International Journal of Agricultural Sciences ISSN: 2167-0447 Vol. 3 (5), pp. 538-543, July, 2013. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Water productivity and profitability of maize under drip fertigation in intensive maize based intercropping system

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Accepted 8 April, 2013

Field experiments were conducted during 2008 and 2009 at Tamil Nadu Agricultural University, Coimbatore to study the effect of drip fertigation in intensive maize (*Zea mays* L.) based intercropping system. During 2008, drip fertigated maize at 150 per cent RDF recorded significantly higher grain yield of 7.3 t ha^{-1}. Whereas during 2009, higher grain yields of 7.5 t ha^{-1} was recorded under drip fertigation of 100 per cent RDF with 50 per cent P and K as Water Soluble Fertilizer (WSF). Drip irrigation helps to save the water upto 43 per cent compared to surface irrigation besides enhancing the water use efficiency. A higher net return (Rs 56858) and B:C ratio (3.24) was obtained under drip fertigation of 150 per cent RDF + radish as intercrop combination. It is inferred 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. Considering the high cost of water soluble fertilizers, drip fertigation of 150 per cent RDF with radish as intercrop could be an alternative option to realize a reasonably good yield and income in maize based intercropping system.

Key words: Drip fertigation, intercropping, maize, maize grain equivalent yield (MEY), WUE, Water Soluble Fertilizer.

INTRODUCTION

Water is the most important and critical input in man's life especially 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. Addressing these issues requires an integrated approach to soil-water-plant-nutrient management at the plant-rooting zone. Fertigation, the latest technology wherein nutrients are applied along with irrigation water 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). Specialty fertilizers are high analysis and totally water soluble and are available in double and multi nutrient combination. One of the important strategies to increase agricultural output is the development of new high intensity cropping system including intercropping system. Diversification of cropping pattern particularly in favour of vegetable crops is becoming popular among farmers because in a balanced diet vegetables are most important component and also it fetches more market prices.

Maize or Indian corn (*Zea mays* L.) is one of the most important cereal crops in the global agricultural economy both as a food for man and feed for animal and the crop of immense potentiality. By 2020 AD, the requirement of maize for various sectors will be around 100 million tonnes, of which the poultry sector demand alone will be around 31 million tonnes (Seshaiah, 2000). Research works on drip irrigation under intercropping situation is very limited. Hence, the present field research was initiated to assess the feasibility of drip fertigation in maize based inter cropping system.

MATERIALS AND METHOD

The experiment was conducted during 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^{-1} available K. The treatment, comprised nine fertigation levels in main plot, M_1, Surface irrigation with soil application of 100 % RDF ; M_2, Drip irrigation with soil application of 100 % RDF; M_3, Drip fertigation of 75 % RDF; M_4, Drip fertigation with 100 % RDF; M_5, Drip fertigation of 125 % RDF; M_6, Drip fertigation of 150 % RDF; M_7, Drip fertigation of 50 % RDF (50 % P and K as WSF); M_8 , Drip fertigation of 75 % RDF (50 % P and K as WSF); M_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. Fertilizer was given based on base crop (maize) requirement. RDF for maize is 150:75:75 kg NPK ha^{-1}.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).

In the surface irrigated plots, ridges and furrows were formed at 60 cm apart and maize was sown at a spacing of 60 x 20 cm. In between the two row of maize one row of inter crops were sown. Paired row planting system was adopted under drip irrigation with spacing of 75 x 20 cm. In between the two rows of maize two rows of inter crops were sown by adopting a spacing of 30 cm between rows. One lateral with inline dripper (discharge rate 4lph) was laid at the centre of the raised flat bed (1.2 m width and 20 m length) and it covered the two row of maize and two rows of intercrops. The lateral spacing between two raised flat beds was 1.5 m with furrow in-between of 30 cm width and 15 cm depth. For radish, beetroot and coriander seeds are sown and for onion bulbs are used for sowing. The planting patterns under drip irrigation are given in Figure. 1.

The recommended doses of inorganic fertilizers were applied directly to soil for the treatments M_1 and M_2. Fertilizer sources used for supplying NPK were urea (46 % N), di ammonium phosphate (18 % N and 46 % P_2O_5) and muriate of potash (60 % K_2O) respectively. The entire quantity of phosphorus was applied as basal in treatments M_1 and M_6 in the form of di ammonium phosphate one day before sowing. In the treatments M_1 and M_2 involving soil application of fertilizers, recommended dose of nitrogen and potassium were applied in the form of urea in three splits (25 % N as basal, 50% N on 25 DAS and 25% N on 45 DAS as top dressing) and muriate of potash in two splits (50% as basal and 50 as top dressing on 45 DAS). For treatments M_3 to M_9, fertilizers were given through drip fertigation. In treatments M_3 to M_6 normal fertilizer was used as sources for supplying NPK through drip irrigation. Normal fertilizers *viz.,* urea and muriate of potash were used to supply N and K respectively. For the treatments M_7 to M_9 50 per cent P and K were supplied through water soluble fertilizer and remaining through normal fertilizer. Mono ammonium phosphate (12: 61: 0) and multi-K (13: 0: 46) were used as water soluble fertilizer for supplying P and K respectively. The fertilizer solution was prepared by dissolving the required quantity of fertilizer with water in 1:5 ratio and injected into the irrigation system through venturi assembly. Considering the nutrient uptake pattern at phenological growth phases of maize, the fertigation schedule was worked out and presented in Table 1.

Fertigation was given in once in three days. The quantity of irrigation water supplied through drip was 173 and 198 mm during 2008 and 2009, respectively. The effective rainfall received during the cropping period was 158 mm (2008) and 130 mm (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 2008 and 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.

Generally the life span of a well maintained drip system would be 10 years. But here in the intercropping system situation, the drip system may be used for three seasons per year, so on an average, 7 years was considered for calculating the economics. The interest rate was fixed at 8 per cent and the depreciation cost of 15 per cent on the drip system was considered. The fixed cost towards the installation of drip fertigation system was worked out to be Rs 72,510. A seasonal cost of Rs 3,453 was included in the cost of cultivation for the annual maintenance and repairs, interest rate and depreciation of the drip system.

RESULTS AND DISCUSSION

Growth parameters

The growth of maize influenced by various fertigation treatments has been elucidated through the positive response on root characters and dry matter production. Roots are the main component in absorption of water and minerals, which are essential in plant physiological processes. The results on rooting depth revealed that there was a significant variation in rooting depth of maize due to irrigation methods, fertigation levels and different intercrops (Table 1). 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

Table1. Fertigation schedule for maize.

Crop stages	Quantity (%)		
	N	P	K
Vegetative stage (6 – 30 days)	25	25	25
Reproductive stage (30 – 60 days)	50	50	50
Maturity stage (60 – 75 days)	25	25	25
Total	100	100	100

Table1. Effect of drip fertigation on root character, DMP, stover yield and crude protein content of maize in intensive maize based intercropping system (pooled data).

Treatments	Root volume (cm^3)		DMP ($t\ ha^{-1}$)		Stover yield ($t\ ha^{-1}$)		Crude protein content (%)	
M_1- SI+ SA of 100 % RDF	74.4		8.1		8.2		9.1	
M_2- DI+ SA of 100 % RDF	75.9		8.9		8.8		9.3	
M_3- DF + 75 % RDF (NF)	77.3		9.7		9.2		9.8	
M_4- DF + 100 % RDF (NF)	80.4		10.77		9.4		10.1	
M_5- DF + 125 % RDF (NF)	81.8		11.87		10.1		11.7	
M_6- DF + 150 % RDF (NF)	85.3		13.4		10.4		12.2	
M_7- DF + 50 % RDF (50 % P & K- WSF)	78.7		99.5		9.3		9.7	
M_8- DF + 75 % RDF (50 % P & K- WSF)	83.3		12.6		9.7		10.6	
M_9- DF + 100 % RDF (50 % P & K -WSF)	86.9		14.2		10.6		11.3	
S_1- Coriander	83.0		12.0		9.8		10.8	
S_2- Radish	79.6		11.4		9.6		10.6	
S_3- Beet root	78.2		10.9		9.3		10.2	
S_4- Onion	81.0		10.4		9.5		10.0	
	SEm±	CD (p-0.05)	SEm±	CD (p-0.05)	SEm±	CD (p-0.05)	SEm±	CD (p-0.05)
M	0.56	1.40	315.7	791.1	107.8	269.6	0.08	0.22
S	0.42	1.06	182.6	454.7	81.2	203.0	0.04	0.10
M x S	0.79	NS	480.6	NS	155.1	387.8	0.12	0.30
S x M	0.67	NS	289.3	NS	116.8	291.9	0.06	NS

(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.

The biological efficiency of any crop species could be reflected in the amount of dry matter it produces. The results of this study (Table 1) clearly showed significant increase in dry matter production of maize. Application of fertilizer (100 % RDF with 50 % P and K as WSF) through fertigation resulted in higher growth characters which were followed by 150 per cent RDF. 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 dry matter production over drip irrigation. The increased P uptake and greater P mobility through frequent or continuous low-volume irrigation can maintain three- dimentional distribution patterns of water and nutrients and provide improved conditions for growth and water and nutrient uptake (Ben-Gal and Dudley, 2003).

Dry matter production and root growth of maize was higher under maize + vegetable coriander intercropping system. Increased dry matter accumulation and root growth under this system may be due to less competition for moisture and nutrient 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 are 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

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

Treatments	Pooled data				
	S_{1-} Coriander	S_{2-} Radish	S_{3-} Beet root	S_{4-} Onion	**Mean**
M_{1-} SI+ SA of 100 % RDF	5065	4968	4607	4841	**4720**
M_{2-} DI+ SA of 100 % RDF	5601	5493	5095	5353	**5386**
M_{3-} DF + 75 % RDF (NF)	6120	6003	5567	5849	**5885**
M_{4-} DF + 100 % RDF (NF)	6574	6447	5979	6283	**6321**
M_{5-} DF + 125 % RDF (NF)	7081	6945	6441	6768	**6809**
M_{6-} DF + 150 % RDF (NF)	7501	7357	6823	7169	**7212**
M_{7-} DF + 50 % RDF (50 % P & K- WSF)	6310	6189	5740	6031	**6068**
M_{8-} DF + 75 % RDF (50 % P & K- WSF)	6842	6710	6223	6539	**6578**
M_{9-} DF + 100 % RDF (50 % P & K -WSF)	7602	7455	6915	7265	**7309**
Mean	**6522**	**6396**	**5932**	**6233**	
	M	S	M at S	S at M	
SEm±	100	72	152	117	
CD (P=0.05)	235	181	380	288	

effect on growth and development of main crop which may be attributed to the fact that coriander is shallow rooted and with short stature and short duration.

Application of fertilizer dose of 150 per cent RDF resulted in higher crude protein content and 75 per cent RDF with drip fertigation resulted in lower crude protein content in maize (Table 1). The protein content of the grain was decided by the nitrogen content of the grain. Since the fertigation dose was higher and sufficient under 150 per cent RDF, it might have resulted in higher uptake of nitrogen and ultimately which resulted in higher protein content of maize.

Grain Yield of maize

Generally the maize grain yield increased with increase in fertilizer level (Table 2). During 2008, drip fertigated maize at 150 per cent RDF recorded significantly higher grain yield of 7.3 t ha^{-1}. The yield increase observed under 150 per cent RDF over drip irrigation with conventional method of fertilizer application was 39 per cent. During 2009, higher maize grain yield (7.5 t ha^{-1}) 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 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 2008 and 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. Different intercrops also influenced the grain yield of maize significantly. Among the four intercrops, vegetable coriander intercropping recorded a higher yield of 6467, 6576 and 6522 kg ha^{-1} during 2008, 2009 and pooed data respectively. 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 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. 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 (Selva rani, 2009). Intercrops also had a significant impact on yield components and yield of maize. Yield components were significantly higher in maize + vegetable coriander intercropping system. 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 increased trend in yield component might be due to the increased supply of nutrients under this cropping system.

The stover yield was higher with drip fertigated maize as compared to surface irrigated crop (Table 1). Same trend was observed with that of grain yield.

Table 3. Effect of drip fertigation on yield of intercrops (kg ha^{-1}) and MEY in maize based intercropping system (Pooled data).

Treatments	Yield of intercrops (t ha^{-1})				Maize grain equivalent yield (t ha^{-1})			
	Coriander	Radish	Beetroot	Onion	Coriander	Radish	Beetroot	Onion
M_{1}- SI+ SA of 100 % RDF	1.6	3.0	3.0	3.5	6.2	7.1	6.7	7.3
M_{2}- DI+ SA of 100 % RDF	1.9	3.9	3.6	4.1	7.0	8.4	7.7	8.3
M_{3}- DF + 75 % RDF (NF)	2.1	4.1	3.8	4.2	7.6	9.0	8.3	8.9
M_{4}- DF + 100 % RDF (NF)	2.3	4.3	4.2	4.5	8.2	9.7	9.0	9.5
M_{5}- DF + 125 % RDF (NF)	2.6	4.7	4.2	5.0	8.9	10.3	9.4	10.1
M_{6}- DF + 150 % RDF (NF)	2.8	5.1	4.4	4.9	9.5	11.0	10.0	10.7
M_{7}- DF + 50 % RDF (50 % P & K- WSF)	2.2	4.0	4.0	4.4	7.9	9.1	8.6	9.2
M_{8}- DF + 75 % RDF (50 % P & K- WSF)	2.6	5.0	4.6	4.7	8.7	10.3	9.6	10.0
M_{9}- DF + 100 % RDF (50 % P & K -WSF)	2.7	5.2	4.8	4.8	9.6	11.2	10.4	10.8
Mean	-	-	-	-	**8.2**	**9.6**	**8.8**	**9.4**
SEm±	44.8	41.4	41.4	32.8	-	-	-	-
CD (P=0.05)	111.8	103.6	104.1	82.2	-	-	-	-

Table 4. Effect of drip fertigation levels on economics and Water Use Efficiency (WUE) of maize based intercropping system.

Treatments	Cost of cultivation (Rs.ha^{-1})	Net income (Rs.ha^{-1})	B C ratio	WUE (kg/ha/mm)
M_{1}- SI+ SA of 100 % RDF	27406	24265	1.90	9.72
M_{2}- DI+ SA of 100 % RDF	26359	32605	2.26	16.35
M_{3}- DF + 75 % RDF (NF)	24305	39434	2.65	17.86
M_{4}- DF + 100 % RDF (NF)	25159	43114	2.74	19.19
M_{5}- DF + 125 % RDF (NF)	26013	46985	2.83	20.67
M_{6}- DF + 150 % RDF (NF)	27653	37545	2.38	18.42
M_{7}- DF + 50 % RDF (50 % P & K- WSF)	30606	41578	2.38	19.97
M_{8}- DF + 75 % RDF (50 % P & K- WSF)	33562	45118	2.36	22.19
M_{9}- DF + 100 % RDF (50 % P & K -WSF)	27406	24265	1.90	9.72
S_{1}- Coriander	24543	37632	2.55	19.21
S_{2}- Radish	24543	37632	2.55	19.21
S_{3}- Beet root	27443	39043	2.44	17.47
S_{4}- Onion	32143	38627	2.21	18.36

Yield of intercrops

In this study, fertigation at 150 per cent RDF produced significantly more leaf yield of coriander (2825 kg ha^{-1}) and radish tuber yield (5101 kg ha^{-1}). Root yield of beet root was significantly a higher under 100 per cent with 50 per cent P and K as WSF (4826 kg ha^{-1}) followed by 75 per cent RDF in which 50 per cent P and K as WSF (Table 3).

In case of onion fertigation of 125 per cent RDF recorded significantly higher bulb yield (4990 kg ha^{-1}) followed by fertigation of 150 per cent RDF. In all intercrops lower yield was recorded under surface irrigation with soil application of fertilizer compared to drip ferigation. Moisture stress and less availability of nutrient 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 per cent P and K as WSF produced a higher MEY in all intercropping system (Table 3). In general, among the different system, the MEY was lower under maize + vegetable coriander system and radish intercropped with maize registered a higher MEY of 11153 kg ha^{-1}.

Water Use Efficiency (WUE)

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, only a portion of the soil surface around the crop was wetted whereas under surface irrigation the entire field was wetted. 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 (10 days) between two irrigations, the rainfall received was utilized effectively and that might be the reason for higher effective rainfall under surface irrigation compared to drip irrigation (Selva Rani, 2009).

Drip fertigation at 150 per cent RDF recorded higher WUE during 2008 and fertigation at 100 per cent RDF with 50 per cent P and K as WSF during 2009 and at farmer's filed experiments. 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 (Ramah, 2008). 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.

Economics

The computed data on the economics of drip fertigation in maize based intercropping system were presented in the Table 4. Though the initial capital investment was high towards drip fertigation system, the benefits obtained would be greater considering the longer life of the system.

The cost of cultivation was generally higher in the fertigated treatments than the soil applied treatments due to high cost of water soluble fertilizers. Higher cost of cultivation (Rs.38,157/ha) was observed in fertigation of 100 per cent RDF with 50 per cent of P and K as WSF and onion as intercrop (M_9S_4). The economic analysis of the fertilizer application methods revealed that the cost of cultivation under drip irrigation and fertigation was higher than the surface irrigation with soil application of fertilizers.

The data on the economics of drip fertigation in maize based intercropping system indicated higher net return (Rs. 61, 343 and Rs. 52, 372 and Rs 56858 /ha in 2008, 2009 and pooled data respectively) and B:C ratio (3.42, 3.06 and 3.24) was obtained under drip fertigation at 150 per cent RDF + radish as intercrop. Drip fertigation at 100 per cent RDF with 50 per cent P and K as WSF in maize + radish intercropping system recorded a higher gross income of Rs. 84,967, Rs. 81,909 and Rs 83438 / ha during 2008, 2009 and pooled data respectively. Drip fertigation at 100 per cent RDF with 50 per cent P and K as WSF resulted in higher productivity in maize based intercropping system (Table 4). However the net return and benefit cost ratio were lower due to high cost of water soluble fertilizers. Drip fertigation technique aims to achieve water saving and efficient use of applied nutrients for higher productivity. Drip irrigation is the need of the hour especially in water scarcity areas. The adoption of drip system should not be merely viewed on the economic point of view. In the context of shrinking land availability for cultivation and diversion of available water for non agricultural activities, it is paramount important that the available water for agriculture purpose needs to be efficiently utilized by adopting modern irrigation techniques like drip system.

The benefits of drip system in terms of water and nutrient savings and enhancement in cropping intensity and productivity of crops are to be taken into consideration. Above all in the water scarcity areas, drip system is the only answer to enhance the productivity of crops.

This study 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. Considering the high cost of water soluble fertilizers, drip fertigation of 150 per cent RDF with radish as intercrop could be an alternative option to realize a reasonably good yield and income in maize based intercropping system.

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