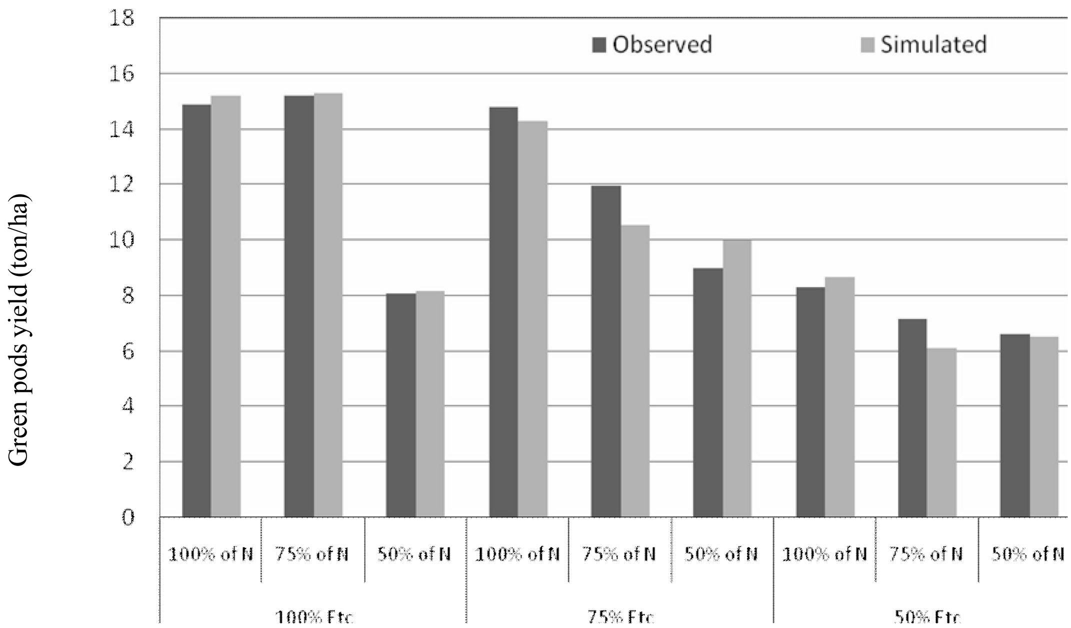


Figure 5. Simulated and Observed Green Pods Yield (ton/ha) under Different Experiment Conditions.

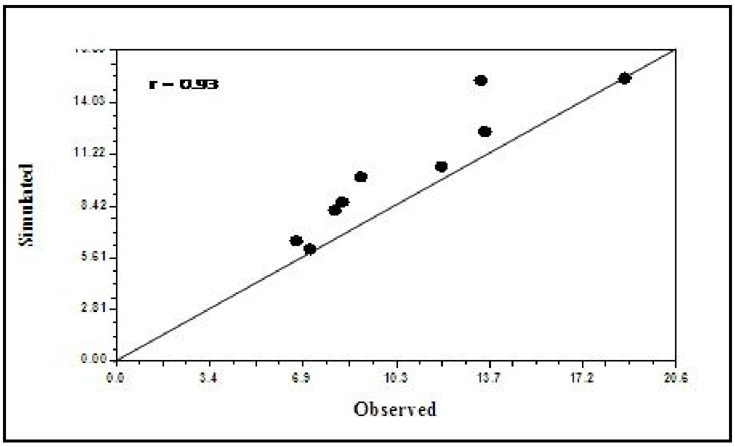


Figure 6. Comparison between Simulated and Observed Crop Yield (ton/ha) under Different Experiment Conditions.

Conclusion

The SALTMED model is a good tool to help in the management of irrigation water as well as the fertilizers under field conditions under drip irrigation system. The model was able to successfully simulate yield, soil moisture, and salinity profiles to give a sight of what will happen in the soil by using different arguments in the farm and the effect of them on the yield to help the farm managers or farmers for deciding the proper amounts of irrigation water and fertilizers, because the right decisions will reduce costs and increase the income.

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