DOI: 10.54083/ResBio/5.1.2023/27-32

Res. Bio., 2023, 5(1):27-32

Research Biotica

e-ISSN: 2582-6743

March, 2023

Article ID: RB162 **Research Article**

Precision Irrigation Strategies for Wheat (*Triticum aestivum* L.) Farming: Influence of Drip Lateral Geometry, Irrigation Regimes and Frequency on Crop Performance

D.D. Vadalia*, H.V. Agravat, G.V. Prajapati, P.A. Pandya and S.H. Parmar

Centre of Excellence on Soil and Water Management, Office of the Research Scientist (Agril. Engg.), Junagadh Agricultural University, Junagadh, Gujarat (362 001), India

Corresponding Author

D.D. Vadalia

✉: daxv30@gmail.com

Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Vadalia *et al*., 2023. Precision Irrigation Strategies for Wheat (*Triticum aestivum* L.) Farming: Influence of Drip Lateral Geometry, Irrigation Regimes and Frequency on Crop Performance. *Research Biotica* 5(1): 27-32.

Abstract

A substantial rise in water consumption as a result of rapid population development and rising living standards has resulted in acute water shortages. Effective water management has become crucial to address this issue. One approach is to adopt irrigation technologies and implement efficient irrigation scheduling to optimize limited water resources. The agricultural industry must find ways to grow more food while using less water, which can be done through improving crop water productivity. The timing and amount of w ter to be applied to crops is determined by irrigation scheduling, which helps to avoid over or under watering. Drip irrigation is increasingly utilized in this region due to its potential for enhancing agriculture production with efficient use of water. Drip irrigation must be scheduled correctly for effective water management in crop production. Realizing the necessity, at Junagadh Agricultural University, an experiment was carried out during year 2018-19, to study effect of drip lateral geometry (3 rows per lateral, 4 rows per lateral and 6 rows per lateral), irrigation regimes (1.0 ET_c and 0.8 ET_c) and irrigation frequency (2 days, 3 days and 5 days) on wheat. Each treatment was replicated twice. Results revealed that higher plant height (115.01 cm), number of productive tiller (480.50), number of grains spike^{-1} (47), test weight (59.83 g) and highest grain yield (4,825 kg ha^{-1}) and straw yield (7,655 kg ha^{-1}) was observed under drip lateral geometry of 3 rows per lateral, scheduled at 0.8 ET_c and 2 days irrigation frequency.

Keywords: Drip irrigation, Irrigation frequency, Lateral geometry, Precision irrigation, Wheat

Introduction

For India's food security, wheat (*Triticum aestivum* L.) is the most crucial and strategically vital cereal crop. After rice, wheat is the second-most significant staple crop in India. With the productivity of 2.98 t ha^{-1}, India stands second with the production of 93 million tonnes from the area of 30 million hectares. Indian subcontinent is facing the problems of ever-growing population and increasing urbanization which has led to increasing the amount of water needed for home, industrial, and agricultural purposes. Precipitation acts as the main water source and the adequacy of effective rainfall is of utmost importance for agricultural activities in the country (Chavda *et al.*, 2016). In India, flood irrigation is used to irrigate the majority of an area growing wheat, which has a very low water use efficiency. Water is a main constraint in arid and semi-arid regions for intensive irrigation (Pandya and Rank, 2014). Groundwater, in particular, is increasingly being exploited in an unsustainable manner to meet irrigation needs (Pandya and Gontia, 2023). The use of flood irrigation, which has a poor water use efficiency (35-40%), is the main cause of the inadequate irrigation coverage (Vadalia and Prajapati, 2022). One of the main factors limiting irrigation coverage is the prevalent use of flood irrigation, which uses water inefficiently (Prajapati and Subbaiah, 2015; Prajapati *et al.*, 2016). Because of significant conveyance and distribution losses, estimates of water use efficiency under the flood irrigation range from 35 to 40% (Rosegrant, 1997).

Article History

RECEIVED on 02nd December 2022 RECEIVED in revised form 18th March 2023 ACCEPTED in final form 21st March 2023

Currently, more than 60% of the wheat-growing region is irrigated, with roughly 50% receiving only one or two irrigations (Chauhan *et al.*, 2015). Lower crop productivity is caused by a number of negative factors including a lack of sufficient groundwater reserves in terms of both quantity and quality, excessive evaporation rates, inadequate rainfall, and increased pest and insect damage from climate change (Prajapati and Subbaiah, 2019). Because there is a range of variables affecting crop production loss, such as pest/ disease infestation, genotypes, etc., restricted water availability is not the only factor responsible (Pandya *et al.*, 2022). The gridded information on temperature are generally being used for various application in agriculture (Parmar *et al.*, 2019). Achieving increased yield per drop of water requires managing favourable soil moisture in the crop root zone and preventing soil losses (Prajapati and Subbaiah, 2018). The economic restriction of traditional irrigation methods, which develops significantly high variations in the soil-water potential, can be partially removed by drip irrigation systems that may supply water to the soil in small amounts as often as required without incurring additional costs (Vadalia *et al.*, 2022).

Micro-irrigation, which mostly uses drip and sprinkler irrigating methods, is one of the demand management techniques recently developed to reduce the consumption of water in Indian agriculture. Only the necessary amount of water is applied using drip irrigation systems. As a result, it would reduce water loss caused by seepage, percolation, and runoff. It helps in achieving saving water for irrigation (Gao *et al.*, 2010; Kharrou *et al.*, 2011), increased water use efficiency (Wang *et al.*, 2013), reduced tillage requirements, better-quality goods, higher crop yields, and more effective fertilizer use (Namara *et al.*, 2005; Burney *et al.*, 2010; Lodhi *et al.*, 2013). It is essential to accurately estimate the crop water requirements (ET_c) of any crop in order to plan irrigation and manage water resources which will increase irrigation efficiency (Parmar and Tiwari, 2020). A strategy for planning the use of a limited water supply and for allocating priority among multiple irrigated crops is to capitalise on the time of the deficit irrigation. There is a need to develop farming techniques that increase productivity per unit of water use, such as irrigation scheduling and planting systems. The benefits of drip irrigation can be fully realized when the system is designed with efficiency in mind and irrigation schedules are implemented correctly (Kunapara *et al.*, 2016). It's crucial to develop an efficient and cost-effective irrigation schedule under a specific agro-climatic condition for the purpose to maintain the ideal soil moisture in the root zone of the wheat crop when implementing drip irrigation. Therefore, this attempt is to study the effect of drip lateral geometry, irrigation regimes and frequency for better yield and monetary benefits for wheat.

Materials and Methods

Field Experimental Details

At the research farm of Research Scientist (Agril Engg), JAU, Junagadh, the experiment was conducted during the rabi season of 2018-19 to evaluate the conjunctive impact of three lateral geometry; 3 rows per lateral (L_1), 4 rows per lateral (L_2), 6 rows per lateral (L_3), two irrigation levels; 0.8 ET_c (I_1) and 1.0 ET_c (I_2), and three irrigation frequencies; 2 days (F_1), 3 days (F_2), 5 days (F_3), on wheat crop. Plot sizes were kept as 2.7 m × 10 m. Large plot technique was adopted and each treatment was replicated twice. The volumetric water content at field capacity and the permanent wilting point were determined as 39% and 15%, respectively, in the sandy loam soil (1.0-1.5 m depth). A tractor-driven cultivator and rotavator were used to plough the field. Wheat (GW-366) seed was sown at a spacing of 22.5 cm during the third week of November using a tractor-mounted seed cum fertiliser drill. The seeding rate was 100 kg ha^{-1}. As per recommended fertiliser N:P:K (120:60:60) dose, 60 kg of nitrogen and the entire amount of phosphate and potash were applied as a base dose. After 21 days, 60 kg of nitrogen was added.

Irrigation Scheduling

For the research, drip irrigation system, having an emitter with a 4 lph discharge and 0.6 m of spacing was adopted. The scheduling of irrigation was done using reference evapotranspiration (ET_0). Penman Monteith (PM FAO-56) approach irrigation water requirement in each treatment was estimated considering adjusted FAO K_c values and ET_0,

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad .... (1)$$

Where, ET_0 = reference evapotranspiration (mm day^{-1}); R_n = net radiation at the crop surface (MJ m^{-2} day); G = soil heat flux density (MJ m^{-2} day); T = mean daily air temperature at 2 m height (°C); u_2 = wind speed at 2 m height (m s^{-1}); e_s = saturation vapour pressure (kPa); e_a = actual vapour pressure (kPa); e_s-e_a = saturation vapour pressure deficit (kPa); Δ = slope vapour pressure curve (kPa°C^{-1}); γ = psychrometric constant [kPa °C^{-1}].

Determination of FAO K_c Values

Crop coefficient for the wheat calculated using procedure suggested by FAO. As suggested by Allen *et al.* (1998) initial stage crop coefficient ($K_{c\,ini}$) was adjusted by multiplying the fraction of the surface wetted by trickle irrigation (0.4) with FAO-56 tabulated value for $K_{c\,ini}$ and $K_{c\,mid}$ and $K_{c\,end}$ were adjusted using the equation (3) and (4),

$$K_{c\,ini} = f_w \times K_{c\,ini\,(tab\,fig)} \quad .... (2)$$

$$K_{c\,mid} = K_{c\,mid\,(tab)} + [\,0.04\,(u_2 - 2) - 0.004\,(RH_{min} - 45)](\frac{h}{3})^{0.3} \quad .... (3)$$

$$K_{cend} = K_{cend\,(tab)} + [\,0.04\,(u_2 - 2) - 0.004\,(RH_{min} - 45)](\frac{h}{3})^{0.3} \quad .... (4)$$

Where, f_w = fraction of surfaced wetted by irrigation or rain (0-1); u_2 = mean value of daily wind speed at 2 m height over grass during the mid-season growth stage (m s^{-1}); for 1 m s^{-1} ≤ u_2 ≤ 6 m s^{-1}; RH_{min} = mean value of daily minimum relative humidity; h = mean plant height during the mid-season.

To compute ET_c for different treatments, reference evapotranspiration (ET_0) was multiplied with determined

Adjusted FAO K_c values,

$ET_c = K_c \times ET_0$ .... (5)

Irrigation scheduling was done based on compute ET_c, Considering the application efficiency of 90% for drip irrigation, Irrigation was applied at 50% deficiency of available water at 2 days, 3 days and 5 days interval at 1.0 ET_c and 0.8 ET_c.

Harvesting of Crops

Crop period of wheat is about 110-120 days. The plant height was measured from each treatment before harvest. Wheat crop was harvested manually with sickle. For each treatment plants from 1 m^2 area were gathered and tied with string to create bunches of plants. All plant bunches were dried in open fields after harvesting for a period of 4-5 days. Crop production parameters, such as productive tillers, the number of grains per spike, grain yield, straw yield, and test weight were evaluated from each treatment and analysed statically using Factorial Completely Randomized Design.

Results and Discussion

The research area generally has a subtropical and semi-arid climate, which is distinguished by a warm and moderately humid monsoon season, a hot and dry summer, and a rather cold and dry winter. In this area, partial monsoon failure occurs every three to four years. The weekly mean of daily maximum and minimum temperatures (27.0 to 42.7 °C, 10.0 to 27.3 °C), maximum and minimum relative humidity (28.1% to 94.6%, 10.4% to 87.3%), wind speed (2.1 km h^{-1} to 12.8 km h^{-1}), bright sunshine hours (0.8 hr to 10.6 h), and pan evaporation (0.6 mm to 10.7 mm) varied over the past 35 years, according to weather data recorded near to the experimental site.

The lowest and highest reference evapotranspiration, temperature, and relative humidity were recorded as 2.10 mm and 5.60 mm, 6.50 °C and 36.50 °C, 8% and 94%, respectively, over the course of the experiment period (November to March). For the growth of irrigated wheat there were more or less harmonic weather conditions.

Crop Coefficient Values

As per FAO-56, crop coefficients for wheat is 0.7, 1.15 and 0.25 for initial, mid and end stage respectively. Adjusted crop coefficient for Initial, Midseason and Maturity was calculated using equations (1 to 3). As shown in table 1, for initial, development, mid and end growth stages stage of wheat adjusted crop coefficient (K_c) was observed as 0.28, 0.28-1.23, 1.23 and 0.38, respectively.

Table 1: K_c value under standard and local adjusted conditions

Plant growth stages	DAS	Actual K_c FAO	K_c adjusted
Initial	0 to 15	0.70	0.28
Development	15 to 40	0.70-1.15	0.28-1.23
Midseason	40 to 90	1.15	1.23
Maturity	90 to 120	0.25	0.38

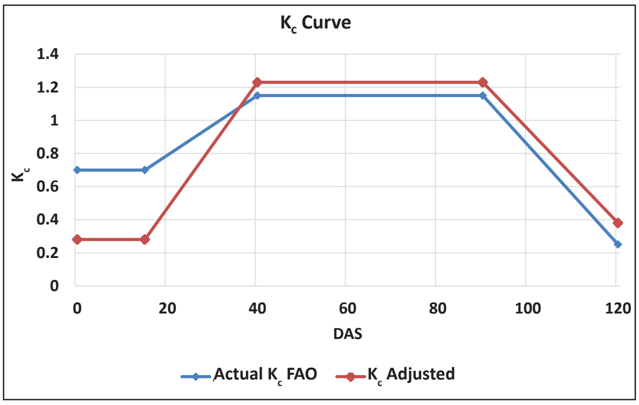

Figure 1: Adjusted crop coefficient curve of K_c FAO

Irrigation Requirement of Wheat

First 50 mm irrigation was applied to all the treatments for uniform emergence and germination; after that irrigation was applied as per treatments. The irrigation was withheld 15 days before maturity. For different treatments total quantity of water applied is presented in table 2.

Table 2: Total quantity of water applied to different treatments

Irrigation regimes	Total depth of irrigation (mm)
I1 (0.8 ET_c)	376.51
I2 (1.0 ET_c)	458.14
Border Irrigation (Control)	600.00

Crop Parameters

Crop yield parameters at harvesting were observed for different lateral geometry, irrigation regimes and irrigation frequency during winter season 2018-19. The statistical analysis on the effect of lateral geometry, irrigation regimes and frequency was carried out and presented in table 3.

Plant Height

The plant height was decrease with increase in lateral spacing. Interaction effect of lateral geometry, irrigation regimes and irrigation frequency on plant height showed statistical significant difference among the treatments. Results revealed that the treatment combination $L_1I_1F_1$ recorded significantly higher plant height (115.01 cm) followed by $L_1I_2F_2$ (99.78 cm) and $L_1I_1F_2$ (93.97 cm). Minimum plant height (65.26 cm) was observed in treatment combination $L_3I_1F_3$. Treatment $L_1I_1F_3$ was at par with $L_3I_1F_2$, treatment $L_2I_1F_1$ was at par with $L_3I_2F_1$ and treatment $L_1I_2F_3$ was at par with $L_2I_2F_2$.

Productive Tillers

The number of productive tillers m^{-2} was significantly influenced by lateral geometry, irrigation regimes and irrigation frequency. The number of productive tillers were decrease with increase in lateral spacing and irrigation frequency, increased with increase in irrigation levels. Treatment $L_1I_1F_1$ recorded significantly higher number of productive tillers (480.5) followed by $L_1I_2F_1$ (423.5) and $L_1I_2F_2$ (411). Treatment $L_2I_1F_3$ was at par with $L_3I_2F_2$. Minimum number of productive tillers (199) was observed in treatment

Table 3: Crop yield parameters of wheat for different treatments at harvest

Treatments	Plant height (cm)	Productive tillers (m^{-2})	Grains spike^{-1} (No.)	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
$L_1 I_1 F_1$	115.01	480.50	47.40	59.83	4825	7655
$L_1 I_1 F_2$	93.97	406.00	42.71	44.22	4015	5801
$L_1 I_1 F_3$	74.34	282.50	31.53	37.98	2960	4916
$L_1 I_2 F_1$	79.96	423.50	43.34	44.88	4195	6635
$L_1 I_2 F_2$	99.78	411.00	42.93	44.46	4180	6574
$L_1 I_2 F_3$	82.24	355.00	41.14	41.87	3750	5508
$L_2 I_1 F_1$	78.63	319.00	41.45	42.65	3885	5578
$L_2 I_1 F_2$	90.24	312.00	38.40	39.49	3245	5282
$L_2 I_1 F_3$	86.60	244.50	30.44	35.24	2289	4081
$L_2 I_2 F_1$	81.12	403.00	42.21	42.91	3945	5603
$L_2 I_2 F_2$	82.34	319.50	38.53	40.19	3270	5440
$L_2 I_2 F_3$	88.02	278.50	30.88	37.81	2945	4454
$L_3 I_1 F_1$	71.03	238.00	27.77	30.83	1852	3006
$L_3 I_1 F_2$	74.12	217.00	20.20	30.55	1502	2943
$L_3 I_1 F_3$	65.26	199.00	24.03	29.79	1489	2833
$L_3 I_2 F_1$	78.66	256.50	30.49	36.48	2650	4299
$L_3 I_2 F_2$	78.11	243.50	30.41	35.20	2220	3875
$L_3 I_2 F_3$	88.06	241.50	29.45	35.10	1985	3363
S.Em. ±	6.18	19.71	1.87	2.30	186.55	278.9
C.D.	18.36	58.57	5.55	6.84	554.28	828.66
C.V.%	10.43	8.91	7.51	8.26	8.60	8.08

*S.Em. ±: standard Error of mean; C.D.: Coefficient of difference at 5%; C.V.: Coefficient of variance

$L_3I_1F_3$ Better plant population and stand establishment of wheat can be ensured by optimal soil moisture.

Number of Grains Spike^{-1}

Grains spike^{-1} was decrease with increase in lateral geometry and irrigation levels, decrease with increase in irrigation frequency. Treatment combination $L_1I_1F_1$ recorded significantly higher number of grains spike^{-1} (47.4) followed by $L_1I_2F_1$ (43.34) and $L_1I_2F_2$ (42.93). Minimum number of grains spike^{-1} (20.2) was observed in treatment $L_3I_1F_2$. Adequate moisture availability during the whole season resulted the higher grains spike^{-1} in treatment $L_1I_1F_1$.

Test Weight (1000 Grains)

The test weight was decrease with increase in lateral geometry and irrigation frequency. Interaction effect of lateral geometry, irrigation regimes and irrigation frequency on test weight showed significant difference. The results revealed that treatment combination $L_1I_1F_1$ recorded significantly higher number of test weight (59.83 g) followed by $L_1I_2F_1$ (44.88 g) and $L_1I_2F_2$ (44.46 g). Minimum test weight (29.79 g) was observed in treatment combination of treatment $L_3I_1F_3$.

Grain Yield

The grain yield was decrease with increase in lateral geometry. Highest grain yield was observed in lateral geometry L_1, which is significantly higher than lateral geometry L_2 and L_3. The current pattern aligns with the predictions made by Dangar *et al.* (2017) and Dholiya *et al.* (2017). It was increased with increase in irrigation levels. Similar results were observed by Hong *et al.* (2006). It was decrease with increase in irrigation frequency. Highest grain yield was observed in frequency F_1 which is significantly higher than frequency F_2 and F_3. Bhowmik *et al.* (2018) and Barkha *et al.* (2017) also observed the same trend.

Interaction effect of lateral geometry, irrigation regimes and irrigation frequency on grain yield showed significant difference. Results revealed that treatment $L_1I_1F_1$ recorded significantly higher grain yield (4,825 kg ha^{-1}) followed by $L_1I_2F_1$ (4,195 kg ha^{-1}) and $L_1I_2F_2$ (4,180 kg ha^{-1}). Minimum grain yield (1,489 kg ha^{-1}) was observed in treatment $L_3I_1F_3$. The cumulative effect of improved growth and yield characteristics led to a higher grain yield. Zhang *et al.* (2002) emphasised that higher water usage doesn't always correspond into the highest yield of wheat. Under certain circumstances, increased water consumption by wheat might result in lower output. In conjunction with that, wheat yield and CWP showed a close linear relationship. Field tests conducted by other researchers (Cabello *et al.*, 2009; Li *et al.*, 2005; Sun *et al.*, 2006) showed similar results, adding more water than ET_c will not will not boost production since the extra water will be lost to deep percolation and/or unproductive soil evaporation. If there is an excessive amount of water allowed, the yield may even decrease due to water logging or nutrient loss from the root zone.

Straw Yield

Straw yield was decrease with increase in lateral spacing and irrigation frequency, increased with increase in irrigation levels. Treatment $L_1I_1F_1$ recorded significantly higher straw yield (7,655 kg ha^{-1}) followed by $L_1I_2F_1$ (6,635 kg ha^{-1}) and $L_1I_2F_2$ (6,573.5 kg ha^{-1}). Minimum straw yield (2,832.5 kg ha^{-1}) was observed in treatment $L_3I_1F_3$. Treatment $L_1I_2F_3$ was at par with $L_2I_1F_1$. This means that increased irrigation does not always equate to increased yield. Dong *et al.* (2007) investigated the North China Plain yield of 19 distinct wheat species using various irrigation techniques, discovered the same results.

Conclusion

Highest plant height (115.01 cm), number of productive tiller (480.50), number of grains $spike^{-1}$ (47), test weight (59.83 gm), grain yield (4,825 kg ha^{-1}) and straw yield (7,655 kg ha^{-1}) of wheat was observed under 3 rows per lateral scheduled at 0.8 ET_c irrigation regimes with 2 days irrigation frequency. Therefore, it can be concluded that to attain better yield and monetary benefits the drip lateral should be spaced at 3 rows of wheat and irrigated at 0.8 ET_c irrigation regimes with 2 days irrigation frequency.

Acknowledgement

The authors are thankful to Centre of Excellence on Soil and Water, Office of the Research Scientist (Agril. Engg.), Junagadh Agricultural University, Junagadh for providing necessary support for the experiment.

References

Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998. Crop evapotranspiration: Guidelines for 16 computing crop water requirements. FAO Irrigation and Drainage Paper 56. FAO, Rome, Italy. pp. 1-134. URL: https://www.fao.org/3/X0490E/x0490e00.htm.

Barkha, S., Bhanvadia, A.S., Dholiya, S.N., 2017. Yield, water use efficiency and economics of wheat (*Triticum aestivum* L.) as influenced by drip irrigation scheduling and nitrogen levels. *Journal of Pharmacognosy and Phytochemistry* 6(5), 314-316.

Bhowmik, T., Bhardwaj, A.K., Pandiaraj, T., Roy, A., 2018. Productivity, water use efficiency and profitability of drip irrigated wheat (*Triticum aestivum*) in Indo-Gangatic Plains of Uttarakhand, India. *International Journal of Current Microbiology and Applied Sciences* 7(2), 3185-3191. DOI: https://doi.org/10.20546/ijcmas.2018.702.383.

Burney, J., Woltering, L., Burke, M., Naylor, R., Pasternak, D., 2010. Solar-powered drip irrigation enhances food security in the Sudano-Sahel. *Proceedings of the National Academy of Sciences* 107(5), 1848-1853. DOI: https://doi.org/10.1073/pnas.0909678107.

Cabello, M.J., Castellanos, M.T., Romojaro, F., Martinez-Madrid, C., Ribas, F., 2009. Yield and quality of melon grown under different irrigation and nitrogen rates. *Agricultural Water Management* 96(5), 866-874. DOI: https://doi.org/10.1016/j.agwat.2008.11.006.

Chauhan, R.P.S., Yadav, B.S., Singh, R.B., 2015. Studies on crop yield responses to deficit irrigation and levels of nitrogen in wheat, water, energy and food security. *The Journal of Rural and Agricultural Research* 15(1), 15-17.

Chavda, D.B., Makwana, J.J., Parmar, H.V., Kunapara, A.N., Prajapati, G.V., 2016. Estimation of runoff for Ozat catchment using RS and GIS based SCS-CN method. *Current World Environment* 11(1), 212-217. DOI: https://doi.org/10.12944/CWE.11.1.26.

Dangar, D.M., Dwivedi, K., Mashru, H.H., 2017. Effect of irrigation regimes and lateral spacing on drip irrigated wheat. *International Journal of Agricultural Science and Research* 7(1), 417-422.

Dholiya, S.N., Bhanvadia, A.S., Barkha, 2017. Growth and yield attributes of wheat (*Triticum aestivum* L.) as influenced by lateral spacing with drip irrigation and nitrogen levels. *Journal of Pharmacognosy and Phytochemistry* 6(5), 694-696.

Dong, B., Zhang, Z., Liu, M., Zhang, Y., Li, Q., Shi, L., Zhou, Y., 2007. Water use characteristics of different wheat varieties and their responses to different irrigation scheduling. *Transactions of the CSAE* 23(9), 27-33.

Gao, Y., Ren, Z., Duan, R., Zhuang, W., Huang, J., Wang, R., 2010. Planting technique for spring wheat with saving water, high yield and high efficiency under drip irrigation system. *Xinjiang Agric. Sci.* 47(2), 281-284.

Hong, Y.S., Chang, M L., Xi, Y.Z., Yan, J.S., Yong, Q.Z., 2006. Effects of irrigation on water balance, yield and WUE of winter wheat in the North China Plain. *Agricultural Water Management* 85(1-2), 211-218. DOI: https://doi.org/10.1016/j.agwat.2006.04.008.

Kharrou, M.H., Raki, S.E., Chehbouni, A., Duchemin, B., Simonneaux, V., LePage, M., Ouzine, L., Jarlan, L., 2011. Water use efficiency and yield of winter wheat under different irrigation regimes in a semi-arid region. *Agricultural Sciences* 2(3), 273-282. DOI: https://doi.org/10.4236/as.2011.23036.

Kunapara, A.N., Subbaiah, R., Prajapati, G.V., Makwana, J.J., 2016. Influence of drip irrigation regimes and lateral spacing on cumin productivity. *Current World Environment* 11(1), 333-337. DOI: https://doi.org/10.12944/CWE.11.1.40.

Li, J., Inanag, S., Li, Z., Eneji, A.E., 2005. Optimizing irrigation scheduling for winter wheat in the North China Plain. *Agricultural Water Management* 76(1), 8-23. DOI: https://doi.org/10.1016/j.agwat.2005.01.006.

Lodhi, A.S., Kaushal, A., Singh, K.G., 2013. Effect of irrigation regimes and low tunnel height on micro climatic parameters in the growing of sweet pepper. *International Journal of Engineering and Science Invention* 2(7), 20-29.

Namara, R.E., Upadhyay, B., Nagar, R.K., 2005. Adoption and impacts of micro-irrigation technologies. Research Report 93. International Water Management Institute, Colombo, Sri Lanka. pp. 45-152.

Pandya, P., Gontia, N.K., Parmar, H.V., 2022. Development of PCA-based composite drought index for agricultural drought assessment using remote-sensing. *Journal of Agrometeorology* 24(4), 384-392. DOI: https://doi.org/10.54386/jam.v24i4.1738.

Pandya, P., Gontia, N.K., 2023. Development of drought severity-duration-frequency curves for identifying drought proneness in semi-arid regions. *Journal of Water and Climate Change* 14(3), 824-842. DOI: https://doi.org/10.2166/wcc.2023.438.

Pandya, P.A., Rank, H.D., 2014. Summer sesame response to irrigation methods and mulching. *Research on Crops* 15(4), 810-815. DOI: https://doi.org/10.5958/2348-7542.2014.01416.8.

Parmar, S.H., Tiwari, M.K., 2020. Estimation of reference and crop evapotranspiration in Panam canal command using remote sensing and GIS. *International Journal of Current Microbiology and Applied Sciences* 9(8), 2141-2151. DOI: https://doi.org/10.20546/ijcmas.2020.908.244.

Parmar, S.H., Tiwari, M.K., Pargi, D.L., Pampaniya, N.K., Rajani, N.V., 2019. Modeling the land surface temperature using thermal remote sensing at Godhra, Gujarat. *Journal of Agrometeorology* 21(1), 107-109. DOI: https://doi.org/10.54386/jam.v21i1.216.

Prajapati, G.V., Subbaiah, R., 2019. Crop coefficients of *Bt* cotton under variable moisture regimes and mulching. *Journal of Agrometeorology* 21(2), 166-170. DOI: https://doi.org/10.54386/jam.v21i2.227.

Prajapati, G.V., Subbaiah, R., 2018. Combined response of irrigation system regimes and mulching on productivity of *Bt* Cotton. *Journal of Agrometeorology* 20 (Special Issue - NASA-2014, Part-II, 47-51.

Prajapati, G.V., Subbaiah, R., Kunapara, A.N., Vithlani, N.S., Makwana, J.J., 2016. Crop coefficient for mulched cotton under variable irrigation regimes. *Current World Environment* 11(2), 648-653. DOI: https://doi.org/10.12944/CWE.11.1.37.

Prajapati, G.V., Subbaiah, R., 2015. Response of *Bt* cotton productivity to conjunctive stimulus of irrigation regimes and mulching. *Research on Crops* 16(3), 509-514. DOI: https://doi.org/10.5958/2348-7542.2015.00071.6.

Rosegrant, W.M., 1997. Water resources in the twenty-first century: challenges and implications for action, food, agriculture and the environment. Discussion paper 20. International Food Policy Research Institute, Washington DC, USA. pp. 10-25.

Sun, H.Y., Liu, C.M., Zhang, X.Y., Shen, Y.J., Zhang, Y.Q., 2006. Effect of irrigation on water balance, yield and WUE of winter wheat in the North China Plain. *Agricultural Water Management* 85, 211-218. DOI: https://doi.org/10.1016/j.agwat.2006.04.008.

Vadalia, D.D., Prajapati G.V., Parmar, S.H., Gohil, G.D., 2022. Determination of growth-stage-specific crop coefficients (K_c) for drip irrigated Wheat (*Triticum aestivum* L.) under different land configurations. *Research Biotica* 4(2), 69-73 DOI: https://doi.org/10.54083/ResBio/4.2.2022/69-73.

Vadalia, D.D., Prajapati, G.V., 2022. Determination of crop coefficients for wheat (*Triticum aestivum* L.) under different land configuration and irrigation systems. *The Pharma Innovation Journal* 11(1), 1245-1249.

Wang, J.D., Gong, S., Xu, D., Yu, Y., Zhao, Y., 2013. Impact of drip and level-basin irrigation on growth and yield of winter wheat in the North China Plain. *Irrig. Sci.* 31(5), 1025-1037. DOI: https://doi.org/10.1007/s00271-012-0384-7.

Zhang, X., Pei, D., Hu, C., 2002. Index system for irrigation scheduling of winter wheat and maize in the piedmont of Mountain Taihang. *Transactions of the CSAE* 18(6), 36-41.