



## Effect of Drip Fertigation and Intercropping on Growth, Yield and Water Use Efficiency of Maize (*Zea mays* L.)

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Field experiments were conducted during *kharif* 2008 and 2009 at Tamil Nadu agricultural University, Coimbatore to study the effect of drip fertigation on growth, yield and economics of intensive maize based intercropping system. During *kharif* 2008, drip fertigated maize at 150 per cent RDF recorded significantly higher grain yield of 7338 kg ha<sup>-1</sup>, whereas during *kharif* 2009, higher grain yield of 7464 kg ha<sup>-1</sup> was recorded under drip fertigation of 100 per cent RDF with 50 per cent P and K as Water soluble fertilizer (WSF). Among the different intercropping systems, radish intercropped with maize registered a higher maize grain equivalent yield (MEY) of 11153 kg ha<sup>-1</sup>. Drip irrigation helped to save the water upto 43 per cent compared to surface irrigation besides enhancing the water use efficiency.

**Key words** : Drip fertigation, maize, 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 average rainfall in Tamil Nadu is 958.5 mm as against the average rainfall of 1200 mm (IMD, 2008) in the country. 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. Hence, further expansion of irrigation may depend upon the adoption of new systems such as pressurized irrigation methods with the limited water resources. Amongst those pressurized irrigation methods, drip irrigation has proved its superiority over other methods of irrigation due to the direct application of water and nutrients in the vicinity of root zone. 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. Addressing these issues requires an integrated approach to soil-water-plant-nutrient management at the plant-rooting zone. Fertigation, a latest technology wherein nutrients are applied along with irrigation water and fertigation opens new possibilities for controlling water and nutrient supplies to crops besides maintaining the desired concentration and distribution of water and nutrients to the soil (Bar-Yosef, 1999).

Diversification of cropping pattern particularly in favour of vegetable crops is becoming popular among farmers because vegetables are most

important component in a balanced diet. The vegetable production (40 mt) and consumption (140g head<sup>-1</sup> day<sup>-1</sup>) in India are rather low and inadequate (Shobana, 2002). By the turn of 2010 India has to produce about 125 mt of vegetables to supply the minimum quantity recommended (250g head<sup>-1</sup> day<sup>-1</sup>). Therefore, the productivity and area under vegetable crops need to be further intensified to overcome the deficit. But diversification of area from field crops to olericulture to meet the demand is not desirable. Short duration vegetables grown in-between the agricultural crops is the recent advancement to fulfill the requirement of vegetables without any reduction of agricultural area.

Maize is one of the world's leading crops cultivated over an area of about 148.5 million hectares with a production of about 699.3 million tonnes and productivity of 4.71 tonnes ha<sup>-1</sup> of grain (USDA, 2007). The demand for maize and vegetable has increased due to the establishment of food and feed production corporate sectors; most of the farmers have changed their cropping system to include maize and vegetable as component crops.

Research works on drip irrigation under intercropping situation is very limited. Input information on optimal schedules for micro-irrigation and fertigation to maize and planting geometry for micro-irrigation will have to be generated from the current levels thus enabling the option of micro-irrigation under intercropping situation. The drip system installed for maize crop can be used for intercrops too simultaneously and helps to reduce the payback period. Considering the above points in view, the present study was undertaken to assess the feasibility of drip fertigation in maize based inter cropping system.

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## Materials and Methods

The experiment was conducted during *kharif* seasons of 2008 and 2009 at Tamil Nadu Agricultural University, Coimbatore. The soil was sandy clay loam with pH 7.53 and EC 0.76 dS /m, having 0.32% organic carbon, 220 kg/ ha available N, 17 kg/ ha available P and 425 kg /ha available K. The treatment comprised of nine fertigation levels in main plot and four intercrops in subplot. The treatment detail is as follow.

### Main Plot

T<sub>1</sub>- Surface irrigation with soil application of 100 % RDF;

T<sub>2</sub>- Drip irrigation with soil application of 100 % RDF; T<sub>3</sub>- Drip fertigation of 75 % RDF;

T<sub>4</sub>- Drip fertigation of 100 % RDF;

T<sub>5</sub>- Drip fertigation of 125 % RDF;

T<sub>6</sub>- Drip fertigation of 150 % RDF;

T<sub>7</sub>- Drip fertigation of 50 % RDF (50 % P and K as WSF); T<sub>8</sub> -

Drip fertigation of 75 % RDF (50 % P and K as WSF); T<sub>9</sub> -

Drip fertigation of 100 % RDF (50 % P and K as WSF)

### Sub plot

S<sub>1</sub>-Vegetable coriander S<sub>2</sub> -Radish

S<sub>3</sub> -Beet root S<sub>4</sub> - Onion.

The experiment was laid out in strip plot design with three replications. Maize hybrid COH (M) 5 was sown with spacing of 75 X 20 cm. The crops chosen as inter crops were coriander (Surabhi), radish (Pusa chetki), beet root (Madhur) and onion (Co (On) 4).

The entire quantity of phosphorus was applied as basal in treatments T<sub>1</sub> to T<sub>6</sub> in the form of di ammonium phosphate one day before sowing. Normal fertilizers viz., urea and muriate of potash were used to supply N and K respectively. Mono ammonium phosphate (12: 61: 0) and multi-K (13: 0: 46) were used as water soluble fertilizer for supplying P and K respectively. Fertigation was given once in three days.

## Results and Discussion

### Growth parameters

The growth parameters of maize were influenced by fertilizer levels significantly. Application of 100 % RDF with 50 % P and K as WSF through fertigation resulted in higher growth a character which was followed by 150 per cent RDF (Table 1). The crops applied with higher dose of nutrients as water soluble fertilizers through fertigation resulted in higher uptake and lead to higher growth characters. Increased plant height and LAI with 100 per cent RDF (238.1 cm and 4.94) through water soluble

**Table 1. Effect of drip fertigation on growth parameters of maize in intensive maize based intercropping system (pooled data)**

Treatment	Plant height (cm)		LAI		DMP (kg ha <sup>-1</sup> )		Root depth (cm)		Root volume (cm <sup>3</sup> )		Root biomass (g plant <sup>-1</sup> )	
T <sub>1</sub>	204.0		3.73		8102		46.2		74.4		13.16	
T <sub>2</sub>	208.7		3.91		8896		50.1		75.9		13.60	
T <sub>3</sub>	213.0		3.99		9658		51.3		77.3		13.92	
T <sub>4</sub>	216.6		4.19		10730		52.5		80.4		15.38	
I <sub>5</sub>	223.9		4.50		11826		52.8		81.8		15.92	
I <sub>6</sub>	233.6		4.76		13421		54.4		85.3		17.06	
T <sub>7</sub>	219.9		4.34		9949		52.2		78.7		14.45	
T <sub>8</sub>	228.1		4.65		12622		53.6		83.3		16.36	
T <sub>9</sub>	238.1		4.94		14218		55.3		86.9		17.72	
S <sub>1</sub>	226.6		4.41		12017		52.9		83.0		16.22	
S <sub>2</sub>	220.1		4.30		11372		51.9		79.6		15.13	
S <sub>3</sub>	216.1		4.26		10912		52.2		78.2		15.12	
S <sub>4</sub>	221.6		4.37		10360		51.6		81.0		14.78	
	SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
T	1.67	4.10	0.036	0.091	315.7	791.1	0.11	0.28	0.56	1.40	0.116	0.291
S	0.86	2.05	0.022	0.053	182.6	454.7	0.08	0.21	0.42	1.06	0.105	0.263

fertilizers might be due to the presence of favourable microclimate to the plants and application of sufficient nutrients in a readily available form that would have accelerated the production of growth regulators such as auxins (IAA) and cytokinins which in turn stimulated the action of cell elongation and cell division and resulted in increased plant height. Similar findings were obtained by Kavitha *et al.* (2007) in tomato.

Application of 100 per cent RDF with 50 per cent P and K as WSF through drip recorded a higher DMP of 14218 kg ha<sup>-1</sup> which was on par with

fertigation at 150 per cent RDF. The plants maintain a turgid condition during the day time under drip irrigation as compared to surface irrigation. There is a possibility of wide opening of stomata for longer period which might have resulted in high exchange of gases. Similarly, leaves might have remained turgid and produced more leaf surface. Thus, the turgor state helps in absorption of more sun light and solar radiation (Kadam, 1990).

Among the different intercrops tested, vegetable coriander as intercrop recorded significantly higher plant height (cm), LAI and DMP of maize than other

intercropping systems. Increased plant height, LAI and dry matter accumulation under this system might be due to less competition for moisture and nutrients as compared to other intercropping system. Vegetable coriander was harvested at 25 DAS. Afterwards, maize was a sole crop. So availability of moisture and nutrients were higher under this intercropping system. This might be the one of the reason for higher growth parameter of maize in maize

+ vegetable coriander intercropping system. Tiwari *et al.* (2002) reported that leafy vegetables like coriander did not show any adverse effect on growth and development of main crop which may be

attributed to the fact that coriander is shallow rooted and short statured with short duration.

#### Root character

Plant roots play a vital role in soil water and solute dynamics by modifying the water and solute uptake patterns in the rooting zone. The results on root depth, volume and bio mass of maize revealed that there was a significant variation due to irrigation methods, fertigation levels and different intercrops (Table 1). Data on rooting depth, root volume and root biomass of maize in the treatments T<sub>3</sub> to T<sub>9</sub> showed that increasing the fertilizer doses increased

**Table 2. Effect of drip fertigation on grain yield of maize in intensive maize based intercropping system**

Treatment	Kharif 2008					Kharif 2009					Pooled data				
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
T <sub>1</sub>	4982	4886	4531	4761	4790	5148	5049	4683	4920	4650	5065	4968	4607	4841	4720
T <sub>2</sub>	5474	5368	4979	5231	5263	5728	5618	5211	5475	5508	5601	5493	5095	5353	5386
T <sub>3</sub>	6013	5898	5470	5747	5782	6226	6107	5664	5951	5987	6120	6003	5567	5849	5885
T <sub>4</sub>	6529	6404	5939	6240	6278	6618	6490	6019	6325	6363	6574	6447	5979	6283	6321
T <sub>5</sub>	7062	6926	6423	6749	6790	7100	6964	6458	6786	6827	7081	6945	6441	6768	6809
T <sub>6</sub>	7632	7485	6942	7294	7338	7369	7228	6703	7043	7086	7501	7357	6823	7169	7212
T <sub>7</sub>	6271	6151	5704	5994	6030	6349	6227	5775	6068	6105	6310	6189	5740	6031	6068
T <sub>8</sub>	6801	6670	6186	6500	6539	6882	6749	6260	6577	6617	6842	6710	6223	6539	6578
T <sub>9</sub>	7440	7297	6768	7111	7154	7763	7613	7061	7419	7464	7602	7455	6915	7265	7309
Mean	6467	6343	5882	6181		6576	6449	5982	6285		6522	6396	5932	6233	
	T	S	T at S	S at T	T	S	T at S	S at T	T	S	T at S	S at T	T	S	
SEd	70	54	105	81	112	77	170	130	100	72	152	117			
CD (P=0.05)	175	135	263	202	252	193	428	321	235	181	380	288			

the rooting character significantly. In order to achieve proper growth, the root zone of a plant must be well supplied with both water and oxygen. Among the fertigation treatments, 100 per cent RDF with 50 per cent P and K as WSF and 150 per cent RDF resulted in higher root parameters. Adequate quantity of nutrients coupled with adequate moisture might have resulted in higher root proliferation. Application of readily available form of fertilizer particularly in frequent intervals (once in three days) by reducing the quantity of nutrients at one application, the crops could able to utilize maximum quantity of nutrients reducing the leaching and volatilization loss and increasing the nutrient use efficiency which might have resulted in higher root growth.

Regarding intercropping system, maize + vegetable coriander recorded a higher rooting depth (52.9 cm), root volume (83 cm<sup>3</sup>) and root biomass (16.22 g plant<sup>-1</sup>) of maize. Interaction effect between fertigation level and intercrops was found to be non significant for rooting depth of maize.

#### Grain Yield of maize

Generally the maize grain yield increased with increase in fertilizer level (Table 2). During *kharif* 2008, drip fertigated maize at 150 per cent RDF recorded significantly higher grain yield of 7338 kg ha<sup>-1</sup>. The yield increase observed under 150 per cent RDF over drip irrigation with conventional method of fertilizer application was 39 per cent.

During *kharif* 2009, higher maize grain yield (7464 kg ha<sup>-1</sup>) was recorded under drip fertigation of 100 per cent RDF with 50 per cent P and K through WSF. The yield increases over drip irrigation with soil application of fertilizer was 35 per cent during *kharif* 2009. 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 14 and 17 per cent during *kharif* 2008 and *kharif* 2009, respectively, as compared to drip fertigation of 100 per cent RDF with normal fertilizer. The pooled data revealed that higher grain yield of maize was observed under fertigation of 100 per cent RDF in which 50 per cent P and K as WSF. However, it was on par with fertigation of 150 per cent RDF through 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. Water soluble fertilizer had higher concentration of available plant nutrient in top layer. The highest number 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. Different intercrops also influenced the grain yield of maize significantly. Among the four intercrops, vegetable coriander intercropping recorded a higher yield of 6467 and 6576 kg ha<sup>-1</sup> during *kharif* 2008 and *kharif* 2009 respectively. This could be due to easy access of resources like moisture and nutrient by maize in this cropping system compared to those in other intercropping systems as also reported by Kumar and Bangarwa (1997). The increased trend in yield

might be due to the increased supply of nutrients under this cropping system.

#### Stover yield of maize

During *kharif* 2008 and *kharif* 2009, drip fertigation of 100 per cent RDF (50 % P and K as WSF) recorded significantly higher stover yield of 10374 and 10891 kg ha<sup>-1</sup> followed by 150 per cent RDF through drip fertigation (10158 and 10585 kg ha<sup>-1</sup>) respectively ( Table 3). The increase in stover

**Table 3. Effect of drip fertigation and intercrops on stover yield and water use efficiency of maize in intensive maize based intercropping system**

Treatment	Stover yield (kg ha <sup>-1</sup> )			Water use efficiency (kg ha cm <sup>-1</sup> )		
	<i>Kharif</i> 2008	<i>Kharif</i> 2009	Pooled data	<i>Kharif</i> 2008	<i>Kharif</i> 2009	Mean
T <sub>1</sub>	8083	8256	8170	9.0	9.7	9.4
T <sub>2</sub>	8395	9162	8779	17.1	17.9	17.5
T <sub>3</sub>	8752	9563	9158	18.8	19.4	19.1
T <sub>4</sub>	9099	9667	9383	20.4	20.7	20.6
T <sub>5</sub>	9830	10279	10055	22.0	22.2	22.1
T <sub>6</sub>	10158	10585	10372	23.8	23.0	23.4
T <sub>7</sub>	9193	9468	9331	19.6	19.8	19.7
T <sub>8</sub>	9506	9973	9740	21.2	21.5	21.4
T <sub>9</sub>	10374	10891	10633	23.2	24.2	23.7
S <sub>1</sub>	9541	9956	9749	20.2	20.6	20.4
S <sub>2</sub>	9375	9809	9592	19.9	20.2	20.1
S <sub>3</sub>	9071	9595	9333	18.4	18.7	18.6
S <sub>4</sub>	9226	9682	9454	19.3	19.7	19.5
	SEd	CD	SEd	CD	SEd	CD
T	84	212	130	326	107	269
S	61	154	100	251	81	203

yield obtained under 100 per cent RDF with WSF was 14.0 and 12.7 per cent over drip fertigation with 100 per cent RDF with normal fertilizer. The lowest stover yield was recorded under surface irrigation and this was 78 and 75 per cent of best treatment during *kharif* 2008 and *kharif* 2009, respectively. The perusal of the stover yield data showed the favourable effect of drip fertigation on the stover yield of maize. The stover yield per hectare was significantly improved by the application of major nutrients through fertigation which boosted the overall vegetative growth and biological efficiency of the plant.

#### Water saving and water use efficiency

The quantity of irrigation water supplied through drip was 173 and 198 mm during *kharif* 2008 and *kharif* 2009, respectively. The effective rainfall received during the cropping period was 158 mm (*kharif* 2008) and 130 mm (*kharif* 2009). The total water used under the drip irrigation treatments was 331 mm and 328 mm. Under surface irrigation method, irrigation was given immediately after sowing followed by life irrigation at 5 cm depth and thereafter irrigation was given as per the IW/CPE ratio of 0.8. Quantity of water applied was 300 and 350 mm during *kharif* 2008 and *kharif* 2009, respectively. An effective rainfall of 192 and 161 mm was received during crop period and totally 492 and 511 mm of water was consumed by surface irrigated crop during both the years. Drip irrigation helps to

save the water upto 32 to 43 per cent compared to surface irrigation.

Different drip fertigation levels and intercrops exerted significant difference on WUE of maize (Table 3). Irrigation given through drip along with a fertigation schedule of 150 per cent RDF recorded a higher WUE of 23.8 kg ha<sup>-1</sup> mm<sup>-1</sup> during *kharif* 2008 and fertigation with 100 per cent RDF with 50 per cent P and K as WSF had a higher WUE of 24.2 kg ha<sup>-1</sup> mm<sup>-1</sup> during *kharif* 2009. The surface method of irrigation had lower values of WUE (9.0 and 9.7 kg ha<sup>-1</sup> mm<sup>-1</sup> during *kharif* 2008 and *kharif* 2009, respectively).

Among the different intercrops, higher WUE of 20.2 and 20.6 kg ha<sup>-1</sup> mm<sup>-1</sup> was observed under maize + vegetable coriander during *kharif* 2008 and *kharif* 2009, respectively. WUE was higher under drip fertigation treatments compared to surface irrigation method. 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. This was in concordance with Suhas Bobade *et al.* (2002). 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 by the treatment.

### Yield of intercrops

In this study, fertigation at 150 per cent RDF produced significantly more leaf yield of coriander (2825 kg ha<sup>-1</sup>) and radish tuber yield (5101 kg ha<sup>-1</sup>) (Table 4). Root yield of beet root was significantly higher under 100 per cent with 50 per cent P and K as WSF (4826 kg ha<sup>-1</sup>) followed by 75 per cent RDF in which 50 per cent P and K as WSF. In case of onion, fertigation of 125 per cent RDF recorded significantly higher bulb yield (4990 kg ha<sup>-1</sup>) followed by fertigation of 150 per cent RDF. In all intercrops lower yield was recorded under surface irrigation with soil application of fertilizer. Moisture stress and

**Table 4. Effect of drip fertigation on yield of intercrops (kg ha<sup>-1</sup>) and MEY in maize based intercropping system (Pooled data)**

Treatment	Yield of intercrops (kg ha <sup>-1</sup> )				Maize grain equivalent yield (kg ha <sup>-1</sup> )			
	Coriander	Radish	Beetroot	Onion	Coriander	Radish	Beetroot	Onion
T <sub>1</sub>	1550	3020	2991	3497	6172	7125	6743	7339
T <sub>2</sub>	1848	3877	3598	4084	6921	8413	7665	8270
T <sub>3</sub>	2121	4133	3812	4234	7634	9005	8290	8874
T <sub>4</sub>	2321	4330	4231	4536	8232	9740	9001	9523
T <sub>5</sub>	2605	4698	4205	4990	8942	10301	9444	10115
T <sub>6</sub>	2825	5101	4387	4875	9518	11000	9956	10691
T <sub>7</sub>	2179	4017	3998	4384	7866	9058	8602	9163
T <sub>8</sub>	2581	4967	4633	4687	8685	10257	9532	9956
T <sub>9</sub>	2742	5178	4826	4785	9560	11153	10362	10808
Mean	-	-	-	-	8170	9617	8827	9415
SEd	44	41	41	32	-	-	-	-
CD (P=0.05)	111	103	104	82	-	-	-	-

significant increase in maize equivalent yield (Kumar *et al.* 2002). Increased equivalent yield of main crop by cultivation of intercrops *viz.*, radish (Reddy *et al.*, 2001) and coriander (Jadhav *et al.*, 1992) under varied component crops was reported earlier.

It is concluded that drip fertigation once in three days at 100 per cent RDF with 50 per cent P and K as water soluble fertilizer could enhance the productivity of maize based intercropping system and save the water upto 43 per cent compared to surface irrigation. Among the intercrops tested radish as intercrop could be an alternative option to realize a reasonably good yield in maize based intercropping system.

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