



Improvement in yield and quality of okra (*Abelmoschus esculentus*) through crop spacing, mulching and irrigation levels in arid regions

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ABSTRACT

The field experiments were conducted during the rainy (*khariif*) seasons of 2018–19 and 2019–20 at College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan to study the effect of crop spacing, mulching and irrigation levels on yield and quality of okra [*Abelmoschus esculentus* (L.) Moench]. Experiment was laid out in split plot design (SPD) with four irrigation levels [40, 60, 80 and 100% pan evaporation (PE)] in the main plot. Two crop geometries (normal sowing and paired row sowing) and three mulches (no mulch, straw and plastic mulch in black colour) were used in the sub-plot and sub-sub-plot, respectively. The study found that using 40% of PE for irrigation led to the shortest time to first flowering (41.72 days). However, the highest fruit yield, leaf area index (LAI), total soluble solids (TSS), protein content and cost-benefit ratio (B:C ratio) were achieved when irrigating at 100% PE followed by 80% PE. Water use efficiency (WUE) was highest (17.24 kg/ha/mm) at 40% PE irrigation level. The highest fruit yield of 153.1 g/plant and 122.4 q/ha was achieved when straw mulch was applied. Considering the combined data, it's worth mentioning that the B:C ratio was significantly greater when utilizing 100 PE irrigation without mulch. Conversely, WUE at 19.1 kg/ha/mm, showed a significant increase when employing 40% PE irrigation along with straw mulch. Therefore, the study demonstrates that utilizing paired row sowing with straw mulch and irrigation at 100% PE resulted in the highest growth attributes, fruit quality of okra and B:C ratio.

Keywords: *Abelmoschus esculentus*, Crop geometries, Drip irrigation, Water use efficiency

Okra [*Abelmoschus esculentus* (L.) Moench] is a significant vegetable plant belonging to the Malvaceae family (Narayan *et al.* 2021). The cultivation of okra centers on its tender fruits, which find extensive use in diverse culinary dishes. Notably, okra fruit is valued for its iodine content, making it valuable in the prevention of goiter. Additionally, its leaves possess anti-inflammatory properties and are employed in the treatment of dysentery (Sarkar *et al.* 2022). Effective water management becomes crucial, especially in Rajasthan's arid regions, characterized by scarce water availability, high temperatures, low soil water retention, and unpredictable rainfall patterns. Drip irrigation (DI), known for its water-saving benefits, extends the coverage of irrigation, boosts crop yields, and maximizes WUE (Yang *et al.* 2023). Proper crop layout around drip

lines is essential to maximize the benefits (Mahmoudi *et al.* 2020), with DI systems achieving an impressive efficiency rate up to 90%, surpassing traditional methods. Drip irrigation has been effective in the cultivation of okra, improving growth, yield, water use efficiency, and farmer profits (Neelakanth *et al.* 2020). Mulching techniques are widely employed in irrigated crop and when combined with DI, they prove highly effective in promoting crop growth and fruit quality. Plastic mulch, helps to raise soil temperature and retain proper moisture, which is advantageous for plant growth. In the case of okra cultivation, various mulching methods are adopted to suppress weeds growth and conserve moisture around the crop's root zone. Straw mulching, a chemical-free approach that involves using organic material to cover the ground, offers several benefits (Sinha *et al.* 2019, Busari *et al.* 2023). In arid and semi-arid areas, okra farming is typically reserved for the rainy season because the harsh conditions of high temperatures and strong winds during spring and summer can lead to plant losses and decreased fruit production. Considering these facts, we formulated a hypothesis to explore whether employing portfolios of efficient management practices such as improved crop establishment methods like varying irrigation levels, crop geometry, and mulching could serve

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as innovative approaches. These approaches have shown promise as potential strategies to boost the profitability of okra cultivation in areas with scarce water resources.

MATERIALS AND METHODS

The field experiments were conducted during the rainy (*kharif*) seasons of 2018–19 and 2019–20 at College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner (28°01'N and 73°22'E at an altitude of 234.70 meter amsl.), Rajasthan. Total rainfall received during the first crop season was 230.2 mm whereas it was 213.8 mm during the second crop season. The temperature ranged from 35.0 to 39.5°C (max) and 16.7 to 26.9°C (min) in 2018–19, and from 32.6 to 40.7°C (max) and 15.8 to 28.0°C (min) in 2019–20. The soil was loamy included 0.13% soil organic carbon, 93.4 kg/ha of available N, 14.3 kg/ha of available P, 203.5 kg/ha of available K, EC of 0.16 dS/m, and pH of 8.5 based on the respective methods and sources (Walkley and Black 1947, Olsen *et al.* 1954, Richards 1954, Subbiah and Asija 1956, Metson 1957).

The experiment was laid out in split plot design (SPD) having 4 irrigation levels (40, 60, 80 and 100% PE) in main-plots and 2 crop geometry in sub-plots (normal sowing with 50 cm row spacing and paired row sowing at 30 cm × 70 cm) and mulch in sub-sub plots (no mulch, straw, and plastic mulch in black colour) with three replications. Drip irrigation was applied based on local evaporative demand data from an Agro-meteorological observatory at University in Bikaner, Rajasthan (Table 1). Two different crop geometries were tested, each with equal plant populations: one with two rows at 50 cm spacing around lateral lines and 50 cm spacing between groups of crop rows, and the other with two rows at 30 cm spacing around laterals and 70 cm spacing between groups of crop rows. Mulch, either mustard straw at a rate of 10 t/ha or plastic sheeting (25 micron in black colour), was used between rows at 20 DAS in marked plots. The well rotten FYM @220 q/ha was applied at the time of field preparation. Uniform full doses of 60 kg/ha P₂O₅, 50 kg/ha K₂O, and half dose of 50 kg/ha through single super phosphate, muriate of potash, and urea, respectively, were applied at the time of sowing as basal dose and remaining half dose of N was top dressed at 30 DAS.

Data were collected for various parameters, including plant population at harvest, days to first flowering, fruit yield per plant, and per hectare, LAI, TSS content, protein content, WUE and B:C ratio. The leaf area index was calculated by using this equation:

$$LAI (cm^2) = L \times W \times K$$

where L, Leaf length (cm); W, Leaf width (cm) and K, 0.62 for okra.

The nitrogen content in fruit was assessed using the colorimetric method given by Snell and Snell (1949). Subsequently, the protein content was computed as:

$$Protein (mg/100 g) = Nitrogen \times 6.25$$

Data subjected to analysis of variance (ANOVA) and

statistical analysis was done by Microsoft Excel (Microsoft Corporation, USA) packages.

RESULTS AND DISCUSSION

Effect of irrigation levels, crop geometry and mulches on yield attributes: The highest fruit yield, averaging 160.9, 163.6, and 162.3 g/plant, was achieved under 100% PE drip irrigation. Conversely, the lowest fruit yield was observed with 40% PE drip irrigation, where average yield 115.7, 117.4, and 116.5 g/plant (Table 1). Higher irrigation levels (80% and 100% PE) ensured stress-free conditions, supporting optimal plant growth throughout the growing season (Basit *et al.* 2021). Paired row sowing (pooled) significantly higher (147.4 g/plant) fruit yield compared to normal sowing (140.9 g/plant). Straw mulch increased yield by 17.9% on a pooled basis compared to no mulch (Table 1). Straw mulch's effectiveness can be attributed to its ability to reduce evaporation and moderate soil temperature, improved moisture availability and nutrient uptake, thus accelerating plant growth and ultimately higher fruit production (Kavian *et al.* 2020).

The interaction between drip irrigation levels and mulches significantly influenced fruit yield (Table 2). In both years and pooled analysis, mulches consistently improved fruit yield compared to no mulch, with 100% PE drip irrigation yielding the best results. Specifically, the combination of 100% PE drip irrigation with straw mulch

Table 1 Effect of irrigation levels, crop geometry and mulches on fruit yield of okra

Treatment	Fruit yield/plant (g)			Fruit yield/ha (q)		
	2018–19	2019–20	Pooled	2018–19	2019–20	Pooled
<i>Irrigation levels</i>						
40% PE	115.7	117.4	116.5	92.00	92.79	92.39
60% PE	140.7	140.2	140.4	111.7	111.5	111.6
80% PE	156.7	158.0	157.4	124.8	125.8	125.3
100% PE	160.9	163.6	162.3	128.4	130.5	129.4
SEm±	2.69	2.66	1.89	2.05	2.24	1.52
CD (P=0.05)	9.30	9.20	5.82	7.09	7.77	4.68
<i>Crop geometry</i>						
Normal sowing	140.2	141.7	140.9	111.2	112.3	111.8
Paired row sowing	146.9	147.8	147.4	117.2	117.9	117.6
SEm±	1.76	1.60	1.19	1.39	1.41	0.99
CD (P=0.05)	5.75	5.20	3.57	4.53	4.61	2.97
<i>Mulch</i>						
No mulch	129.8	129.75	129.8	103.1	102.5	102.8
Straw mulch	151.7	154.50	153.1	121.2	123.5	122.3
Plastic mulch	149.0	150.2	149.6	118.4	119.4	118.9
SEm±	2.03	1.83	1.37	2.04	1.71	1.33
CD (P=0.05)	5.86	5.28	3.87	5.88	4.94	3.76

Table 2 Interaction effect of irrigation levels and mulches on fruit yield (g/plant) of okra

Mulch	Irrigation levels											
	2018–19				2019–20				Pooled			
	40% PE	60% PE	80% PE	100% PE	40% PE	60% PE	80% PE	100% PE	40% PE	60% PE	80% PE	100% PE
No mulch	96.1	117.1	147.3	158.9	98.9	113.2	151.9	154.9	97.5	115.2	149.6	156.9
Straw mulch	126.9	153.8	162.8	163.8	129.1	156.5	162.4	170.0	128.0	155.1	162.6	166.9
Plastic mulch	124.2	151.3	160.2	160.3	124.2	151.0	159.8	165.9	124.2	151.1	160.0	163.1
	SEm±			CD	SEm(±)			CD	SEm(±)			CD
				(P=0.05)				(P=0.05)				(P=0.05)
Irrigation at same level of mulch	3.52			10.14	3.21			9.24	2.38			6.73
Mulch at same level of irrigation	4.07			11.72	3.67			10.57	2.74			7.74

*CD (P=0.05) for geometry at same level of irrigation; **CD (P=0.05) for irrigation at same level of different mulches.

produced the highest fruit yield (166.9 g/plant), statistically on par with plastic mulch under the same irrigation level. Conversely, the lowest fruit yield (97.5 g/plant) was observed with 40% PE irrigation and no mulch. These findings are consistent with previous research in okra conducted by (Kamble *et al.* 2020, Saha *et al.* 2020).

In the harvested plots, although paired row sowing demonstrated the highest plant population per hectare (Fig. 1A), the crops sown in paired rows with dimensions of 30 cm × 70 cm received optimal watering owing to their proximity to drip lines. At the time of harvest, straw mulch exhibited the highest plant population (79601, 79877 and 79739 plants per hectare in 2018–19, 2019–20 and pooled respectively). Conversely, the control plot without any mulch treatment displayed the lowest plant population, followed by the plastic mulch treatment. Drip irrigation facilitated an increase in the photosynthetic surface area and a consequent acceleration in the photosynthetic rate, leading to enhanced plant growth according to recent studies by Lakshmi *et al.* (2023).

The results (Fig. 1B) indicated that the minimum number of days for first flower initiation (41.7 days) was recorded with drip level of 40% PE, while the maximum number of days for first flower initiation (46.8 days) was recorded with a drip level of 100% PE. This could be attributed to the limited capacity of the okra crop to assimilate nutrients during its reproductive phase as opposed to the vegetative stage. This reduced nutrient absorption during reproductive stage may lead to a decrease in water uptake

by the plant, causing the root system to deteriorate when resources are redirected towards the development of flowers and fruits (Keyvan Rad *et al.* 2022). Minimum days taken to first flowering were recorded in straw mulch (42.7) which was at par with plastic mulches whereas maximum days was taken to first flowering (46.4 days) in control (no mulch). Straw mulch took the shortest time to initiate flowering and fruiting compared to other mulches.

Drip irrigation set at 100% PE, okra exhibited the highest

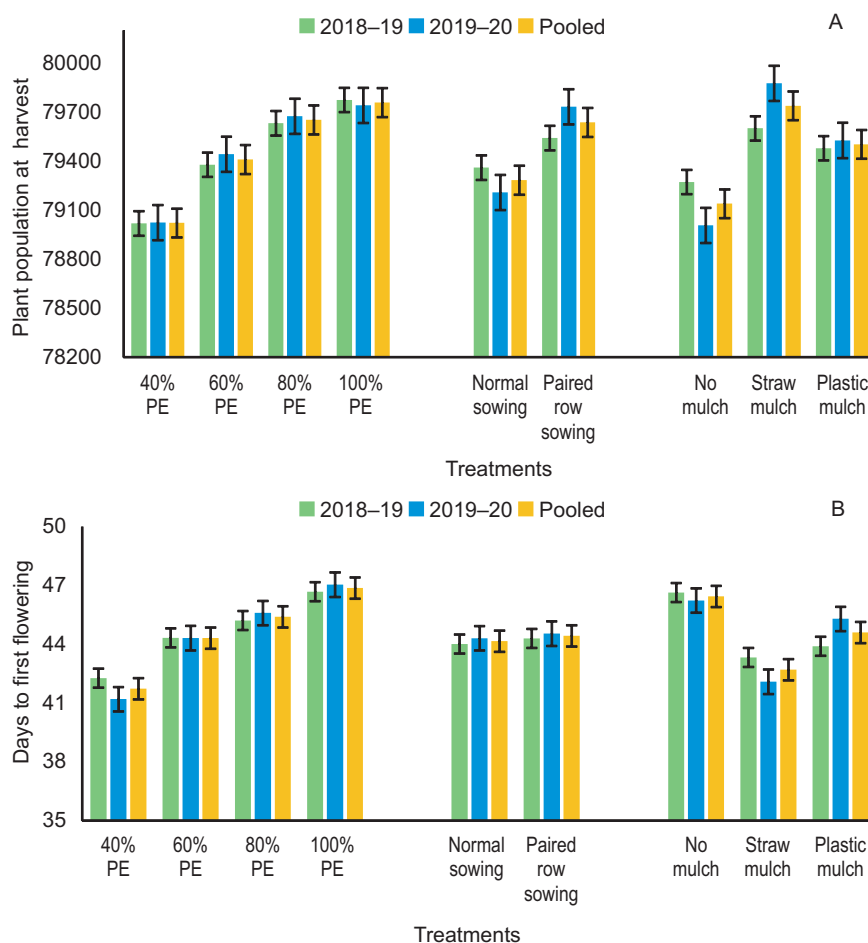


Fig. 1 Effect of irrigation levels, crop geometry and mulches on plant population (A) and days to first flowering (B) of okra.

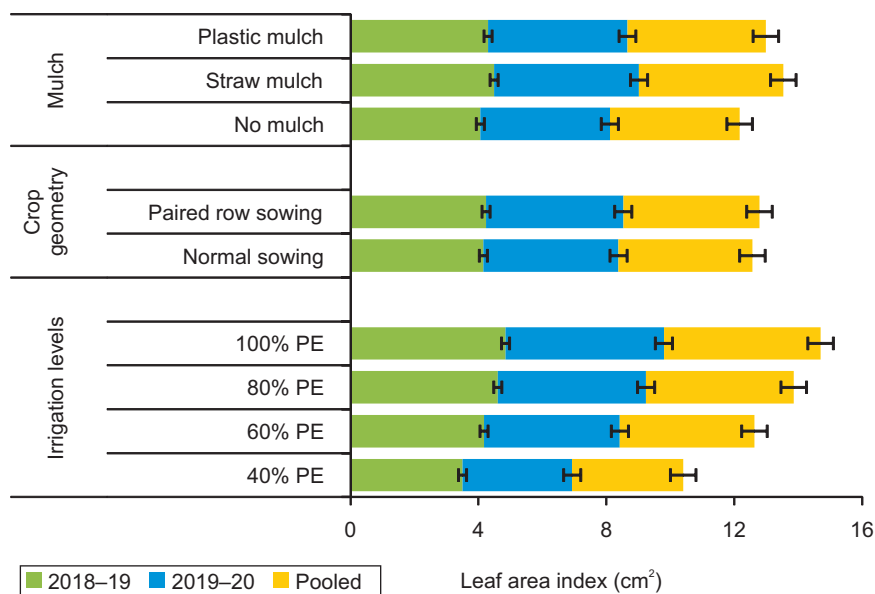


Fig. 2 Effect of irrigation levels, crop geometry and mulches on leaf area index.

LAI, measuring 4.85 to 4.95 cm² at harvest (Fig. 2). This performance was akin to that of 80% PE, surpassing both 60% and 40% PE irrigation levels. Notably, the minimum LAI during harvest was associated with 40% PE, followed by 60% PE, possibly due to water stress. These findings align with prior studies on okra and broccoli (Mahmoudi *et al.* 2020). Crop arrangement significantly influenced LAI, with paired row and normal sowing displaying higher LAI at harvesting stage (4.24 to 4.29 cm²). Straw mulch demonstrated comparable LAI to plastic mulch, maintaining the highest values (4.49 to 4.53 cm² at harvest), while no mulch resulted in the lowest LAI for okra.

Effect of irrigation levels, crop geometry and mulches on fruit quality attributes: The TSS content in okra fruit was significantly influenced by DI levels (Fig. 3). 100% PE drip irrigation had the highest TSS (3.36–3.40°Brix), akin to 80% PE, surpassing 40% and 60% PE. TSS rose by 23.3% (40% PE) and 10.8% (60% PE) with 100% PE. Adequate water potentially boosted dry matter, akin to tomato findings (Ibrahim *et al.* 2014). Paired row sowing had the highest TSS (3.13–3.17°Brix), followed by normal sowing (3.08–3.12°Brix). Straw mulch increased TSS (3.16–3.20°Brix) vs plastic mulch and no mulch.

The protein content in okra fruit was significantly influenced by DI levels (Table 3). Okra crops irrigated with 100% PE drip irrigation had the highest protein content (9.22, 9.32, and 9.27%), comparable to 80% PE irrigation but significantly higher than 40% PE and 60% PE. This increase in protein content could be attributed

to improved nitrogen availability and enhanced activity of the nitrate reductase enzyme, both of which contribute to higher protein levels (Li *et al.* 2022). Crop geometry did not significantly affect protein content, with paired row sowing showing slightly higher protein content (8.58, 8.89 and 8.74%) compared to normal sowing (8.4, 8.7 and 8.6%). Straw mulch resulted in the highest protein content (9.11, 9.28 and 9.20%) compared to no mulch, though it was statistically similar to plastic mulch. Straw mulch increased protein content by 14.85 and 4.55% over no mulch and plastic mulch, respectively. This higher nutrient concentration in plants under straw mulch can be attributed to balanced nutrient supply, improved photosynthetic efficiency, and greater

dry matter production, ultimately leading to increased nitrogen content and higher protein levels (Kamble *et al.* 2020).

Effect of irrigation levels, crop geometry and mulches on water use efficiency: The highest WUE, reaching 17.2 kg/ha/mm, was observed at 40% PE irrigation, while the lowest, at 14.06 kg/ha/mm, was noted with 100% PE drip irrigation (Table 3). Increasing DI levels from 40% PE to 100% PE resulted in a decrease in WUE, primarily due to reduced water losses, including minimized deep percolation and runoff. Drip irrigation's precision in delivering water efficiently to the root zone contributed to higher WUE at 40% PE (Neelakanth *et al.* 2020). Among mulching practices, straw mulch exhibited the highest WUE at 17.15 kg/ha/mm, comparable to plastic mulch and superior to no mulch. Higher WUE values were consistently linked to

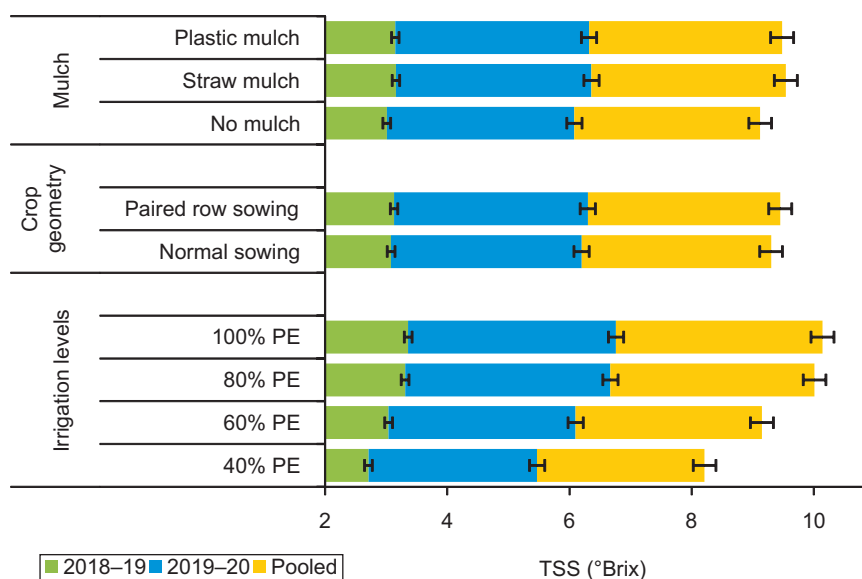


Fig. 3 Effect of irrigation levels, crop geometry and mulches on TSS content.

Table 3 Effect of irrigation levels, crop geometry and mulches on protein content, WUE and economics of okra

Treatment	Protein content (%) in fruit			Water use efficiency (kg/ha/mm)			B:C ratio		
	2018–19	2019–20	Pooled	2018–19	2019–20	Pooled	2018–19	2019–20	Pooled
<i>Irrigation levels</i>									
40% PE	7.42	7.85	7.64	18.39	16.09	17.24	2.80	2.81	2.80
60% PE	8.33	8.91	8.62	18.40	15.21	16.81	3.29	3.21	3.25
80% PE	9.07	9.22	9.15	17.48	14.15	15.81	3.62	3.56	3.59
100% PE	9.22	9.32	9.27	15.64	12.48	14.06	3.64	3.54	3.59
SEm±	0.16	0.14	0.11	0.42	0.33	0.27	0.07	0.07	0.05
CD (P=0.05)	0.57	0.49	0.33	1.45	1.15	0.82	0.23	0.24	0.15
<i>Crop geometry</i>									
Normal sowing	8.44	8.76	8.60	16.94	14.07	15.51	3.24	3.20	3.22
Paired row sowing	8.58	8.89	8.74	18.01	14.90	16.45	3.44	3.36	3.40
SEm±	0.13	0.15	0.10	0.22	0.21	0.15	0.04	0.05	0.03
CD (P=0.05)	NS	NS	NS	0.71	0.69	0.46	0.14	0.15	0.09
<i>Mulch</i>									
No mulch	7.70	8.32	8.01	15.55	12.73	14.14	3.89	3.74	3.82
Straw mulch	9.11	9.28	9.20	18.68	15.62	17.15	3.51	3.50	3.51
Plastic mulch	8.73	8.88	8.80	18.20	15.10	16.65	2.61	2.59	2.60
SEm±	0.14	0.15	0.10	0.37	0.20	0.21	0.06	0.05	0.04
CD (P=0.05)	0.41	0.44	0.29	1.06	0.57	0.59	0.18	0.14	0.11

mulch application, regardless of irrigation levels, improving soil moisture utilization and reducing evaporation. Straw mulch acted as a surface barrier, limiting water loss and positively impacting fruit production, aligning with similar findings (Kavian *et al.* 2020, Changade *et al.* 2023).

Effect of irrigation levels, crop geometry and mulches water use efficiency on B:C ratio: B:C ratio favoured 100% PE drip irrigation, with ratios of 3.62, 3.56 and 3.59, respectively, followed by 80% PE, outperforming 40% PE and 60% PE (Table 3). Lower irrigation costs contributed to higher returns, aligning with findings by Kumar and Kumar (2020) on straw mulch in fenugreek. These results underscore the role of DI with mulch in enhancing land and water productivity, consistent with studies by (Dagore *et al.* 2021). Paired row sowing at 30 cm × 70 cm spacing provided the highest B:C ratio (3.44, 3.36, 3.40) compared to 50 cm normal spacing, attributed to increased fruit yield. Similar findings were reported by Farhan and Sugirtharan (2023). In contrast, no mulch yielded the highest B:C ratio (3.89, 3.74, 3.82), surpassing straw and plastic mulch, aligning with findings by Kumar and Kumar (2020).

Study revealed that among the four irrigation levels considered, 100% PE irrigation emerged as the most favourable option for promoting better growth, yield, quality attributes, and achieving a favourable B:C ratio in okra cultivation followed by 80% PE irrigation. The 40% PE level of drip irrigation demonstrated the highest WUE. Furthermore, we observed that adopting paired row sowing significantly enhanced fruit yield, WUE, and the B:C ratio compared to normal sowing methods. Incorporating straw mulch into the cultivation process resulted in significantly

higher LAI, TSS, protein content, B:C ratio and WUE for okra, with plastic mulch showing comparable results. Finally, when considering the economic aspect (B:C ratio), it is worth noting that 100% PE irrigation without mulch yielded the highest returns. However, in terms of WUE, the 40% PE drip irrigation level combined with either straw or plastic mulch proved to be the most efficient. These insights can significantly contribute to improving okra production in water-limited environments.

REFERENCES

- Basit A, Zahid A, Shah S T, Ullah I, Ullah S, Nawaz M K, Khalid M A, Ullah I, Ali F and Ali S. 2021. Effect of sowing methods and picking intervals on fresh yield and seed production of okra (*Abelmoschus esculentus* L.). *Pakistan Journal of Weed Science Research* 27(3).
- Busari M A, Bankole G O, Adiamo I A, Abiodun R O and Ologunde O H. 2023. Influence of mulch and poultry manure application on soil temperature, evapotranspiration and water use efficiency of dry season cultivated okra. *International Soil and Water Conservation Research* 11(2): 382–92.
- Changade N M, Sharma V and Kumar R. 2023. Performance of okra (*Abelmoschus esculentus*) to different irrigation levels and mulches under drip irrigation system. *The Indian Journal of Agricultural Sciences* 93(3): 318–20.
- Dagore P, Parte V, Markam U and Kujur A. 2021. Moisture and economics study by the effect of mulching and methods of irrigation on okra (*Hibiscus esculentus* L. Moench). *Plant Archives* 21(1).
- Farhan, Ibrahim Imrana and Sugirtharan M. 2023. Effect of surface and drip irrigation on growth, yield and water use efficiency of okra (*Abelmoschus esculentus*): A review. *Advances in Technology* 1–19.

- Ibrahim A, Wahb-Allah M, Abdel-Razzak H and Alsadon A. 2014. Growth, yield, quality and water use efficiency of grafted tomato plants grown in greenhouse under different irrigation levels. *Life Sciences Journal* **11**(2): 118–26.
- Kamble M, Bhuibhar B W, Khodke U M and Pimpale S V. 2020. Effect of irrigation levels and plastic mulches on plant growth parameter of okra (*Abelmoschus esculentus* L.). *International Journal of Current Microbiology and Applied Science* **9**(9): 857–65.
- Kavian A, Kolehhouei M, Gholami L, Jafarian Z, Mohammadi M and Rodrigo-Comino J. 2020. The use of straw mulches to mitigate soil erosion under different antecedent soil moistures. *Water* **12**(9): 2518.
- Keyvan Rad S, Madani H, Heidari Sharifabadi H, Mahmoudi M and Nourmohamadi G. 2022. Effects of different irrigation intervals and sowing time on yield attributing traits of okra (*Abelmoschus esculentus* L.). *Arabian Journal of Geosciences* **15**(8): 740.
- Kumar R and Kumar M. 2020. Effect of drip irrigated mulch on soil properties and water use efficiency. A review. *Journal of Soil and Water Conservation* **19**(3): 300–09.
- Lakshmi B, Pooja B, Akshitha C, Anjali D, Haripriya G and Srivalli R. 2023. Effect of irrigation levels on growth and yield of okra under mulching. *Research Highlights in Agricultural Sciences* **9**: 90–7.
- Li X, Zhang H, Li F, Deng H, Wang Z and Chen X. 2022. Evaluating effects of regulated deficit irrigation under mulched on yield and quality of pumpkin in a cold and arid climate. *Water* **14**(10): 1563.
- Mahmoudi M, Khelil M N, Ghrib R, Douh B and Boujelben A. 2020. Assessment of growth and yield of okra (*Abelmoschus esculentus*) under surface and subsurface drip irrigation using treated waste water. *International Journal of Recycling Organic Waste in Agriculture* **9**(4): 349–56.
- Metson A J. 1957. Methods of chemical analysis for soil survey samples. *Soil Science* **83**(3): 245.
- Narayan S, Javeed I, Hussain K, Khan F A, Mir S A, Bangroo S A and Malik A A. 2021. Response of okra (*Abelmoschus esculentus*) to foliar application of micronutrients. *The Indian Journal of Agricultural Sciences* **91**(5): 749–52.
- Neelakanth J K, Gundlur S S and Rajkumara S. 2020. Effect of paired row technique using drip irrigation system on brinjal in Vertisols of malaprabha command in northern Karnataka. *Journal of Pharmacognosy and Photochemistry* **9**(3): 1701–03.
- Olsen S R, Cole C V, Watanabe F S and Dean L. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular number 939. Washington, DC, United States.
- Richards L A. 1954. *Diagnosis and Improvement of Saline and Alkali Soils*. Handbook No. 60. US Department of Agriculture. Washington DC.
- Saha S, Chandrashekar K, Sonke L R and Mahapatro G K. 2020. Efficacy of rice straw mulch for the sustainable production and insect pest management in okra (*Abelmoschus esculentus*). *The Indian Journal of Agricultural Sciences* **90**(10): 1865–70.
- Sarkar M, Bora L, Patel B K and Kundu M. 2022. Present status of okra (*Abelmoschus Esculentus* (L.) Moench) diseases and their management strategies. *Diseases of Horticultural Crops: Diagnosis and Management*, pp. 325–43. Apple Academic Press.
- Sinha J, Sahu R, Sahu R K and Nigam G K. 2019. Used plastic materials as mulches: An alternative to conventional black plastic mulch for small and marginal farmers. *Physics and Chemistry of the Earth, Parts A/B/C* **109**: 70–8.
- Snell F D and Snell C T. 1949. *Colorimetric Methods of Analysis*, pp. 802–07. Van Nostrand Co., New York.
- Subbiah B V and Asija G L. 1956. A rapid procedure for the determination of available nitrogen in soils. *Current Science* **25**: 259–60.
- Walkley A and Black I A. 1947. An examination of the degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29–38.
- Yang P, Wu L, Cheng M, Fan J, Li S, Wang H and Qian L. 2023. Review on Drip Irrigation: Impact on crop yield, quality, and water productivity in China. *Water* **15**(9): 1733.