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Influence of Drip Fertigation and Intercropping on Yield, Agronomic Efficiency and Partial Factor Productivity of Maize

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Field investigations were carried at Tamil Nadu Agricultural University during *kharif* 2008 and 2009 to study the effect of drip fertigation on nutrient use efficiency of maize (*Zea mays*) based intercropping systems. Results revealed that irrespective of different levels of fertilizer, fertigation significantly increased the partial factor productivity (PFP) and agronomic efficiency (AE) as compared to surface method of fertilizer application. Among the intercropping systems tested, higher nutrient use efficiency was realised under maize + vegetable coriander intercropping system. Partial Factor Productivity (PFP) decreased with increasing rates of fertigation. Drip fertigation with 50 per cent RDF in which 50 per cent of P and K as WSF resulted in higher PFP of 80.90 and 161.80 kg kg^{-1} N and P, respectively. The pooled data revealed that higher grain yield of maize (7309 kg ha^{-1}) was observed under fertigation of 100 per cent RDF in which 50 per cent P and K as WSF. Drip fertigation of 100 per cent RDF (50 per cent P and K as WSF) increased the yield upto 55 per cent compared to surface irrigation and soil application of fertilizer. Fertigation with normal fertilizer increased the yield upto 18 kg per kg of nutrient applied, whereas water soluble fertilizer (50 per cent) increased the yield upto 25 kg per kg of nutrient applied.

Key words: Drip fertigation, PFP, NUE, AE, maize, intercropping

Applying plant nutrients by dissolving them in irrigation water (termed as fertigation) particularly with the micro irrigation system is the most efficient way of nutrient application. Fertigation has the potential to supply a right mixture of water and nutrients to the root zone, and thus meeting plants' water and nutrient requirements in most efficient possible manner. Fertigation allows an accurate and uniform application of nutrients to the wetted area where most active roots are concentrated. Therefore, it is possible to dispense adequate nutrient quantity at an appropriate concentration to meet the crop demand during a growing season (Ram *et al.,* 2011). Speciality fertilizers are high analysis and totally water soluble and are available in double and multi nutrient combination. They are available in liquid or crystalline form and they serve as a better nutrient source under fertigation (Biswas, 2010).

Increasing demand for food due to population pressure and practically less scope for expansion of area under cultivation warrants the stepping up of food production through increased cropping intensity. 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. 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 also helps to reduce the payback period. Considering the above points in view, the present study was conducted to assess the nutrient use efficiency of drip fertigation in maize based inter cropping system.

Materials and Methods

The experiment was conducted during *kharif* 2008 and 2009 at Coimbatore. The soil was sandy clay loam with *p*H 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 nine fertigation levels in main

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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. Recommended dose of fertilizer for maize was 150:75:75 kg NPK ha^{-1}. The experiment was laid out in strip plot design with many 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_1 and T_6 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. Drip irrigation and fertigation was given once in three days with calculating amount of water. For surface irrigation method, subsequent irrigations were scheduled at 5.0 cm depth with IW / CPE ratio 0.8.

The partial factor productivity (Pfp) from applied nutrients is a useful measure of nutrient use efficiency because it provides integrative index that quantifies total economic output related to utilization of all nutrient resources in the system (Cassmen *et al.,* 1996). It is the ratio of yield in kg ha^{-1} to applied nutrients and stated as,

$$Pfp = \frac{Y}{Nr}$$

Where, Y is the yield in kg ha^{-1} and Nr is the amount of fertilizer nutrients applied kg ha^{-1}. Agronomic Efficiency (AE) means the crop response to applied nutrients. AE is calculated by kg crop yield increase per kg nutrient applied.

Results and Discussion

Grain yield

Generally the maize grain yield increased with increase in fertilizer level (Table 1) . During *kharif* 2008, drip fertigated maize at 150 per cent RDF recorded significantly higher grain yield of 7338 kg 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 *kharif* 2009, higher 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. 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 (T_9) 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 (T_4). The pooled data revealed that higher grain yield of maize (7309 kg ha^{-1}) was observed under fertigation of 100 per cent RDF in which 50 per cent P and K was applied as WSF. However, it was on par with fertigation of 150 per cent RDF through normal fertilizer (7212 kg ha^{-1}).

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 *kharif* 2008*, kharif* 2009 and pooled 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. Intercrops also had a significant impact on grain yield of maize. 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 might be due to the increased supply of nutrients under this cropping system.

Yield increase

Data on yield increase due to drip fertigation compared to surface irrigation and soil application of fertilizer are presented in Table 1. The yield increase due to drip irrigation as compared to surface irrigation was 14 per cent. Drip fertigation of 100 per cent RDF (50 per cent P and K as WSF) increase the yield upto 55 per cent compared to surface irrigation and soil application of fertilizer. With proper method of application and form of fertilizer, we can achieve more than 50 % of increased yield from same quantity of fertilizer used. This yield increase was mainly due to increased nutrient use efficiency by crops.

Table 1. Effect of drip fertigation and intercrops on grain yield of maize

Treatment	Grain yield (kg ha^{-1})			Yield increase (%)		
	2008	2009	Mean	2008	2009	Mean
T_1 – SI + SA of 100 % RDF	4790	4650	4720	-	-	-
T_2 – DI + SA of 100 % RDF	5263	5508	5386	10	18	14
T_3 – DF + 75 % RDF (NF)	5782	5987	5885	21	29	25
T_4 – DF + 100 % RDF (NF)	6278	6363	6321	31	37	34
T_5 – DF + 125 % RDF (NF)	6790	6827	6809	42	47	44
T_6 – DF + 150 % RDF (NF)	7338	7086	7212	53	52	53
T_7–DF+50%RDF(50%P&K-WSF)	6030	6105	6068	26	31	29
T_8–DF+75%RDF(50%P&K-WSF)	6539	6617	6578	37	42	39
T_9 – DF + 100 % RDF(50 % P & K-WSF)	7154	7464	7309	49	61	55
S_1 – Coriander	6467	6576	6522	-	-	-
S_2 – Radish	6343	6449	6396	-	-	-
S_3 – Beet root	5882	5982	5932	-	-	-
S_4 – Onion	6181	6285	6233	-	-	-
	SEd	CD	SEd	CD		
T	70	176	113	252		
S	54	135	78	194		
T x S	105	263	170	428		
S x T	81	203	131	322		

SI- Surface Irrigation, SA- Soil Application, NF- Normal Fertilizer, WSF – Water Soluble Fertilizer

Partial factor productivity / Nutrient use efficiency

Drip fertigation levels as well as intercrops significantly influenced the nitrogen use efficiency of maize (Table 2). Drip fertigation with 50 per cent RDF (50 % P and K as WSF) resulted in higher NUE of 80.90 kg kg N^{-1} and the lowest NUE of 32.05 kg kg N^{-1} was recorded by surface irrigation with soil application of fertilizer. Similar to NUE, PUE was higher (161.80 kg kg P^{-1}) under the drip fertigation of 50 per cent RDF (50 % P and K as WSF). KUE was exactly similar to that of PUE due to the fact that P and K were applied at equal dose of 75 kg ha^{-1} irrespective of sources of fertilizer and methods of fertilizer application. Nutrient use efficiency in fertigation increases as a result of controlled and regular application of fertilizer (Yadav *et al.,* 2012). Among the intercropping systems, higher NUE was realised under maize + vegetable coriander intercropping system.

Drip fertigation with 50 per cent RDF in which 50 per cent of P and K applied as WSF resulted in higher nutrient use efficiency. Among the fertigation levels, the lowest nutrient use efficiency was

Table 2. Effect of drip fertigation and intercrops on Nitrogen, Phosphorus and Potassium Use Efficiency (kg kg^{-1} of NPK) of maize based intercropping system

Treatment	NUE			PUE&KUE		
	2008	2009	Mean	2008	2009	Mean
T_1 – SI + SA of 100 % RDF	31.93	31.49	32.05	63.87	62.98	64.11
T_2 – DI + SA of 100 % RDF	35.09	36.72	35.91	70.17	73.44	71.81
T_3 – DF + 75 % RDF (NF)	51.40	53.22	52.31	102.8	106.4	104.60
T_4 – DF + 100 % RDF (NF)	41.85	42.42	42.14	83.71	84.84	84.28
T_5 – DF + 125 % RDF (NF)	36.21	36.41	36.31	72.43	72.82	72.63
T_6 – DF + 150 % RDF (NF)	32.61	33.00	32.47	65.23	66.00	64.94
T_7–DF+50%RDF(50%P&K-WSF)	80.40	81.40	80.90	160.8	162.8	161.80
T_8–DF+75%RDF(50%P&K-WSF)	58.13	58.82	58.48	116.3	117.6	116.95
T_9–DF+100%RDF(50%P&K-WSF)	47.69	49.76	48.73	95.39	99.52	97.46
S_1 – Coriander	47.99	48.91	48.45	95.99	97.81	96.90
S_2 – Radish	47.07	47.97	47.52	94.14	95.93	95.04
S_3 – Beet root	43.65	44.49	44.07	87.31	88.97	88.14
S_4 – Onion	45.87	46.74	46.31	91.74	93.49	92.62
	Kharif 2008		*Kharif 2009*		*Kharif 2008*		*Kharif 2009*	
	SEd	CD	SEd	CD	SEd	CD	SEd	CD
T	0.60	1.49	0.59	1.49	0.39	0.98	0.26	0.62
S	0.37	0.90	0.46	1.14	0.30	0.75	0.59	1.48
T x S	0.93	NS	0.89	NS	0.56	NS	0.39	NS
S x T	0.69	NS	0.69	NS	0.46	NS	0.90	NS

SI- Surface Irrigation, SA- Soil Application, NF- Normal Fertilizer, WSF – Water Soluble Fertilizer

recorded by 150 per cent RDF which recorded higher yield. This clearly showed that fertigation through drip at 50 per cent RDF through water soluble fertilizer has exhibited higher response than that of higher dose of 150 per cent RDF.

Nutrients may be used very effectively when applied continuously through the irrigation system at rates not exceeding the requirements of the plants. Drip fertigation with water soluble fertilizers resulted in higher nutrient use efficiency compared to surface application of fertilizer with drip irrigation. These findings were in accordance with the findings of Suganya *et al.* (2007). Though the entire quantity of fertilizers was applied in surface applied plots (T_2), the crop uptake was low and so the nutrients were not utilized efficiently. But, in fertigated plots, the nutrients were supplied according to the need of the crop and dosage increased according to the stages and so the applied nutrients were utilized efficiently.

Table 3. Effect of drip fertigation on Agronomic Efficiency of maize

Treatment	Agronomic Efficiency (kg/kg of NPK applied)		
	2008	2009	Mean
T_3 – DF + 75 % RDF (NF)	-	-	-
T_4 – DF + 100 % RDF (NF)	19.8	15.0	17.4
T_5 – DF + 125 % RDF (NF)	20.2	16.8	18.5
T_6 – DF + 150 % RDF (NF)	20.7	14.7	17.7
T_7 –DF+50%RDF(50%P&K-WSF)	-	-	-
T_8 – DF + 75 % RDF(50 % P & K- WSF)	20.4	20.5	20.4
T_9 – DF + 100 % RDF(50 % P & K -WSF)	22.5	27.2	24.8

SI- Surface Irrigation, SA- Soil Application, NF- Normal Fertilizer, WSF – Water Soluble Fertilizer

The nutrient use efficiency was lower under fertigation level of 150 per cent RDF. The reason might be that the crop uptake increases as the dosage increases and then slows down or declines after a critical limit. Excess dose of fertilizer might have resulted in high leaching loss and denitrification of applied fertilizers though the yield was high under excess fertigation level. This reveals that applying excess fertilizer leads to soil pollution due to the leached out nutrients, so optimum dose of 100 per cent RDF was sufficient to achieve higher yield by reducing the leaching of the nutrients and preventing the soil pollution to some extent. Efficiency of nutrients was decreased with increased level of nutrients. Dua *et al.* (2007) reported that Partial Factor Productivity **(**PFP) decreased with increasing rates of fertigation. Nitrogen uptake increased with N rate, but it is obvious that N use efficiency decreased with increasing the N rate (Iqbal *et al.*, 2003). Under continuous fertigation of P in corn the yield increased along with decreased P application rates. In addition to increased efficiency of P fertilization, an important consequence would be a reduction in environmental contamination due to P transport into ground and surface water from agricultural sources (Ben-Gal and. Dudley, 2003).

The favourable effect on nutrient use efficiency was well pronounced under drip fertigation when compared to surface irrigation. Drip fertigation with water soluble fertilizers resulted in increased nutrient use efficiency than conventional application of normal fertilizers under surface irrigation. This might be due to the greater mobility and availability of nutrients to the root zone of the crops under drip fertigation, since water soluble fertilizers contained readily available form of nutrients.

Scheduling fertilizer application based on the need of the crop once in three days offered the possibility of reducing nutrient losses, thereby increased the nutrient use efficiency when compared to conventional application methods, wherein the large quantity of fertilizers were applied as basal during sowing which led to greater loss of applied nutrients. During later growth stage, the uptake of nutrients was low due to limited availability of nutrients under surface irrigation resulting in poor nutrient use efficiency for all the major nutrients of NPK. In fertigation, nutrient use efficiency could be as high as 90 per cent compared to 40-60 per cent in conventional methods. The amount of fertilizer lost through leaching can be as low as 10 per cent in fertigation whereas it is 50 per cent in the traditional system (Solaimalai *et al*., 2005).

Nutrient use efficiency was higher under vegetable coriander as intercrop. Competition for moisture and nutrient were less under this system compared to other systems. Nutrient requirement was less for vegetable coriander compared to other crops. More nutrient availability leads to more grain production which in turn resulted in higher nutrient use efficiency.

Agronomic efficiency

Agronomic efficiency (AE) means crop yield (kg) increase per kg of nutrient applied. In this experiment, two forms of fertilizer i.e normal fertilizer and water soluble fertilizer were used. So calculate the agronomic efficiency separately for each form and presented in Table 3. Among the fertigation with normal fertilizer treatments, higher AE was realized under fertigation of 125 per cent RDF (18.5 kg/kg). Beyond 125 per cent it starts to decline the yield increases per kg of nutrient applied. Fertigation with normal fertilizer increases the yield upto 18 kg per kg of nutrient applied, whereas water soluble fertilizer (50 per cent) increased the yield upto 25 kg per kg of nutrient applied. This is mainly because of higher availability and solubility of water soluble fertilizer compared to normal fertilizer under fertigation system. This finding is in accordance with the finding of Ramah *et al* (2008).

Conclusion

It was concluded that drip fertigation of 100 per cent RDF in which 50 per cent P and K was applied

as WSF increased the yield upto 55 per cent compared to surface irrigation and soil application of fertilizer. With proper method of application and form of fertilizer, we can achieve more than 50 % of increased yield from same quantity of fertilizer used. Also fertigation with normal fertilizer increases the yield upto 18 kg per kg of nutrient applied, whereas water soluble fertilizer (50 per cent) increased the yield upto 25 kg per kg of nutrient applied.

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