World Journal of Agricultural Sciences 9 (3): 277-283, 2013
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2013.9.3.2941

Nutrient Distribution Under Drip Fertigation Systems

S. Anitta Fanish and P. Muthukrishnan

Department of Agronomy, Tamil Nadu Agricultural University Coimbatore, India-641003

Abstract: Drip fertigation provides an efficient method of fertilizer delivery and if properly managed and can reduce overall fertilizer application rates and minimizes the adverse environmental impact on crop production. The availability of nutrients at root zone of the crops influences the uptake and yield of the crop. The nitrogen availability steadily increased with increased depth upto 30 cm after that declined in all the distances. The highest available phosphorus in soil was confined to 0-15 cm of soil layer under all fertigation levels. The available phosphorous decreased with increase in distance and soil depth. With regards to potassium, soil K content was significantly higher in the surface soil than in the subsoil, this might be due to majority of applied K was held in the surface soil and the downward movement was slow. Among the different treatments, drip fertigation with 100% RDF in which 50% P and K as WSF increased the maize grain yield to the tune of 15.5% as compared to drip fertigation of 100% RDF with normal fertilizer. 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 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.

Key words: Nutrient · Distribution · Drip Fertigation Systems

INTRODUCTION

Drip fertigation allows precise timing and uniform distribution of fertilizer nutrients. By definition, fertigation is the precise application of water soluble fertilizer through sprinkler and drip irrigation [1]. It is an efficient and agronomically sound method of providing soluble plant nutrients directly to the active plant root zone. The increasing acres of micro-irrigated crops provides an excellent opportunity to explore new methods of providing complete and balanced plant nutrient programs that have the potential to improve plant health and increase yields. Proper fertigation management begins with knowledge of the nutrient status of the soil. Most soils contain substantial quantities of available macronutrients and are frequently sufficiently supplied with micronutrients. Usually the optimizing nutrient management with drip irrigation would require that attention be paid to soil nutrient dynamics, crop nutrient requirements, as well as soil and plant monitoring techniques.

Fertilizers should be applied in a form that becomes available in synchrony with crop demand for maximum utilization of nutrient from fertilizers. Careful application of nutrient and water should be able to minimize the amount of nutrient moving below the root zone. The method of fertilizer application is very important in obtaining optimal use of fertilizer. This will increase the amount of fertilizer used by the plant and reduce the amount lost by leaching. The purpose of this study was to observe the nutrient distributions under two fertigation levels with water soluble and normal fertilizer.

MATERIAL AND METHODS

The experiment was conducted during 2008 and 2009 at Tamil Nadu Agricultural University, Coimbatore. The experimental soil was texturally classified as sandy clay loam having 26.52% field capacity, 13.53% permanent wilting point with 1.33 g cc^{-1} bulk density. Soil pH was 7.53 with an EC of 0.76 dSm^{-1} and organic carbon content of 0.32%. Soil was low in nitrogen (220 kg ha^{-1}), medium in phosphorus (17 kg ha^{-1}) and high in potassium (425 kg ha^{-1}). Hybrid maize (CoHM 5) was used as test crop. Treatment comprised of six levels of fertigation *viz*. T_1 - drip fertigation of 75 % RDF through normal fertilizer;

Corresponsing Author: S. Anitta Fanish, Department of Agronomy,
Tamil Nadu agricultural University Coimbatore, India-641003

T_2 - drip fertigation of 100 % RDF through normal fertilizer; T_3 - drip fertigation of 75 % RDF in which 50% of P and K through WSF and remaining through normal fertilizer; T_4 - drip fertigation of 100 % RDF in which 50% of P and K through WSF and remaining through normal fertilizer; T_5 - drip irrigation with soil application of 100% RDF; T_6 - surface irrigation with soil application of 100%. RDF for maize is 150:75:75 kg NPK ha^{-1}. 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. Paired row planting system was adopted under drip irrigation with spacing of 75 x 20 cm. 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. The lateral spacing between two raised flat beds was 1.5 m with furrow in-between of 30 cm width and 15 cm depth.

The recommended doses of inorganic fertilizers were applied directly to soil for the treatments T_5 and T_6. Fertilizer sources used for supplying NPK were urea, di-ammonium phosphate (DAP) and muriate of potash (MOP) respectively. The entire quantity of phosphorus was applied as basal in the form of di-ammonium phosphate one day before sowing and 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 T_1 to $T_{4,}$ fertilizers were given through drip fertigation. For T_1 and T_2 normal fertilizer was used as sources for supplying N and K through drip irrigation. Normal fertilizers *viz.* urea and MOP were used to supply N and K respectively. For the treatments T_3 to T_4 50% 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 ratios 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 once in three days.

The soil sampling was done along as well as across the lateral pipe. The soil samples were taken with soil auger at a radial distance (horizontal) of 0, 30 and 60 cm between lateral and 0, 10 and 20 cm between dripper at a depth of 0-15, 15-30 and 30-45 cm (vertical). Soil nutrient dynamics was estimated by analyzing available nitrogen, phosphorus and potassium content of soil. Graphical software package SURFER was used to show the three dimensional view of nutrient distribution vertically and horizontally from the emitter.

RESULTS AND DISCUSSION

Nutrient Dynamics under Drip Fertigation: The mobility of nutrients in the soil depends on the quantity and kinds of fertilizer applied, form of nutrient ions, moisture content of the soil and other reacting ions present in soil solution. The availability of nutrients at root zone of the crops influences the uptake and yield of the crop. Leaching, volatilization and fixation of nutrients in the soil are some of the factors that affect the availability of soil nutrients.

Nitrogen Dynamics: The available nitrogen was increased steadily with increased distance from the dripper along and between the laterals up to a distance of 30 cm (Table 2a and 2b). Among the distance the peak available nitrogen (201, 207 and 203 kg ha^{-1} at a depth of 0-15, 15-30 and 30-45 cm, respectively) was recorded at a distance of 30 cm from dripper between laterals. The nitrogen availability steadily increased with increased depth up to 30 cm after that declined in all the distances. The peak available soil nitrogen (207 kg ha^{-1}) was recorded in the depth of 15-30 cm at a distance of 30 cm from the dripper. In between laterals, the nitrogen concentration steadily increased up to 30 cm distance from dripper and declined thereafter. The nitrogen content of the soil decreased with decrease in RDF levels.

Table 1: Fertigation schedule for maize.

	Quantity (%)		
Crop stages	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

Table 2a: Nitrogen dynamics (kg ha^{-1}) under drip fertigation at 75% RDF.

	Distance from dripper (cm)											
	Conventional fertilizer						Water soluble fertilizer					
	Across the lateral			Along the lateral			Across the lateral			Along the lateral		
Depth (cm)	0	30	60	10	20	30	0	30	60	10	20	30
0-15	195	201	197	190	198	203	203	212	207	196	207	215
15-30	200	207	205	195	204	211	214	221	218	200	216	224
30-45	197	203	201	192	190	200	210	216	210	198	210	218

Table 2b: Nitrogen dynamics (kg ha^{-1}) under drip fertigation at 100% RDF.

	Distance from dripper (cm)											
	Conventional fertilizer						Water soluble fertilizer					
	Across the lateral		Along the lateral		Across the lateral		Along the lateral					
Depth (cm)	0	30	60	10	20	30	0	30	60	10	20	30
0-15	200	205	202	198	210	218	225	230	233	220	232	235
15-30	209	215	213	206	219	226	230	232	238	225	236	240
30-45	202	204	205	203	212	221	228	226	230	228	230	232

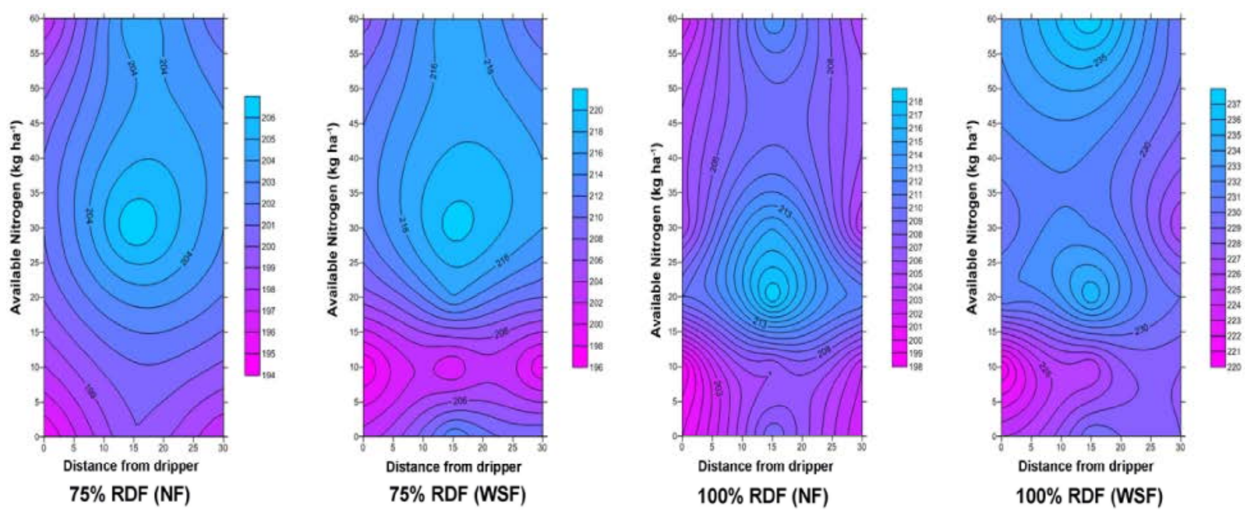

Fig. 1: Nitrogen dynamics under drip fertigation

The mobility of nutrients was well proven under drip fertigation system. An understanding of such transformation on nutrient mobility is very important in elucidating the soil fertility interactions. In drip fertigation treatments, the nitrogen concentration in the soil increased as the distance from the emitter increased up to certain distance and decline thereafter.

The nitrogen concentration in upper soil (0-15 cm) was lower than bottom layers (15-30) (Fig.1). The higher nitrogen concentration was observed in the layer of 15-30 cm depth and at the distance of 20 cm from the emitter. Urea is relatively mobile in soil and it is not strongly adsorbed by soil colloids. It tends to be more evenly distributed down the soil profile below the emitter and had moved laterally in the profile to 15 cm radius from the emitter. The available N content was confined to maximum at immediately below the emitter and moved laterally up to 15 cm and vertically up to 15-25 cm and thereafter dwindled. Data shows that the nitrogen content in the soil profile neither accumulates at the periphery of the wetting front nor leached from the root zone. These are in accordance with the findings of [2-4].

Table 3a: Phosphorus dynamics (kg ha^{-1}) under drip fertigation at 75 % RDF (WSF).

	Distance from dripper (cm)					
	Across the lateral			Along the lateral		
Depth (cm)	0	30	60	10	20	30
0-15	22.9	19.8	18.3	18.0	20.7	19.4
15-30	20.2	19.4	18.2	17.6	19.5	19.2
30-45	18.2	18.1	17.8	17.7	18.1	17.7

Table 3b: Phosphorus dynamics (kg ha^{-1}) under drip fertigation at 100 % RDF (WSF).

	Distance from dripper (cm)					
	Across the lateral			Along the lateral		
Depth (cm)	0	30	60	10	20	30
0-15	23.2	20.6	18.8	19.4	20.8	19.7
15-30	20.7	20.4	18.2	19.7	20.3	20.2
30-45	19.4	18.6	17.9	19.9	19.2	18.8

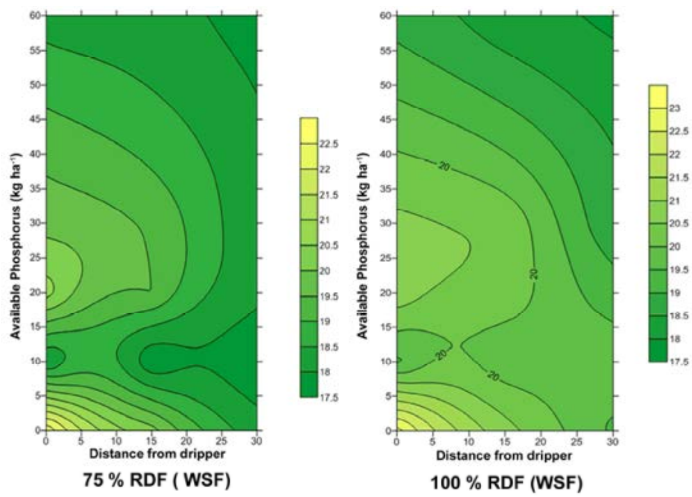

Fig. 2: Phosphorus dynamics under drip fertigation

Phosphorus Dynamics: Among all the elements required by a plant, phosphorus is one of the most important nutrients for crop production [5].

The highest available phosphorus in soil was confined to 0-15 cm of soil layer under all fertigation levels (Table 3a and 3b). The available phosphorous decreased with increase in distance and soil depth. Higher phosphorous availability was recorded under higher RDF (100%) and it decreased with lower levels of fertilizer dose. The peak availability of phosphorous was recorded just below the dripper. Higher phosphorous availability of 23.2 kg ha^{-1} was observed under just below the dripper at 0-15 cm depth. In along the laterals phosphorous availability was increased up to 20 cm (18.0 to 20.1 kg ha^{-1}) and thereafter it declined (19.4 kg ha^{-1}).

A spectacular movement of phosphorus in the soil was found under drip fertigation. Extend of movement of orthophosphate from the emitter is very much dependent upon the phosphate adsorption of the soil. Rauschkolb [6] observed considerable vertical and horizontal movement of phosphate in clay loam soil. However, the distance of phosphate movement was proportional to the application rate, since movement resulted from saturation of adsorption sites on the soil near the point of application and subsequent mass flow with the soil water. Generally, the applied orthophosphate is confined to the soil volume directly surrounding the emitter. The movement of P in this experiment appeared to be directed downward as it moved with the irrigation water. There was little lateral movement of P under these conditions expecting at the soil surface and this was probably due to surface flow of liquid. Extend of P movement in soil is dependent on saturation of reaction sites in soil.

Unlike nitrogen, the higher concentration of phosphorus was seen at 0-15 cm soil layer than at 15-30 and 30-45 cm at all the distance from the emitter (Fig. 2).

Table 4a: Potassium dynamics (kg ha^{-1}) under drip fertigation at 75% RDF.

	Distance from dripper (cm)											
	Conventional fertilizer						Water soluble fertilizer					
	Across the lateral			Along the lateral			Across the lateral			Along the lateral		
Depth (cm)	0	30	60	10	20	30	0	30	60	10	20	30
0-15	393	384	381	375	385	380	428	422	415	400	419	405
15-30	382	381	375	368	377	373	420	417	402	385	403	395
30-45	375	372	348	365	372	370	412	404	385	380	398	390

Table 4b: Potassium dynamics (kg ha^{-1}) under drip fertigation at 100 % RDF.

	Distance from dripper (cm)											
	Conventional fertilizer						Water soluble fertilizer					
	Across the lateral			Along the lateral			Across the lateral			Along the lateral		
Depth (cm)	0	30	60	10	20	30	0	30	60	10	20	30
0-15	410	398	390	383	407	393	441	432	425	407	438	430
15-30	403	379	372	375	390	382	437	429	412	395	430	425
30-45	395	374	368	370	385	375	431	425	408	386	402	398

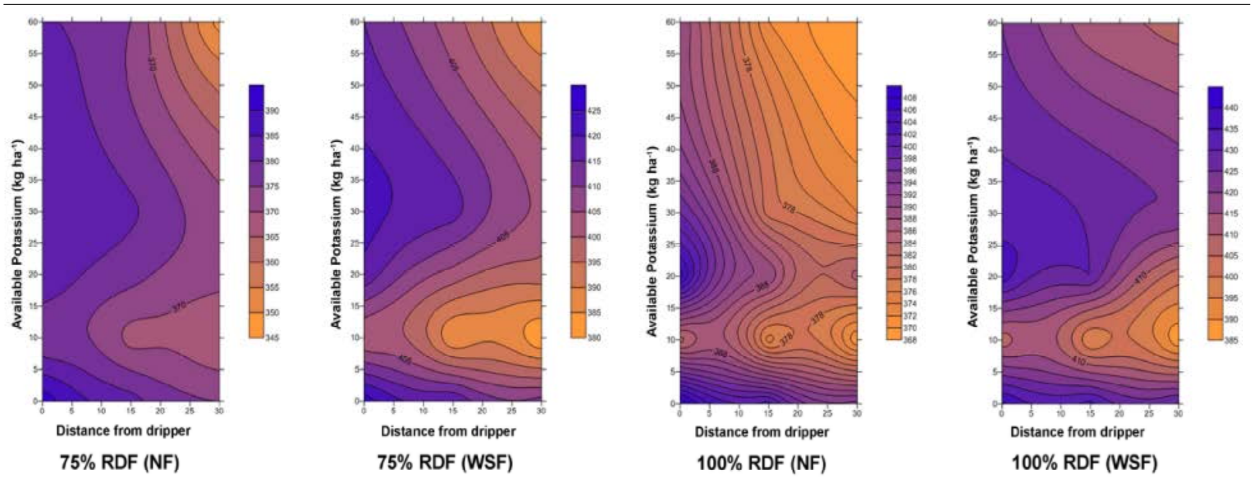

Fig. 3: Potassium dynamics under drip fertigation

The restricted mobility of phosphorus might be due to its strong reaction as stated by Harjinder Singh [7]. Phosphorus is less mobile in the soil and tends to accumulate near the point of application *i.e.* under the dripper, with little being leached downward or moved laterally [8].

Potassium Dynamics: At the end of fertigation, potassium availability (Table 4a and 4b) was higher in the top layers. Available potassium content in the soil varied with layers and distance from the dripper point. Increased fertilizer levels increased the potassium availability. Potassium availability was more (in the range of 407 to 441 kg ha^{-1}) under water soluble fertilizer as compared to normal fertilizer (383 to 410 kg ha^{-1}) in all the sampling depth. In between the laterals, peak potassium availability of 410 and 441 kg ha^{-1} was observed just below the dripper at a depth of 0-15 cm in drip fertigation at 100 per cent RDF of normal and water soluble fertilizer, respectively. In along the lateral high amount of potassium (407 and 438 kg ha^{-1}for normal and water soluble fertilizer, respectively) was noticed at top soil layer (0-15 cm) with a distance of 20 cm from dripper. The same trend was also observed for drip fertigation at 75% RDF.

After the fertigation the highest K concentration was found in 0-15 cm soil depth than at the lower layer *i.e.* 15-30 cm depth. The peak quantity of K was recorded in 0-15 cm depth under emitter (Fig. 3).

Table 4: Effect of drip fertigation on grain yield of maize.

Treatments	Grain yield (Kg ha^{-1})
T_1- Drip Fertigation + 75 % RDF (NF)	5885
T_2- Drip Fertigation + 100 % RDF (NF)	6321
T_3- Drip Fertigation + 75 % RDF (50 % P & K- WSF)	6578
T_4- Drip Fertigation + 100 % RDF (50 % P & K -WSF)	7309
T_5- Drip Irrigation+ 100 % RDF	5386
T_6- Surface Irrigation+ 100 % RDF	4720
SEd	100
CD (P=0.05)	235

Potassium availability in the surface soil may change rapidly due to fluctuating soil moisture in response to wetting and drying during summers, a process that may enhance soil K fixation. In this experiment soil K content was significantly higher in the surface soil than in the subsoil, this might be due to majority of applied K was held in the surface soil and the downward movement was slow. Slow downward movement of applied K may be partially attributed to net upward flux of soil water in the soil profile as a result of high evapotranspiration. This is in line with the findings of Zeng [9]. Mmolawa and Or [10] who also reported similar findings, that potassium (K) distribution in the soil profile is characterized by decreasing soil K content with depth. K content increased significantly throughout the 0-15 cm soil profile even though movement of surface applied K in the soil profile was slow.

Higher concentration of potassium was found in the upper layers of the soil i.e. at 0 to 20 cm soil depth and lower concentration of potassium was found in the lower layers of the soil i.e. 20 to 40 cm soil depth under fertigation. Peak quantity of potassium under fertigation treatment was always found to be in the soil depth of 0-10 cm at the emitter [11]. Suganya [12] inferred that the available K content was maximum in the surface layer due to entrance of K ions on soil exchange complex resulting in very small movement to deeper layer.

Grain Yield of Maize: Generally the maize grain yield increased with increase in fertilizer level (Table 4). Drip fertigated maize at 100% RDF with 50% P and K through WSF recorded significantly higher grain yield of 7.3 t ha^{-1}. The yield increases over drip irrigation with soil application of fertilizer was 35%. 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 15.5% as compared to drip fertigation of 100% RDF with normal fertilizer. 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 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. Iqbal [13] reported that application of DAP at the lower rate (33 kg P ha^{-1}) through fertigation resulted in almost the same wheat grain yield as obtained by the higher dose (44 kg P ha^{-1}) applied by broadcast method. The highest number of fruits plant^{-1} under liquid fertilizer treatments could be due to continuous supply of NPK from the liquid fertilizers as reported by Kadam and Karthikeyan [14] in tomato. Hebbar [15] 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 [16].

REFERENCES

1. Billsegars, 2003. Fertigation in IMC Global (ed.) Efficient fertilizer use: Manual, Fourth Edition. Accessed at http: // www.agcentral.com /imcdemo/10 fertigation. Html. Brandt, A.E. Bresler, N. Diner, I. Ben-Asher, J. Heller and D. Goldberg. 1971. Infiltration from a trickle source. I. Mathematical models. Soil Sci. Soc. Am. Proc., 35: 675-682.
2. Janagarathinam, T., 2007. Optimization of water and nutrient requirement by drip fertigation for enhanced productivity of white onion (*Allium cepa.* var. cepa L.). Ph.D. Thesis. TNAU, Coimbatore.
3. Arulraja, S., 2008. Response of sweet sorghum to drip fertigation. M.Sc. (Ag). Thesis, TNAU, Coimbatore.
4. Achakzai, A.K.K., Habibullah, B.H. Shah and M.A. Wahid, 2012. Effect of nitrogen fertilizer on the growth of mungbean (Vigna radiate L.) grown in Quetta. Pak. J. Bot., 44(3): 981-987.
5. Ryan, I., 2002. Efficient use of phosphate fertilizer for sustainable crop production in WANA. IMPHOS: Phosphate Newsletter, pp: 2-5.
6. Rauschkolb, R.S., D.E. Rolsten, R.J. Miller, A.B. Carlton and R.G. Burau. 1976. Phosphorus fertilization with drip irrigation. Soil Sci. Soc. Am. J., 40: 68-72.

7. Harjinder Singh. N.K. Narda and J.K. Chawla, 2004. Effect of irrigation frequency on subsurface drip irrigated vegetables. Hort. Tech., 13: 115-120.
8. Alva, A.K. and M. Mozzofari, 1995. Nitrate leaching in a deep sandy soil as influenced by dry broadcast of fertigation of nitrogen for citrus production. In: International Symposium on Fertigation Technology, Israel, 26-31 March 1995, pp: 67-77.
9. Zeng, D.Q., P.H. Brown and B.A. Holtz, 2000. Potassium fertigation improves soil K distribution, Builds Pistachio Yield and Quality. Fluid Journal. pp: 1-2.
10. Mmolawa, K. and D. Or, 2000. Root zone solute dynamics under drip irrigation: A review. Plant and Soil. 222: 163-190.
11. Mishra, P., D.K. Singh and R. Ravi Babu, 2006. Impact of method of irrigation and fertilizer application on distribution of potassium in soil under radish. *IE (I) Journal.,* 87: 20-23.
12. Suganya, S., A. Anitha and K. Appavu, 2007. Moisture and nutrient distribution system under drip fertigation systems. In: Third International Ground Water Conference on "Water, Environment and Agriculture-Present problems and future challenges". pp: 7-10.
13. Iqbal, Z., A.I. Latif, S.Ali and M. Mohsin Iqbal, 2003. Effect of fertigated phosphorus on P use efficiency and yield of wheat and maize. Sonngklanakarin J. Sci. Technol., 25(6): 697-702.
14. Kadam, J.R. and S. Karthikeyan, 2006. Effect of soluble NPK fertilizers on the nutrient balance, water use efficiency, fertilizer use efficiency of drip system in a Tomato. Internat. J. Plant. Sci., 1: 92-94.
15. Hebbar, S.S., B.K. Ramachandrappa, H.V. Nanjappa and M. Prabhakar, 2004. Studies on NPK drip fertigation in field grown tomato (*Lycopersicon esculentum* Mill.). Europ. J. Agron., 21: 117-127.
16. Selva Rani, A., 2009. Drip fertigation studies in maize (*Zea mays L.)* - Bhendi (*Abelmoschusb esculentus* L. Moench) cropping sequence. Ph.D. Thesis, TNAU, Coimbatore.