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Effect of drip fertigation and intercrops on yield and water use efficiency of maize (*Zea mays*) under maize based intercropping system

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ABSTRACT

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 in intensive maize based intercropping system. During Kharif 2008, drip fertigated maize at 150 per cent recommended dose of fertilizer (RDF) recorded significantly higher grain yield of 7338 kg ha^{-1}. Whereas during Kharif 2009, higher grain yields of 7464 kg ha^{-1} 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^{-1}. Drip irrigation helps to save the water upto 43 % compared to surface irrigation besides enhancing the water use efficiency.

Key words*:* Drip fertigation, maize based intercropping system, WUE

Water is the vital source for crop production and is the most limiting factor in Indian agricultural scenario. Though India has the largest irrigation network, the irrigation efficiency does not exceed 40%. The average rainfall in Tamil Nadu is 958.5 mm as against the average rainfall of 1200 mm (Anon, 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 in 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 (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. 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 148.48 million ha with a production of about 699.32 million tonnes and productivity of 4.71 tonnes ha^{-1} of grain (USDA, 2007). The demand for maize and vegetables has increased due to the establishment of food and feed for poultry 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, thus enabling the option of micro-irrigation under intercropping situation. The drip system installed for maize crop can be used for intercrops too simultaneously which 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.

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 *p*H 7.53 and EC 0.76 dS m^{-1}, having 0.32% organic carbon, 220 kg ha^{-1} available N, 17 kg ha^{-1} available P and 425 kg /ha available K. The treatments comprised of nine fertigation levels in main plot and four intercrops in subplot. The treatment detail is as follow.

The treatments, comprised of nine fertigation levels in main plot, 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 with 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 plots, S_1, vegetable coriander; S_2 , radish; S_3, beet root; S_4 , 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

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treatments T_1 to T_6 in the form of diammonium 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 and irrigation was given once in three days.

RESULTS AND DISCUSSION

Growth parameters

Growth and development in plants are a consequence of excellent coordination of several processes operating at different growth stages. The growth of maize influenced by various fertigation treatments was elucidated through the positive response on plant height, leaf area index and dry matter production. The growth parameters of maize were influenced by fertilizer levels significantly. Application of fertilizer (100 % RDF with 50 % P and K as WSF) through fertigation resulted in higher growth characters than the other treatments (Table 1). The crops responded to higher dose of fertilizers which were applied as water soluble fertilizers through fertigation resulted in higher uptake and lead to higher growth characters. Increased plant height (238.1 cm) and LAI (4.94) with 100% RDF through water soluble fertilizers, might be due to favourable microclimate and application of sufficient nutrients in readily available form which have accelerated the production of growth regulators such as auxins (IAA) and cytokinins thus stimulating the action of cell elongation and cell division as manifested through increased plant height. Similar findings were obtained by Kavitha *et al.* (2007) in tomato.

The biological efficiency of any crop species depends on the amount of dry matter it produces. Applying 100% RDF with 50% P and K as WSF through drip recorded a higher dry matter production (DMP) of 14218 kg ha^{-1} which was on par with fertigation at 150% RDF (Table 1). 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, facilitating absorption of more sun light and solar radiation. Among the different intercrops tested vegetable coriander recorded significantly higher plant height (cm), LAI and DMP of maize than the other intercrops. 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 crop was grown as sole maize. So availability of moisture and nutrients were higher under this intercropping system. This might be the one of the reasons for higher growth parameters 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 the main crop which might be attributed to the fact that coriander is shallow rooted, short statured and of 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 significant variations 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_3 to T_9 showed that increasing the fertilizer doses increased the rooting characters 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% RDF resulted in higher root parameters. Adequate quantities 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 quantities 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. Comparing the intercropping systems, maize + vegetable coriander recorded a highest rooting depth (52.9 cm), root volume (83 cm^3) and root biomass (16.22 g plant^{-1}) of maize.

Grain yield of maize

Generally the maize grain yield increased with increase in fertilizer levels (Table 2). During *Kharif* 2008, drip fertigated maize at 150 per cent RDF recorded significantly the highest grain yield of 7338 kg ha^{-1}. The yield increase was 39% under 150 per cent RDF over drip irrigation with conventional method of fertilizer application. During *Kharif* 2009, the highest maize grain yield (7464 kg ha^{-1}) was recorded under drip fertigation of 100 per cent RDF with 50 per cent P and K through WSF. The yield increase over drip irrigation with soil application of fertilizer was 35 per cent during *Kharif* 2009. In the present investigation, drip fertigation with 100 per cent RDF in which 50 % of P and K were applied as WSF increased the grain yield to the tune of 14 and 17 % during *Kharif* 2008 and *Kharif* 2009, respectively as compared to drip fertigation of 100 per cent RDF with normal fertilizers. The pooled data revealed that higher grain yield of maize was observed under fertigation of 100 per cent RDF in which 50 % of P and K were applied as WSF. However, it was on par with fertigation of 150 per cent RDF through normal fertilizers. Different intercrops also influenced the grain yield of maize significantly. Among the four intercrops, vegetable coriander recorded the highest yield of 6522 kg ha^{-1} (pooled data). The increase in yield under 100 % RDF with P and K applied as WSF might be due to fertigation with more readily available form which resulted in higher availability of all the three major nutrients (NPK) in the soil solution leading to higher uptake and better translocation of assimilates from source to sink. The highest yields of intercrops 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. Intercrops also had a significant impact on yield of maize. This could be explained by easy access of resources like moisture and nutrients by maize in this cropping system compared to those in other intercropping system (Kumar and Bangarwa, 1997). The increased trend in yield might be due to the increased supply of nutrients under cropping system.

Table 1: Effect of drip fertigation on plant height, leaf area index (LAI) and dry matter production (DMP) of maize (pooled data)

Treatment	Plant height (cm)	LAI	DMP (kg ha^{-1})	Root depth (cm)	Root volume (cm^3)	Root biomass (g plant^{-1})
Fertigation						
T_1	204.0	3.73	8102	46.2	74.4	13.16
T_2	208.7	3.91	8896	50.1	75.9	13.60
T_3	213.0	3.99	9658	51.3	77.3	13.92
T_4	216.6	4.19	10730	52.5	80.4	15.38
T_5	223.9	4.50	11826	52.8	81.8	15.92
T_6	233.6	4.76	13421	54.4	85.3	17.06
T_7	219.9	4.34	9949	52.2	78.7	14.45
T_8	228.1	4.65	12622	53.6	83.3	16.36
T_9	238.1	4.94	14218	55.3	86.9	17.72
Intercrop						
S_1	226.6	4.41	12017	52.9	83.0	16.22
S_2	220.1	4.30	11372	51.9	79.6	15.13
S_3	216.1	4.26	10912	52.2	78.2	15.12
S_4	221.6	4.37	10360	51.6	81.0	14.78

	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)	SEm (±)	LSD (0.05)
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**
T x S	**2.81**	**7.05**	**0.053**	**NS**	**480.6**	**NS**	**0.14**	**NS**	**0.79**	**NS**	**0.163**	**NS**
S x T	**1.43**	**4.07**	**0.076**	**NS**	**289.3**	**NS**	**0.11**	**NS**	**0.67**	**NS**	**0.147**	**NS**

Stover yield of maize

During *Kharif* 2008 and *Kharif* 2009 drip fertigation of 100% RDF (50 % P and K as WSF) recorded significantly highest stover yield of 10633 kg ha^{-1} followed by 150% RDF through drip fertigation (10372 kg ha^{-1}) respectively (Table 3). The increase in stover yield under 100% RDF with WSF was 13.35 % over drip fertigation with 100% RDF applied as normal fertilizer. The lowest stover yields were recorded under surface irrigation during *Kharif* 2008 and 2009.

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. 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 helped to save the water up to 32 to 43 % 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 % RDF recorded highest WUE of 23.8 kg ha^{-1} mm^{-1} during *Kharif* 2008 while fertigation with 100 % RDF with 50 % of P and K as WSF recorded the highest WUE of 24.2 kg ha^{-1} mm^{-1} during *Kharif* 2009. The surface method of irrigation had lowest values of WUE (9.0 and 9.7 kg ha^{-1} mm^{-1} during *Kharif* 2008 and *Kharif* 2009, respectively). Among the different intercrops, higher WUE of 20.2 and 20.6 kg ha^{-1} mm^{-1} was observed under maize + vegetable coriander during *Kharif* 2008 and, *Kharif* 2009, respectively.

The WUE was higher under drip fertigation treatments compared to surface irrigation method. The increase in WUE in all the drip irrigated treatments over surface irrigation was mainly due to considerable saving of irrigation water, greater increase in yield of

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

Treatment	*Kharif* 2008					*Kharif* 2009					Pooled data				
	Intercrop														
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
Fertigation															
T_1	4982	4886	4531	4761	4790	5148	5049	4683	4920	4650	5065	4968	4607	4841	4720
T_2	5474	5368	4979	5231	5263	5728	5618	5211	5475	5508	5601	5493	5095	5353	5386
T_3	6013	5898	5470	5747	5782	6226	6107	5664	5951	5987	6120	6003	5567	5849	5885
T_4	6529	6404	5939	6240	6278	6618	6490	6019	6325	6363	6574	6447	5979	6283	6321
T_5	7062	6926	6423	6749	6790	7100	6964	6458	6786	6827	7081	6945	6441	6768	6809
T_6	7632	7485	6942	7294	7338	7369	7228	6703	7043	7086	7501	7357	6823	7169	7212
T_7	6271	6151	5704	5994	6030	6349	6227	5775	6068	6105	6310	6189	5740	6031	6068
T_8	6801	6670	6186	6500	6539	6882	6749	6260	6577	6617	6842	6710	6223	6539	6578
T_9	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**	
SEm(±)	**56.6**	**43.5**	**89.9**	**65.3**		**81.4**	**62.5**	**138.2**	**103.7**		**75.8**	**58.4**	**122.6**	**92.9**	
LSD(0.05)	**175.5**	**135.0**	**263.3**	**202.5**		**252.4**	**193.8**	**428.4**	**321.5**		**235**	**181**	**380**	**288**	

Table 3: Effect of drip fertigation and intercrops on stover yield and water use efficiency of maize

Treatment	Stover yield (kg ha^{-1})						Water use efficiency (kg ha cm^{-1})		
	Kharif 2008		*Kharif* 2009		Pooled data		*Kharif* 2008	*Kharif* 2009	Mean
Fertigation									
T_1	8083		8256		8170		9.0	9.7	9.4
T_2	8395		9162		8779		17.1	17.9	17.5
T_3	8752		9563		9158		18.8	19.4	19.1
T_4	9099		9667		9383		20.4	20.7	20.6
T_5	9830		10279		10055		22.0	22.2	22.1
T_6	10158		10585		10372		23.8	23.0	23.4
T_7	9193		9468		9331		19.6	19.8	19.7
T_8	9506		9973		9740		21.2	21.5	21.4
T_9	10374		10891		10633		23.2	24.2	23.7
Intercrop									
S_1	9541		9956		9749		20.2	20.6	20.4
S_2	9375		9809		9592		19.9	20.2	20.1
S_3	9071		9595		9333		18.4	18.7	18.6
S_4	9226		9682		9454		19.3	19.7	19.5
	SEm (±)	**LSD (0.05)**	**SEm (±)**	**LSD (0.05)**	**SEm (±)**	**LSD (0.05)**			
T	**70.8**	**212.3**	**105.4**	**326.8**	**88.4**	**269.6**	-	-	-
S	**51.5**	**154.6**	**81.1**	**251.4**	**66.6**	**203.0**	-	-	-
T x S	**106.0**	**318.0**	**147.6**	**457.5**	**127.1**	**387.8**	-	-	-
S x T	**77.3**	**231.9**	**113.5**	**351.9**	**95.7**	**291.9**	-	-	-

crops and higher nutrient use efficiency. This was in accordance with Bobade *et al.* (2002). Ardell (2006) reported that application of N and P fertilizers 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 highest leaf yield of coriander (2825 kg ha^{-1}) and radish tuber yield (5101 kg ha^{-1}) (Table 4).

Table 4: Effect of drip fertigation on yield of intercrops (kg ha^{-1}) and MEY in maize based intercropping system (Pooled data)

Treatments	Yield of intercrops (kg ha^{-1})				Maize grain equivalent yield (kg ha^{-1})			
	Coriander	Radish	Beetroot	Onion	Coriander	Radish	Beetroot	Onion
T_1	1550	3020	2991	3497	6172	7125	6743	7339
T_2	1848	3877	3598	4084	6921	8413	7665	8270
T_3	2121	4133	3812	4234	7634	9005	8290	8874
T_4	2321	4330	4231	4536	8232	9740	9001	9523
T_5	2605	4698	4205	4990	8942	10301	9444	10115
T_6	2825	5101	4387	4875	9518	11000	9956	10691
T_7	2179	4017	3998	4384	7866	9058	8602	9163
T_8	2581	4967	4633	4687	8685	10257	9532	9956
T_9	2742	5178	4826	4785	9560	11153	10362	10808
Mean	-	-	-	-	**8170**	**9617**	**8827**	**9415**
SEm(±)	**44.8**	**41.4**	**41.4**	**32.8**	-	-	-	-
LSD(0.05)	**111.8**	**103.6**	**104.1**	**82.2**	-	-	-	-

Tuber yield of beet root was significantly highest under 100 % with 50 % of P and K as WSF (4826 kg ha^{-1}) followed by 75 per cent RDF in which 50 % of P and K was applied as WSF.In case of onion fertigation of 125 per cent RDF recorded significantly highest bulb yield (4990 kg ha^{-1}) followed by fertigation of 150 per cent RDF. In general, lowest yield of intercrops were recorded under surface irrigation with soil application of fertilizer. Moisture stress and less availability of nutrients might be reasons for yield reduction under surface irrigation method.

Maize grain equivalent yield

In pooled analysis, fertigation with 100 per cent RDF with 50 % of P and K was applied as WSF produced highest MEY between the intercropping systems (Table 4). In general, among the different systems, the MEY was lowest under maize + vegetable coriander system. Radish intercropped with maize registered a higher MEY of 9615kg ha^{-1}. Successive increase in NPK levels applied to maize crop in intercrop situation resulted in significant increase in maize equivalent yield (Kumar *et al.*, 2002).Increased equivalent yield of main crop by addition 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 % of P and K applied as water soluble fertilizer could enhance the productivity of maize based intercropping system and save the water upto 43 % 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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