UNDERSTANDING THE INTERACTION OF DEFICIT IRRIGATION AND MULCHING IN RAISED-BED IRRIGATION SYSTEM FOR EFFICIENT WATER USE

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ABSTRACT

Deficit irrigation, mulching and planting methods are important factors that influence the sugar beet yield and water use efficiency. A two years (2011/12 and 2012/13) field study was conducted at Sugar Crops Research Institute, Mardan, Pakistan to investigate the interactive effects of regulated deficit irrigation regimes, mulching and planting methods on sugar beet yield components and water use efficiency under semi-arid environment. The experimental setup consisted of three factors (irrigation, mulching and planting methods) replicated three times. Thirty six treatments comprising of four levels of irrigation regimes designated as (i) no deficit i.e. full irrigation (FI) , (ii) 20% deficit irrigation (DI_{20}), (iii) 40% deficit irrigation (DI_{40}) and (iv) 60% deficit irrigation (DI_{60}); three levels of mulching (i) No Mulch (NM), (ii) Black Film Mulch (BFM) and (iii) Straw Mulch (SM) and three planting methods (i) Conventional Ridge-Furrow (CRF) planting (ii) medium raised bed (MRB) planting and (iii) Wide Raised-Bed (WRB) planting. Soil moisture, irrigation water applied, and crop growth was monitored through the growing season. Seasonal water used was determined by soil moisture depletion studies. At maturity stage the crop was harvested. Sugar beet roots yield and biomass were recorded in field, and sugar content in laboratory. Accordingly from the collected data, Root Irrigation Water Use Efficiency (RIWUE), Sugar Irrigation Water Use Efficiency (SIWUE), Root Crop Water Use Efficiency (RCWUE) and Sugar Crop Water Use Efficiency (SCWUE) were determined. The effect of treatments on sugar beet root yield, sugar content and sugar yield, RIWUE, SIWUE, RCWUE and SCWUE were statistically evaluated. The sugar beet yield response factors under different management practices were determined by Stewart's model. AquaCrop model was used to predict the sugar beet canopy cover (CC), root yield and biomass under different irrigation and soil management strategies.

Results of the study indicated that irrigation regimes significantly affected (at $p < 0.05$) all the yield components and water use efficiency. Compared to full irrigation (FI), the 20%, 40% and 60% deficit irrigation regimes (DI_{20}, DI_{40} and DI_{60}), reduced the sugar beet root yield that amounts 6.97, 20.03 and 35 %, respectively. Sugar yield was significantly decreased (at $p < 0.05$) beyond DI_{20} with maximum decrease of 24.25% was observed for DI_{60}. Both the irrigation and crop water use efficiency were increased with increasing level of irrigation deficit. The highest RIWUE with 17.06, SIWUE with

2.94, RCWUE with 9.72 and SCWUE with 1.67 kg m^{-3} were obtained from DI_{60}, respectively. Mulching practices also significantly affected all the yield components and water use efficiency. Maximum root yield (61.67 tons ha^{-1}) and sugar yield (9.96 tons ha^{-1}) were obtained in BFM. This was followed by SM with 58.18 tons ha^{-1} root yield and 9.29 tons ha^{-1} sugar yield. RIWUE, SIWUE, RCWUE and SCWUE obtained from BFM were 50.28, 19.58, 39.14 and 19.50% higher compared to that produced by NM. Among the planting methods, highest root yield (61.04 tons ha^{-1}), sugar yield (9.73 tons ha^{-1}), RIWUE (14.89 kg m^{-3}), SIWUE, (2.42 kg m^{-3}), RCWUE (10.63 kg m^{-3}) and SCWUE (1.74 kg m^{-3}) were recorded from MRB.

The interactions of irrigation regimes, mulching and planting methods significantly affected sugar beet yield and water use efficiency components. The interaction of FI×BFM×MRB produced significantly higher root yield (74.57 tons ha^{-1}) among all the interactions. However, significantly higher sugar yield was obtained from DI_{20}×BFM×MRB. Comparing the results of DI_{40}×BFM×MRB with conventional practices (FI×NM×CRF), it was observed that the root yield, sugar yield, RIWUE, SIWUE, RCWUE and SCWUE obtained from the former were 10.32, 32.07, 135.55, 180.87, 91.28 and 127.96% higher from the later.

The seasonal crop yield response factors $(K_y)_{root}$ obtained under different planting methods was ranged from 0.93 to 0.99 for NM, 0.53 to 0.61 for BFM and 0.65 to 0.71 for SM, respectively. Similarly $(K_y)_{sugar}$ obtained was ranged from 0.69 to 0.81 for NM, 0.31 to 0.50 for BFM and 0.43 to 0.47 for SM, respectively.

The relationships between sugar beet root yield and seasonal evapotranspiration (ET) was curvilinear for mulch conditions and linear for No Mulch. However, the relationship between sugar yield and ET was curvilinear irrespective of the mulching condition.

The Food and Agricultural Organization (FAO) AquaCrop model was used to predict the sugar beet CC, root yield and biomass under different in-field water management practices. On the basis of different statistical indicators, such as Root Mean Square Error (RMSE), Normalized Root Mean Square Error (NRMSE), index of agreement

(d_{index}), Nash–Sutcliffe Efficiency Factor (EF) and the Mean Bias Error (MBE), it was observed that the AquaCrop model was in an excellent agreement between the observed and simulated values of CC for all the calibrated fields irrespective of the mulching condition and planting methods. The model also accurately simulated both the biomass and root yield for all the calibrated fields. Validation results for conventional ridge furrow planting (CRF) indicated good agreement between the simulated biomass and root yield with their observed values. In medium raised bed planting, no significant deviations of the simulated biomass and root yield from the measured values were found for MRB×NM×DI_{20} . However deviation observed was significant for increased stress level. In wide raised bed planting, good agreement between simulated and measured biomass and root yield was found for all stress levels applied under SM treatments. Under BFM treatment, the model performed very well for DI_{20} and DI_{40} treatments. For NM treatments, the model performance was good only under DI_{20}. For DI_{60}, the model highly overestimated both the biomass and root yield for NM and BFM treatment.