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Influence of drip fertigation on water productivity and profitability of maize

S. Anitta Fanish

Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu– 641 003, Indian.

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Field experiments were conducted during the 2008 and 2009 cropping season at Tamil Nadu Agricultural University, Coimbatore to study the effect of drip fertigation on water use efficiency in intensive maize (*Zea mays* L.) based intercropping system. In 2008, drip fertigated maize at 150% recommended dose of fertilizer (RDF) recorded significantly higher grain yield of 7.3 t ha^{-1}. Whereas in 2009, higher grain yields of 7.5 t ha^{-1} was recorded under drip fertigation of 100% RDF with 50% P and K as water soluble fertilizer (WSF). Drip irrigation helps to save the water up to 43% compared to surface irrigation besides enhancing the water use efficiency. The highest net return (Rs 56858) and B:C ratio (3.24) was obtained under drip fertigation of 150% RDF + radish as intercrop combination. It is inferred that drip fertigation once in three days at 100% RDF with 50% P and K as water soluble fertilizer enhanced the productivity of maize-based intercropping system. Considering the high cost of water soluble fertilizers, drip fertigation of 150% 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 grain equivalent yield (MEY), water use efficiency (WUE).

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% of the global population with only 2.4% of land and 4% 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, a latest technology wherein nutrients are applied along with the irrigation water and 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 in analysis and totally water soluble and are available in double and multi nutrient combinations. One of the important strategies to increase agricultural output is 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 gives more income.

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

E-mail: fanish_agri@yahoo.co.in.

Table 1. 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

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 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 METHODS

Study site

The experiment was conducted during of 2008 and 2009 cropping seasons at Tamil Nadu Agricultural University, Coimbatore, India. The farm is situated in North Western Agro-Climatic Zone of Tamil Nadu at 11°N latitude and 77°E longitude with an altitude of 426.7 m above MSL. The soil was sandy clay loam with pH 7.53; EC, 0.76 dS m^{-1}; organic carbon, 0.32%; available N, 220 kg ha^{-1}; available P, 17 kg ha^{-1} and available K, 425 kg $ha^{-1.}$

Experimental design, treatments and field management

The experiment was laid out in split plot design with three replications. The treatments comprised of nine fertigation levels in main plot, M_1, surface irrigation with soil application of 100% RDF (150:75:75 kg NPK per ha); 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 water soluble fertilizer (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 consisting $S_{1,}$ Vegetable coriander; S_2, Radish; $S_{3,}$ Beet root and S_4, Onion. Fertilizer was given based on base crop (maize) requirement. RDF for maize is 150:75:75 kg NPK ha^{-1}. Maize hybrid COH (M) 5 was sown with spacing of 75 × 20 cm.

In the surface irrigated plots, ridges and furrows were formed at 60 cm apart and maize was sown at a spacing of 60×20 cm. In between the two row of maize, one row of inter crops was sown. Paired row planting system was adopted under drip irrigation with spacing of 75 × 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 in-line drippers (discharge rate, 4 L/h) 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 were sown and for onion, bulbs were used for sowing.

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 doses (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 doses (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% P and K were supplied through water soluble fertilizer and the 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 ventury 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 the 2008 and 2009 cropping season, 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 and 328 mm for each year, respectively. 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. The quantity of water applied was 300 and 350 mm in 2008 and 2009, respectively. An effective rainfall of 192 and 161 mm was received during crop growth period, and totally 492 and 511 mm of water was consumed by surface irrigated crop during each year.

Economic analysis

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% and the depreciation cost of 15% 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 was influenced by various fertigation treatments as shown through the positive response on root characters and dry matter production. Roots are the main component in the 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 2). Among the fertigation treatments, 100% RDF with 50% P and K as WSF and 150% RDF resulted in higher root parameters. Adequate quantity of nutrients coupled with adequate moisture might have resulted in higher root proliferation. With the 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 were able to utilize maximum quantity of nutrients, thereby reducing 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 2) 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% RDF. The crops responded to higher dose of fertilizers which were applied as water soluble fertilizers through fertigation which 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-dimensional distribution patterns of water and nutrients and provide improved conditions for growth, water and nutrient uptake (Ben-Gal and Dudley, 2003).

Dry matter production and root growth of maize was highest 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 one of the reasons for higher growth parameter of maize in maize + vegetable coriander intercropping system. Tiwari et al. (2003) 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 with short stature and short duration. Application of fertilizer dose of 150% RDF resulted in higher crude protein content and 75% RDF with drip fertigation resulted in lower crude protein content in maize (Table 2). 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% RDF, it might have resulted in higher uptake of nitrogen and ultimately resulted in higher protein content in maize.

Maize grain yield

Generally the maize grain yield increased with increase in fertilizer level (Table 3). In 2008, drip fertigated maize at 150% RDF recorded significantly higher grain yield of 7.3 t ha^{-1}. The yield increase observed under 150% RDF over drip irrigation with conventional method of fertilizer application was 39%. In 2009, higher maize grain yield (7.5 t ha^{-1}) was recorded under drip fertigation of 100% RDF with 50% P and K through WSF. The yield increase over drip irrigation with soil application of fertilizer was 35% in 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% RDF in which 50% P and K as WSF increased the grain yield to the tune of 14 and 17% during 2008 and 2009, respectively, compared to drip fertigation of 100% RDF with normal fertilizer. The pooled data revealed that higher grain yield of maize was observed under fertigation of 100% RDF with 50% P and K as WSF.

However, it was on par with fertigation of 150% RDF through normal fertilizer. Different intercrops also influenced the grain yield of maize significantly. Among the four intercrops, vegetable coriander intercrop recorded a highest yield of 6467, 6576 and 6522 kg ha^{-1} in 2008, 2009 and pooled data, respectively. The increase in yield under 100% RDF with P and K as WSF might be due to the fact that fertigation with more readily available form of fertilizer 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 the top layer of soils. 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

Table 2. 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 and K- WSF)	78.7		99.5		9.3		9.7	
M_8- DF + 75% RDF (50% P and K- WSF)	83.3		12.6		9.7		10.6	
M_9- DF + 100% RDF (50% P and 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

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 compared to surface irrigated crop (Table 2). The same trend was observed with that of grain yield.

Yield of intercrops

In this study, fertigation at 150% 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 highest under 100% with 50% P and K as WSF (4826 kg ha^{-1}) followed by 75% RDF in which 50% P and K as WSF (Table 4). In case of onion, fertigation of 125% RDF recorded significantly higher bulb yield (4990 kg ha^{-1}) followed by fertigation of 150% 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 the reasons for yield reduction under the surface irrigation method.

Maize grain equivalent yield

In pooled analysis, fertigation with 100% RDF with 50% P and K as WSF produced a highest MEY in all intercropping system (Table 4). In general, among the different system, the MEY was lowest under maize + vegetable coriander system while radish intercropped with maize had a higher MEY of 11153 kg ha^{-1}.

Water use efficiency (WUE)

The water saving under drip irrigation was due to

Table 3. 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 and K- WSF)	6310	6189	5740	6031	6068
M_8. DF + 75% RDF (50% P and K- WSF)	6842	6710	6223	6539	6578
M_9. DF + 100% RDF (50% P and 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	

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 during which the soil moisture was always maintained near to the field capacity. Hence much of the rainfall received during the crop period has gone as ineffective rainfall under drip irrigation.

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 Table 5. Though the initial capital investment was high for the drip fertigation system, however, 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% RDF with 50% 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% RDF + radish as intercrop. Drip fertigation at 100% RDF with 50% P and K as WSF resulted in highest productivity in maize-based intercropping system (Table 5). 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 areas with water deficit problems. 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

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 (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 and 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 and 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 and 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 5. 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 and K- WSF)	30606	41578	2.38	19.97
M_8- DF + 75% RDF (50% P and K- WSF)	33562	45118	2.36	22.19
M_9- DF + 100% RDF (50% P and 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

areas, drip system is the only answer to enhance the productivity of crops.

Conclusion

Drip fertigation once in three days at 100% RDF with 50% P and K as water soluble fertilizer enhanced the productivity of maize-based intercropping system. Considering the high cost of water soluble fertilizers, drip fertigation of 150% 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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