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Water Productivity of Vegetables Crop under Temperate Condition of Kashmir Valley

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A B S T R A C T

Improving water productivity can make an excellent contribution to global food production and poverty improvement. The purpose of the study was to evaluate the water productivity, crop water use efficiency and irrigation water use efficiency of tomato cucumber and bottle gourd crop under water stress condition. A field experiment was conducted at the experimental site of Sher-e- Kashmir University of Agricultural Sciences & Technology, Srinagar, Jammu and Kashmir during 2018. The average yield of tomato, cucumber and bottle gourd was 30.65 ton/ha, 18.41 ton/ha and 19.15 ton/ha. The maximum and minimum yield for the tomato was 43.2 ton/ha and 12.31 ton/ha. The range of water productivity for tomato crop was 5.3 – 13.45 kg/m^3. Crop water use efficiency varies from 36.59 – 125.65kg/ha/mm for tomato crops. The highest irrigation water use efficiency was 330 kg/ha/mm for tomato crops. The best result is obtained in case of treatment 11because irrigation was provided at the initial and development stage only. The crop needed more water in the initial and development growth stage. At mid and late-stage water is provided by the rainfall, so there is no need for irrigation at these stages. Similarly, range of water productivity and crop water use efficiency for cucumber crops found to be 6.59 to 15.75 kg/m^3 and 24.53 to 80.96 kg/ha/mm. The highest irrigation water use efficiency for cucumber crop was found in treatment 14 (321.48 kg/ha/mm). For bottle gourd crop maximum water productivity (15.93 kg/m^3) found in T9 and highest irrigation water use efficiency (272.43 kg/ha/mm) in treatment 11. Therefore, irrigating the field when the crop needs help to enhance water productivity and save the most precious resource water.

Keywords

Water productivity, Crop water use efficiency, irrigation water use efficiency, Field experiments

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Introduction

The world human population increasing very rapidly in the last couple of decades while the available resources for food production are being depleted due to the adverse effects of human activity on the ecosystem (Kahramanoğlu, 2017). The crisis of water shortage increases day by day (Barlow, 2017). Water is the most valuable resource on earth (Liu *et al.,* 2017). The total volume of water on the earth is 1.38 billion cubic kilometers (Moussa, 2018). Out of which 97.5 % is salty water only 2.5 % is freshwater. India contains

4 % of the world's water resource which is about 761 cubic kilometers (Henderson, 2019). 688 km^3 water is used for irrigation (Dharminder *et al.,* 2019) and in terms of groundwater, it is approximately 70 percent (Poddar *et al.,* 2014). On the basis of consumptive use 80–90% of all the water is consumed in agriculture (Hamdy *et al.,* 2003). Farmers apply excess water when it is available (Jain *et al.,* 2000). Unfortunately, water use efficiency in this sector is very poor not exceeding 45% with more than 50% water losses; thereby, the needs of present context to enhancing water productivity in the agricultural sector compared with other sector water use (Surendran *et al.,* 2016). Total food production needs a boost for feeding a growing world population and this need to be accomplished under an increasing scarcity of water resources (Barlow and Clarke, 2017; Himanshu *et al.,* 2019; Surendran *et al.,* 2016). The production of more food under a water-scarce situation can be achieved by maximizing crop yield per unit of water consumption (Bouman, 2007; Kijne *et al.,* 2003; Kumar *et al.,* 2017), which is termed "crop water productivity" (CWP) (Molden, 1997; Kijne *et al.,* 2003). The definition of crop water productivity can be given as the physical mass of production or the economic value of production measured against gross inflows, net inflow, depleted water, process depleted water, or available water (Molden, 1997). CWP can often be enhanced by increasing efficiency with the reduction of water losses from drainage, seepage and nonproductive evaporation.

To date, very little information is available regarding the productivity, profitability and water use efficiency (WUE) due to flood irrigation of different irrigated crops (Bhatt *et al.,* 2019; Herath *et al.,* 2013). WUE is important to water use indicators in the study of sustainable irrigated agriculture (Ucar *et al.,* 2017). We can distinguish physical water productivity that is defined as the ratio of the mass of product to the amount of water consumed ('more crop per drop'). Techniques for estimating water balance range from very simple methods, such as lumped models and field-experiment techniques, to highly complex computer-based models that can calculate water balance at various temporal and spatial scales (Ghandhari and Moghaddam, 2011; Jahangeer *et al.,* 2017). The selection of an appropriate technique depends on the objectives of the study and the availability of data (Zhang *et al.,* 2002). Increasing a model's complexity does not necessarily improve its accuracy (Walker and Zhang, 2001), and simple lumped models may also be equally well or better than more complex alternatives (Jakeman and Hornberger, 1993). Crop models like (DSSAT, RZWQM2) are also useful for detecting suitable irrigation management and irrigation application under different climatic variables (Clothier *et al.,* 1994; Jones *et al.,* 2003; L. Ma *et al.,* 2012).

Vegetable production gives economic benefits to the farmer but improper irrigation or excess use of water increases the production cost. To maximize the benefits farmers should do well-managed irrigation water practices (Guha, 2018). Studies show that there was significantly increased grain yield, evapotranspiration, and water use efficiency in the vegetable crop by using deficit irrigation as compared to rain-fed (Cantore *et al.,* 2016; Kifle and Gebretsadikan, 2016). In order to respond to emerging crises in agricultural water management, it is ever more recommended that efforts should focus on improving water productivity (Singh., 2005; Sharma *et al.,* 2018; Surendran *et al.,* 2019). Hence, the purpose of the study was to evaluate the water productivity, crop water use efficiency and irrigation water use efficiency of tomato cucumber and bottle gourd crop under water stress conditions in northern Indian state to ensure better planning for sustainable water management. The study assesses different growth stages and identifies critical growth stages for irrigation applications for selected crops. The research output help in efficient crop-growth-stage-based deficit irrigation strategies for tomato, cucumber and bottle guard cotton under limited irrigation water availability also on changing the viewpoint of decision-makers and researchers regarding the efficient use of water resources.

Materials and Methods

Study area

The experiment was conducted at the field site in the SKUAST-K Shalimar campus which is located at 34.01° N latitude and 74.5° E longitude at an elevation of 1606 meters above the mean sea level. The SKUAST-K Shalimar campus is situated at about 15 Km away from Srinagar (Jammu and Kashmir). The study area map is shown in (Fig 1) and the climate of the field site is of temperate type. The mean meteorological data for cropping season recorded at Meteorological Observatory, Division of Agronomy, SKUAST-Kashmir, Shalimar are presented in table 1.

Experimental layout

The field experiment was conducted to identify and categorize the stages that are most sensitive to soil moisture stress for tomato, cucumber and bottle gourd crop. The test crops were planted at the recommended planting period of the area (May 2018). The following different types of treatment strategy applied for the field experiments.

1. Check – irrigated at the optimal irrigation schedule i.e. irrigating when the total available moisture was 40% to field capacity based on FAOCROPWAT 8.
2. Dispossess irrigation water application during any of one growth stage
3. Dispossess irrigation water application during any of the two growth stages
4. Dispossess irrigation water application during any of the three growth stages
5. Dispossess irrigation water application during all growth stages

The site selected for the experiment was leveled with medium fertility status and good drainage. The soil texture of the field was found to be silty clay loam. The field for each crop was divided into 48 plots of size 6.0 m × 2.0 m, separating each plot from the adjoining plots by 30 cm wide small bunds, moreover, The seeds were sown by transplanting them manually in furrows. The spacing of cucumber crop, tomato, and bottle guard is 45×100 cm, 35×60 and 60×100, respectively. The proper plant population was maintained and all cultural practices have been done to all treatments in accordance with the recommendation made for the area. Irrigation water was applied as per moisture content status in the upper 0-15 cm soil layer and stages of crop. The details about the crops and sowing and harvesting details are presented in table 2.

The Soil moisture content before and after irrigation was monitored gravimetrically at 60cm depth interval up to maximum root depth. The average bulk density 1.47 g/cm^3, field capacity 24% and pH of 7.2 was found for the soil present at the experimental field. The irrigation treatments are divided on the bases of crop growth stages. The crop growth stage divided into four different stages like Initial, developmental, midseason and crop maturity. On the bases of crop growth stages total, sixteen types of irrigation scheduling were applied at the experimental field. The details of irrigation and crop growth stage are presented in table 3.

Irrigation scheduling

Estimation of the potential evapotranspiration of the area is the first step to organize the irrigation schedules of the experiment. Numbers of empirical and semi-empirical formulas are used to calculate potential evapotranspiration from meteorological data (Surendran *et al.,* 2019). "The FAO Penman-Monteith method is recommended as the standard method for the definition and computation of the reference evapotranspiration, ET_o". By using the CROPWAT 8 simulation tool developed by FAO in 2006, monthly ET_o of the area was computed using minimum and maximum temperature, relative humidity, wind speed and sunshine hour data. Kc value of every crop largely depends on the crop growth stage and regional climate. The Kc values of tomato, cucumber and bottlegourd crops at the different stages were obtained from FAO Cropwat software. The irrigation scheduling of each treatment plot was prepared on the basis of crop water requirement (CWR) of tomato at the different stages (initial, development, mid and late-stage) of the growing period and the soil water holding capacity. The irrigation criteria were irrigating when the soil water was depleted to a critical point (40% of total available water (TAW) for crops) which is taken from FAO CROPWAT 8, and the irrigation applied was the amount to replenish crop water use to field capacity. The net irrigation requirement was 60% of TAW multiplied the root depth at a specific growth stage. The gross irrigation can be calculated by dividing net irrigation to application efficiency**.**

Actual Crop-Evapotranspiration (ETc) and Kc value

The reference evapotranspiration was estimated for respective crop duration. The value of Kc for different crops with stage-wise was obtained from FAO drainage paper no.-56. So, ETc was calculated from following equation 1.

$$ETc = Kc \times ETo \quad (1)$$

Where, ETc, Actual crop-evapotranspiration (mm), Kc,crop coefficient and ETo, reference evapotranspiration (mm).

The Kc value of different crops at different growth stages namely initial, developmental, mid-season and late-season stage are shown in Table 4 For most of the crops it is found that for the mid-season stage the Kc value is higher because of fully grown and maximum coverages of the ground surface.

Duration of growth stages

To find out crop coefficient (Kc) for different crops at different growth stages, the duration of growth period must be known. The observed duration of growth was as per data provided by FAO drainage paper no-56. The observed duration of different growth stages and their length of time are given in Table 5.Figure 2 shows the different developmental stages of the selected crops.

Water productivity, crop water use efficiency, and irrigation water use efficiency

Water Productivity plays a crucial role in modern agriculture which aims to increase yield production per unit of water used, both under rainfed and irrigated conditions. Water productivity with dimensions of kg/m^3 is defined as the ratio of the mass of marketable yield (Y) to the volume of water consumed by the crop (ET). Mathematically water productivity can be represented as follow in equation 2 (Ali and Talukder, 2008)

$$WP = \frac{Y}{Wa} \quad (2)$$

Where, WP, Water productivity (Kg/m^3), Y, Economic Yield (kg) and Wa, Total Water applied (m^3).

Crop water use efficiency is mostly used to describe irrigation effectiveness in terms of crop yield (crop productivity). It is defined as the ratio of the economic yield or biological yield produced per unit of crop evapotranspiration (Odhiambo *et al.,* 2011). The crop water use efficiency was calculated as equation 3.

$$CWUE = \frac{Y}{ETc} \quad (3)$$

Where, CWUE, Crop water use efficiency (Kg/ ha/mm) and ETc, Crop evapotranspiration (ha/mm)

Irrigation water use efficiency (Eq.4) is an indices to characterize crop yield in relation to the total depth of water applied through irrigation (Odhiambo *et al.*, 2011).

$$IWUE = \frac{Y}{IW} \quad (4)$$

Where, IWUE = Irrigation water use efficiency (Kg/ha/mm) and IW, Irrigation water applied (ha/mm)

Results and Discussion

The actual rainfall recorded during the growing season was 316.4 mm. The monthly average rainfall at the field site was presented in table 6 below. Figure 3 shows the daily recorded values of climatic variables at the field site during the cropping season. The highest temperature is recorded during the month of June of the initial stages of the vegetable crops. The rainfall was concentrated in the mid and late part of the crop growth stages. The growing season of selected vegetables varies from May to September month of the year. The daily estimated actual and reference evapotranspiration for all the selected crop was presented in figure 4. These parameters are calculated separately for each vegetable (tomato, cucumber and bottle guard) by using vegetable specific crop coefficients. The actual evapotranspiration for tomato during the middle stage of the crop is slightly higher as compared to the cucumber and bottle guard crop.

Table7 presented the water productivity for the tomato crops were higher for the treatmentT11. In T11 irrigation water was provided at the initial and development stages only and in mid, late-season rainfall water was used up by the crop. So dispossess irrigation at mid and last stage helps to increase water productivity for the tomato crops.

Table 8 shows the regression analysis between irrigation and yield, water productivity, water use efficiency and irrigation water use efficiency for the tomato crops. Figure 5(a,b) shows the variation of actual and predictable yield of tomato against the different irrigation treatment. Trend line graph shows the R^2 values 0.34 with all sets of irrigation treatment during the growing season.

Table9 shows the estimated water productivity for the cucumber crops and it was higher for the treatmentT11. In T11 irrigation water was provided at the initial and development stages only. Table 10 shows the regression analysis for the cucumber crops. Figure 6(a,b) shows the variation of actual and predictable yield of cucumber crops against the different irrigation treatment and trend line with applied irrigation treatment during the growing season.

Table11 presented the estimated water productivity for the bottle guard crops. The estimated water productivity was higher for the treatment T11 as tomato and cucumber crops. Table 12 shows the regression analysis for the bottle guard crops. Figure 7(a,b) shows the variation of actual and predictable yield of bottle guard against the different irrigation treatment and trend line with applied irrigation treatment during the growing season.

Table.1 Weather parameter during the period of the experiment (May –September 2018)

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sunshine hours	Solar Radiation MJ/m²/day
May	9	24.6	61	46	7.3	20.6
June	13.4	28.3	64	41	7.2	20.9
July	17.2	28.8	73	29	5.7	18.4
August	16.6	30.7	67	31	7.8	20.3
September	11.9	28	66	34	7	17.1

Table.2 Details of crops grown at the field site

S.No.	Crops	Sowing date	Harvesting date	Duration (day)
1.	Cucumber	25/05/2018	10/09/2018	105
2.	Bottle guard	25/05/2018	05/09/2018	100
3.	Tomato	25/05/2018	10/09/2018	105

Table.3 Irrigation treatments details applied during the experiment

Treatments	Growth stages			
	Initial	**Development**	**Midseason**	**Maturity**
T1	1	1	1	1
T2	0	1	1	1
T3	1	0	1	1
T4	1	1	0	1
T5	1	1	1	0
T6	0	0	1	1
T7	0	1	0	1
T8	0	1	1	0
T9	1	0	0	1
T10	1	0	1	0
T11	1	1	0	0
T12	0	0	0	1
T13	0	0	1	0
T14	0	1	0	0
T15	1	0	0	0
T16	0	0	0	0

Note: 1 means irrigated and 0 means not irrigated during crop growth stages

Table.4 Kc value of selected crops for different growth stages

Crops	Duration (Days)	Growth stages			
		Initial	Development	Midseason	Late season
Tomato	105	0.6	0.87	1.15	0.8
Cucumber	105	0.6	0.80	1.0	0.75
Bottle gourd	100	0.6	0.70	1.0	0.80

Table.5 Length of different growth stages of the selected crops

Crops	Duration (days)	Growth stages (days)			
		Initial	Development	Midseason	Late season
Tomato	105	10	30	35	30
Cucumber	105	20	30	40	15
Bottle gourd	100	20	30	30	20

Table.6 The actual rainfall during the growing period

Month	Actual rain fall (mm/month)
May	0
June	61.6
July	134.2
Aug	120.6
Total	316.4

Table.7 Water productivity and related components of irrigation waterfor tomato crop

Treatment No	Yield (ton /ha)	Total water (m^3/ha)	Water productivity (kg/m^3)	Rank for yield
T1	39.31	5890	6.67	4
T2	28.6	4960.32	5.77	11
T3	34.51	5227.76	6.60	6
T4	40.7	5385.1	7.56	3
T5	43.2	5290.72	8.17	1
T6	21.78	4110.6	5.30	13
T7	33.54	4589	7.31	8
T8	31.32	4430.82	7.07	9
T9	36.19	3360.12	10.77	5
T10	34.21	3570.61	9.58	7
T11	41.69	3100	13.45	2
T12	18.86	2785	6.77	15
T13	20.13	2785	7.23	14
T14	29.81	2785	10.70	10
T15	24.3	2558.35	9.50	12
T16	12.31	917.63	13.41	16

Table.8 The regression relationship between irrigation and yield, water productivity (WP), crop water use efficiency (CWUE) and irrigation water use efficiency (IWUE) in tomato crop

Dependent variable	Regression equation	R^2	P
Yield	Y = 12.35 + 0.004 X	0.50	0.0023
WP	Y = 13.28 – 0.001 X	0.44	0.0048
CWUE	Y = 37.16 + 0.013 X	0.49	0.0024
IWUE	Y = 194.62 + 0.011 X	0.04	0.4410
R^2 – coefficient of determination; *P* – statistically significant value			

Table.9 Water productivity and related components of irrigation water forCucumber crop

Treatment No	Yield (ton /ha)	Total water (m^3/ha)	Water productivity (kg/m^3)	Rank for yield
T1	28.31	3431.2	8.25	1
T2	16.89	2563.87	6.59	11
T3	18.71	2841.23	6.59	7
T4	26.11	2918.4	8.95	4
T5	28.31	2880.11	9.83	1
T6	14.97	1774.92	8.43	13
T7	17.56	2380	7.38	8
T8	16.95	2257.76	7.51	10
T9	20.22	1283.97	15.75	5
T10	18.73	1405.34	13.33	6
T11	26.96	1397.45	19.29	3
T12	9.37	1180.65	7.94	15
T13	10.86	1067.72	10.17	14
T14	17.17	1396.9	12.29	9
T15	15.1	1287.43	11.73	12
T16	8.36	576.71	14.50	16

Table.10 The regression relationship between irrigation and yield, water productivity (WP), crop water use efficiency (CWUE) and irrigation water use efficiency (IWUE) in cucumber crop

Dependent variable	Regression equation	R^2	P
Yield	Y = 8.45 + 0.005 X	0.47	0.0032
WP	Y = 15.67 – 0.002 X	0.37	0.0117
CWUE	Y = 25.33 + 0.014 X	0.46	0.0040
IWUE	Y = 180.32 + 0.011 X	0.02	0.6263

Table.11 Water productivity and related components of irrigation water for Bottle gourd crop

Treatment No	Yield (ton /ha)	Total water (m^3/ha)	Water productivity (kg/m^3)	Rank for yield
T1	33.60	3660.00	9.18	1
T2	18.35	2784.78	6.59	10
T3	21.32	3090.15	6.90	7
T4	32.00	3138.90	10.19	2
T5	30.98	3100.10	9.99	4
T6	15.50	2260.20	6.86	11
T7	20.87	2478.93	8.42	8
T8	19.90	2320.80	8.57	9
T9	24.85	1560.10	15.93	5
T10	21.79	1700.00	12.82	6
T11	31.55	1367.32	23.07	3
T12	6.70	900.43	7.44	15
T13	7.21	850.65	8.48	13
T14	9.38	870.10	10.78	12
T15	7.10	760.80	9.33	14
T16	5.30	440.30	12.04	16

Table.12 The regression relationship between irrigation and yield, water productivity (WP), crop water use efficiency (CWUE) and irrigation water use efficiency (IWUE) for bottle gourd crop

Dependent variable	Regression equation	R^2	P
Yield	Y = 4.72 + 0.007 X	0.59	0.0004
WP	Y = 12.79– 0.001 X	0.09	0.2590
CWUE	Y = 16.83 + 0.022 X	0.58	0.0006
IWUE	Y = 84.23 + 0.036 X	0.30	0.0271

Figure.1 The location map of the experimental field site

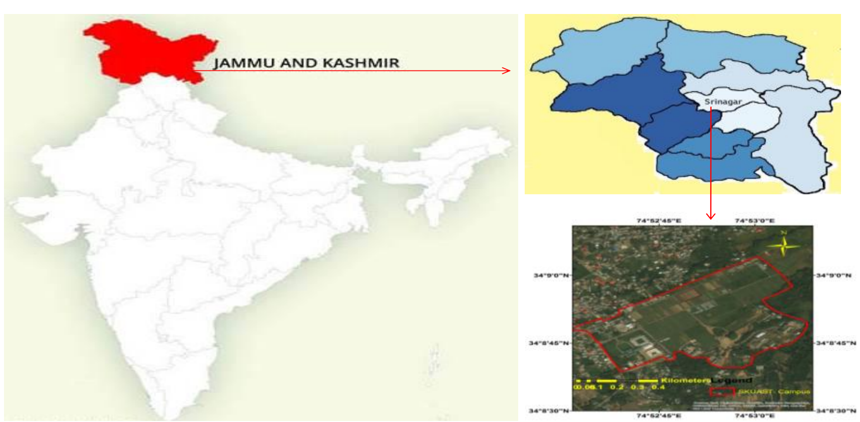


Figure.2 Different growth stages of selected vegetable crops

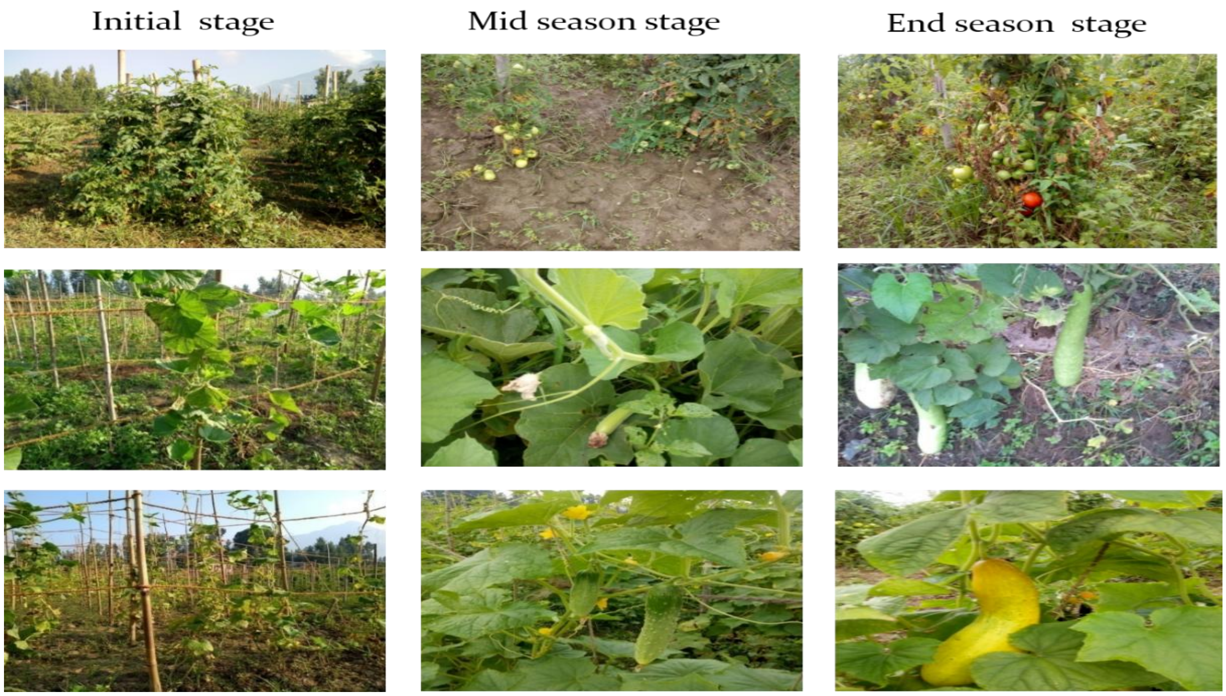


Figure.3 Daily measured rain events, evaporation, the maximum and minimum temperature during the cropping season of the selected crops at the field sites.

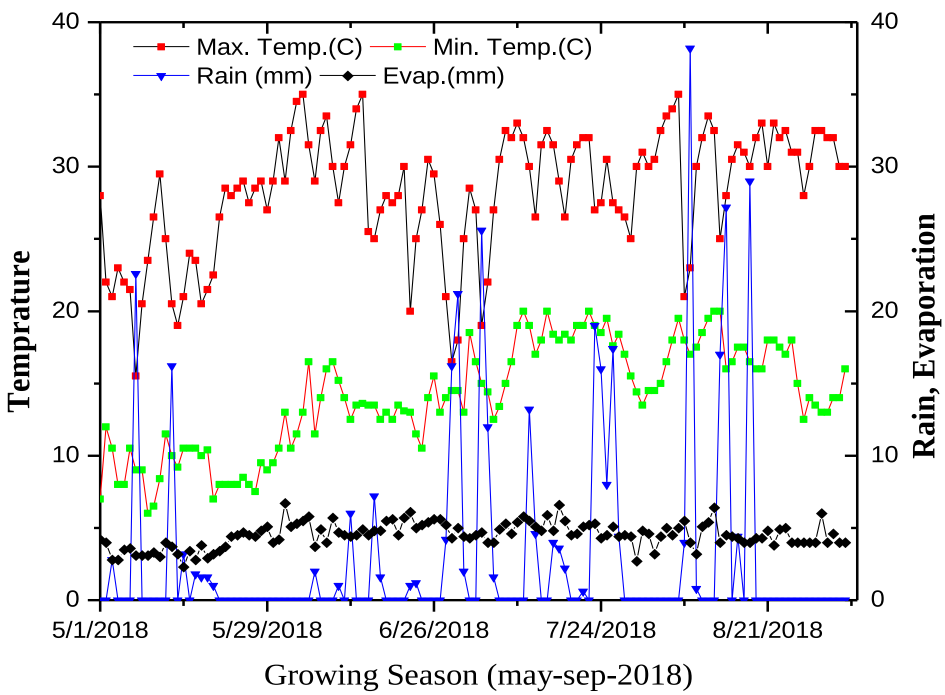


Figure.4 Daily estimated ET_c and ET_0 for the selected crop during 25th May – 10th Sep 2018 (a) Tomato, (b) Cucumber and (c) Bottle gourd

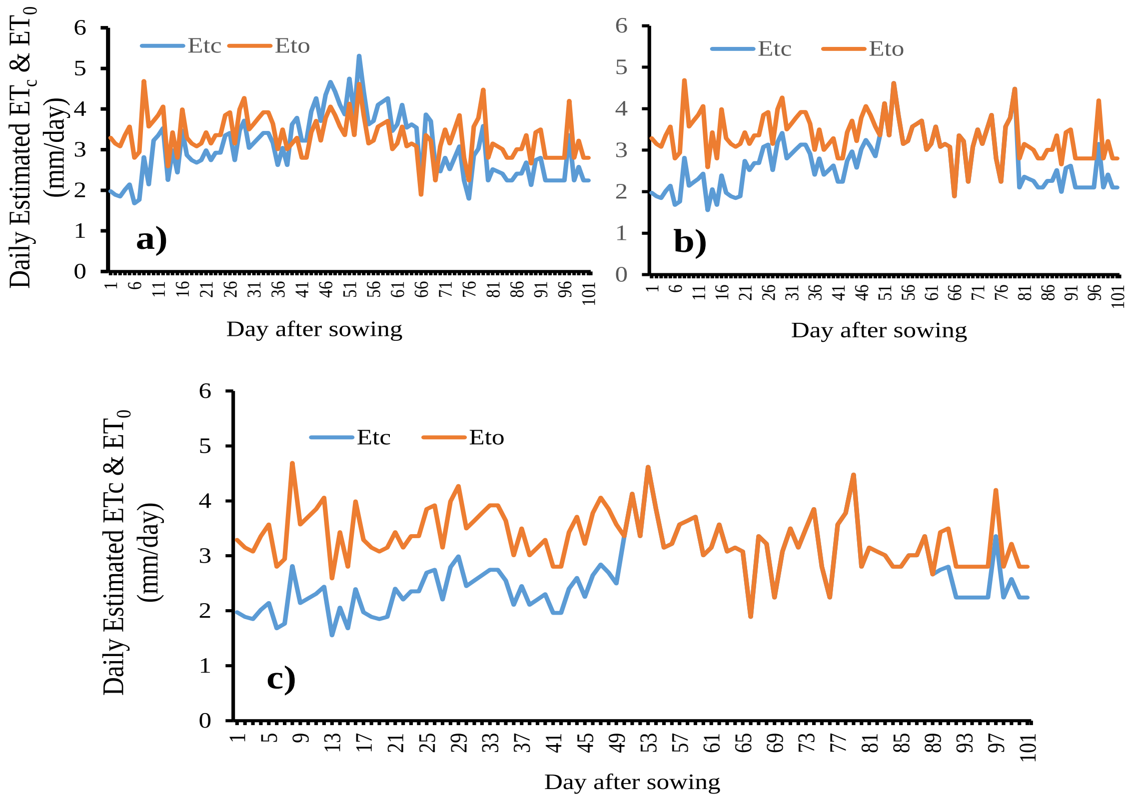


Figure.5 Actual and predictable yield in tomato crop (a) Trend line showing the relationship between water and yield of tomato crop (b).

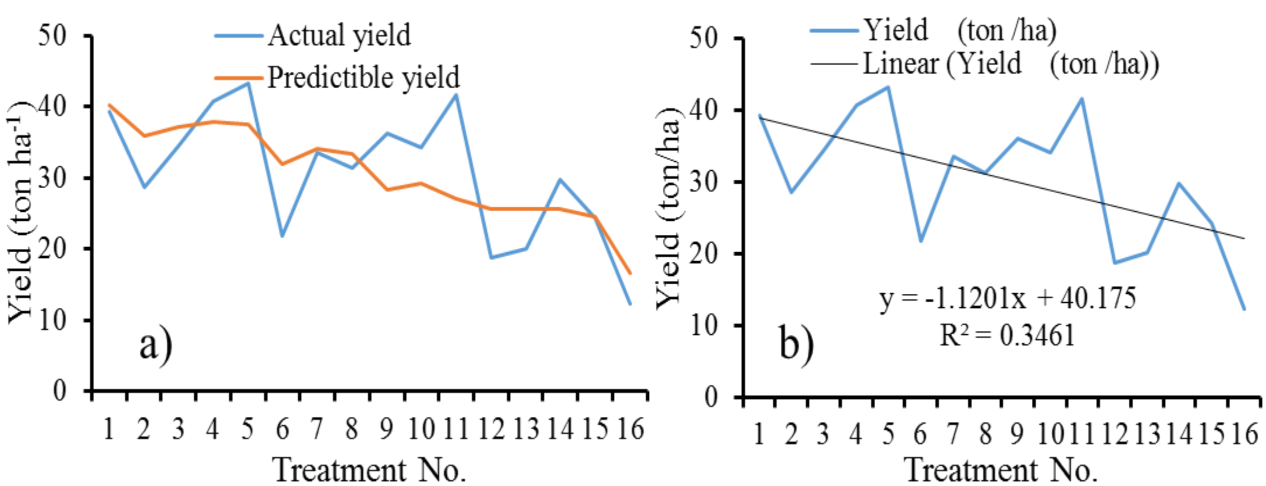


Figure.6 Actual and predictable yield in cucumber crop (a) Trend line showing the relationship between water and yield of cucumber crop (b).

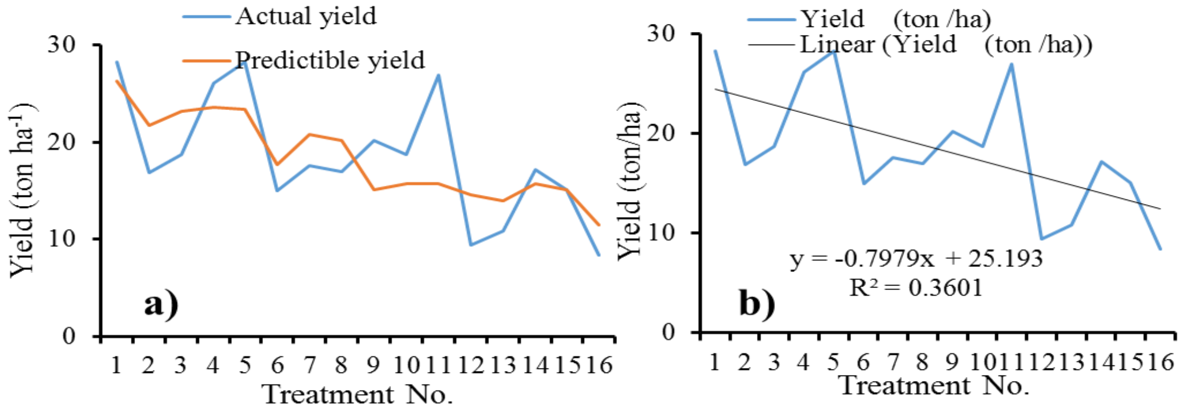


Figure.7 Actual and predictable yield in bottle guard crop (a) Trend line showing the relationship between water and yield of bottle guard crop (b).

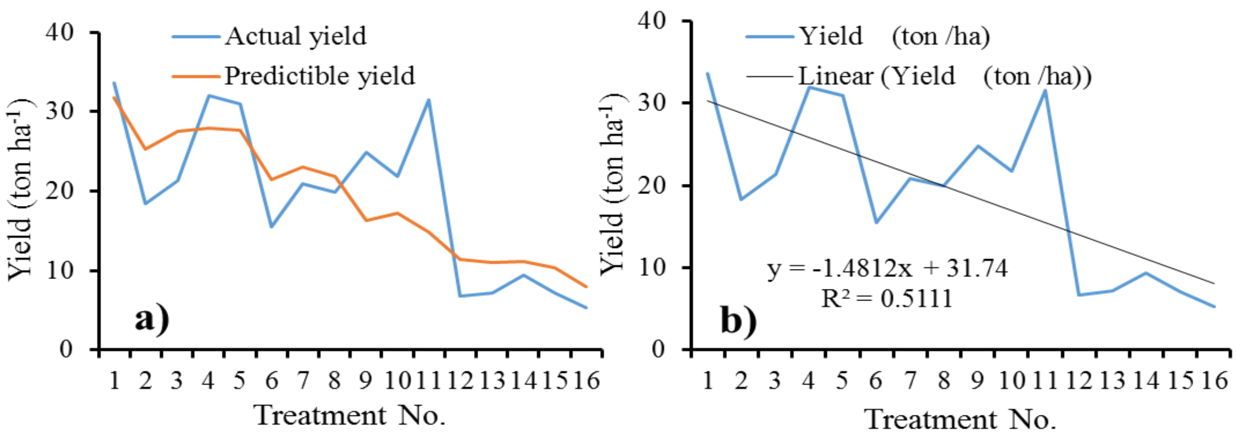


Fig.8 CWUE of bottle gourd, cucumber, and tomato

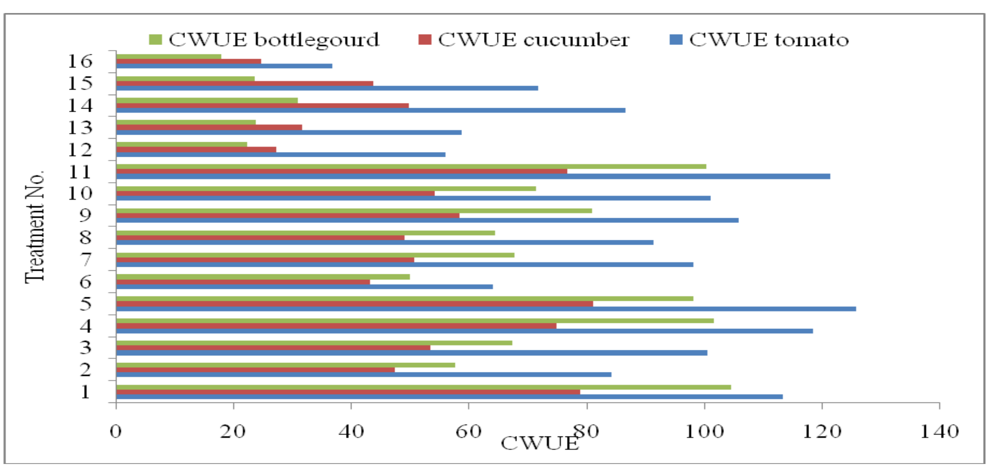
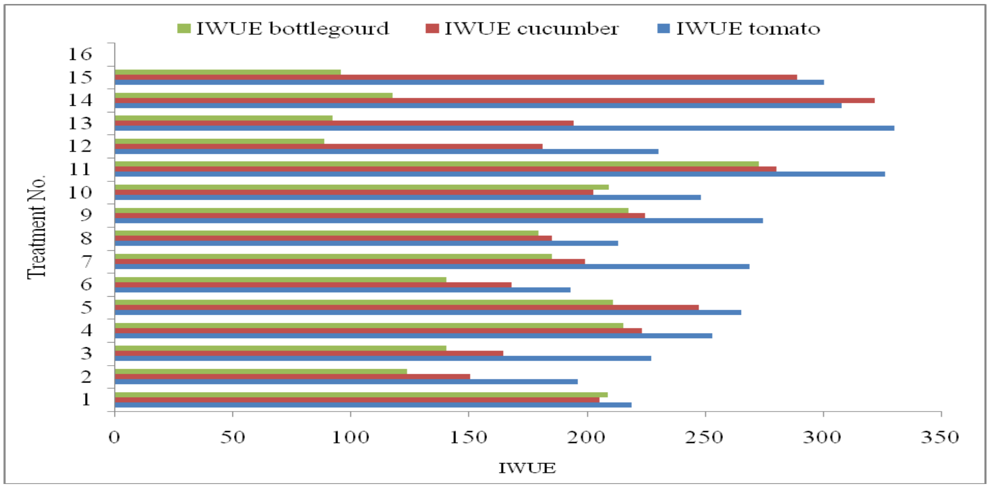


Fig.9 IWUE of bottle gourd, cucumber, and tomato



Irrigation treatment T 11 shows the higher water productivity for the all selected crops. In this irrigation treatment irrigation was applied at the initial and development stages of the crops. The crop needed more water in the initial and development growth stage. During the mid and late-stages crops used rainfall for their growth hence no need for irrigation at these stages.

Figure 8 represented the CWUE (kg/ha/mm) for all crops with applied irrigation treatments and it were in the range of 36.59-125.37, 24.53-80.96 and 17.79-101.53 for tomato, cucumber, and bottle gourd crop. The lowest CWUE obtained in treatment 16 because it totally depends on the rainfall. Zero irrigation was given to T16, therefore, the total yield for this treatment was very low. Similarly, fig 9 shows the IWUE of tomato, cucumber and bottle gourd crop with applied different irrigation treatments.

For tomato, cucumber and bottle gourd crop treatment 1 (T1) is with full irrigation in all stages, based on the crop water demand to relate with the stress at the different growth stages. There is no significant difference in yield between irrigating all growth stages and only the first two stages because of considerable rainfall contribution at a mid and late stage. The average yield of tomato, cucumber and bottlegourd was 30.65 ton/ha, 18.41 ton/ha and 19.15 ton/ha. The maximum and minimum yield for the tomato was 43.2 ton/ha and 12.31 ton/ha. The range of water productivity for tomato crop was 5.3 – 13.45kg/m^3. A similar result was also found by Singh *et al.*, (2010) and Jha *et al.*,(2017). Crop water use efficiency varies from 36.59 – 125.65kg/ha/mm for tomato crops. Zeng *et al.*, (2009) support our results and report showing that major irrigation water deficiencies led to greater WUE, but to lower yields. The highest irrigation water use efficiency was 325.7 kg/ha/mm for T11 in tomato crops. Similar findings have been accounted for by Rashidi *et al.*, (2008). The main factor responsible for lower water productivity in treatment 6 was due to higher amount of irrigation water applied in comparison to actual need, at mid and late-stage neglecting the effect of texture, while in treatment 11 was found higher productivity because the yield of tomato is higher at lower use of water.

WANG *et al.*, (2007) found no significant differences for tomato yield under different soil water potentials. Treatment 11 and treatment 16 shows almost equal water productivity in tomato crops but with a large difference in yield. Better water productivity means a reasonable yield with moderate use of water. Similarly, range of water productivity and crop water use efficiency for cucumber crops found to be 6.59 to 15.75 kg/m^3 and 24.53 to 80.96 kg/ha/mm. These results are also in agreement with (Yaghi *et al.,* 2013). (Oliveira *et al.*, 2011) supports our results conclude that WUE reflects the conversion rate of the fruit, i.e., the amount of fresh matter produced by each unit of water applied. Thus, the concept of WUE is relative, i.e., a greater efficiency does not correspond to increased yield. Similarly, (Dermitas and Ayas, 2009) established that the cucumber plant showed higher WUE values for lower water stress rates. Thus, improved WUE may be achieved by reducing the water supply. However, excessive reduction of irrigation reduced the crop yields (Li *et al.*, 2017a).

The highest irrigation water use efficiency for cucumber crop was found in T14 (321.48 kg/ha/mm). For bottle gourd crop maximum water productivity (15.93 kg/m^3) found in T9 and highest irrigation water use efficiency (272.43 kg/ha/mm) in treatment 11. The same result was founded by (Shatoury *et al.,* 2014), Rosin *et al.,* (2017).

By irrigating only the first two stages means the average harvested yield of T4, T5 and T11 was 41.86 ton/ha, 27.12 ton/ha and 31.51 ton/ha for tomato, cucumber and bottle gourd crop respectively. With this rainfall condition, either irrigation or no irrigation in the late and mid-stage didn’t show any significant difference in yield.

Table 7, 8 and 9 shows the yield and water productivity for different irrigation scheduling, this helps the farmers to choose the best combination based on the water availability, the irrigated area.

Taking the input amount of water as the independent variable and defining the yield, WP, CWUE and IWUE as the dependent variables, then, regression analysis was conducted (Table 8, Table 10 and Table 12) for tomato, cucumber and bottle gourd crop. Results showed that the effects of irrigation amount on each dependent variable were significant (P <0.05). Water use efficiency can be increased by two means, either by increasing yield by genetic manipulation, developing high genetically potential variety which is a task of life science or as a water conservator, reduction in evaporation and reduction in transpiration rate up to maximum extent that would not deter to crop production, increasing water holding capacity, reduction in runoff and percolation losses could of immense significance.

In conclusion, within the scenarios of water scarcity, the concept of water productivity plays a strategic role in the sustainability of water resources. The increasing water scarcity and mismanagement of the available water resources are nowadays major threats to sustainable development for the various sectors, especially domestic, industrial and agricultural. This experiment was carried out aiming at improving water productivity and water use efficiency of tomato, cucumber and bottle gourd crop for the temperate condition of Kashmir. The experiment stressed vegetable crops at different growth stages to identify its sensitivity to water stress at different growth stages, the critical time for irrigation application in the case of limited water resources and the level of water productivity under water-stressed conditions. The initial and development stage of vegetables needs more water than the mid and end-stage (Studer and Spoehel, 2019). So by providing limited water to the mid and end-stage, water can be saved significantly, hence water productivity also increases.

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