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# Effect of drip irrigation scheduling and mulching on plant growth, physiology, yield, water use efficiency and weed growth in spring-summer okra (*Abelmoschus esculents* Muench)

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## Abstract

Spring summer okra requires high and frequent application of water due to high evapo-transpiration demand. Deficit irrigation (supply less water than required) coupled with mulching is good agricultural practice to enhance water use efficiency in vegetable crops. In this study, three drip irrigation scheduling and two types mulches were evaluated with surface irrigation and without mulch. Maximum soil moisture content of 12.2% and 13.5% was reported under organic mulch, respectively at 20 and 30 cm depth. Plants grown under organic and black-silver mulch have registered 52.5% and 35% higher chlorophyll content than control. Maximum stomatal conductance was reported with 100% PE + black-silver mulching (956.05 mmole/m$^2$/sec). Significantly higher fruit yield (555.42 g/plant and 112.05 q/ha) was observed with drip irrigation at 100% PE, whereas in mulches, it was maximum under organic mulch (585.13 g/plant and 112.30 q/ha). As far as interaction of irrigation x mulch was concerned, the maximum yield of 684 g/plant and 125.32 q/ha was reported with drip irrigation 100% PE + organic mulch, which was 64.8% higher in yield with 15.2% water saving than the control.

**Keywords:** Drip irrigation, mulching, yield, water use efficiency, weed, okra.

## Introduction

Irrigation scheduling is very critical to make the most efficient use of water, as excessive or inadequate irrigation reduces the yield. Due to high evaporative demand during summer, okra requires high quantity of water (about 486 mm) under surface irrigation (Bahadur et al. 2013a), and water deficit at flowering and fruit-development stages reduces more than 70% yield (Mbagwu and Adesipe 1987). Drip irrigation system has higher water and nutrient-use-efficiency, enhances plant growth, yield, quality, and has flexibility in scheduling water application. Use of different types of soil mulching materials such as crop straw and residues, polyethylene, etc. have great potential to conserve moisture, control weeds, maintain soil temperature, soil structure and nutrient dynamics, which favorably affect the crop yield (Mulumba and Lal, 2008). A combination of drip irrigation and mulching further improves the water use efficiency by curtailing the amount of water as well as the number of irrigations applied. It has been reported that besides enhanced fruit yield, drip irrigation with or without mulch save considerable quantity of water (Bahadur et al. 2009, 2013). The present study was undertaken to find the effects of irrigation quantities through drip and use of organic and polyethylene mulch on plant growth, physiology, weed growth, water use efficiency and yield in spring-summer okra.

## Materials and Methods

Field experiment was conducted at ICAR-IIVR, Varanasi during 2016 and 2018 with four levels of irrigation (drip irrigation at 60%, 80% and 100% PE compared with surface irrigation at 100% PE) and three levels of mulch (organic and polyethylene mulches compared with no mulch). Under organic mulch 7-10 cm thick pea straw (approx. 12 tones/ha), and in polyethylene mulch 25 µ thick black-silver mulch was applied 20 days after seed sowing. The experiment was conducted in split-plot design with three replications wherein irrigation treatments were laid in main plots and mulching in sub-plots. Drip irrigation was scheduled daily or alternate day with different timing as per quantities determined based on USWB open pan evaporation (PE) values, whereas in surface irrigation 100% PE irrigation was supplied at 5-7 days intervals. Farm yard manures was applied @ 20 tones/ha and NPK fertilizers at 120:60:80 kg/ha. Under drip irrigation system, 25% NPK was applied in soil during sowing while rest 75% fertilizers were fertigated in 10 split doses through water soluble

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fertilizers such as, 18:18:18 NPK, urea and muriate of potash. In surface irrigation system, 50% N and 100% PK was applied in soil at sowing and rest of N was given as top dressing twice, 30 and 45 days after sowing. The soil of experimental plot was sandy loam, Typic Utochrept (Inceptisol) with pH 7.2, EC 0.32 dS/m, organic carbon 0.38% and available N, P and K was 246, 19.5 and 175 kg/ ha, respectively. Moisture content (0.30 m depth) at 0.33 bars (field capacity) and at 15 bars (wilting point) was 22.3% and 6.4%, respectively whereas bulk density of soil was 1.38 g/cm$^3$. The average monthly maximum and minimum temperatures during experiment periods were 37.8°C and 22.3°C, respectively in 2016 and 36.5°C and 20.4° C in 2018. The average monthly pan evaporation was 68.9 cm and 73.4mm/day, respectively in 2016 and 2018.

## Results and Discussion

**Soil moisture:** Maximum soil moisture in upper 10 cm soil was reported at 100% PE under organic mulch (13.8%) followed by black-silver mulch (12.6%). At deeper soil depths, the highest soil moisture of 12.2% and 13.5% was reported under organic mulch, respectively at 20 and 30 cm depth followed by black-silver PE mulch (11.8% and 12.4%). The lowest soil moisture of (8.6%, 9.4% and 9.6%) was reported under 60% PE without mulch (Fig. 1 A-D). Mahadeen (2014) also reported that black polythene much retained 4.5-5.0% more soil moisture (30-60 cm depth) in okra and summer squash compared to bare soil. Polyethylene mulch helps in conserving water by reducing 25-50% evaporation from soil surface, controlling weed growth and reducing soil compaction (Ramakrishna et al. 2006).

**Plant height, chlorophyll content and stomatal conductance:** The maximum plant height of (83.04 cm) was recorded with 100% PE, and among mulch, both organic andblack-silver mulch significantly enhanced the plant height by 33.2% and 36.6% than un-mulched control (Table-1). The interaction of irrigation and mulch was also highly significant, and maximum plant height of 89.13 cm was reported with drip irrigation at 100% PE + organic mulch application ($I_4M_1$), which was 43.2% higher than the control ($I_1M_0$).Like our findings, Tiwari et al (1998) also reported significantly higher plant height in okra withdrip irrigationand straw mulch.Chlorophyll content index (CCI) did not affect significantly with irrigation treatment, whereas mulching has highly significant effect on CCI. Plant grown under organic and black-silver mulch have recorded 52.5% and 35% higher CCI, respectivelyover non-mulch.

**Table 1**: Effect of drip irrigation scheduling and mulching on plant growth, physiology, yields, WUE and weed growth in okra

| Treatment | Plant height (cm) | CCI | gs (mmol/m$^2$/sec) | No. of fruits/ plant | Fruit weight (g) | Yield/ plant (g) | Yield (q/ha) | WUE (kg/ha-cm) | Weeds (g/m$^2$) |
|---|---|---|---|---|---|---|---|---|---|
| Irrigation | | | | | | | | | |
| Surface irrigation at 100% PE ($I_1$) | 73.00 | 35.83 | 617.85 | 32.1 | 20.05 | 468.33 | 88.15 | 11.34 | 132.10 |
| Drip irrigation at 60% PE ($I_2$) | 66.71 | 34.98 | 559.68 | 29.9 | 20.64 | 444.33 | 79.12 | 24.84 | 71.18 |
| Drip irrigation at 80% PE ($I_3$) | 76.92 | 38.49 | 724.63 | 33.5 | 22.72 | 491.42 | 98.70 | 20.86 | 82.08 |
| Drip irrigation at 100% PE ($I_4$) | 83.04 | 41.54 | 780.98 | 37.3 | 23.42 | 555.42 | 112.05 | 18.94 | 88.83 |
| SEm± | 1.10 | 0.94 | 5.84 | 1.16 | 0.54 | 12.42 | 3.85 | 1.13 | 3.33 |
| $CD_{0.05}$ | 3.53 | 3.00 | 18.67 | 3.71 | 1.72 | 39.69 | 12.31 | 3.62 | 10.65 |
| Mulching | | | | | | | | | |
| Organic mulch ($M_1$) | 80.94 | 44.54 | 733.38 | 36.8 | 22.13 | 585.13 | 112.30 | 22.78 | 54.70 |
| Black-silver PE mulch ($M_2$) | 83.03 | 39.40 | 831.23 | 34.1 | 22.52 | 486.25 | 90.62 | 18.37 | 8.51 |
| No mulch ($M_0$) | 60.78 | 29.19 | 447.74 | 28.6 | 20.47 | 398.25 | 80.61 | 15.84 | 217.44 |
| SEm± | 0.93 | 0.83 | 9.66 | 0.89 | 0.44 | 14.44 | 2.64 | 0.97 | 2.97 |
| $CD_{0.05}$ | 2.71 | 2.40 | 28.15 | 2.59 | 1.28 | 42.07 | 7.69 | 2.83 | 8.66 |
| Irrigation x Mulch | | | | | | | | | |
| $I_1M_1$ | 76.00 | 44.85 | 667.00 | 36.0 | 20.73 | 517.50 | 93.82 | 13.45 | 100.08 |
| $I_1M_2$ | 80.75 | 38.93 | 757.03 | 34.3 | 19.53 | 465.25 | 67.50 | 9.68 | 16.48 |
| $I_1M_0$ | 62.25 | 23.73 | 429.53 | 26.0 | 19.89 | 422.25 | 76.05 | 10.90 | 279.75 |
| $I_2M_1$ | 75.50 | 41.73 | 643.10 | 33.3 | 22.05 | 546.25 | 111.91 | 31.53 | 32.58 |
| $I_2M_2$ | 77.38 | 37.00 | 676.78 | 31.8 | 21.26 | 431.25 | 86.85 | 24.47 | 4.73 |
| $I_2M_0$ | 47.25 | 26.23 | 359.15 | 24.8 | 18.62 | 355.50 | 65.70 | 18.51 | 176.25 |
| $I_3M_1$ | 83.13 | 44.48 | 786.63 | 37.0 | 22.89 | 592.75 | 118.12 | 24.96 | 41.60 |
| $I_3M_2$ | 83.25 | 38.88 | 935.08 | 34.0 | 23.74 | 515.50 | 97.87 | 20.68 | 5.88 |
| $I_3M_0$ | 64.38 | 32.13 | 452.20 | 29.5 | 21.55 | 366.00 | 80.10 | 16.93 | 198.75 |
| $I_4M_1$ | 89.13 | 47.13 | 836.80 | 41.0 | 22.87 | 684.00 | 125.32 | 21.19 | 44.55 |
| $I_4M_2$ | 70.75 | 42.80 | 956.05 | 36.5 | 25.58 | 533.00 | 110.25 | 18.64 | 6.95 |
| $I_4M_3$ | 69.25 | 34.70 | 550.08 | 34.3 | 21.81 | 449.25 | 100.57 | 17.00 | 215.00 |
| SEm± | 1.86 | 1.65 | 19.33 | 1.78 | 0.88 | 21.88 | 7.17 | 3.11 | 5.95 |
| $CD_{0.05}$ | 5.41 | NS | 56.31 | NS | NS | 63.71 | 20.88 | 9.06 | 17.33 |

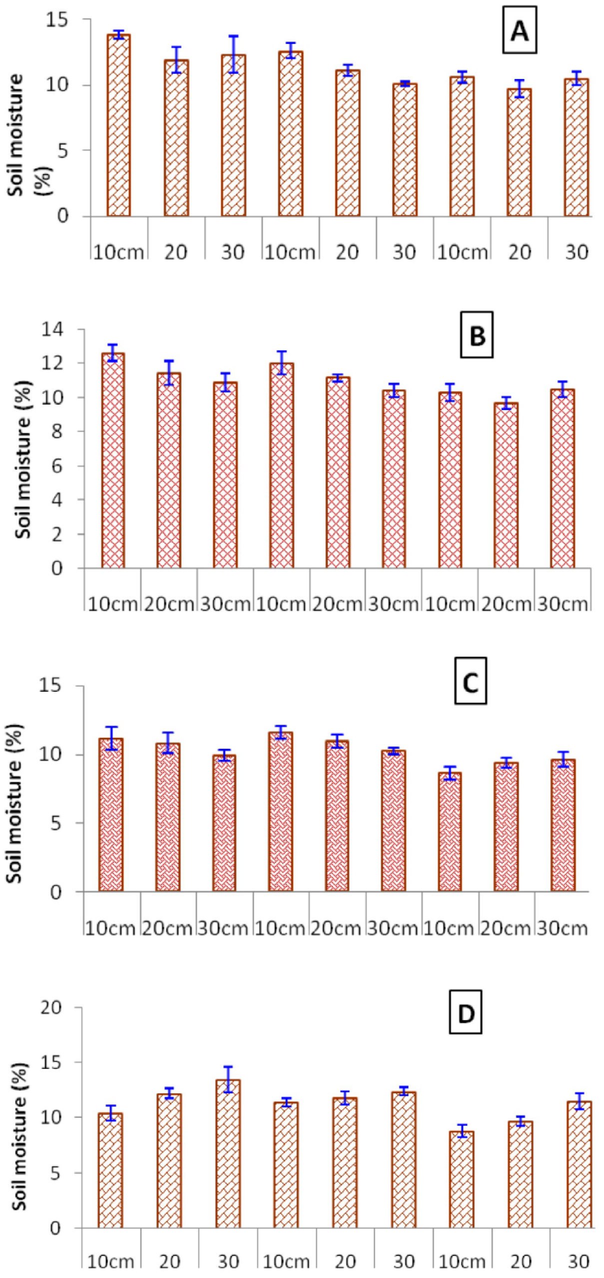


**Figure 1.** Soil moisture content under different mulches at diffrerent soil depths with drip irrigation scheduling at (A) 100% ET, (B) 80% ET, (C) 60% ET and (D) surface irrigation

Although CCI of leaves with irrigation x mulch effect varied from 23.73 (in $I_1M_0$) to 47.13 (in $I_4M_1$), but it was statistically non-significant.

Stomatal conductance (gs) is an important physiological trait that directly related to the rate of transpiration and photosynthesis, particularly during water deficit condition. In our study, gs was significantly affected with both irrigation scheduling and mulching. Among irrigation, drip at 100% PE and 80% PE had significantly higher gs (780.98 and 724.63 mmol/ m$^2$/sec) over drip at 60% PE or surface irrigation. Similarly, black-silver mulch has registered maximum gs (831.23 mmol/ m$^2$/ sec) followed by organic mulch (733.38 mmol/ m$^2$/sec) with 85.6% and 63.8% higher gs, respectively than non-mulched plants.Interaction of irrigation x mulch was also highly significant, and maximum gs of 956.05 mmole/m$^2$/sec was reported in $I_4M_2$ followed by $I_3M_2$ (935.08 mmole/m$^2$/sec) An optimum soil moisture and hydrothermal regime of soil under 100% PE + mulch may have contributed for improved CCI, gs and other physiological attributes of plant. Similar findings with use of organic mulches have also been reported earlier by Huang et al. (2008) and Bahadur et al (2009).

**Yield attributes:** Yield contributing traits such as number of fruits/plant and fruit weight influenced significantly with irrigation scheduling and mulching, however interaction of these two factors was not reported significant (Table 1). Among irrigation scheduling, drip irrigation at 100% PE recorded maximum fruits (37.3/plant) followed by 80% PE (33.5/ plant). These two treatments also registered significantly higher fruit weight (23.42 and 22.72 g) than the conventional irrigation (20.05 g) (Fig. 2).

It can be seen that the highest number of fruits and fruit weight were recorded under organic andblack-silver mulch system. As far as yield was concerned, it significantly varied with irrigation and mulch treatments. The maximum and significantly higher fruit yield of 555.42 g/plant and 112.05 q/ha was observed with drip irrigation at 100% PE, whereas in mulches, it was maximum under organic mulch (585.13 g/plant and 112.30 q/ha). The interaction of irrigation x mulch was also highly significant, and maximum fruit yield of 684 g/plant and 125.32 q/ha was reported with $I_4M_1$ (drip at 100% PE + organic mulch), which was 64.8% higher than the control ($I_1M_0$).In corroborate to our findings, Tiwari et al (1998) also reported that the use of drip alone or in combination with different mulches can increase the okrayield by 45–72% over furrow irrigation. A significant enhancement in growth and yield

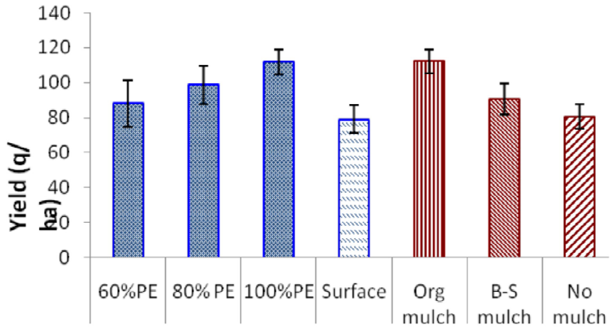


**Figure 2.** Yield of okra under different irrigation schedulings and mulches

of okra under organic mulch (pea straw) may be attributed to conserved soil moisture, moderate plant water status, soil temperature, soil mechanical resistance and increased availability of plant nutrients (Mulumba and Lal 2008; Huang et al. 2008).

**Water use efficiency and weed growth:** Irrigationamount supplicated under surface, drip at 100% PE, 80% PE and 60% PE were 698 cm, 592 cm, 473 cm and 355 cm, respectively. This way a total of 15.2%, 32.2% and 49.1% water have been saved in drip at 100%, 80% and 60% PE, respectively than the conventional surface irrigation. Water use efficiency expressed as the ratio of yield obtained and total quantity of water supplied. Among irrigation schedulings, the maximum WUE of 24.84 kg yield/ha/cm of water was reported with drip irrigation at 60% PE, which was more than two-folds over conventional surface irrigation (Table -1). Mulching materials also influence this parameter significantly, and the maximum WUE of 22.78 kg/ha/cm was reported under organic mulch. Interaction effect of irrigation scheduling and mulch was also highly significant, andmaximum WUE of 31.53 kg/ha/cm was observed in drip irrigation at 60% PE + organic mulching ($I_2M_1$). This treatment combination registeredmore than 3-folds higher WUE than the control. Earlier, Panigrahi et al (2011) also reported maximum WUE in okra with irrigation at 50% soil moisture depletion coupled with black-polythene mulching. Mulching (organic or plastic) reduce the surface evaporation of water considerably therefore supply of even less quantity of water produced yields *at par* to full irrigation, and thereby the higher WUE was achieved in $I_2M_1$(60 % PE + organic mulching).

Weed population was significantly affected with irrigation scheduling and mulching. Surface irrigation encouraged more weed growth as compared to drip irrigation, whereas mulching particularly black-silver poly-ethylene mulch remarkably restricted the weed growth. Black-silver mulch and organic mulch recorded 2455% and 297.5% less weed growth (dry weight/ $m^2$ area) than the un-mulched control. As far as the interaction of I x M was concerned, the lowest weed growth (4.73 g dw/$m^2$) was recorded in $I_2M_2$ followed by $I_3M_2$ (5.88 g dw/$m^2$). The maximum weeds (297.75 gdw/$m^2$) was reported in surface irrigation without mulch. Restricted weed growth under black-silver polythene and pea straw mulch may be due to poor light penetration beneath the mulch. Earlier, Bahadur et al (2009) also reported65.4% reduction of weed growth in okra with pea straw mulching compared to non-mulched plots.Later Bahadur et al (2013b) also reported 96% and 78% reduction in weed dry weight in tomato field, respectively under black polyethylene and paddy straw mulch.

## सारांश

ग्रीष्म ऋतु में उगाई जाने वाली भिण्डी में उच्च वाष्पीकरण–वाष्पोत्सर्जन माँग के कारण ज्यादा पानी और कम अन्तराल पर देने की आवश्यकता होती है। ड्रिप सिंचाई पद्धति माँग की तुलना में कम जल की आपूर्ति के साथ–साथ कार्बनिक या पालीथीन पलवार (मल्च) का प्रयोग करने से परम्परागत सतही सिंचाई के अपेक्षा कम पानी में भी सब्जी फसलों से अधिक उत्पादन लिया जा सकता है। इस अध्ययन में 3 ड्रिप सिंचाई सूची एवं 2 प्रकार के पलवार का मूल्यांकन सतही सिंचाई व बिना पलवार के किया गया। अधिकतम मृदीय नमी की मात्रा 12.2 प्रतिशत तथा 13.5 प्रतिशत कार्बनिक पलवार के तहत क्रमशः 20 व 30 सेमी. की गहराई पर पाया गया। कार्बनिक तथा काले–चाँदनी वाले पलवार में उगाये गये पौधों में 52.5 प्रतिशत तथा 35 प्रतिशत अधिक हरित लवक की मात्रा नियंत्रक की तुलना में पाया गया। अधिकतम पर्ण रन्ध्रीय चालकता 100 प्रतिशत पी.ई. + काले–चाँदनी वाले पलवार (956.05 एम मोल/मी.$^2$/सेकण्ड) से प्राप्त हुआ। सार्थक रूप से अधिक फल उपज (552.42 ग्राम/पौध 112.05 कु./हे.) 100 प्रतिशत पी.ई. के साथ ड्रिप सिंचाई से पाया गया जबकि पलवारों में सबसे अधिक कार्बनिक पलवार 585.13 ग्राम/पौध व 112.30 कु./हे.) में रहा। जहाँ तक भिण्डी की उतपादकता का सवाल हैं, तो सबसे अधिक उपज (684 ग्राम/पौधा और 125.32 कुन्तल/हे.) 100 प्रतिशत पी.ई. पर ड्रिप सिंचाई करने तथा कार्बनिक पलवार (मटर का भूसा 12 टन/हे. की दर से) दर्ज की गयी, जो कि सतही सिंचाई तथा बिना मल्च के अपेक्षा लगभग 65.0 प्रतिशत अधिक थी। इसके अलावा इससे 15.2 प्रतिशत पानी की बचत भी दर्ज की गयी।

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