مجلة المثنى للعلوم الزراعية المجلد (8) العدد(4) لسنة 2021
Al-Muthanna J. For Agric Sci. Print ISSN: 2226-4086 Online ISSN:2572-5149
DOI 10.52113/mjas04/8.4/13

مجلة المثنى للعلوم الزراعية
https://muthjas.mu.edu.iq/

The Effect of Apply Levels of Nano-Nitrogen and Urea Fertilizer on Ammonium Availability at Horizontal and Vertical Distance in Desert Area Soil

Malath T. Al-Ansari [1*], Abdulmahdi S. Al- Ansari [2] & Mohsen A. Disher [2]

[1] Basrah Agricultural Directorate, Ministry of Agriculture. Iraq.

[2] Department Soil Sciences and Water Resources, College of Agriculture, University of Basrah, Iraq

Article Info.
Received 2020 / 5 / 15
Accepted date 2020 / 7 /15
Keywords
urea, Nano nitrogen, Ammonium, Desert area.

Abstract

A greenhouse experiment was conducted at desert area farm in Al- Zubair district, Basrah government during winter season 2018-2019 to study the effect of applying different levels of urea fertilizer (46%N): 0, 100, 200 and 400 kgN.ha^{-1} and nano nitrogen fertilizer (20%N): 0,50,100 and 200 kgN.ha^{-1} with sequences applied at 30 days' period in soil profile. Ammonium ion was estimated by Kjeldahl method, the results showed a significant increasing in ammonium availability in soil during growth season for both fertilizers at values 109.22 and 117.66 mg.kg^{-1} at march month for urea and nano nitrogen fertilizers respectively. Also results showed significantly decreased of available ammonium when ever got away horizontally and vertically from centre of applying for both fertilizers and with all adding levels. Results showed increased of average ammonium in soil received nano nitrogen compared with soil received urea at values 68.56 and 40.30 mg.kg^{-1} respectively.

Corresponding author: E-mail(*malathtalib72@gmail.com*)

Introduction

Nitrogen is one of important elements in nutrition of plants, that its consider essential elements in production of amino acid of protein and in chlorophyll formation. So it have role in improved and increase of yield (Liu *et al.*, 2015).

Soil nitrogen expose to many deterioration operations such as leaching or volatilization as gases by denitrification and immobilization (Raut *et al.*, 2014), that decreased in nitrogen fertilizer use efficiency (Ichami *et al.*, 2018).

Modern agriculture activities depend on used new agricultural technology to increase total yield and improved quality, the use of chemical fertilizer increase yield but still it considers dangerous on human and animal's health beside its negative effects on environment, so it's very important to used and conducting new technology to increase fertilizers use efficiency to achieves nutrition plants demand and decreased pollution dangerous in soil and water environmental and one of this new fertilizers technology is used of nano fertilizers (Qureshi *et al.*, 2018).

Nano technology is one of an interested science with study of matter and its properties at atomic and molecular level, nanometre is a part of thousand micrometer, its mean part per millions of millimetre and equal one of billion from meter nm (Mustafa *et al.*, 2018). Nano-meter can be a carrier for fertilizers or can control on material (smart or slow release

fertilizers) that can have increased of fertilizer used efficiency through release nutrition elements and decreased environmental pollution (Singh & Prasad, 2016).

De Rosa *et al.* (2010) defined nano fertilizers as a product that delivers nutrients to crops in one of three ways such as the nutrient can be encapsulated inside nanomaterials such as nanotubes or Nano porous materials, coated with a thin protective polymer film, or delivered as particles or emulsions of nanoscale dimensions.

Due to on study about nitrogen nano fertilizers transformation in desert area soil compared with urea fertilizer, conduct this experiment to study the effect of apply nitrogen nano fertilizer on ammonium availability in soil profile and compared with urea that it is add traditional.

Materials and Methods

This experiment was conducted on one of the tomato farm in location 18, Raha region - Zubier district Basrah province south of Iraq at desert land (Typic Torripasmment) soil (Al-Atab , 2008), during the winter season 2018-2019.

Soil samples were collected randomized from study area within 15 and 30 cm horizontally distance and, 20 and 40 cm vertically depth drying and sieved from 2 mm mish and analysed of some physical and chemical properties described in table (1).

Table (1): Some soil physical and chemical properties for study area.

Soil properties	Unit	Value
EC 1:1	dS m^{-1}	5.80
pH 1:1	-	7.65
CEC	Cmol kg^{-1}	6.65
O.M.	g Kg^{-1}	7.32
O.C.		4.25
Total N		0.43
C:N Ratio	-	9.88
Ava. NH_4^+-N	mg Kg^{-1}	83.00
NO_3^--N		14.00
NO_2^--N		0.00
CaCO3	g Kg^{-1}	120.00
Ca^{+2}	Mmol.L^{-1}	13.56
Mg^{+2}		7.70
Na^+		10.45
K^+		1.80
HCO_3^-		3.50
$CO_3^=$		0.00
$SO_4^=$		15.80
Cl^-		13.00
Sand	g Kg^{-1}	890.00
Silt		65.00
Clay		45.00
Texture	Loamy sand	

The experiment including two main factors:

T1: Type of nitrogen fertilizer:

1.Urea fertilizer (46%N) Iraqi made (produced in southern general company for fertilizers).

2.Nano nitrogen fertilizer (20%N) Iranian made (Sepehar parmis Co.).

T2: Nitrogen fertilizers levels:

a. Urea fertilizer 0,100,200,400 kgN.ha^{-1}.

b. Nano nitrogen fertilizer 0,50,100,200 kgN.ha^{-1}.

A greenhouse preparing with 9×52 m (468 m^2 total area), the above fertilizers was divided to five doses distributed during growing season as one dose per month. Fertilizers solution (urea and nano) was injected separately through drip system subsurface by fertigation.

A compound soil sample was collected at five-time period every 30 days between date to other beginning from December 2018 to April 2019, samples was collected from begin, mid and end of each experimental units and keep at plastic bag to avoid humidity and pollution and storage in the refrigerator at 3C̊ to stop any microbiology activity. Available ammonium was determined as method described in Bremner & Keeny (1966).

A randomized complete block design was conducted as a factorial experiment. Analysis of variance of data was done at Gen-State program, comparison of means don by Duncan test at 0.05 and used t test to compared between both fertilizers (Al-Rawi & Khalafallah 1980).

Results and Discussion

Available ammonium (NH_4^+) in soil:

Fig. (1) showed concentration of available ammonium in soil during growing season at apply both sources of nitrogen fertilizer urea (A-1) and nano nitrogen (B-1). Results showed a significant increasing in concentration of available ammonium during growing season for both fertilizers, as increasing value from 39.45 mg.kg^{-1} at December to 109.22 mg.kg^{-1} at April when apply urea fertilizer, and from 39.12 mg.kg^{-1} to 116.59 mg.kg^{-1} when apply nano nitrogen fertilizer. Increasing of ammonium concentration for both fertilizer during growing season. This results agreed with Fanish, & Muthukrishnan, (2013) and Moreno-Cornejo *et al*., (2014), when they had mentioned to increasing the concentration of ammonium availability in soil during time of collection samples.

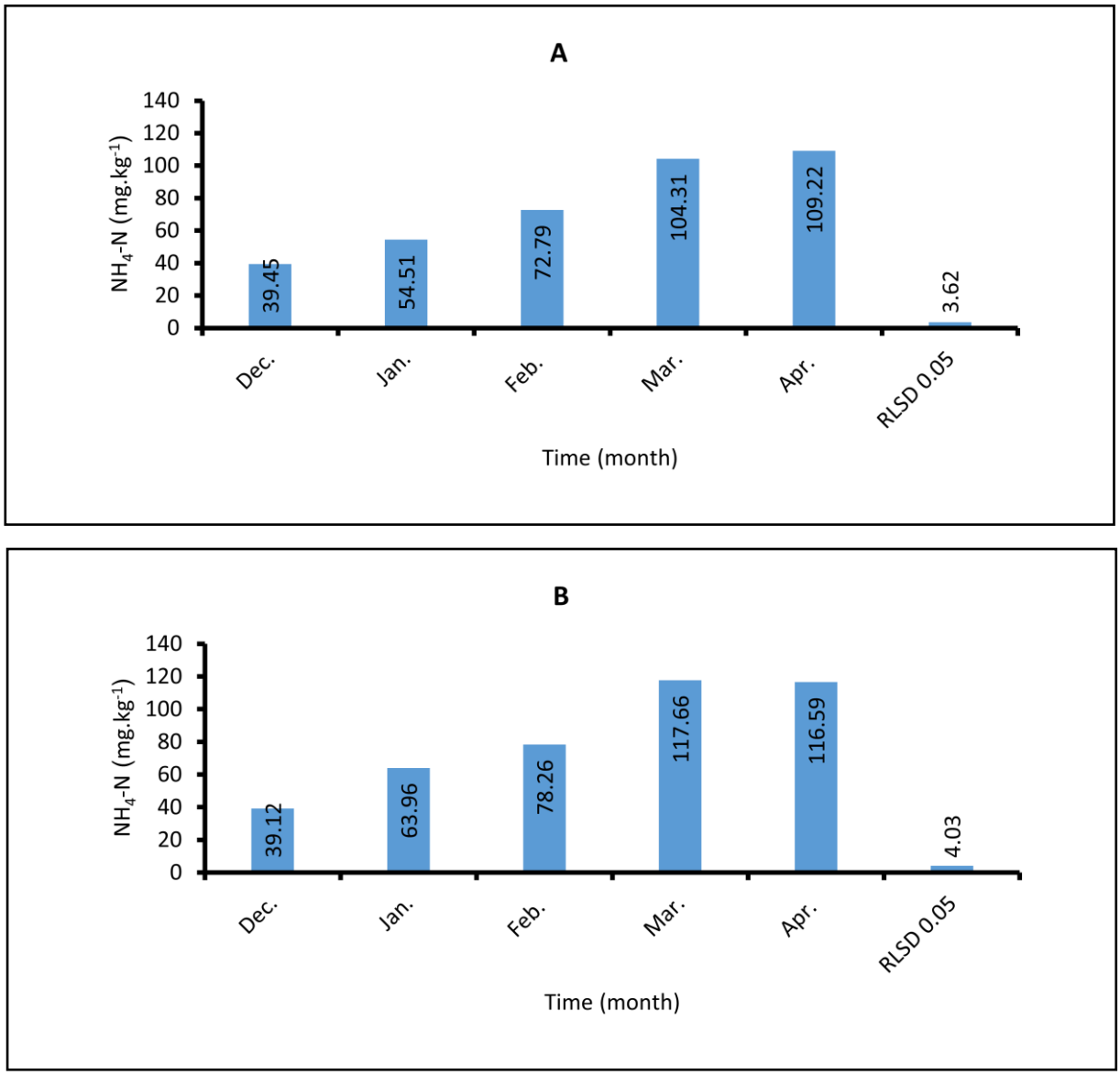


Fig. (1): Effect of sampling time on concentration of available ammonium during growth season: A-urea fertilizer, B-nano nitrogen fertilizer.

Results in fig. (2) showed the effect of apply different levels of nitrogen fertilizers on concentration of available ammonium in soil when added nitrogen from urea (A-2) and nano nitrogen (B-2). Figure showed a significant increase available ammonium in soil with increasing of apply nitrogen from both fertilizers compared with control treatment, value of available nitrogen increased from 47.20, 64.46, 87.80 to 104.74 $mg.kg^{-1}$ when added urea at 0, 100, 200 and 400 $kgN.ha^{-1}$ respectively, and increased from 47.20, 82.88, 95.90 to 106.48 $mg.kg^{-1}$ when apply 0, 50, 100 and 200 $kgN.ha^{-1}$ of nano nitrogen respectively. Data show significant difference between levels for both fertilizer (urea and nano) where increasing of available ammonium concentration in soil with increasing of amount apply fertilizer, level of 400 $kgN.ha^{-1}$ urea was significant superiority compared with 100 and 200 $kgN.ha^{-1}$ as 62.5 and 19.30 % respectively, also level of 200 $kgN.ha^{-1}$ from nano nitrogen was a significant superiority compared with 50 and 100 kg N. ha^{-1} as 29.41 and 11.03 % respectively.

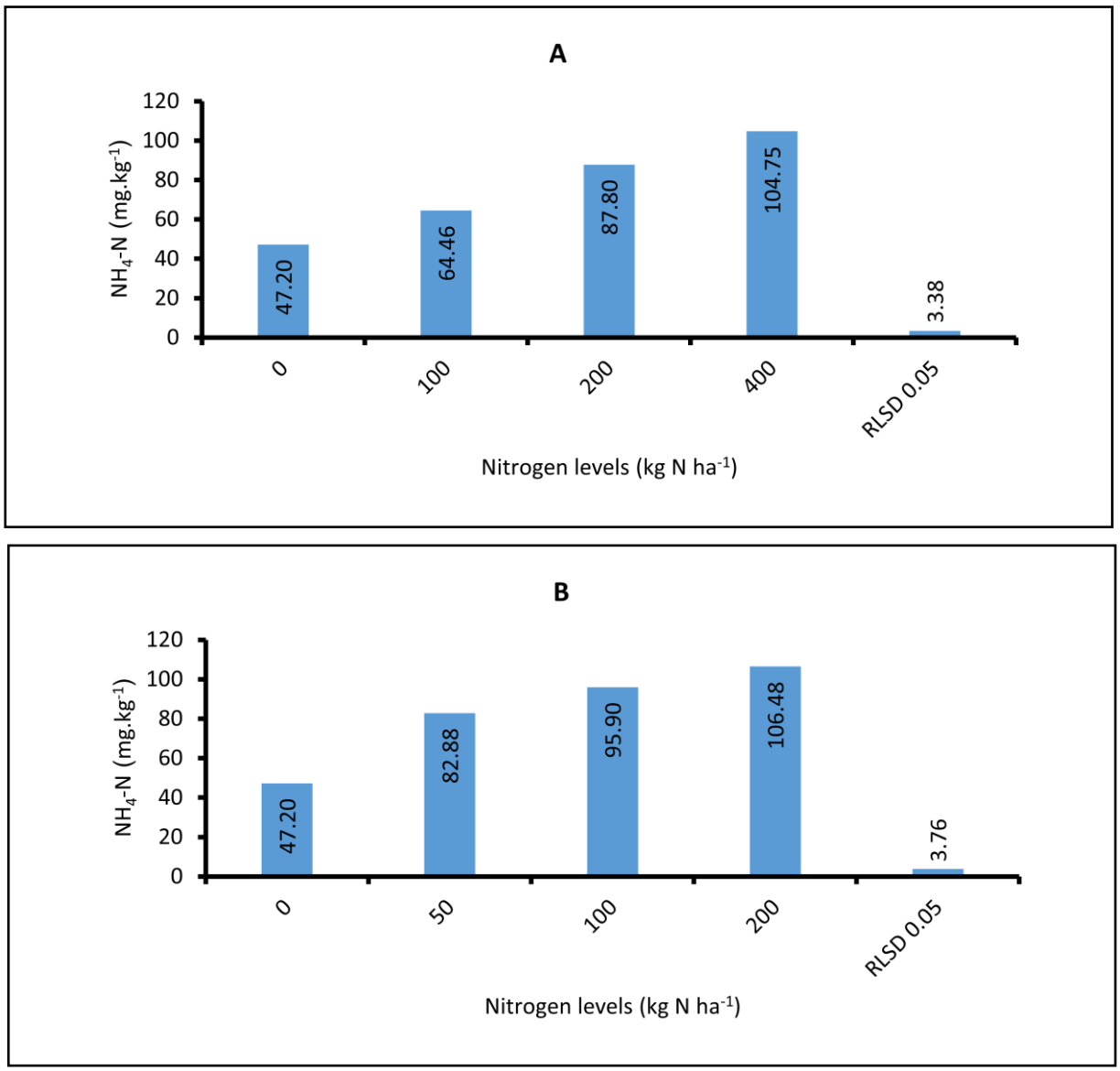


Fig. (2): Effect of nitrogen fertilizer levels on concentration of available ammonium in soil: A-urea fertilizer B-nano nitrogen fertilizer.

Fig. (3) showed the relation between horizontal distance and concentration available nitrogen in soil, data showed a significant effect of horizontal distance on ammonium concentration, where decreased in available ammonium whenever got from central adding fertilizer, distance 0-15 cm for both fertilizer (urea and nano), as values of ammonium concentration was 81.28 and 70.83 mg.kg^{-1} at distance 0-15 cm and 15-30 cm respectively when added urea fertilizer (Fig. 3-A) while the values were 87.22 and 79.02 mg.kg^{-1} when added nano nitrogen fertilizer (Fig. 3-B). The reason may be due to accumulation of ammonium in root zone near the plant by continuous applied nitrogen fertilizer through drip system with irrigation water (Fertigation), that can have increased ammonium concentration near the drip and decreased gradually whenever got away horizontally from dripper (Sawyer, 2019) and (Siddique *et al.*, 2019).

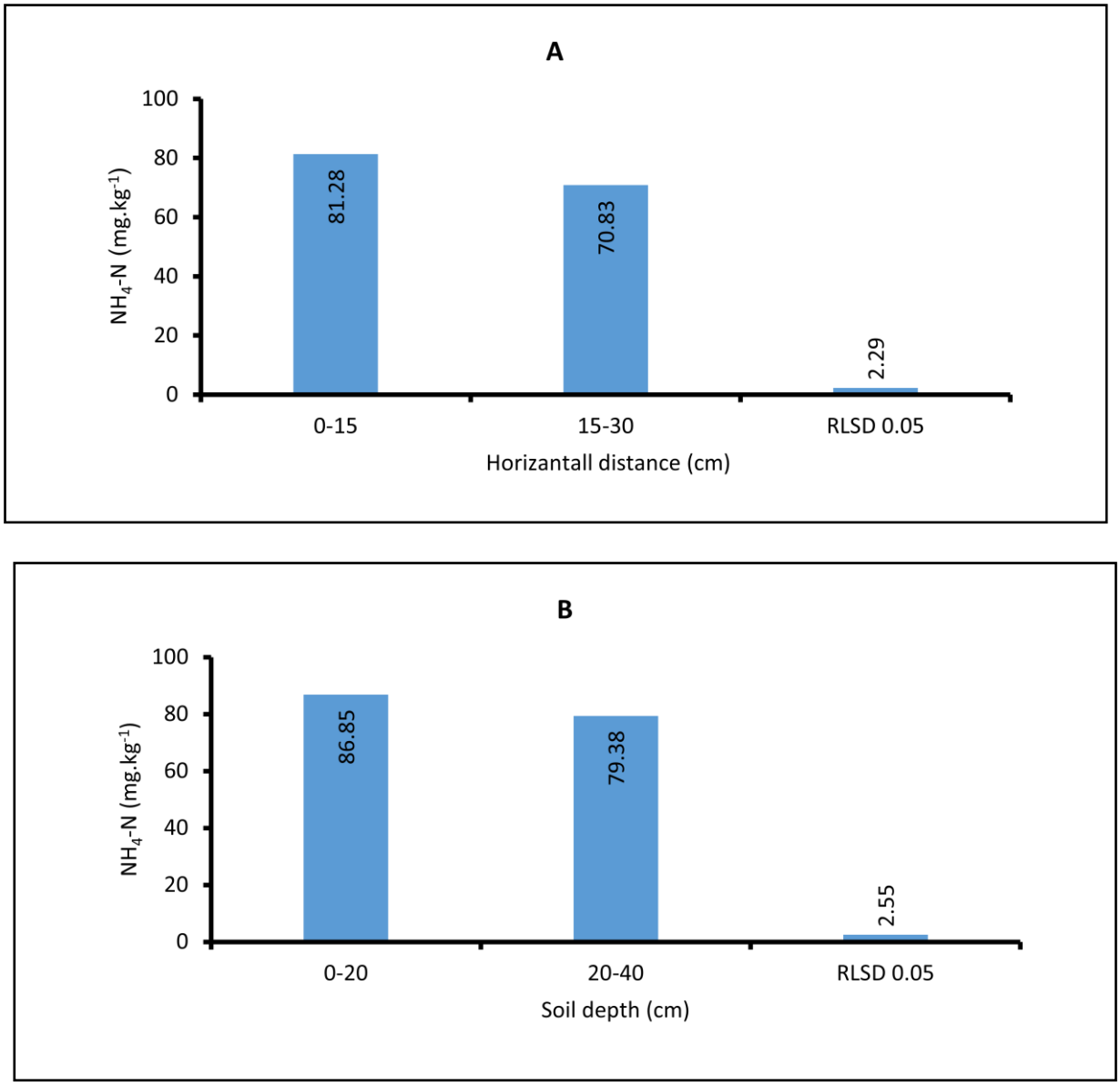


Fig. (3): Effect of horizontal distance of available ammonium concentration in soil: A-urea fertilizer, B-nano nitrogen fertilizer.

Fig. (4) showed the effect of sampling depth 0-20 cm and 20-40 cm on concentration available ammonium in soil when apply urea fertilizer (4-A) and nano nitrogen fertilizer (4-B). Data showed a significant decreased on ammonium availability with increased soil depth for both fertilizer as values 79.49 and 72.61 $mg.kg^{-1}$ for urea fertilizer respectively. For nano nitrogen fertilizer, values were 86.85 and 79.38 $mg.kg^{-1}$ respectively, with decreased percentage 8.60 % at 20-40 cm. The reason of decreased availability of ammonium with increased depth in soil may be related to slow movement of ammonium through the soil layers due to positive cation of ammonium. This results

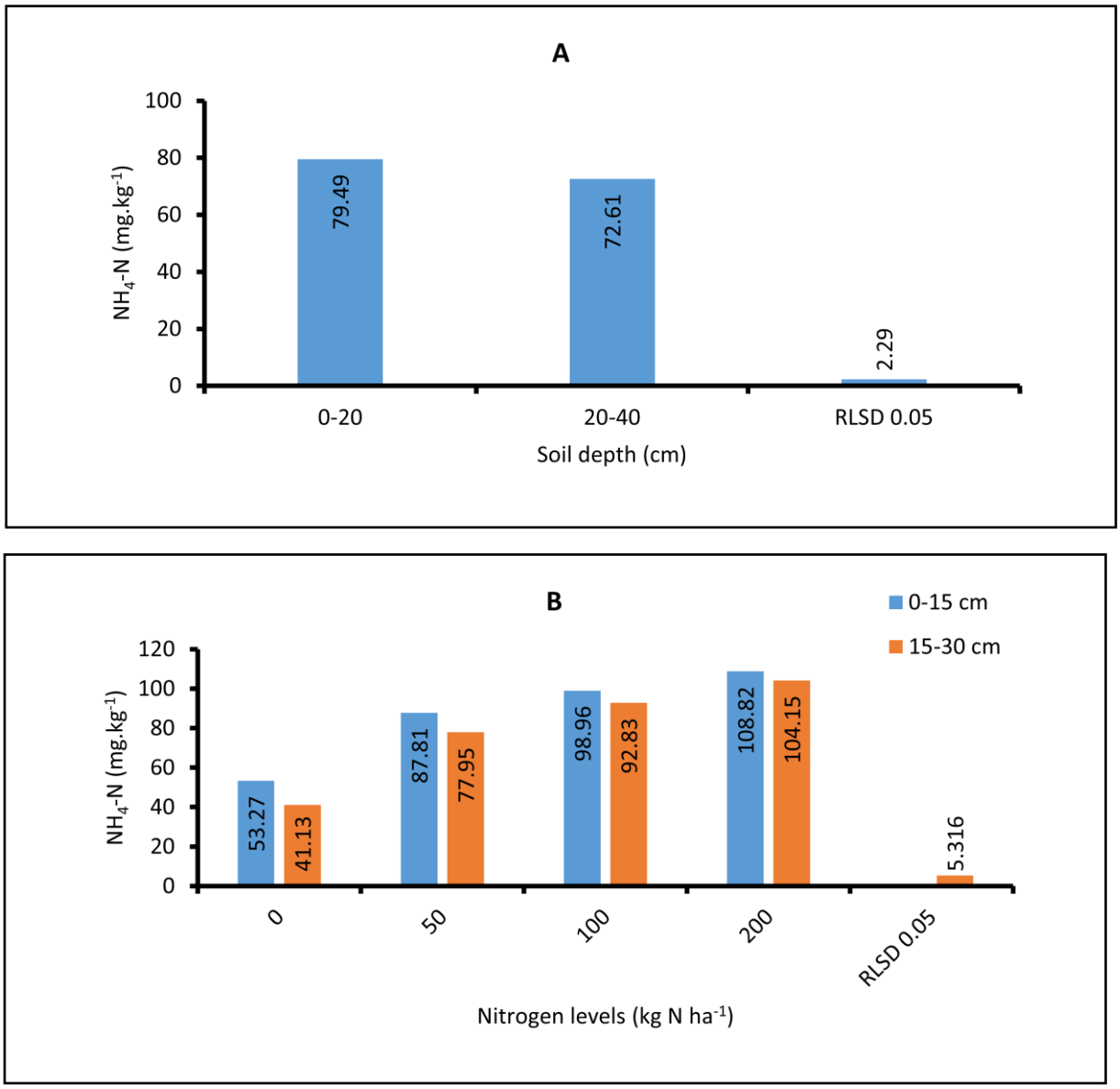


Fig. (4) Effect of depth on concentration ammonium availability in soil: A-urea fertilizer B-nano nitrogen fertilizer.

agreed with Rajeshwaran & Arulmozhielvan (2019) mentioned to increased availability ammonium in soil layers and decreased with increased depth

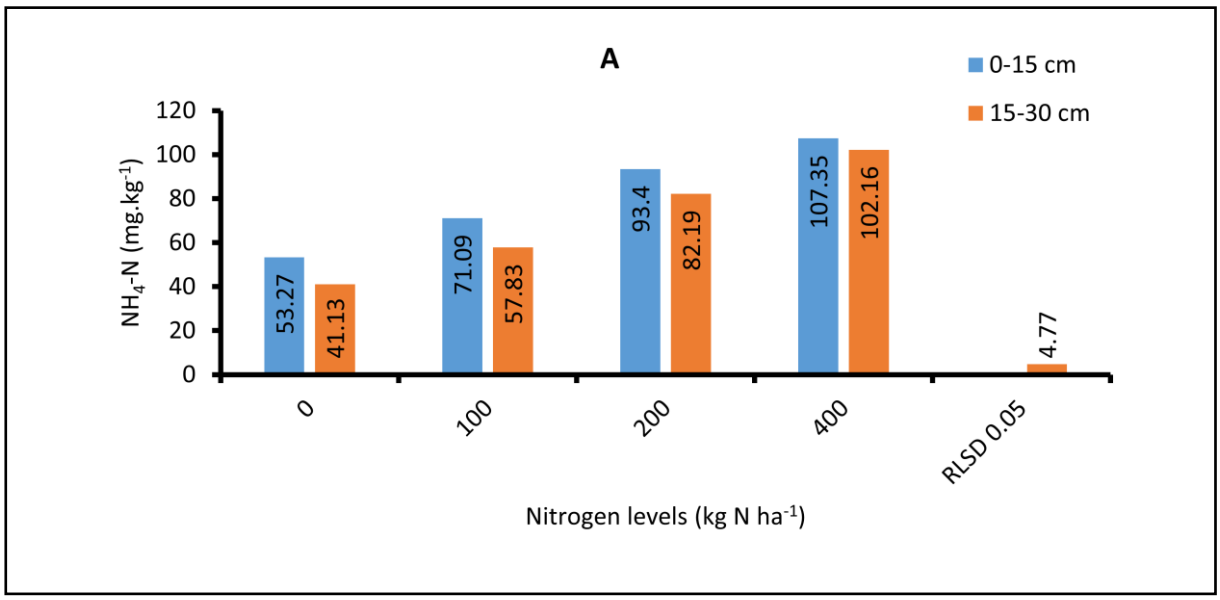


Fig. (5) Effect of interaction between adding nitrogen fertilizer levels and horizontal distance on available ammonium: A-urea fertilizer B-nano nitrogen fertilizer

Fig. (5) showed effect of interaction between horizontal distance and levels of apply nitrogen fertilizer on ammonium availability in soil. When used urea fertilizer (5-A) and nano nitrogen fertilizer (5-B). Data showed decreased of ammonium available whenever got away from central adding both fertilizer, higher concentration of available ammonium in soil when added urea fertilizer at 0-15 cm when apply 400 kgN.ha^{-1} it was 107.4 mg.kg^{-1}, while lowest value of ammonium concentration it was 41.13 mg.kg^{-1} at 15-30 cm at control treatment with 61.85 % decreased percentage compared with the high value, while highest value was 108.8 mg.kg^{-1} of available ammonium when added 200 kgN.ha^{-1} of nano fertilizer at 0-15 cm, and lowest value was 41.1 mg.kg^{-1} at 15-30 cm for control treatment with 62.22 % decreasing percentage, the reason of decreased ammonium concentration at horizontal distance away from central apply fertilizer, may be to positive charge of ammonium ion that contributed restriction in soil and accumulation near of central apply nitrogen zone (Chilundo *et al.* 2018).

Fig. (6) showed interaction between soil depth and apply nitrogen fertilizers on ammonium available in soil. Data in fig. (6-A) showed a significant decreased in ammonium concentration was108.95 mg.kg^{-1} at 0-20 cm when apply 400 kgN.ha^{-1}, while lowest value of ammonium concentration was 45.73 mg.kg^{-1} at 20-40 cm at control treatment with 58.02 % decreasing percentage. Fig. (6-B) showed decreasing in available ammonium when apply 200 kgN.ha^{-1} of nano

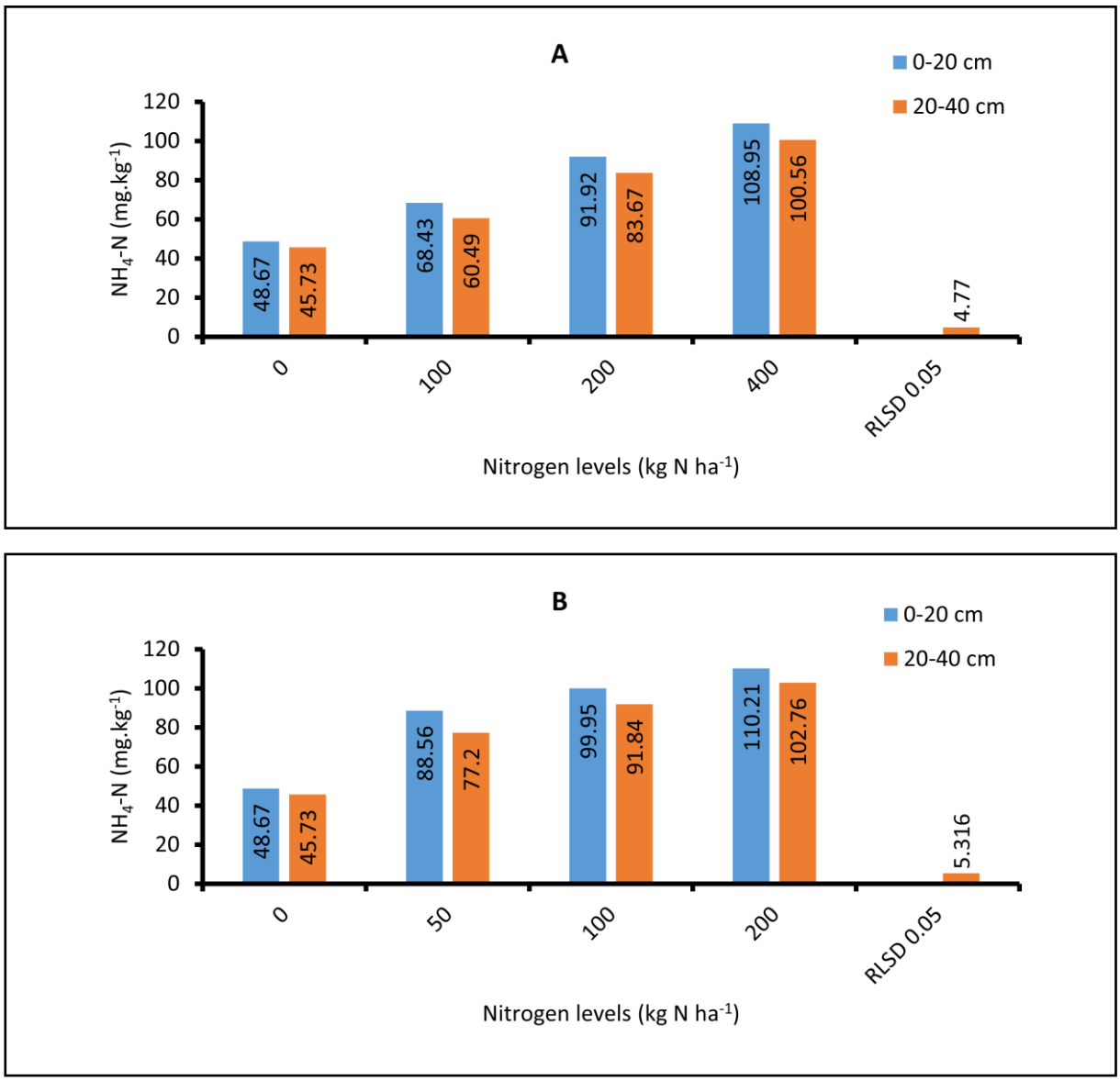


Fig. (6): Effect of interaction between apply levels nitrogen fertilizers and soil depth on available ammonium: A-urea fertilizer, B-nano nitrogen fertilizer.

nitrogen fertilizer with increased depth, highest value was 110.21 mg.kg^{-1}, while lowest value at 20-40 cm for control treatment was 45.73 mg.kg^{-1} with 58.50 % decreasing percentage.

Fig. (7): showed effect of interaction between apply levels of nitrogen fertilizer and soil sampling date on soil available ammonium for both fertilizers. Data in fig. (7-A) showed a significant increase in available ammonium with increased urea fertilizer levels at sampling period during growing

season, highest available ammonium value in soil at 400 kgN.ha^{-1} was 162.2 mg.kg^{-1} at end of growing season with a significant compared of other levels of beginning growing season at lowest value 28.63 mg.kg^{-1} of control treatment. Fig. (7-B) showed increasing on soil ammonium availability with increasing adding nano nitrogen fertilizer levels at sampling period during growing season, highest available ammonium value was 157.59 mg.kg^{-1} at level 200 kgN.ha^{-1} at end of growing season compared with other levels for all sampling period, lowest available ammonium value was 28.63 mg.kg^{-1} at control treatment at beginning of growing season. Akbari *et al.* (2020) find increase of available ammonium in soil with increase wheat growing season due to continuous apply nitrogen fertilizer to soil.

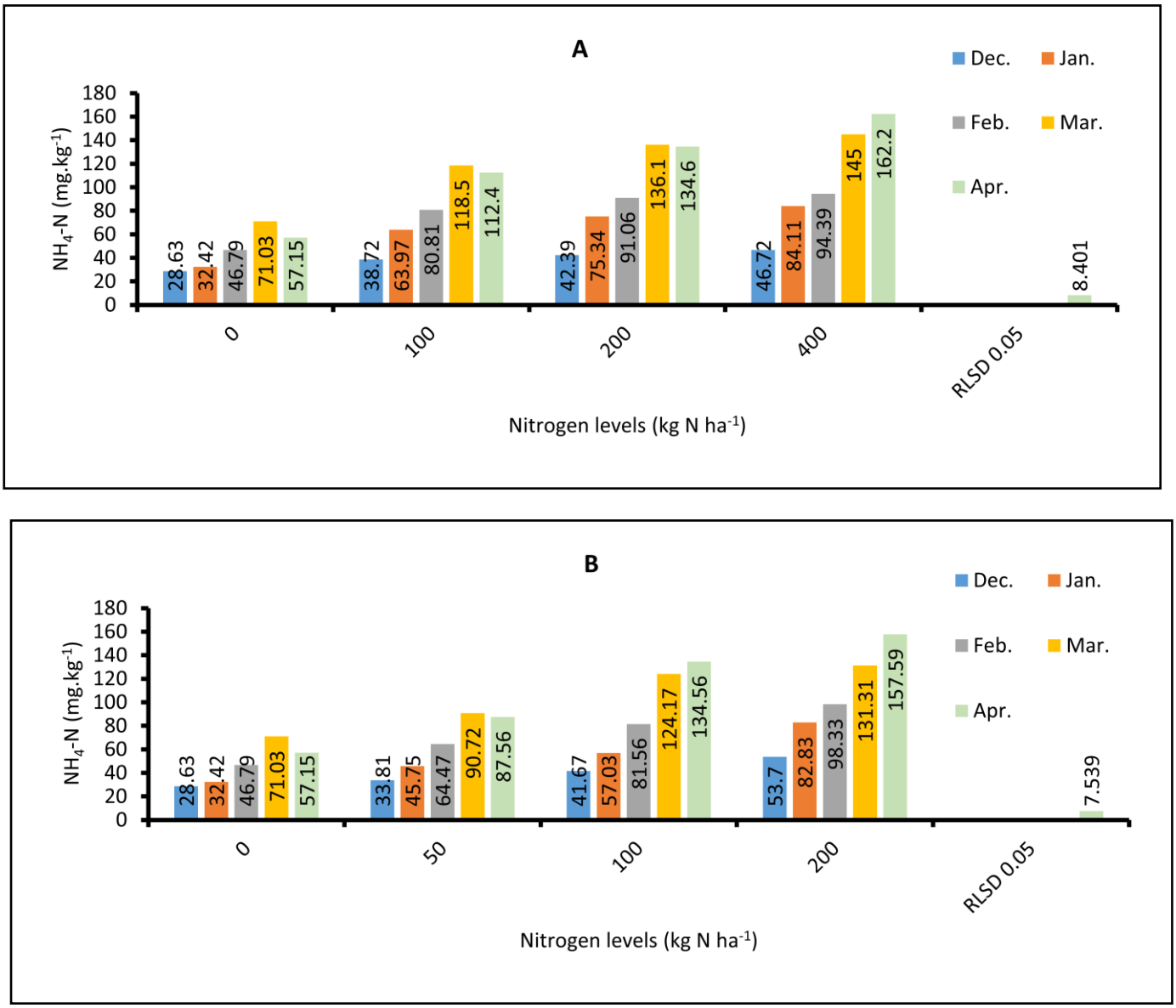
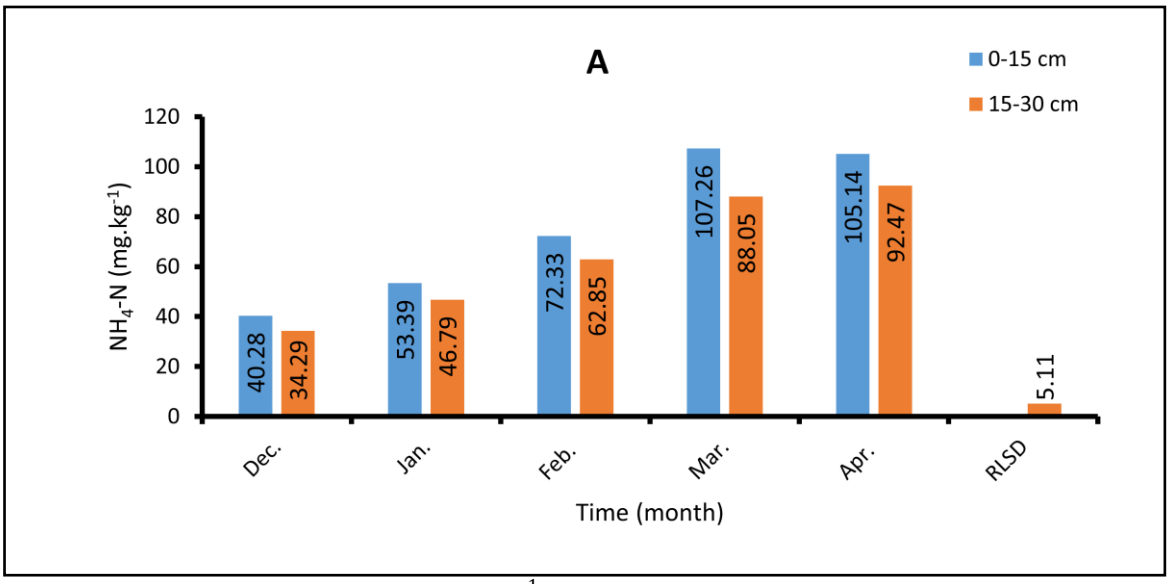


Fig. (7): Effect of interaction between apply nitrogen fertilizers levels and period of soil sampling on available ammonium in soil: A-urea fertilizer, B-nano nitrogen fertilizer.

Fig. (8) showed effect of interaction between horizontal distance and plant growth period on available ammonium in soil with increased levels of apply urea and nano nitrogen fertilizer. Data in fig. (8-A) showed increased of available ammonium near central apply fertilizer zone with increasing apply levels of urea with increasing growth plant at March with significant difference between values. Highest value for



available ammonium at 400 kgN.ha^{-1} in end of growing season at 0-15 cm was 107.26 mg.kg^{-1} at March month, while lowest value was 34.29 mg.kg^{-1} at 15-30 cm. Data in fig. (8-B) showed a significant increasing in available ammonium in central apply fertilizer zone with increasing of apply nano nitrogen fertilizer levels with increasing plant growth period, highest value was 117.7 mg kg^{-1} at end of growing season at March of 200 kgN.ha^{-1} at 0-15 cm, while lowest value was 34.67 mg.kg^{-1} at 15-30 cm distance.

Fig. (8): Effect of interaction between horizontal distance and soil sampling period on available ammonium in soil: A-urea fertilizer, B-nano nitrogen fertilizer.

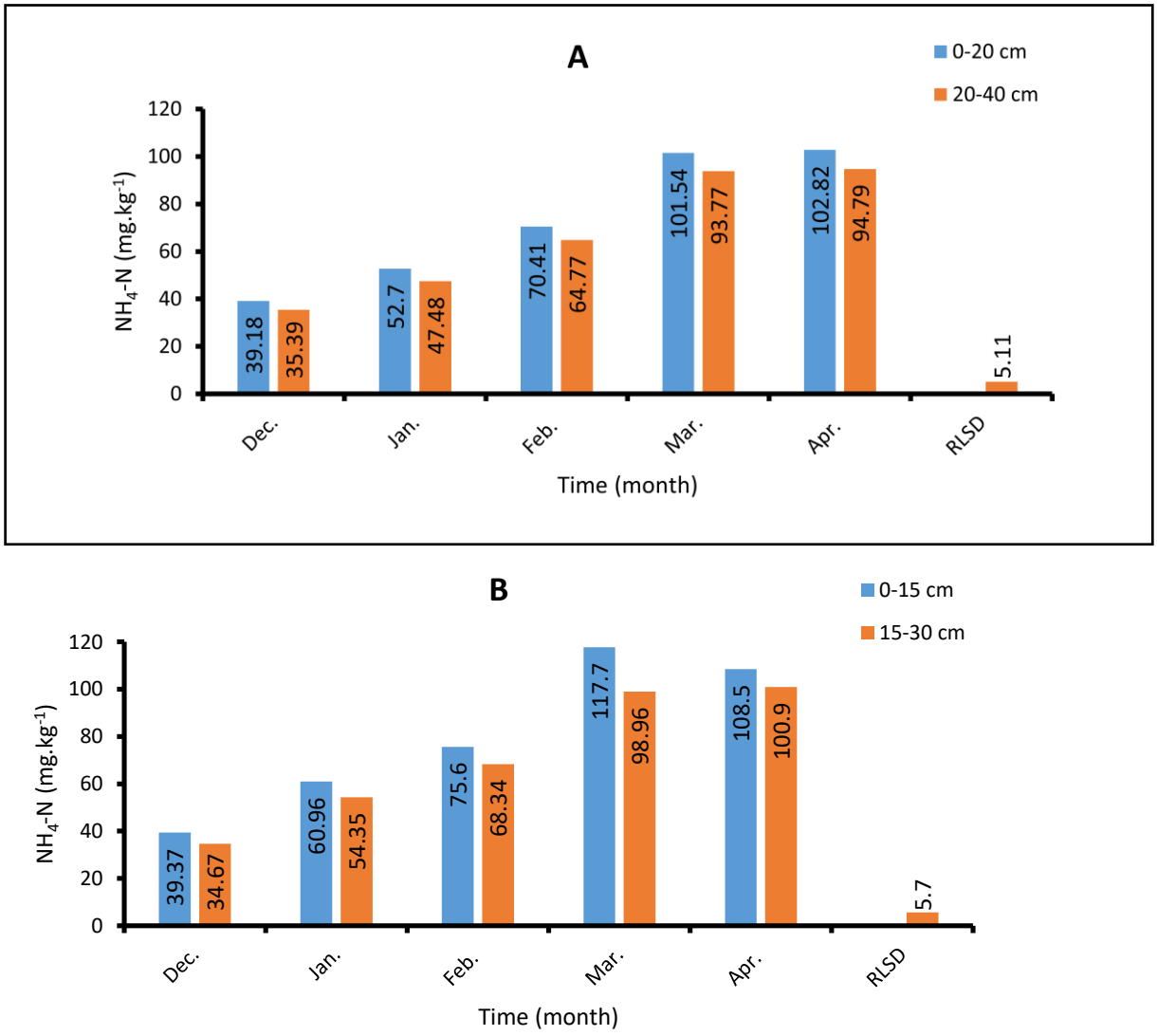


Fig. (9) showed the interaction between soil depth and sampling period on available ammonium with increase apply nitrogen fertilizer levels. Fig. (9-A) showed a significant increase of available ammonium in soil during plant growth season with a significantly effect of urea fertilizer, highest value of available ammonium at end of growth season at April was 102.82 mg.kg^{-1} at 400 kgN.ha^{-1} of 0-20 cm deep. While lowest value at beginning of growth season was 35.39 mg.kg^{-1} at 20-40 cm deep. Fig. (9-B) showed increasing of available ammonium in soil with increasing apply nano nitrogen fertilizer during growth season, the highest value was 112.00 mg.kg^{-1} at 200 kgN.ha^{-1} of 0-20 cm at April, while the lowest value was 33.88 mg.kg^{-1} at 20-40 cm.

Fig. (9): Effect of interaction between soil depth and sampling period on concentration available ammonium in soil: A-urea fertilizer, B-nano nitrogen fertilizer.

Data in table (2) showed the tripartite interaction of sampling period during growth season, levels of apply nitrogen fertilizer and horizontal distance on available ammonium in soil. Data showed a significant increase of available ammonium during growth season with increased apply nitrogen, data find 15-30 cm horizontal distance for both fertilizer was a significant increased on available ammonium with 163.5 mg.kg^{-1} at the end of growth season compared with 0-15 cm horizontal distance of 400 kgN.ha^{-1} and compared with value 31.86 mg.kg^{-1} for control treatment. A significant increased on available ammonium with 162.6 mg.kg^{-1} when apply 200 kgN.ha^{-1} of nano nitrogen fertilizer of 0-15 cm compared with value 31.86 mg.kg^{-1} of control treatment at beginning growth season the increase concentration of available ammonium in soil with time may be due to recurrent addition of fertilizer doses (Akbari *et al.* 2020).

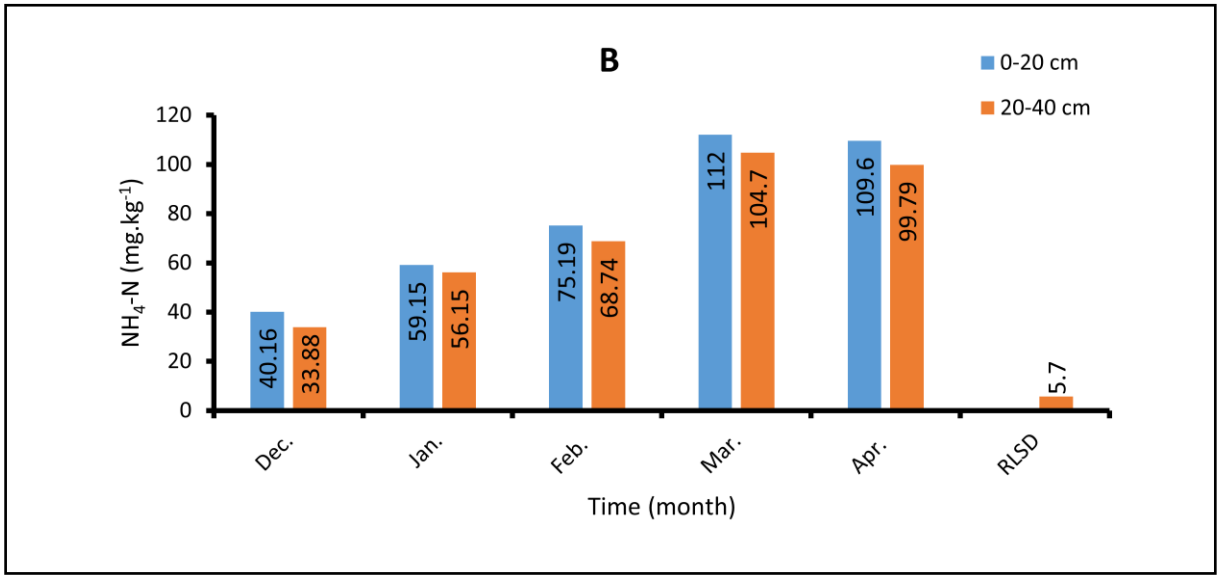


Table (2): Effect of interaction between sampling period, horizontal distance and apply nitrogen levels on available ammonium in soil.

Nano fertilizer				Urea fertilizer				Horizontal distance (cm)	Time (month)
Nitrogen levels (kgN.ha^{-1})				Nitrogen levels (kgN.ha^{-1})					
200	100	50	0	400	200	100	0		
50.72	42.78	39.61	31.86	55.28	44.17	38.22	31.86	15-0	Dec.
42.72	42.12	37.83	25.39	52.11	39.17	29.39	25.39	30-15	
84.78	77.78	69.33	36.44	83.33	62.72	48.22	36.44	15-0	Jan.
83.45	72.89	58.61	28.39	82.33	51.33	43.5	28.39	30-15	
96.78	91.95	81.45	53.9	93.33	87.67	72.83	53.9	15-0	Feb.

92.00	90.17	80.17	39.67	103.3	75.45	56.11	39.67	30-15	
149.2	144.6	135.00	79.83	141.31	132.40	103.00	79.83	15-0	Mar.
140.8	127.6	102.1	62.23	121.31	116.04	78.51	62.23	30-15	
162.6	137.7	113.7	64.33	163.5	140.1	93.45	64.33	15-0	Apr.
161.8	131.5	111.2	49.98	151.7	129.1	81.67	49.98	30-15	
RLSD $_{0.05}$ = 11.88				RLSD $_{0.05}$ = 10.66					

Table (3) showed the tripartite interaction between sampling period, apply nitrogen fertilizer levels and soil depth on available ammonium in soil when adding both fertilizers. Data showed a significant increase in available ammonium in soil during growth season with increased apply nitrogen fertilizer levels, 0-20 cm deep for urea fertilizer was significant increasing with 163.4 mg.kg^{-1} compared with 20-40 cm at 400 kgN.ha^{-1} in end of growth season and compared with 30.58 mg.kg^{-1} for control treatment at beginning of growth season. For nano nitrogen fertilizer, value of available ammonium was 167.2 mg.kg^{-1} for 200 kgN.ha^{-1} in 0-20 cm at end of growth season and significantly compared with 30.58 mg.kg^{-1} for control treatment for seam depth. Available ammonium for 50 , 100 and 200 kgN.ha^{-1} of nano nitrogen fertilizer was significantly increasing compared with 100 , 200 and 400 kgN.ha^{-1} of urea fertilizer levels for both horizontal distance 0-15 and 15-30 cm. Available ammonium in soil from nano nitrogen fertilizer were superiority at 50 kgN.ha^{-1} level compared with apply 100 kgN.ha^{-1} of urea fertilizer, and seam result of available ammonium at 200 kgN.ha^{-1} level for both horizontal distance 0-15 and 15-30 cm and that may be due to increase efficiency of nano fertilizers in the release of nutrients, Singh *et al*. (2017) mentioned the increase in the efficiency of nano fertilizers in releasing nutrients compared to conventional fertilizers, and therefore it increases the nutrient availability in the soil.

Table (3): Effect of sampling period, soil depth and nitrogen levels on available ammonium in soil.

Nano fertilizer				Urea fertilizer				Depth (cm)	Time (month)
Nitrogen levels (kgN.ha^{-1})				Nitrogen levels (kgN.ha^{-1})					
200	100	50	0	400	200	100	0		
49.11	45.89	44.61	30.58	55.89	43.50	35.34	30.58	0-20	Dec.
44.33	38.89	32.83	26.67	51.50	39.83	32.28	26.67	40-20	
87.23	74.95	66.28	33.65	85.50	61.89	48.83	33.65	0-20	Jan.
81.00	75.75	61.67	31.19	80.17	52.17	42.67	31.19	40-20	
98.89	94.50	87.00	47.77	103.3	85.53	67.78	47.77	0-20	Feb.
89.89	87.61	74.61	45.80	93.33	77.72	61.17	45.80	40-20	
148.6	145.2	121.3	72.37	136.7	129.0	97.28	72.37	0-20	Mar.
141.5	127.1	115.6	69.68	126.0	119.3	84.17	69.68	40-20	
167.2	139.2	123.6	58.97	163.4	139.8	92.95	58.97	0-20	Apr.

157.1	129.9	101.3	55.33	151.8	129.3	82.17	55.33	40-20	
RLSD $_{0.05}$ = 11.88				RLSD $_{0.05}$ =10.66					

Data in table (4) showed interaction between apply nitrogen levels, horizontal distance and soil depth on available ammonium in soil. value of available ammonium was 112.09 mg.kg^{-1} when apply urea fertilizer with 400 kgN.ha^{-1} at 0-15 cm horizontal distance and 0-20 cm deep with a significant compared with 15-30 cm horizontal distance and 20-40 cm deep of control treatment. Value of available ammonium for apply 200 kgN.ha^{-1} nano nitrogen fertilizer was 112.18 mg.kg^{-1} in 0-15 cm horizontal distance and 0-20 cm deep with significantly compared of control treatment. A significant increase of apply 50 , 100 and 200 kgN.ha^{-1} nano nitrogen fertilizer levels compared with 100, 200 and 400 kgN.ha^{-1} of urea fertilizer levels in 0-20 and 20-40 cm, available ammonium in soil when apply 50 kgN.ha^{-1} nano nitrogen fertilizer significantly compared with 200 kgN.ha^{-1} of urea fertilizer at both deep.

Table (4): Effect of interaction between apply nitrogen level, horizontal distance and soil depth on available ammonium.

Nano fertilizer		Horizontal distance (cm)	Nitrogen levels (kgN.ha^{-1})	Urea fertilizer		Horizontal distance (cm)	Nitrogen levels (kgN.ha^{-1})
Depth (cm)				Depth (cm)			
40-20	20-0			40-20	20-0		
51.96	54.59	15-0	0	51.96	54.59	15-0	0
39.51	42.75	30-15		39.51	42.75	30-15	
83.49	92.14	15-0	50	66.00	76.18	15-0	100
70.91	84.98	30-15		54.98	60.69	30-15	
99.05	98.87	15-0	100	90.40	96.40	15-0	200
84.63	101.03	30-15		76.94	87.45	30-15	
105.45	112.18	15-0	200	102,60	112.09	15-0	400
100.07	108.23	30-15		98.51	105.80	30-15	
RLSD $_{0.05}$ = 7.51				RLSD $_{0.05}$ = 6.74			

Fig. (10) showed general mean of available ammonium in soil when apply urea and nano nitrogen fertilizer. Result of t test for compared between both fertilizers showed a significant difference on available ammonium in soil at end of growth season, mean of available ammonium was 68.58 mg.kg^{-1} when apply nano nitrogen a significantly compared with 40.30 mg.kg^{-1} when apply urea fertilizer. Increasing of available ammonium in soil at end of growth season when apply nano nitrogen fertilizers may be due to ability of nano fertilizer to release nutrients continuously and

regularity at long time in growing season. This results agreed with Qureshi *et al*. (2018) mentioned to release nutrient from nano fertilizers under slow and control release mechanism for all season of plant growth.

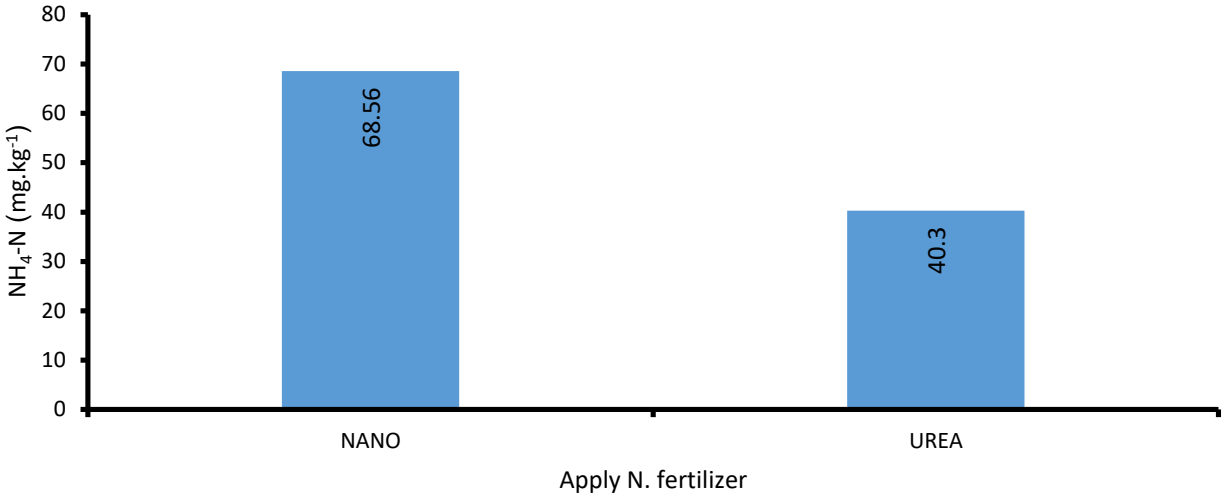


Fig. (10) Effect of fertilizer type on available ammonium in soil.

Conclusion

Concentration of available ammonium in soil decreased whenever got away horizontally and vertically from central of apply fertilizer area and increasing with increasing apply urea and nano nitrogen fertilizers. It can reduced of apply nitrogen to soil to 50 % of nano fertilizer compared with traditional fertilizer without effective on available ammonium in soil.

References

Akbari, F.; Fallah, S.; Dahmardeh, M. & Pessarakli, M. (2020). Interaction effects of nitrogen and phosphorus fertilizer on nitrogen mineralization of wheat residues in a calcareous soil. J. Plant Nutr., 43(1), 1-12. doi: 10.1080/01904167.2019.1659328.

Al-Atab, S, M (2008). Variation of soil properties and classification in some area of Basrah Governorate. PhD thesis. college of agriculture, university of Basrah.

Al- Rawi, K.M. & Khalefalah, A.M. (1980). Design and Analysis of Agriculture Experiments. High. Educ. Sci. Res. Min., Univ. Mosul, Dar Al-Kuteb Publ. Prin. (In Arabic).

Bremner, J.M. & Keeney, D.R. (1966). Determination and isotope ratio

analysis of different forms of nitrogen in soils. 3-Exchangeable ammonium, nitrate and nitrite by extraction- distillation methods. Soil Sci. Soc. Amer. Proc., 30: 577-582. doi:10.2136/sssaj1966.03615995003000005001

Chilundo, M., Joel, A., Wesström, I., Brito, R., & Messing, I. (2018). Influence of irrigation and fertilisation management on the seasonal distribution of water and nitrogen in a semi-arid loamy sandy soil. Agricultural water management, 199, 120-137.

De Rosa, M.C.; Monreal, C.; Schnitzer, M.; Walsh, R. & Sultan, Y. (2010). Nanotechnology in fertilizers. Nature Nanotechnology, 5(2): 91-91. doi:10.1038/nnano.2010.2.

Fanish, S.A. & Muthukrishnan, P. (2013). Nutrient distribution under drip fertigation systems. World J. Agric. Sci., 9(3): 277-283. doi: 10.5829/idosi.wjas.2013.9.3.2941.

Ichami, S.M.; Shepherd, K.D.; Sila, A.M.; Stoorvogel, J.J. & Hoffland, E. (2018). Fertilizer response and nitrogen use efficiency in African smallholder maize farms. Nutr. Cycling Agroecosys., 113(1): 1-19. doi:10.1007/s10705-018-9958-y.

Liu, Q.; Chen, X.; Wu, K. & Fu, X. (2015). Nitrogen signaling and use efficiency in plants: what's new? Curr. Opin. Plant Biol., 27: 192-198. doi: 10.1016/j.pbi.2015.08.002.

Moreno-Cornejo, J.; Zornoza, R. & Faz, A. (2014). Carbon and nitrogen mineralization during decomposition of crop residues in a calcareous soil. Geoderma, 230: 58-63. doi: 10.1016/j.geoderma.2014.03.024.

Mustafa, E.; Arzum I. & Meltem, B. (2018). Nanotechnology. (1st Edition) . Denizli: Baski, Bilal Ofset, BASIM-YAYIN & MATBAACILIK.

Ndaiwi. R. Dakhil; AlMashhadani S. Ahmad & Al-Atab S.M. Salah (2009). Pedological variation in soil between Alluvial and Desert areas in Basrah Governorate. 1- Variation in morphological properties. Euphrates J. Agric. Sci., 1(1): 161-172. (In Arabic)

Qureshi, A.; Singh, D.K. & Dwivedi, S. (2018). Nano-fertilizers: A novel way for enhancing nutrient use efficiency and crop productivity. Int. J. Curr. Microbiol. App. Sci., 7(2): 3325-3335. doi:10.20546/ijcmas.2018.702.398.

Rajeshwaran, T.S.R. & Arulmozhiselvan, K. (2019). Movement of available nitrogen in soil layers from Nutripellet pack placement site under surface irrigation. Pharm. Innov. J.; 8(6): 1200-1204.
www.thepharmajournal.com

Raut, N.; Sitaula, B.K.; Bakken, L.R. & Dörsch, P. (2014). Fluxes of CH_4, N_2O, and kinetics of denitrification in disturbed and undisturbed forest soil in India. Can. J. Soil Sci., 94(2): 237-249. doi:10.4141/cjss2013-017.

Sawyer, J.E. (2019). Understanding Anhydrous Ammonia Application in Soil. Integrated Crop Management News. 2528.IOWA

STATE UNIVERSITY , Digital Repository, Integrated Crop Management News. https://crops.extension.iastate.edu/cropnews/2019/03/understanding-anhydrous-ammonia-application-soil**.**

Siddique, I.A.; Al Mahmud, A.; Hossain, M.; Islam, M.R.; Gaihre, Y.K. & Singh, U. (2019). Movement and retention of NH 4-N in wetland rice soils as Affected by urea application Methods. J. Soil Sci. Plant Nutr:1-9. doi:10.1007/s42729-019-00148-2

Singh, A. & Prasad, S.M. (2016). Nanotechnology and its role in agro-ecosystem: a strategic perspective. Int.J. Environm. Sci. Technol., 14(10): 2277-2300. doi:10.1007/s13762-016-1062-8.

Singh, M.D.; Chirag, G.; Prakash, P.O.; Mohan, M.H.; Prakasha, G. & Vishwajith, (2017). Nano fertilizers is a new to increase nutrients use efficiency in crop production. Int. J. Agric. Sci., 9(7):3831-3833.http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217