*Eco. Env. & Cons. 30 (August Suppl. Issue) : 2024; pp. (S6-S11)*
*Copyright@ EM International*
*ISSN 0971–765X*

**DOI No.: http://doi.org/10.53550/EEC.2024.v30i05s.002**

# Effect of mulch on maize (*Zea maize* L.) yield and water productivity under different methods of irrigation

**M.S. Kahlon and Madhu Dhingra**

***Department of Soil Science, Punjab Agricultural University, Ludhiana 141 004, Punjab, India***

(Received 25 January, 2024; Accepted 21 March, 2024)

**ABSTRACT**

Irrigations methods significantly affect the crop as well as the water productivity. To investigate the effect of methods of irrigation under mulch conditions on water productivity and *kharif* maize (*Zea maize* L.) yield, a field experiment was conducted at Research Farm of Department of Soil Science, Punjab Agricultural University, Ludhiana. Three irrigation methods tested include drip irrigation, furrow irrigation and flood irrigation under mulch and un-mulch conditions. Mulch was applied at the rate of 6 t $ha^{-1}$. In all the treatments row to row spacing was 60 cm while plant to plant spacing was kept at 20 cm. The maximum plant height (2.6 m) was recorded in drip irrigation followed by furrow irrigation (2.4 m) and minimum under flood irrigated conditions, i.e. 2.1 m. Similarly, the maximum hundred maize grain weight (32.5 g) was recorded in drip irrigated maize followed by furrow irrigated (30.1 g) and least under flood irrigated maize (28.6 g). Crop productivity was also found to be significantly affected by mulching. The highest mean yield of 6.6 t/ha was recorded in drip irrigated plots with mulching while the minimum yield was recorded in flood irrigated maize i.e. 5.9 t/ha under un-mulched conditions. The water productivity was observed to be increased by 48% under drip irrigation with mulching over un-mulched flood irrigation. Maize cob size, cob weight, leaf area index and number of grain per cob were also found to be significantly influenced with mulching and irrigation methods. Bigger size cobs with more number of grains per cob were recorded under drip irrigated maize followed by furrow irrigated and the smallest under flood un-mulched irrigated conditions. The results revealed that for achieving maximum grain yield and water productivity of maize, the drip method of irrigation need to adopt along with mulching.

***Key words:*** *Irrigation, Drip, Furrow, Flood irrigation, Maize, Water productivity*

## Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops after wheat and rice in Punjab, India. Water requirement of maize is much less than rice during *khraif* growing season. However, the rice-wheat cropping system dominates in the Punjab state, and the high water requirement of the cropping system is met by pumping out underground water resources which has led to the over exploitation of the underground water resources. The erratic and uneven rainfall has further aggravated the problem. Moreover, the crops are irrigated by flood irrigation method in which the water is prone to various losses like evaporation, deep percolation, etc. For more precise use of water, the micro irrigation along with mulching may play important role. Water is the most important and critical input in agriculture. The pressure for the most efficient use of water for agriculture is intensifying with the increased competition for water resources among various sectors with mushrooming population. In spite of having the largest irrigated area in the world, India too has started facing severe water scarcity in different regions. Efficient utilization of available water resources is crucial for India, which shares 17 per cent of the global population with only 2.4 per cent of land and 4 per cent of the water resources. Improper management of water and nutrient has contributed extensively to the current water scarcity and pollution problems in many parts of the world, and is also a serious challenge to future food security and environmental sustainability. Maize is grown almost all over the country under varied soil and climatic conditions. Most of the maize in India is grown under low rainfall and heat stress conditions. In these conditions, irrigation is the major factor determining yield. It is consequently essential to determine the water regimes leading to highest yield. In Punjab maize was planted in around 0.11 M ha area and the average productivity is 3.9 t $ha^{-1}$. Soil moisture conservation practices like mulching and periodical application of water through various methods like drip irrigation help in greater supply of soil moisture to plant. Irrigation water can be conserved and maintained under water limited conditions by irrigation management (Mansouri *et al.,* 2010). Now a days, drip irrigation is proved to be promising for efficient water use in different crops as the water is applied frequently in small amount. But still in drip irrigation, the water is exposed to soil evaporation losses and mulching will help in overcoming this problem. Drip irrigation improves both the yield and the water productivity of crops (Barkunan *et al.,* 2019). Drip irrigation system is the application of irrigation water directly to the root system of the crops by placing drip pipes on the surface. In this system, the water loss is controlled as compared to other irrigation systems. The main advantage of this system is the deep percolation and evaporation losses are controlled and significantly increasing the crop yield by 25-30% compared to the flood irrigated crop (Pawar *et al.,* 2013).When there is lack of water, drip irrigation is the primary option for effectively utilizing water to maintain production in maize (Brar and Vashist, 2020). Maize grain yield increased significantly by irrigation water amount and irrigation frequency (Yazar *et al.,* 1999; Kara and Biber, 2008; Farré and Faci, 2009). The water availability is usually the most important natural factor limiting expansion and development of agriculture in northern western region of India. Maize has been reported to be very sensitive to drought (Otegui *et al*., 1995). Keeping in view the limited water supply conditions, a field experiment was conducted to investigate the effect of different irrigation methods on maize yield and water productivity under mulch conditions.

## Materials and Methods

The study was conducted during *kharif* season at the research farm of the Department of Soil Science, PAU, Ludhiana, Punjab, India (30°56′N latitude, 70° 52′E longitude and 247 m above mean sea level). The region experiences semi-arid climate with extremely hot during summers and cold during winter. The annual average temperature is 18.7 ºC and annual average total precipitation is 700 mm. The soils in the research field are deep, medium textured and well drained. The field capacity, wilting point and bulk density of top 15 cm of the soil were 21.3%, 10.8 % and 1.61 $Mg/m^3$, respectively. Basic intake rate was measured by double ring in filtrometer and found as 1.2 cm $hr^{-1}$ (Table 1). Soil was sampled from 0-15 cm depth to determine soil chemical characteristics e.g. nitrozen, phosphorus, potassium, pH, EC and OC etc. Phosphorus was determined colorimetrically and K by flame photometer. The concentration (kg/ha) of available N, $P_2O_5$ and $K_2O$ were 246.8, 23.8 and 186.7, respectively (Table 2). The soil was prepared by plowing and disking. Prior to sowing the soil was formed into drip irrigated ridges by placing drip laterals on the ridges with emitter spacing at 30 cm and discharge of emitter was 2 litre per hour, furrow irrigated ridges and flat plots. In all the methods of irrigation the row to row spacing was maintained as 60 cm, while the plant to plant spacing was kept as 20 cm. The treatments consisted of three methods of irrigation drip, furrow and flood under mulch and un-mulch conditions. Under drip irrigation, for maize N, P and $K_2O$ were applied at a rate of 125, 60 and 30 kg $ha^{-1}$. The sources of these fertilizers were urea, mono ammonium phosphate and MOP, respectively. However, for furrow and flat sown conditions the sources of N, P and K were Urea, Diammonium Phosphate (DAP) and Muriate of Potash (MOP), respectively. The entire quantity of P and K with one third of N were applied as basal dose at the time of final land preparation and other one third at knee height stage and one third at silking stage as top dressing. All other agronomic practices were kept uniform for all the treatments. The height of five randomly chosen plants per plot was measured from the ground surface to the plant's tip at 80 DAS for maize. The values were then averaged to single plant. For each treatment, one hundred grains were physically counted, weighed up to three decimal places after drying. The cob length and number of grains per cob were determined by taking sample from five plants from each treatment. The crop was harvested in the last week of October.

The RLWC was determined according to the method described by Barrs and Weatherley (1962) and later modified by Esparza-Rivera *et al* (2006). Three plants were randomly sampled from each plot to determine RLWC. The RLWC determination was accomplished by excising discs from the uppermost, medium and lower leaves with two discs from each leaf, thus making a total of six discs per plant and eighteen discs per plot. These disks were collected in plastic vials and weighed immediately, providing a measure of fresh weight (FW). After weighing, the disks were soaked in de-ionized water for 4 hours and then weighed again to obtain a fully turgid weight (TW). Finally, the leaf discs were dried at 60 °C till the constant weight achieved to obtain the dry weight (DW).

$$\text{RLWC (\%)} = \frac{\text{FW–DW}}{\text{TW–DW}} \times 100$$

The LAI was measured at 70 DAS using leaf area meter at three randomly selected plants within plot.

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Ground area}}$$

The harvested maize crop produced from each plot was decobbed separately. Grain yields were recorded in kg from 24 $m^2$ area in each plot and finally expressed in t $ha^{-1}$. The WP was calculated by dividing the grain yield of corresponding treatment with the amount of irrigation water applied for each treatment.

$$\text{Water productivity} = \frac{\text{Grain yield}}{\text{Amount of water applied}}$$

Analysis of variance (ANOVA) was carried out using computer program CPSC-I (Cheema and Singh, 1991). Randomized block design was used and comparisons were made at 0.05 level of significance.

## Results and Discussion

### Maize plant height and cob length of maize

Maize plant height was significantly affected by the methods of irrigation application. As observed from the data presented in Table 3, under mulched maximum plant height was recoded in drip irrigated plots (2.6 m) followed by furrow irrigated (2.4 m) and least in flood irrigation (2.1 m). Irrespective of irrigation methods, there was increase of 16.7 % in maize plant height under mulch conditions as compared to un-mulch conditions. The mean plant height increased by 24.0% in drip irrigation as compared to flood irrigation. The reason for more plant height under drip irrigation is that the water was applied at regular interval and soil moisture remained near field capacity and plant never feels any moisture stress. However, in flat flood irrigation as the water was applied after ten to fifteen days interval, there are chances that crop may suffer from moisture stress. Similar results were recorded by Brar and Vashist (2020) when surface drip irrigation with mulch was applied to the field, the plant height was observed to be higher for spring maize. The maximum plant height of spring maize as affected by different mulch levels were also observed by Guo *et al* (2021). The cob length of maize under mulched condition was also reported to be increased by 5.7% over un-mulched treatment. Among irrigation methods, the cob length was observed to be maximum in drip (23.2 cm) followed by furrow (21.1 cm) and minimum in flood irrigated plots, i.e. 18.9 cm. Thus, the increase of 18.5% was recorded under drip as compared to flood irrigation.

### Hundred grain weight and Number of grains per cob

The maximum hundred grain weight HGW (g) was under drip irrigation (32.5) followed by furrow irrigation (30.1) and least under flood irrigation (28.6). Irrespective of mulch conditions there was 12.9 % increase in hundred grain weight of maize under drip irrigation as compared to flood irrigation (Table 4). This might be attributed to proper physiological functioning, tissue development, cell division, enhanced plant growth and thereby increased TGW in drip irrigation where moisture stress was never observed. Low moisture supply decreases maize HGW due to decreased supply of carbohydrates and amino compounds to the grain. Increased translocation of photosynthates to the grain under drip irrigation might be responsible for increasing the grain mass. Selvaraju and Iruthayaraj (1994) reported improvement in grain weight of maize under higher irrigation compared to that under moisture stress condition. Similarly the number of grains per cob was recorded to be highest in drip irrigation (347) under mulch condition and minimum (306) under flood irrigation. Thus, the increase of 11.9 % of number of grains per cob was recorded with drip mulch conditions.

### Relative Leaf Water Content and LAI

The data related to effect of irrigation methods on relative leaf water content (RLWC) and Leaf area index (LAI) is presented in Table 5. Maximum RLWC (%) was observed under drip irrigated plots (84.9) followed by furrow irrigation (83.6) and least under flood irrigation (80.5). Increase in RLWC under drip may be due to greater water extraction and uptake by plants owing to more water availability. The RLWC increased by 6.2 % under drip with mulch as compared to flat flood irrigation under un mulched conditions. Khalel (2015) showed that maximum RLWC was attributed due to higher irrigation regime and Wang *et al.* (2021) also stated that when the amount and frequency of irrigation were reduced, RLWC would be reduced for maize. It can be seen from the Table 5 that the leaf area index (LAI) affected significantly with methods of irrigation. The unmulched plots showed less difference between the data compared to the mulched plots. It might be due to less plant growth in unmulched plots. The data clearly revealed that mulched plots have maximum LAI. Similar results were recorded by Brar *et al.* (2019). LAI is direct function of number of leaves plant$^{-1}$ and leaf area is an important parameter indicating the photosynthetic capacity of plant

**Table 1.** Physical properties of surface soil (0-15 cm) of experimental site.

| Texture | BD(Mg/m$^3$) | IR (cm/hr) | HC (cm/hr) | FC (%) | PWP(%) |
|---|---|---|---|---|---|
| SL | 1.61 | 1.2 | 1.4 | 21.3 | 10.8 |

BD-Bulk density; IR-Infiltration rate; HC-Hydraulic conductivity; FC-Field capacity; PWP- Permanent wilting point

**Table 2.** Chemical characteristics of surface soil (0-15 cm) of experimental site.

| pH | EC (dS/m) | OC (%) | Available N (kg/ha) | Available P (kg/ha) | Available K (kg/ha) |
|---|---|---|---|---|---|
| 7.3 | 0.21 | 0.44 | 246.8 | 23.8 | 180.7 |

**Table 3.** Effect of different irrigation methods on maize plant height (m) and cob length(cm) under mulch and un mulch conditions

| Irrigation methods | Maize plant height (m) | | Cob length (cm) | | Mean Plant Height (m) | Mean Cob length (cm) |
|---|---|---|---|---|---|---|
| | Un- mulched | Mulched | Un- mulched | Mulched | | |
| Drip irrigation | 2.4 | 2.6 | 21.7 | 23.2 | 2.5 | 22.5 |
| Furrow irrigation | 2.0 | 2.4 | 20.3 | 21.1 | 2.2 | 20.7 |
| Flood irrigation | 1.7 | 2.1 | 17.6 | 18.9 | 1.9 | 18.3 |
| Mean | 2.0 | 2.4 | 19.9 | 21.1 | | |
| LSD (<0.05) | 0.5 | 0.4 | 2.9 | 2.6 | | |

**Table 4.** Effect of different irrigation methods on hundred maize grain weight (g) and number of grains per cob under mulch and un mulch conditions

| Irrigation methods | Hundred grain weight (g) | | Number of grains per cob | | Mean hundred grain weight (g) | Mean number of grains per cob |
|---|---|---|---|---|---|---|
| | Un- mulched | Mulched | Un- mulched | Mulched | | |
| Drip irrigation | 31.1 | 32.5 | 337 | 347 | 31.8 | 332 |
| Furrow irrigation | 28.3 | 30.1 | 317 | 329 | 29.2 | 323 |
| Flood irrigation | 26.7 | 28.6 | 306 | 321 | 27.7 | 313 |
| Mean | 28.7 | 30.4 | 320 | 332 | | |
| LSD (<0.05) | 1.9 | 1.7 | 13.4 | 8.6 | | |

**Table 5.** Effect of different irrigation methods on relative leaf water content (RLWC, %) and leaf area index (LAI) under mulch and un mulch conditions

| Irrigation methods | RLWC (%) | | LAI | | Mean RLWC (%) | Mean LAI |
|---|---|---|---|---|---|---|
| | Un- mulched | Mulched | Un- mulched | Mulched | | |
| Drip irrigation | 82.4 | 84.9 | 4.0 | 4.3 | 83.7 | 4.2 |
| Furrow irrigation | 81.6 | 83.6 | 3.7 | 3.9 | 82.6 | 3.8 |
| Flood irrigation | 79.7 | 80.5 | 3.5 | 3.8 | 80.1 | 3.7 |
| Mean | 81.2 | 83.0 | 3.7 | 4.0 | | |
| LSD (<0.05) | 0.6 | 0.9 | 0.3 | 0.3 | | |

and have marked influence on growth and yield of crop. In maize, maximum value of LAI was found under drip (4.3) followed by furrow (3.9) and minimum under flat flood irrigation (3.8). The LAI increased by 6.5 % with mulching when compared to un-mulch treatment. The increase in LAI under drip may be due to more leaves plant$^{-1}$(because of lesser senescence and longer period of leaf retention) and synthesis of growth favouring constituents in plant that increases leaves m$^{-2}$ and hence LAI.

**Cob weight and stover yield**

The data related to effect of irrigation methods on cob weight and stalk yield is presented in Table 6. Under mulch conditions, the maximum cob weight (g) was observed under drip irrigated plots (285) followed by furrow irrigation (276) and least under flat irrigation (268). Increase in cob weight under drip may be due to better moisture availability throughout the crop growing season. The cob weight increased by 9.2 % under drip with mulch as compared to flood irrigation under un mulched conditions. It can be seen from the Table 6 that the stover yield was affected significantly with methods of irrigation. Maximum stover yield was recorded under drip mulch (12.8 t/ha) while the minimum was recorded under flood un-mulch conditions (9.2 t/ha). There was 19.2 % increase in mean stover yield under drip irrigation as compared to flat flood irrigation.

**Grain yield and Water Productivity**

Maximum grain yield was found under drip irrigation (6.6 t ha$^{-1}$) which was higher by 3.2% and 10.7% higher than furrow irrigation and flood irrigation. The highest grain yield with drip irrigation might be attributed due to the proper water supply that led to increased overall plant growth. This led to improved root and above-ground plant development as well as improved photosynthesis, which ultimately increased the grain yield. A higher source amount generated a more efficient sink, which increased grain production. This might be also due to the fact that irrigation applied at regular interval had enhanced the cell metabolisms that reported in better yield. From the table 7, the results revealed that irrespective of irrigation methods the grain yield under mulch (6.2 t ha$^{-1}$) was significantly higher than un-mulched treatment (5.7 t ha$^{-1}$). Wang *et al* (2021) also revealed that drip irrigated treatments reported higher grain yield and biological yield than the conventional practices. Water productivity (WP) was observed to be significantly affected both by the irrigation methods (Table 7). Under mulch treatment, the WP was observed to 22.1, 16.1 and 13.3 t/ha-cm under drip, furrow and flood method of irrigation, respectively. When compared with irrigation methods and mulch treatment there was increases of water productivity by 47.1 % under drip irrigation with mulching than flood un-mulch conditions. Humphreys *et al.* 2005 reported that net irrigation

**Table 6.** Effect of different irrigation methods on cob weight (g) and stover yield (t/ha) under mulch and un mulch conditions

| Irrigation methods | Cob weight (g) | | Stover yield (t/ha) | | Mean cob weight (g) | Mean stover yield (t/ha) |
|---|---|---|---|---|---|---|
| | Un- mulched | Mulched | Un- mulched | Mulched | | |
| Drip irrigation | 278 | 285 | 11.1 | 12.8 | 282 | 12.0 |
| Furrow irrigation | 265 | 276 | 10.3 | 11.6 | 271 | 10.9 |
| Flood irrigation | 259 | 268 | 9.2 | 10.1 | 263 | 9.7 |
| Mean | 267 | 276 | 10.2 | 11.5 | | |
| LSD (<0.05) | 7.7 | 9.4 | 0.7 | 0.9 | | |

**Table 7.** Effect of different irrigation methods on maize grain yield (t/ha) and water productivity (kg/ ha-mm) under mulch and un mulch conditions

| Irrigation methods | Maize grain yield (t/ha) | | Water productivity (kg/ha-mm) | | Mean Grain Yield (t/ha) | Mean water productivity (kg/ha-mm) |
|---|---|---|---|---|---|---|
| | Un- mulched | Mulched | Un- mulched | Mulched | | |
| Drip irrigation | 6.1 | 6.6 | 20.7 | 22.1 | 6.4 | 21.4 |
| Furrow irrigation | 5.7 | 6.2 | 14.4 | 16.1 | 6.0 | 15.3 |
| Flood irrigation | 5.4 | 5.9 | 11.7 | 13.3 | 5.6 | 12.5 |
| Mean | 5.7 | 6.2 | 15.6 | 17.2 | | |
| LSD (<0.05) | 0.5 | 0.4 | 2.9 | 3.3 | | |

water productivity was about 33 percent higher under drip irrigation than furrow due to both higher yield and lower quantity of irrigation water applied. They reported highest grain yield with drip irrigation (11.5 t/ha) and least under furrow irrigation (9.9 t/ha).

## Conclusion

The water productivity enhances by 47 % under mulched condition with drip irrigation as compared with flood un-mulched condition. Maize plant height, hundred grain weight and maize yield were also found to be significantly influenced with mulching and irrigation methods. The results revealed that for achieving maximum maize grain yield and irrigation water productivity of maize, the drip method of irrigation need to be adopted under mulched conditions in Northwest India.

**Conflict of Interest**- None

## References


Barkunan, S.R., Bhanumathi, V. and Sethuram, J. 2019. Smart sensor for automatic drip irrigation system for paddy cultivation. *Comput Electr Engg.* 73: 180-193.

Barrs, H.D. and Weatherley, P.E. 1962. A re-examination of the relative turgidity technique for estimating water deficits in leaves. *Aust J Biol Sci.* 15: 413-428.

Brar, H.S. and Vashist, K.K. 2020. Drip irrigation and nitrogen fertilization alter phonological development and yield of spring maize (*Zea mays* L.) under semi-arid conditions. *J Plant Nutri.* 43:1757-1767.

Brar, A.S., Buttar, G.S. and Vashist, K.K. 2019a. Enhancing crop and water productivity of spring maize (*Zea mays* L.) through drip fertigation. *Indian J Agron.* 64: 87-92.

Esparza-Rivera, J.R., Stone, M.B., Stuchnoff, C., Pilon-Smits, E. and Kendall, P.A. 2006. Effects of ascorbic acid applied by two hydrocooling methods on physical and chemical properties of green leaf stored at 5 °C. *J Food Sci.* 71:270-276.

Guo, Q., Huang, G., Guo, Y., Zhang, M., Zhou, Y. and Duan, L. 2021. Optimizing irrigation and planting density of spring maize under mulch drip irrigation system in the arid region of Northwest China. *Field Crops Res.* 266:108141.

Humphreys, E., Meisner, C., Gupta, R., Timsina, J., Beecher, H.G., Tang YongLu, Yadvinder-Singh, Gill, M.A., Masih, I., Zheng Jia Guo and Thompson, J.A. 2005. Water savings in rice–wheat systems. *Plant Prod. Sci.* 8: 242-258.

Kara, T. and Biber, C. 2008. Irrigation frequencies and corn (*Zea mays* L.) yield relation in Northern Turkey. *Pakistan J. Bio. Sci*. 11(1): 123-126.

Khalel, A.M.S. 2015. Effect of drip irrigation intervals and some antitranspirants on the water status, growth and yield of potato (*Solanum tuberosum* L.). *J Agric Sci Technol.* 5:15-23.

Mansouri, F.C.S., Sanavy, A.M.M. and Saberali, S.F. 2010. Maize yield response to deficit irrigation during low-sensitive growth stages and nitrogen rate under semi-arid climatic conditions. *Agric Water Manage.* 97:12-22.

Otegui, M.E., Andrade, F.H. and Suero, E.E. 1995. Growth, water use, and kernel abortion of maize subjected to drought at silking. *Field Crops Res.* 40 (2): 87-94

Pawar, D.D., Dingre, S.K., Shinde, M.G. and Kaore, S.V. 2013. Drip fertigation for higher crop productivity. *MPKV Res Pub.* 99:3.

Uddin, M.T. and Dhar, A.R. 2020. Assessing the impact of water-saving technologies on Boron rice farming in Bangladesh: economic and environmental perspective. *Irrig Sci.* 38:199-212.

Wang, D., Li, G., Mo, Y., Zhang, D., Xu, X., Wilkerson, C.J. and Hoogenboom, G. 2021. Evaluation of subsurface, mulched and non-mulched surface drip irrigation for maize production and economic benefits in northeast China. *Irrig Sci.* 39:159-71.

Yazar, A., Howell, T.A., Dusek, D.A. and Copeland, K.S. 1999. Evaluation of crop water stress index for LEPA irrigated corn. *Irrig. Sci.* 18: 171-180.