DOI : 10.5958/0974-0112.2015.00035.3

Indian J. Hort. 72(2), June 2015: 178-182

Effect of different nitrogen sources and nitrification inhibitors on soil nitrogen distribution in Kinnow orchard

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ABSTRACT

A field experiment was conducted on 2-year-old Kinnow mandarin to find out effect of different nitrogen sources and nitrification inhibitors on ammonical and nitrate nitrogen distribution in Kinnow young plants during 2011-12. There were 13 treatments comprising four nitrogen sources (ammonium sulphate, calcium nitrate, mixture of ammonium sulphate and calcium nitrate and urea), two nitrification inhibitor (dicyandiamide 5% of fertilizers, *meliacin* 0.1% of fertilizers) and control. Recommended fertilizers dose was applied in three splits, *i.e.* in February, June and September. Nitrification inhibitors were mixed with different nitrogenous fertilizers before application and then applied in the field. The process of nitrification slow down when N-fertilizers (ammonium sulphate, mixture of ammonium sulphate & calcium nitrate and urea) treated with DCD and meliacins. Thus the inhibitory effect of DCD and meliacins on the nitrification process resulted in more NH_4^+ accumulation in soil. The concentration of NH_4^+-N in soil at 0-30 (44.1, 55.7, 42.7 mg kg^{-1} soil below drippers and 37.8, 41.9, 36.0 mg kg^{-1} soil at 30 cm away from drippers) and 30-60 cm depth (24.2, 20.2, 23.2 mg kg^{-1} soil below drippers and 20.0, 23.5, 23.6 mg kg^{-1} soil at 30 cm away from drippers) in all three split applications respectively, was significantly higher when ammonium sulphate followed by urea fertilizers treated with DCD than they are in alone form. Due to nitrification inhibitors, NO_3^--N availability remains high on surface level, reduced NO_3^- leaching and increase N fertilizer utilization efficiency in Kinnow production.

Key words: Kinnow, nitrification inhibitor, nitrogen sources.

INTRODUCTION

Nitrogen fertilization is one of the primary concern in the Kinnow production. Excessive N fertilizer rates typically increase N leaching and may also result in ground water contamination (Alva and Paramasivam, 1). It has been estimated that 50-70 per cent of the nitrogen applied in soil is lost (Hodge *et al.*, 6) largely due to loss of added N by nitrification, denitrification, leaching, immobilization, run-off and ammonia volatilization. Plants grown in nutrient solution under controlled conditions absorb nitrate more readily than ammonium ions, while other plants prefer ammonium. In several crops, combination of NH_4^+ and NO_3^- usually result in greater vegetative growth than either N form alone. Nitrate has the advantage of immediate availability for plant and microbes, but it has disadvantages of high solubility and mobility in the soil. In contrast to nitrate, ammonium ion is not subjected to losses, because it can be held by soil clay minerals. Nitrification leads to the formation and emissions of N_2O and NO, while denitrification causes formation and emission of N_2O and N_2, while leaching of NO_3 (produced *via* nitrification) leads to ground water pollution (Prasad and Power, 8). Therefore, nitrification inhibitors are now being combined with fertilizers in order to increase fertilizer use efficiency. Nitrification inhibitors, when added with nitrogen fertilizers to the soil, delay the transformation of ammonium to nitrite ion by slowing down the enzymatic activity of the soil nitrifiers and thus indirectly delaying conversion of NO_2 to NO_3 (Zacherl and Amberger, 14).

Dicyandiamide (DCD) has been proven to be effective in reducing nitrification rates (Cookson and Cornforth, 4) and nitrate leaching (Williamson *et al.*, 13). Previous studies demonstrated that the nitrification inhibitor (NI) dicyandiamide (DCD) added to ammonium sulphate nitrate (ASN) improved the N-fertilizer efficiency and reduced NO_3 leaching in young and mature citrus trees (Serna *et al.*, 10, 11). In addition to synthetic nitrification inhibitors, natural products from the neem (*Azardirachta indica* Juss) are reported to have nitrification inhibiting properties and widely used in under field conditions. The use of a small quantity of neem oil can serve the purpose and may be used successfully for the coating of

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urea. But not all the chemical components (group of compounds) of neem oil have nitrification-inhibiting properties. The major components in neem oil are free fatty acid (FFA), pure oil, meliacins, saturated and unsaturated fractions. Kumar *et al*. (7) found in a soil incubation experiment that the meliacins content in neem oil directly affected the nitrification inhibition. Nevertheless, there is no information about the behavior of the DCD and meliacins in Kinnow cultivated under field conditions. The overall objective of this study was to examine whether DCD and meliacins can be used to reduce nitrification in Kinnow orchards. We hypothesized that when N-fertilizers are treated with DCD and meliacins, most of the mineral N released through mineralization from the N-fertilizers would remain in soil as NH_4^+, avoiding excessive build up of NO_3^- in soil and thus reducing the risk of nitrate leaching.

MATERIALS AND METHODS

The field experiment with two-year-old Kinnow / *Jatti khatti* plants was carried out during 2011-12 at the Todapur Orchard of Division of Fruits and Horticultural Technology, IARI, New Delhi. It is situated at the latitude of 28°38' 22" N and 38°39' 05" N and longitude of 77°9' 45" E and 77°10' 24"E at an average elevation of 228.61 m above the mean sea level. Climate of Delhi is categorized as semi-arid, subtropical with hot dry summer and cold winter and it falls in the Agro-eco-region-IV. The maximum and minimum temperature during the experiment was 44.2° and 1.7°C. The total rainfall received during the experiment was 689.8 mm. Soils of IARI represent a typical alluvium profile of *Yamuna* origin. The pH of experimental site ranges between 7.8-8.3. Chemical properties of soil in the experimental field showed below (Table 1).

The experiment comprised of four nitrogen sources (ammonium sulphate as ammonical form, calcium nitrate as nitrate form, mixture of ammonium sulphate and calcium nitrate as nitrate and ammonical form and urea), two nitrification inhibitor (Dicyandiamide @ 5% of N-fertilizers and *meliacin* @ 0.1% of N-fertilizers) and one control. Thus, there was total 13 treatment combinations [T_1 = control, T_2 = ammonium sulphate (AS), T_3 = calcium nitrate (CN), T_4 = ammonium sulphate + calcium nitrate, T_5 = Urea (UR), T_6 = ammonium sulphate (AS) + dicyandiamide (DCD), T_7 = ammonium sulphate + meliacins, T_8 = calcium nitrate (CN) + dicyandiamide, T_9 = calcium nitrate + meliacins, T_{10} = ammonium sulphate + calcium nitrate + dicyandiamide, T_{11} = ammonium sulphate + calcium nitrate + meliacins, T_{12} = urea (UR) + dicyandiamide and T_{13} = urea + meliacins]. Recommended fertilizers dose was applied in three splits, *i.e.*, during Winter season in September (75 g N : 37.5g P : 52.5 g K plant^{-1}), during spring season in February (150 g N : 75 g P : 105 g K plant^{-1}) and during rainy season in June (75 g N : 37.5 g P : 52.5 g K plant^{-1}). nitrification inhibitor mixed with different nitrogenous fertilizers before application and then applied in the field by ring method. The experiment was laid out in randomized block design and replicated thrice. Experimental unit having two plants per treatment. Kinnow orchard was installed with online drip irrigation system. The control head of the system consisted of sand filter, flow control valve, screen filter, pressure gauges etc. The lateral lines were placed along the Kinnow row having four online emitters of four litres per hour (4 l/hr) capacity surrounding the tree. Irrigation was scheduled daily as per consumptive water requirement calculated as per formula given below;

Daily water use (L) = Evaporation (mm) × 0.7 × canopy ground area (m^2)

Ammonical and nitrate nitrogen distribution was analyzed from the soil samples drawn both laterally (at below and 30 cm away from drippers) and vertically (at 0-30 and 30-60 cm depths) at 30 days after each fertilizer application. For the estimation of mineral N (NH_4^+ and NO_3^--N), portions of 10 grams of processed soil samples were extracted with 100 ml of 2 M KCl for 1 h. Extracts were then analyzed for NH_4^+-N by steam distillation with MgO in a micro-Kjeldahl system, and for NO_3^--N after reduction with devarda's alloy followed by distillation (Bremner and

Table 1. Chemical properties of soil in the experimental field.

Radial distance (cm)	Available nutrient							
	Depth (cm)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Fe (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)
30	0-30	130.70	30.47	280.03	3.45	2.46	35.38	3.23
	30-60	90.46	25.13	245.32	3.06	2.94	26.29	2.96
60	0-30	109.03	29.96	263.62	3.21	2.32	37.26	3.08
	30-60	84.73	23.24	236.69	2.72	2.72	21.74	2.55

Keeney, 3). The data were statistically analysed for analysis of variance (ANOVA) using IASRI Server using SSCNARS portal. Means were separated using Fisher's Least Significant Difference at 5 per cent level of significance. Grouping of letters on treatments were made using pdglm800.sas.

RESULTS AND DISCUSSION

The amounts of NH_4^+-N and NO_3^--N in the soil were measured in order to estimate the residual concentration of these anions in the upper and deeper soil layers. Tables 2 & 3 show the NH_4^+-N and NO_3^--N concentrations. The concentration of NH_4^+-N in soil at 0-30 cm depth below and 30 cm away from drippers was significantly higher when respective N-fertilizers treated with nitrification inhibitors (both DCD and meliacins) than they are in alone form except nitrate nitrogen fertilizers in all split applications. This indicates that the NH_4^+ was nitrified in the soil when amended with N-fertilizers without treating nitrification inhibitors (both DCD and meliacins). Whereas, nitrification inhibitors slow down the nitrification when N-fertilizers treated with these nitrification inhibitors. Thus, the inhibitory effect of DCD and meliacins on the nitrification process resulted in more NH_4^+ accumulation in soil. The NH_4^+ concentrations as depicted in Table 2 were significantly lower in control and nitrate N-fertilizers treatments, whereas, significantly higher in the AS + DCD treatment (44.1, 55.7, 42.7 mg kg^{-1} soil below drippers and 37.8, 41.9, 36.0 mg kg^{-1} soil at 30 cm away from drippers in all three split applications respectively) followed by urea + DCD and AS + meliacins treatments. Among N-fertilizers alone, the ammonical N-fertilizer form retained more NH_4^+-N in the upper soil profile (0-30 cm) than the other form of N-fertilizers used in this study.

The concentration of NH_4^+ in soil at 30-60 cm depth below and 30 cm away from drippers followed a similar trend as of 0-30 cm depth but the concentration of the NH_4^+ was lower. The NH_4^+ concentrations as depicted in Table 2 were significantly lower in control and nitrate N-fertilizer treatments whereas, significantly higher in the AS+DCD treatment (24.2, 20.2, 23.2 mg kg^{-1} soil below drippers and 20.0, 23.5, 23.6 mg kg^{-1} soil at 30 cm away from drippers in all three split applications, respectively) followed by urea + DCD and AS+meliacins treatment.

The concentration of NO_3^--N in soil at 0-30 cm depth below and 30 cm away from drippers was significantly higher in the treatments containing nitrification inhibitors, *i.e.,* DCD and meliacins except nitrate nitrogen fertilizers in all split applications. This implies that nitrification leads to formation of NO_3^- within a few days when fertilizers not treated with nitrification inhibitors. This NO_3^--N utilized by the plants and excess NO_3^- leached to the ground level. Whereas, when N-fertilizers treated with nitrification inhibitors (*i.e.* DCD and meliacins) nitrification slow down and the NO_3^--N slowly available for longer periods, which lower the chances of leaching. The NO_3^--N concentrations as presented in Table 3 were significantly lower in control, whereas, significantly higher in the AS + DCD treatment (33.9, 41.0, 31.4 mg NO_3^--N kg^{-1} soil below drippers and 27.3, 37.0, 31.1 mg NO_3^--N kg^{-1} soil at 30 cm away from drippers in all three split applications respectively) followed by urea + DCD and AS + meliacins treatment. Among N-fertilizers alone, the ammonical N-fertilizer form retained more NO_3^--N in the upper soil profile (0-30 cm) than the other form of N-fertilizers at 30 days after application.

The concentration of NO_3^--N in soil at 30-60 cm depth below and 30 cm away from drippers was significantly higher in all treatments not containing nitrification inhibitors, *i.e.*, DCD and meliacins in all split applications. The concentration of NO_3^- N in soil at 30-60 cm depth found lower in treatments containing nitrification inhibitors, as most of the NO_3^- N remain in the upper soil layer (0-30 cm depth) due to slow nitrification. Between different treatments the lowest NO_3^--N found in AS + DCD (18.8, 20.5, 19.1 mg NO_3^--N kg^{-1} soil below drippers and 16.8, 18.3, 19.9 mg NO_3^--N kg^{-1} soil at 30 cm away from drippers in all three split applications respectively) followed by AS + meliacins and AS + DCD treatment. The highest NO_3^--N found in T_3 and T_9 treatments at below and 30 cm away from drippers during the first split application whereas, in second and third split application highest NO_3^--N was found in T_3, T_8 and T_9 treatments at below and 30 cm away from drippers.

When the nitrogen source is in the ammonical form, resistance to leaching occurs due to cationic attraction of ammonium ions by clay and humus. Nitrate ions are highly mobile in the soil, contributing to the contamination of ground waters, can suffer denitrification and accumulate in plant tissues, whereas, the ammonium ion is not as readily subject to leaching loss (Barker and Mills, 2). The concentration of NH_4^+-N was significantly higher in the soil received with nitrification inhibitors treated fertilizers than in soil that only received fertilizers alone. Most NH_4^+-N from fertilizer was retained in the soil surface layer (0-30 cm) and retention was more with nitrification inhibitors. Soil NH_4^+-N contents in N + DCD and N + DCD + S treatments were higher than that of N treatment within 40 days after fertilization in apple orchard Ge *et al.* (5). In a previous study, Serna *et al.* (10) also observed that DCD was able to delay nitrification, to reduce NO_3^- leaching and

Table 2. Distribution of NH_4^+-N from different nitrogen fertilizers with or without nitrification inhibitors in the Kinnow soil profile.

Treatment	First split application				Second split application				Third split application			
	Below dripper		30 cm away from dripper		Below dripper		30 cm away from dripper		Below dripper		30 cm away from dripper	
	0-30#	30-60	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
T1	12.3 ± 0.7^{f}	8.0 ± 0.6^{f}	10.4 ± 0.4^{f}	6.9 ± 0.3^{d}	10.7 ± 0.4^{g}	8.4 ± 0.9^{d}	7.8 ± 0.4^{e}	7.3 ± 0.3^{c}	9.7 ± 0.4^{e}	8.3 ± 0.3^{g}	9.5 ± 0.4^{g}	5.8 ± 0.3^{f}
T2	30.9 ± 0.7^{cd}	21.1 ± 0.6^{bc}	29.3 ± 0.6^{bc}	19.1 ± 0.4^{a}	40.7 ± 0.9^{c}	20.6 ± 2.0^{a}	31.1 ± 0.7^{c}	20.7 ± 1.6^{a}	28.3 ± 0.6^{c}	18.8 ± 0.4^{bcd}	27.7 ± 0.6^{c}	15.2 ± 0.3^{cd}
T3	13.8 ± 0.6^{f}	9.0 ± 0.7^{f}	9.6 ± 0.4^{f}	5.6 ± 0.5^{d}	9.7 ± 0.4^{g}	7.1 ± 0.3^{d}	7.9 ± 0.4^{e}	7.0 ± 0.9^{c}	11.2 ± 0.5^{e}	7.6 ± 0.3^{g}	9.7 ± 0.4^{g}	5.1 ± 0.2^{f}
T4	25.2 ± 0.9^{e}	16.8 ± 1.3^{e}	20.9 ± 0.5^{e}	12.4 ± 0.5^{c}	26.1 ± 0.7^{f}	14.7 ± 0.2^{c}	20.9 ± 0.5^{d}	14.7 ± 1.6^{b}	22.9 ± 0.6^{d}	13.9 ± 0.3^{f}	20.0 ± 0.5^{f}	11.3 ± 0.3^{e}
T5	28.4 ± 1.2^{de}	19.2 ± 0.6^{cde}	25.7 ± 1.1^{d}	19.9 ± 1.3^{a}	34.5 ± 1.5^{de}	18.9 ± 0.5^{ab}	30.7 ± 1.5^{c}	16.4 ± 1.5^{b}	28.9 ± 1.3^{c}	17.5 ± 0.8^{de}	23.5 ± 1.1^{e}	13.9 ± 0.7^{d}
T6	44.1 ± 1.5^{a}	24.2 ± 1.7^{a}	37.8 ± 1.3^{a}	20.0 ± 1.3^{a}	55.7 ± 1.9^{a}	20.2 ± 0.7^{a}	41.9 ± 1.4^{a}	23.5 ± 0.8^{a}	42.7 ± 1.4^{a}	23.2 ± 0.8^{a}	36.0 ± 1.2^{a}	23.6 ± 0.8^{a}
T7	41.0 ± 0.9^{ab}	23.3 ± 1.1^{ab}	35.2 ± 0.8^{a}	19.5 ± 0.5^{a}	50.3 ± 1.2^{b}	21.5 ± 1.5^{a}	36.8 ± 0.8^{b}	21.5 ± 1.0^{a}	37.0 ± 0.9^{b}	20.1 ± 0.5^{b}	34.9 ± 0.8^{a}	19.8 ± 0.5^{b}
T8	13.5 ± 0.6^{f}	8.9 ± 0.5^{f}	10.5 ± 0.3^{f}	5.9 ± 0.7^{d}	9.9 ± 0.2^{g}	7.8 ± 0.3^{d}	7.3 ± 0.2^{e}	6.5 ± 0.2^{c}	11.7 ± 0.3^{e}	9.1 ± 0.2^{g}	11.0 ± 0.3^{g}	5.7 ± 0.5^{f}
T9	12.7 ± 0.7^{f}	9.4 ± 0.7^{f}	9.9 ± 0.4^{f}	6.2 ± 0.4^{d}	10.7 ± 0.4^{g}	8.2 ± 0.3^{d}	6.1 ± 0.3^{e}	7.1 ± 0.3^{c}	10.0 ± 0.4^{e}	8.6 ± 0.3^{g}	9.1 ± 0.4^{g}	5.2 ± 0.4^{f}
T10	31.9 ± 1.8^{c}	20.6 ± 0.8^{bcd}	28.4 ± 1.6^{c}	16.2 ± 0.9^{b}	32.9 ± 0.1^{e}	16.1 ± 0.7^{bc}	31.0 ± 0.1^{c}	15.0 ± 0.6^{b}	28.0 ± 1.4^{c}	18.3 ± 0.1^{cd}	27.2 ± 0.1^{cd}	15.5 ± 0.8^{c}
T11	29.1 ± 1.6^{cd}	18.3 ± 0.7^{de}	25.4 ± 1.0^{d}	14.5 ± 0.8^{bc}	36.8 ± 1.4^{d}	16.9 ± 1.3^{bc}	32.2 ± 1.2^{c}	17.2 ± 1.5^{b}	27.0 ± 1.0^{c}	16.0 ± 0.6^{e}	25.3 ± 0.9^{de}	13.9 ± 0.5^{d}
T12	42.9 ± 1.0^{ab}	23.9 ± 0.6^{a}	36.5 ± 0.9^{a}	20.6 ± 1.0^{a}	52.5 ± 1.2^{ab}	21.7 ± 1.0^{a}	40.0 ± 0.9^{a}	21.8 ± 1.1^{a}	38.1 ± 0.9^{b}	22.0 ± 0.5^{a}	35.2 ± 0.8^{a}	20.0 ± 0.5^{b}
T13	40.7 ± 1.9^{b}	22.9 ± 1.0^{ab}	31.7 ± 1.6^{b}	21.0 ± 1.1^{a}	42.3 ± 1.9^{c}	20.0 ± 0.9^{a}	33.4 ± 1.5^{c}	23.0 ± 1.0^{a}	35.6 ± 1.6^{b}	19.9 ± 0.9^{bc}	30.3 ± 1.4^{b}	18.4 ± 0.8^{b}
LSD 3.45 (P≤0.05)		2.78	2.67	2.22	3.39	2.91	2.75	2.93	2.94	1.59	2.40	1.60

Data represent the mean ± standard error of three independent determinates. Means within a column that did not differ significantly at 5% level of significance when compared with Fisher's Least Significant Difference are followed by the same superscript letters; # Depth in cm

Table 3. Distribution of NO_3^--N (mg kg^{-1} soil) from different nitrogen fertilizer with or without nitrification inhibitors in the Kinnow soil profile.

Treatment	First split application				Second split application				Third splits application			
	Below dripper		30 cm away from dripper		Below dripper		30 cm away from dripper		Below dripper		3 0cm away from dripper	
	0-30#	30-60	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
T1	13.9 ± 0.6^{e}	10.1 ± 0.4^{g}	12.7 ± 0.6^{f}	8.1 ± 0.4^{h}	11.1 ± 0.5^{i}	9.9 ± 0.4^{g}	8.1 ± 0.4^{g}	25.3 ± 1.1^{b}	11.1 ± 0.5^{h}	8.1 ± 0.3^{f}	12.4 ± 0.6^{h}	7.4 ± 0.3^{g}
T2	28.3 ± 0.6^{b}	21.51 ± 0.5^{de}	25.9 ± 0.6^{b}	22.0 ± 0.5^{cd}	32.8 ± 0.7^{de}	25.6 ± 0.6^{bcd}	26.2 ± 0.6^{d}	22.1 ± 0.5^{cde}	24.7 ± 0.5^{cd}	20.3 ± 0.4^{de}	24.8 ± 0.5^{bc}	24.6 ± 0.5^{cd}
T3	20.4 ± 0.9^{d}	29.0 ± 1.3^{a}	17.3 ± 0.8^{e}	26.5 ± 1.2^{a}	25.2 ± 1.1^{h}	33.6 ± 1.5^{a}	19.7 ± 0.9^{f}	30.6 ± 1.4^{a}	17. 9 ± 0.8^{g}	29.7 ± 1.3^{a}	16.9 ± 0.8^{g}	28.7 ± 1.3^{a}
T4	23.8 ± 0.6^{c}	25.6 ± 0.6^{bc}	21.1 ± 0.5^{d}	23.8 ± 0.6^{bc}	26.6 ± 0.7^{gh}	27.6 ± 0.7^{b}	23.8 ± 0.6^{de}	24.7 ± 0.6^{bc}	19. 9 ± 0.5^{fg}	22.5 ± 0.6^{cd}	21.0 ± 0.5^{ef}	25.7 ± 0.6^{bc}
T5	24.0 ± 1.1^{c}	25.3 ± 1.1^{bc}	25.1 ± 2.1^{bc}	22.1 ± 1.1^{cd}	30.8 ± 1.4^{ef}	25.7 ± 1.1^{bcd}	25.9 ± 1.2^{d}	22.7 ± 1.1^{cd}	21.7 ± 1.0^{ef}	26.1 ± 1.1^{b}	22.5 ± 1.1^{cde}	25.8 ± 1.2^{bc}
T6	33.9 ± 1.1^{a}	18.8 ± 0.6^{f}	27.3 ± 0.9^{b}	16.8 ± 0.6^{g}	41.0 ± 1.4^{a}	20.5 ± 0.7^{f}	37.0 ± 1.3^{a}	18.3 ± 0.6^{g}	31.4 ± 1.1^{a}	19.1 ± 0.6^{e}	31.1 ± 1.1^{a}	19.9 ± 0.7^{f}
T7	31.9 ± 0.7^{a}	19.4 ± 0.4^{ef}	30.7 ± 0.7^{a}	17.3 ± 0.4^{fg}	38.9 ± 0.9^{ab}	21.0 ± 0.5^{f}	34.7 ± 0.8^{ab}	19.7 ± 0.5^{efg}	28.9 ± 0.7^{b}	18.8 ± 0.4^{e}	29.4 ± 0.7^{a}	20.2 ± 0.5^{f}
T8	23.4 ± 0.6^{c}	27.6 ± 0.7^{ab}	21.4 ± 0.8^{d}	25.2 ± 0.6^{ab}	25.8 ± 0.6^{h}	32.3 ± 0.8^{a}	21.6 ± 0.5^{ef}	28.7 ± 0.7^{a}	19.1 ± 0.5^{g}	31.7 ± 0.8^{a}	19.1 ± 0.5^{fg}	29.4 ± 0.7^{a}
T9	22.6 ± 0.9^{cd}	28.4 ± 1.2^{a}	22.5 ± 1.0^{cd}	26.1 ± 1.2^{a}	26.5 ± 1.1^{gh}	31.5 ± 1.3^{a}	19.3 ± 0.9^{f}	29.2 ± 1.3^{a}	18.0 ± 0.7^{g}	32.1 ± 1.3^{a}	18.5 ± 0.8^{g}	27.9 ± 1.3^{ab}
T10	27.5 ± 0.1^{b}	23.6 ± 0.1^{cd}	22.6 ± 0.1^{cd}	19.1 ± 0.1^{ef}	29.4 ± 0.1^{fg}	24.6 ± 0.1^{cde}	25.5 ± 0.1^{d}	21.5 ± 0.1^{def}	25.9 ± 0.1^{c}	23.1 ± 0.8^{c}	22.5 ± 0.1^{de}	21.9 ± 0.1^{ef}
T11	27.0 ± 1.0^{b}	23.8 ± 0.9^{cd}	21.9 ± 0.8^{d}	20.2 ± 0.8^{de}	29.1 ± 1.1^{fg}	26.0 ± 1.0^{bc}	24.1 ± 0.9^{de}	21.6 ± 0.8^{def}	23.4 ± 0.9^{de}	23.3 ± 0.9^{c}	23.2 ± 0.9^{bcde}	23.1 ± 0.9^{de}
T12	28.7 ± 0.7^{b}	21.6 ± 0.5^{de}	27.3 ± 0.6^{b}	20.1 ± 0.5^{de}	36.6 ± 0.9^{bc}	22.3 ± 0.5^{ef}	32.9 ± 0.8^{b}	19.3 ± 0.5^{fg}	26.1 ± 0.6^{c}	21.2 ± 0.5^{cde}	25.2 ± 0.6^{b}	23.0 ± 0.5^{de}
T13	28.3 ± 1.3^{b}	22.2 ± 1.0^{d}	25.8 ± 1.2^{b}	18.9 ± 0.9^{efg}	34.7 ± 1.6^{cd}	23.1 ± 1.1^{def}	29.1 ± 1.3^{c}	18.1 ± 0.8^{g}	25.7 ± 1.2^{c}	23.7 ± 1.1^{bc}	24.6 ± 1.1^{bcd}	22.8 ± 1.0^{de}
LSD 2.55 (P≤0.05)		2.41	2.83	2.23	3.04	2.64	2.60	2.54	2.25	2.59	2.30	2.51

Data represent the mean ± standard error of three independent determinates. Means within a column that did not differ significantly at 5% level of significance when compared with Fisher's Least Significant Difference are followed by the same superscript letters, #Depth in cm to increase N uptake by trees. Preliminary studies carried out in young citrus trees grown in soil culture in pots, revealed a remarkable effect of nitrification inhibitor, 3,4-dimethylpyrazole phosphate (DMPP) on decreasing NO_3^--N levels both in soil and in leaching water, as well as an increase in N uptake of treated plants (Serna *et al*., 12). Quinones *et al*. (9) was carried out an experiment with clementine cv. Nules mandarin grafted on Troyer citrange (*Citrus sinensis* × *Poncirus trifoliata*) rootstock under field conditions and found that the NH_4^+-N concentration in the 0-20 and 20-40 cm soil layers was significantly higher in the ammonium sulphate (AS) + nitrification inhibitor (NI) treatment.

From the findings of these experiment, it can be concluded that the addition of the nitrification inhibitor to NH_4^+ containing N sources will reduce NO_3^- leaching and increase N fertilizer utilization efficiency in Kinnow production.

ACKNOWLEDGEMENT

Authors are grateful to Department of Science and Technology, New Delhi, Govt. of India for grant of Senior Research Fellowship to the first author.

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Received : March, 2013; Revised : February, 2015;
Accepted : May, 2015