Madras Agric. J., 98 (7-9): 243-247, September 2011
https://doi.org/10.29321/MAJ.10.100286

# Influence of Drip Fertigation on Yield, Water Saving and Water Use Efficiency in Maize (*Zea mays* L.) Based Intercropping System

**P. Muthukrishnan and S. Anitta Fanish***
Department of Agronomy
Tamil Nadu Agricultural University, Coimbatore - 641 003

**Field experiment was conducted at farmer's field at Palani taluk of Dindigul district in Tamil Nadu during *kharif* 2008 with the objective of evaluating the drip fertigation on water saving and Water Use Efficiency (WUE) in intensive maize based intercropping system. The experiment was laid out in strip plot design with three replications. The experiment consisted of 9 fertigation levels in main plot and 4 intercrops in sub plot. Among the different fertigation levels, higher maize grain yield of 7300 kg ha$^{-1}$ was recorded under drip fertigation of 100 per cent RDF with 50 per cent P and K through water soluble fertilizer (WSF) followed by application of 150 per cent RDF through drip (7050 kg ha$^{-1}$). The yield increase over drip irrigation with soil application of fertilizer was 39 per cent. Drip irrigation helped to save water upto 43.65 per cent compared to surface irrigation method. Among the different intercrops tested, higher WUE of 21.0 kg ha$^{-1}$ mm$^{-1}$ was observed under maize + vegetable coriander intercropping system.**

**Key words**: Drip fertigation, maize, intercropping system, water saving, water use efficiency.

Water is the vital source for crop production and is the most limiting factor in Indian agriculture. Though India has the largest irrigation network, the irrigation efficiency has not been achieved more than 40%. The per capita water availability, in terms of average utilizable water resources in the country, has dropped from 6008 m$^3$ in 1947 to 1250 m$^3$ at present and is expected to dwindle down to 760 m$^3$ (Singh, 2006). There are 140 m.ha of arable land in India of which 41.2 mha are being irrigated. Due to water scarcity, the available water resources should be very effectively utilized through water saving irrigation technologies. The need of the hour is, therefore, to maximize the production per unit of water. Adoption of micro-irrigation might help in raising the irrigated area, productivity of crops and water-use-efficiency (Sivanappan, 2005).

Maize (*Zea mays*) is the one of the most important cereal crops in the global agricultural economy both as a food for man and feed for animal. It is a miracle crop which has very high yield potential. There is no cereal crop on the earth that has so immense potential as that of maize and so it is called as 'Queen of cereals'. Globally, maize is cultivated in more than 130 counteries and occupies an area of 148.3 m ha with the production of 712.3 million metric tonnes and productivity of 4.82 tonnes ha$^{-1}$ (USDA, 2007). Tamil Nadu has a pride of place in the national maize scenario due to steadily increasing area under maize than other millets. At present, the area under maize has exceeded 2.87 lakh ha with the production of 12.58 lakh tonnes and productivity of 4389 kg ha$^{-1}$. Poultry sector is the leading consumer of maize grains in Tamil Nadu. Currently its requirement is about 20 lakh tonnes per year. In Tamil Nadu the major maize growing districts are Dindigul, Perambalur, Coimbatore, Erode, Karur and Theni both under irrigated as well as rainfed conditions. One of the possible ways to bridge the gap between demand and supply is to increase the productivity per unit area by adopting the precision agriculture technology in maize. Productivity of maize can be increased by growing with precision technologies such as drip fertigation.

Short duration vegetables grown in-between the agricultural crops is the recent advancement to fulfil the requirement of vegetables without any reduction of agricultural area. The drip system installed for maize crop can be well utilized for intercrops. Besides nutritional benefit, vegetable has more market value than maize grain, so it can help to reduce the payback period of drip system. Hence, a field experiment was conducted at farmers holding to study the effect of drip fertigation and intercrops on yield, water saving and water use efficiency of maize in intensive maize-based intercropping system.

## Materials and Methods

A field experiment was conducted during *kharif,* 2008 at farmer's field in Palani taluk of Dindigul

*Corresponding author email: fanish_agri@yahoo.co.in

district, Tamil Nadu. The experimental soil was sandy clay loam, low in available N (180 kg $ha^{-1}$), medium in available P (13 kg $ha^{-1}$) and high in available K (525 kg $ha^{-1}$). The soil has pH value of 7.35, EC of 0.72 $dSm^{-1}$ and organic carbon content of 0.45 per cent. The experiment was laid out in strip plot design with three replications. The experiment consisted of 9 treatments in main plot viz.$T_1$ - Surface irrigation with soil application of 100 % RDF, $T_2$ - Drip irrigation with soil application of 100 % RDF, $T_3$ - Drip fertigation of 75 % RDF, $T_4$ - Drip fertigation of 100 % RDF, $T_5$ - Drip fertigation of 125 % RDF, $T_6$ - Drip fertigation of 150 % RDF, $T_7$- Drip fertigation of 50 % RDF (50 % P and K as WSF), $T_8$- drip fertigation of 75 % RDF ( 50 % P and K as WSF), $T_9$- Drip fertigation of 100 % RDF (50 % P and K as WSF) and four intercrops in sub plot *viz*., $S_1$ - Vegetable coriander, $S_2$ - Radish, $S_3$ - Beet root, $S_4$ - Onion. The field was uniformly levelled and formed into raised flat beds for maize. The raised flat bed size was 1.2 m width and 20 m length. The lateral spacing between two raised flat beds was 1.5 m with furrow in-between of 30 cm width and 15 cm depth. In the surface irrigated plots, ridges and furrows were formed at 60 cm apart. The maize hybrid NK 6240 was grown as test crop. The crops chosen as intercrops were vegetable coriander (Surabhi), radish (Pusa Chetki), beet root (Madhur) and onion (Local variety).

Irrigation was scheduled based on climatological approach. First irrigation was given immediately after sowing. For surface irrigation method, subsequent irrigations were scheduled at 5.0 cm depth with IW / CPE ratio of 0.8 for maize. For irrigation through drip, subsequent irrigations were scheduled once in three days based on the following formula and applied each time as per the treatment schedule. For drip fertigation system the operating pressure was maintained at 1.0 kg $cm^2$. The volume of water to be supplied was calculated by the following formula,

WRc = CPE X Kp x Kc x Wp x A, where,

WRc = Computed water requirement (l $plant^{-1}$)

CPE = Cumulative pan evaporation for three days (mm)

Kp = Pan factor (0.75)

Kc = Crop factor

Wp = Wetted percentage (80)

A = Area per plant

Time of operation of drip system to deliver the required volume of water per plot was computed based on the formula

$$\text{Time of operation} = \frac{\text{Volume of water required (WRc)}}{\text{Emitter discharge x No. of emitters}}$$

For computing total water use, the effective rainfall was also included and expressed in mm. Effective rainfall is a part of rainfall available for the consumptive use of the crop. When rainfall is of high intensity, only a portion of rainfall can enter the soil and get stored in the root zone. In case of low intensity rainfall, depending on the amount of moisture already present in the root zone of the crop, even the entire rainfall may be effective rainfall. Immediately after drip irrigation, moisture content in the root profile was assumed to be nearer to field capacity. The additional cultivated area (X) means the area that could be cultivated by utilizing the irrigation saved from drip irrigation

$$X = \frac{\text{Water saved from drip irrigation}}{\text{Total water used for drip irrigation}} \times 100$$

## Results and Discussion

### *Water Saving under Drip Irrigation*

The quantity of irrigation water supplied through drip was 163 mm and the effective rainfall received during the cropping period was 130 mm. The total water used under the drip irrigation was 293 mm (Table 1).

Under surface irrigation method, irrigation was given immediately after sowing followed by life irrigation at 5 cm depth thereafter irrigation was given as per the IW/CPE ratio of 0.8. Quantity of water applied through surface was 350 mm. An effective rainfall of 170 mm was received during crop period and totally 520 mm of water was consumed by surface irrigated crop.

**Table 1. Effect of drip irrigation on water saving**

| Season | Irrigation method | Water applied (mm) | Effective rainfall (mm) | Total water used (mm) | Water saving (%) | Additional cultivated area (%) |
|---|---|---|---|---|---|---|
| *Kharif* | Surface | 350 | 170 | 520 | - | - |
| 2008 | Drip | 163 | 130 | 293 | 43.65 | 77.5 |

The water consumed under drip irrigation was 43 per cent lower than that of surface irrigation method. This infers that much quantity of water could be saved by drip irrigation and utilized for cultivating additional area. The water saving under drip irrigation was due to low application rate at frequent intervals matching the actual crop water needs at various stages. Under drip irrigation, irrigation was practiced frequently once in three days due to which the soil moisture was always maintained nearer to the field capacity. Hence much of the rainfall received during the crop period has gone as ineffective rainfall under drip irrigation. But under surface irrigation method, due to the long gap between two irrigations, the rainfall received was utilized effectively and that might be the reason for higher utilization of effective rainfall under surface irrigation compared to drip irrigation. This finding is in agreement with Ramah *et al.* (2008).

***Grain Yield***

Generally the maize grain yield increased with increase in fertilizer level (Table 2). Higher maize grain yield of 7300 kg ha$^{-1}$ was recorded under drip fertigation of 100 per cent RDF with 50 per cent P and K through WSF followed by application of 150 per cent RDF through drip (7050 kg ha$^{-1}$). The yield increase over drip irrigation with soil application of fertilizer ($T_2$) was 39 per cent.

Application of water soluble fertilizer also influenced the grain yield of maize compared to straight fertilizer. In this present investigation, drip fertigation with 100 per cent RDF in which 50 per cent P and K as WSF increased the grain yield to the tune of 22.4 per cent as compared to drip fertigation of 100 per cent RDF with normal fertilizer. The increase in yield under 100 per cent RDF with P and K as WSF might be due to the fact that fertigation with more readily available form obviously resulted in higher availability of all the three (NPK) major nutrients in the soil solution which led to higher uptake and better translocation of assimilates from source to sink thus in turn increased the yield. The higher yield of fruits per plant under liquid fertilizer treatments could be due to continuous supply of NPK from the liquid fertilizers as reported by Kadam and Karthikeyan (2006) in tomato. Hebbar *et al.,* (2004) reported that fertigation with normal fertilizer gave significantly lower yield compared to fertigation with water soluble fertilizers. This was attributed to complete solubility and availability of the water soluble fertilizer as compared to normal fertilizer. Water soluble fertilizer had higher concentration of available plant nutrient in top layer.

**Table 2. Effect of drip fertigation levels and intercrops on grain yield and water use efficiency of maize**

| Treatment | Grain yield (kg ha$^{-1}$) | | | | | Water Use Efficiency (kg ha$^{-1}$ mm$^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | Mean | $S_1$ | $S_2$ | $S_3$ | $S_4$ | Mean |
| $T_1$ | 4725 | 4590 | 4275 | 4410 | 4500 | 9.1 | 8.8 | 8.2 | 8.5 | 8.7 |
| $T_2$ | 5500 | 5343 | 4976 | 5133 | 5238 | 18.8 | 18.2 | 17.0 | 17.5 | 17.9 |
| $T_3$ | 5807 | 5641 | 5254 | 5419 | 5530 | 19.8 | 19.3 | 17.9 | 18.5 | 18.9 |
| $T_4$ | 6262 | 6083 | 5666 | 5845 | 5964 | 21.4 | 20.8 | 19.3 | 19.9 | 20.4 |
| $T_5$ | 7156 | 6951 | 6474 | 6679 | 6815 | 24.4 | 23.7 | 22.1 | 22.8 | 23.3 |
| $T_6$ | 7403 | 7191 | 6698 | 6909 | 7050 | 25.3 | 24.5 | 22.9 | 23.6 | 24.1 |
| $T_7$ | 6038 | 5865 | 5463 | 5635 | 5750 | 20.6 | 20.0 | 18.6 | 19.2 | 19.6 |
| $T_8$ | 6726 | 6534 | 6086 | 6278 | 6406 | 23.0 | 22.3 | 20.8 | 21.4 | 21.9 |
| $T_9$ | 7665 | 7446 | 6935 | 7154 | 7300 | 26.2 | 25.4 | 23.7 | 24.4 | 24.9 |
| Mean | 6365 | 6183 | 5758 | 5940 | | 21.0 | 20.3 | 18.9 | 19.5 | |
| | T | S | T x S | S x T | | | | | | |
| SEd | 93.4 | 71.3 | 161.5 | 121.9 | | - | - | - | - | |
| CD (P=0.05) | 235.6 | 180.8 | 403.8 | 307.5 | | - | - | - | - | |

Different inter crops also influenced the grain yield of maize significantly. Among the four intercrops, vegetable coriander intercropping recorded a higher yield of 6365 kg ha$^{-1}$. This could be explained by easy access of resources like moisture and nutrient by maize in this cropping system compared to those in other intercropping system (Kumar and Bangarwa, 1997).

The interaction effect between fertigation levels and intercrops was found to be significant. Among the different fertigation levels and intercropping systems, significantly higher grain yield of 7665 kg ha$^{-1}$ was recorded under fertigation of 100 per cent RDF with 50 per cent P and K as WSF in maize + vegetable coriander intercropping system.

***Water Use Efficiency (WUE)***

Different drip fertigation levels and intercrops exerted significant difference on WUE of maize (Table 2). Irrigation given through drip along with a fertilizer level of 100 per cent RDF with 50 per cent P and K as WSF ($T_9$) had a higher WUE of 24.9 kg ha$^{-1}$ mm$^{-1}$ followed by fertigation with 150 per cent RDF through normal fertilizer ($T_6$). The surface method of irrigation recorded the lowest WUE of 8.7 kg ha$^{-1}$ mm$^{-1}$ and this was 65 per cent lower than that of drip irrigation. The increase in WUE in all drip-irrigated treatments over surface irrigation was mainly due to considerable saving of irrigation water, greater increase in yield of crops and higher nutrient use efficiency. Increase in irrigation amount did not increase the marketable yield of crops but reduced the irrigation production efficiency significantly (Imtiyaz *et al.,* 2000). Ardell (2006) reported that application of N and P fertilizer will frequently increase crop yields, thus increasing crop water use efficiency. Adequate levels of essential plant nutrients are needed to optimize crop yields and WUE.

The lower WUE under surface irrigation might be due to higher consumption of water and lower yield recorded under the treatment. Similarly

Ahluwalia *et al.* (1993) reported that the irrigation water use efficiency was greater to the extent of 145 and 155 per cent in the drip method compared to the furrow method in tomato and cauliflower, respectively. Among the different intercropping systems, higher WUE of 21.0 kg $ha^{-1}$ $mm^{-1}$ was observed under maize + vegetable coriander intercropping system.

***Effective Utilization of Land and Water in the Cropping System***

The data on water saving and additional area to be cultivated due to saving of water through drip irrigation system is presented in Table 2. Drip irrigation method helps to save the water upto 43.65 per cent compared to surface method of irrigation. Utilizing this amount of water saved through drip irrigation, we could cultivate 77 per cent of cultivable area additionally. By using the same quantity of water we could cultivate nearly 180 per cent of area when compared to surface irrigation method.

***Intercrop yield***

Drip fertigation levels significantly affected the yield of intercrops (Table 3). With regards to vegetable coriander, fertigation of 125 per cent RDF produced a higher leaf yield of 1512 kg $ha^{-1}$ followed by 100 per cent RDF with 50 per cent P and K as WSF (1400 kg $ha^{-1}$). In radish, fertigation with 100 per cent RDF with 50 per cent of P and K as WSF recorded significantly higher tuber yield of 4064 kg $ha^{-1}$ followed by 75 per cent RDF with 50 per cent P and K as WSF (3875 kg $ha^{-1}$).

**Table 3. Effect of drip fertigation levels on yield of intercrops**

| Treatment | Coriander (kg $ha^{-1}$) | Radish (kg $ha^{-1}$) | Beetroot (kg $ha^{-1}$) | Onion (kg $ha^{-1}$) |
|---|---|---|---|---|
| $T_1$ | 672 | 2548 | 2293 | 3263 |
| $T_2$ | 752 | 2356 | 2623 | 3562 |
| $I_3$ | 909 | 3349 | 3546 | 4238 |
| $I_4$ | 1200 | 3548 | 3886 | 4357 |
| $T_5$ | 1512 | 2876 | 4619 | 4572 |
| $T_6$ | 1304 | 3768 | 4126 | 4478 |
| $T_7$ | 998 | 3068 | 4318 | 3829 |
| $T_8$ | 1103 | 3875 | 4830 | 4027 |
| T | 1400 | 4064 | 4991 | 4129 |
| SEd | 30.2 | 42.0 | 63.9 | 35.4 |
| CD (P=0.05) | 75.5 | 105.5 | 154.7 | 88.6 |

In case of beet root, a higher root yield was obtained under 100 per cent with 50 per cent P and K as WSF (4991 kg $ha^{-1}$) followed by 75 per cent RDF in which 50 per cent P and K as WSF recorded the yield of 4830 kg $ha^{-1}$. Significantly a higher onion bulb yield was obtained under fertigation of 125 per cent RDF (4572 kg $ha^{-1}$) followed by fertigation of 150 per cent RDF (4478 kg $ha^{-1}$). For all intercrops lower yield were recorded under surface irrigation with conventional method of fertilizer application.

***Influence of drip irrigation on moisture content Vs yield***

The soil moisture content was found to be higher under drip irrigation, which was higher than field capacity of the soil on first and second day after irrigation (Table 4a-4c). On the third day, it reaches field capacity below the dripper and the moisture content decreased as the distance from the dripper increased. In the surface irrigated plots, the moisture content was above the field capacity during first two days after irrigation, but it tends to decline below the field capacity and reaches 14 to 17 per cent on 8th day after irrigation during which time the crop experiences water stress (Table 5).

**Table 4a. Moisture dynamics at 24 hrs after drip irrigation (moisture content %)**

| Depth (cm) | Distance from dripper (cm) | | | | | |
|---|---|---|---|---|---|---|
| | Between lateral | | | Along lateral | | |
| | 0 | 30 | 60 | 10 | 20 | 30 |
| 0-15 | 26.79 | 24.86 | 21.67 | 25.89 | 25.06 | 24.23 |
| 15-30 | 27.52 | 25.13 | 20.78 | 26.63 | 25.34 | 25.15 |
| 30-45 | 25.73 | 23.17 | 18.53 | 23.84 | 22.67 | 21.16 |

**Table 4b. Moisture dynamics at 48 hrs after drip irrigation (moisture content %)**

| Depth (cm) | Distance from dripper (cm) | | | | | |
|---|---|---|---|---|---|---|
| | Between lateral | | | Along lateral | | |
| | 0 | 30 | 60 | 10 | 20 | 30 |
| 0-15 | 25.32 | 21.26 | 19.24 | 24.04 | 23.34 | 21.13 |
| 15-30 | 27.21 | 23.10 | 20.41 | 23.72 | 22.82 | 21.02 |
| 30-45 | 24.45 | 21.47 | 17.10 | 21.16 | 20.27 | 19.54 |

**Table 4c. Moisture dynamics at 72 hrs after drip irrigation (moisture content %)**

| Depth (cm) | Distance from dripper (cm) | | | | | |
|---|---|---|---|---|---|---|
| | Between lateral | | | Along lateral | | |
| | 0 | 30 | 60 | 10 | 20 | 30 |
| 0-15 | 22.26 | 19.38 | 17.62 | 21.67 | 21.57 | 20.43 |
| 15-30 | 23.14 | 21.57 | 19.84 | 22.34 | 20.73 | 19.83 |
| 30-45 | 21.91 | 19.42 | 16.34 | 19.56 | 18.11 | 17.17 |

**Table 5. Moisture depletion pattern under surface irrigation**

| Days after irrigation | Moisture content (%) | | |
|---|---|---|---|
| | Depth (cm) | | |
| | 0-15 | 15-30 | 30-45 |
| 1 | 28.05 | 28.32 | 26.82 |
| 2 | 26.92 | 27.15 | 24.32 |
| 3 | 24.45 | 24.63 | 22.78 |
| 4 | 23.92 | 23.13 | 20.55 |
| 5 | 21.56 | 21.68 | 19.04 |
| 6 | 19.73 | 19.98 | 17.46 |
| 7 | 18.00 | 18.28 | 16.46 |
| 8 | 16.45 | 16.86 | 14.78 |

The crop irrigated with drip experienced full irrigation without any stress period due to which the roots extracted adequate moisture along with the adequate nutrients efficiently, without any leaching loss which might have increased the yield of the crops. The soil water distribution under all drip fertigation treatments indicated that it was relatively high near the dripper and decreased as the distance from the dripper point increased. This finding was in concordance with the findings of Chakraborty *et al.* (1999).

## Conclusion

The results of this experiment revealed that among the fertilizer treatments, drip fertigation of 100 per cent RDF with 50 per cent P and K as WSF has recorded the highest yield. Drip irrigation helps to save water upto 43 per cent and it could be utilized to cultivate 77 per cent of cultivated area additionally. Among the different intercropping systems, maize + vegetable coriander system recorded more grain yield of maize and recorded higher WUE. Hence, it is concluded that, drip fertigation of 100 per cent RDF with 50 per cent of P and K as water soluble fertilizer with vegetable coriander as intercrop would be an ideal practice to achieve higher yield and water saving benefits as compared to surface irrigation method in intensive maize based intercropping system.

## References

Ahluwalia, M. S., Bladev, S. and Gill, B.S. 1993. Drip irrigation system-its hydraulic performance and influence on tomato and cauliflower crops. *J. Water Manage.,* **1**: 6-9.

Ardell, D.H. 2006. Water use efficiency under different cropping situation. *Ann. Agric. Res.,* **27**: 115-118.

Chakraborty, D., Singh, A.K., Kumar, A. and Khanna, M. 1999. Movement and distribution of water and nitrogen in soil as influenced by fertigation in broccoli (*Brassica oleracea* var. Italic L.). *J. Water Manage.*, **7**: 8-13.

Hebbar, S.S., Ramachandrappa, B.K., Nanjappa, H.V. and Prabhakar, M. 2004. Studies on NPK drip fertigation in field grown tomato (*Lycopersicon esculentum* Mill.). *Europ. J. Agron.*, **21**: 117-127.

Imtiyaz, M., Mgadla, N.P., Manase, S.K., Chendo, K. and Mothobi, E.O. 2000. Yield and economic return of vegetable crops under variable irrigation. *Irrig. Sci.,* **19:** 87-93.

Kadam, J.R. and Karthikeyan, S. 2006. Effect of soluble NPK fertilizers on the nutrient balance, water use efficiency, fertilizer use efficiency of drip system in a Tomato. *Int. J. Plant. Sci.*, **1**: 92-94.

Kumar, S. and Bangarwa, A.S. 1997. Yield and yield components of winter maize (*Zea mays* L.) as influenced by plant density and nitrogen levels. *Agric. Sci. Digest,* **17**: 354-359.

Ramah, K. 2008. Study on drip irrigation in maize (Zea mays L) based cropping system. Ph.D., Thesis, TNAU, Coimbatore.

Singh, H.P. 2006. Micro irrigation-an option for sustainability. National Conference on Micro-irrigation (NCOM), June 3-5.

Sivanappan, R.K. 2005. To overcome the demand for water. *Kisan World,* **32**: 47.

USDA. 2007. World Agricultural Production. Foreign Agricultural Service. Circular Series, WAP 06-07, 2007.

Received: April 4, 2011; Accepted: September 2, 2011