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The effect of nanofertilizers on nitrate leaching and its distribution in soil profile with an emphasis on potato yield

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ABSTRACT

Selecting the type and amount of proper fertilizers containing nitrogen, to achieve maximum production with minimum adverse environmental effects is essential. The purpose of the present study was to study the effect of slow released fertilizers made by nanotechnology on nitrate leaching and its distribution in the soil profile compared with urea fertilizer in potato cultivation. The treatments included Nano- Nitrogen Chelate (NNC), Sulphur Coated Nano- Nitrogen Chelate (SNNC), Sulphur Coated Urea (SCU) and Urea (U) in 3 levels of nitrogen input by designing a factorial experiment in CRD with 3 replications. The results of variance analysis showed that each treatment had a significant effect on yield and leaching and soil nitrate. So that soil nitrate during the growing season of potato in NNC, SNNC and SCU fertilizers were 10.36%, 29.92% and 23.95 % more than U fertilizer, respectively. Comparison of nitrate leaching treatments showed that NNC, SNNC and SCU fertilizers leading to a reduction of 33%, 41% and 6% nitrate leaching in compared to U fertilizer. In contrast, the potato yield with using fertilizers of NNC, SNNC and SCU were 38 %, 45 % and 43 %, respectively more than U fertilizer. In total, according to higher production and nitrate leaching effects on human health and the environment, the use of Nano-Chelate fertilizers are recommended.

KEYWORDS

Nano- nitrogen chelate;
Sulphur coated nano-nitrogen chelate;
Sulphur coated urea;
Urea;
Agria.

INTRODUCTION

Nitrogen is one of the most important macronutrients in access to yield and suitable quality in crops production. The lack of this element can be seen more than other nutrients. Also less soil is found without need for nitrogen[34] Nitrogen is essential for plant chlorophyll. It also causes increase in crop protein and then it's yield. But too much use of nitrogen fertilizer isn't economical and can also contaminate groundwater resources. Nitrogen leaching into groundwater creates serious environmental problems that are a consequence of the oxygen lack in living bodies[16]. Therefore, to achieve sustainable agriculture with more yield and maintaining the society's health is the goal of researchers in agriculture. In this regard, use of chemical fertilizers has long been condemned because of their harmful effects on the environment and quality of agricultural products, and researchers are looking for better alternatives. Suitable management of water and fertilizer[1] or changes in the structure of fertilizers and utilization of new technologies can have positive results in reducing nitrogen leaching[8]. Nanofertilizers and slow released fertilizers are appropriate alternatives to conventional fertilizers for gradual and controlled supply of nutrients in soil. Alternative nanofertilizers such as nano-chelate with chemical fertilizers reduce pollutions which is economical[24]. According to a study of Cui et al[8], nanotechnology can reduce the rate of fertilizer nutrients loss through leaching and increase their availability to plants which ultimately leads to reduced water and soil pollution[15]. According to a study of Naderi and Danesh-Shahraki[29], nanofertilizers cause increased nutrient use efficiency, reduce soil pollution, reduce fertilizer application number and in general, to minimize the negative impacts of fertilizer. By using nanoparticles and nanocapsules suitable fertilizer can be produced. DeRosa et al.[9] and Barmaki et al.[5] reported that nanofertilizers application can increase nutrient efficiency and yield substantially. The results of Peyvandi et al.[31] study about comparison of effect of nano- iron chelate and iron chelate on Basilicum growth parameters showed that nano-chelate use efficiency was higher than iron chelate. Similarly, the effect of nano- iron chelate in comparison with iron chelate was significantly on growth and activity of some antioxidant[32]. Akhlaghi (2005) reported that SCU as a slow released fertilizer has high efficiency and more benefits for crops. Several researchers indicated applying SCU increases nitrogen use efficiency (NUE) significantly in winter wheat[11,17,19]. Lotfollahi et al.[17] reported that using SCU before planting compared to urea increased wheat yield and NUE. In order to increase NUE in 22 wheat fields in 14 provinces of Iran during 2005-2004, Malakouti et al.[19] stated that replacing SCU fertilizer with urea, besides the 12% increase in yield, increased NUE 39%. According to Ryan and Hariq[35] nitrogen fertilizers, especially SCU, increased NUE by declining leaching and sublimation. Ziaeyan and Keshavarz[38] indicated the use of slow released nitrogen fertilizers in potato cultivation is more economic than other nitrogen fertilizers. The study of Zvomuya et al.[39] with purpose of comparison of Urea and SCU fertilizers showed that SCU can increase NUE and tuber yield. Accordingly, El-Gindy et al.[10] studied the reaction of potato to slow released fertilizers in different irrigation systems and stated residual effect of nitrogen in slow released fertilizers was more than Urea. In order to solve environmental issues, public health promoting and reducing nitrate pollution in groundwater and agricultural products, also taking into economic aspects, the use of nitrogen fertilizers with high NUE is needed. In this research, condition of nitrogen different levels of four fertilizers including Nano- Nitrogen Chelate (NNC), Sulphur Coated Nano- Nitrogen Chelate (NNCS), Sulphur Coated Urea (SCU) and Urea (U) in soil profile, leaching and it's effect on potato yield in a greenhouse experiment was studied.

MATERIAL AND METHODS

To evaluate the nitrogen condition in soil, leaching and it's effect on potato yield (*Solanum tuberosum* L.), a factorial experiment in CRD was performed in the year 2013 in agriculture faculty greenhouse, Bu-Ali Sina University, Hamedan, Iran. The conditions of the greenhouse were 14 h light, temperature 13.8- 51.9 ° C and relative humidity 5-57 %. Potatoes were grown in 36 drainage lysimeters with 55 cm diameter and 90 cm height. In order to evaluate soil nitrate changes during the growing season, 15 cm diameter holes were created on the body of the lysimeters. In each lysimeter to prevent soil particles entering, a drainage tube from polyethylene with distance of 3 cm from the bottom of the lysimeters, a sand filter layer with thickness of 5 cm around the tube, and a filter layer geotextile with thickness of 2 mm was installed. In order to make the primary physical conditions, four heavy irrigations were carried out after sinking the lysimeter soil height was reduced to 80 cm. Then, three samples from the lysimeters soil were sent to the laboratory and some physical and chemical properties of soil were determined. Similarly, the chemical characteristics of irrigation water were determined by sending water sample to a lab. Nitrate requirement was provided from four fertilizer sources including NNC (with purity of 27% nitrogen), SNNC (with purity of 27% nitrogen), SCU (with purity of 36% nitrogen) and U (with purity of 46% nitrogen).

Chelating is a Greek word and term in chemistry, which includes elements such as nitrogen to prevent nitrate leaching under different and adverse environmental conditions until to be available for plants during the growing season. Nano-chelate fertilizers are produced with self assembling method, which was obtained from Khazra Company (Corporation). This combination is registered with Patent No. US20120100372. Image of scanning electron microscopy (SEM) that shows information on topography, shape, size and arrangement of particles in the surface, indicates NC size is 20-22 nm and NCS size is 44.07-83.89 Figure 1.

Inside each lysimeter 6 potatoes were cultivated, which considering the amount of nitrogen required for each tuber and the nitrogen content of the same input for all four treatments were used U in 3 levels: 100, 200 and 300 kg/ha, SCU in 3 levels: 113, 227 and 341 kg/ha, NNC in 3 levels: 127, 255 and 383 L/ha and SNNC in 3 levels: 127, 255, 383 L/ha. Fertilizers were d broadcast on the lysimeters soil surface with irrigation water in two stages at planting (1 July) and flowering time (1 August). Irrigation period was 7 days and totally 16 stages irrigation was performed in each irrigation and 10 liter water was added gradually to the soil surface. Since more absorbed nitrogen is as nitrate

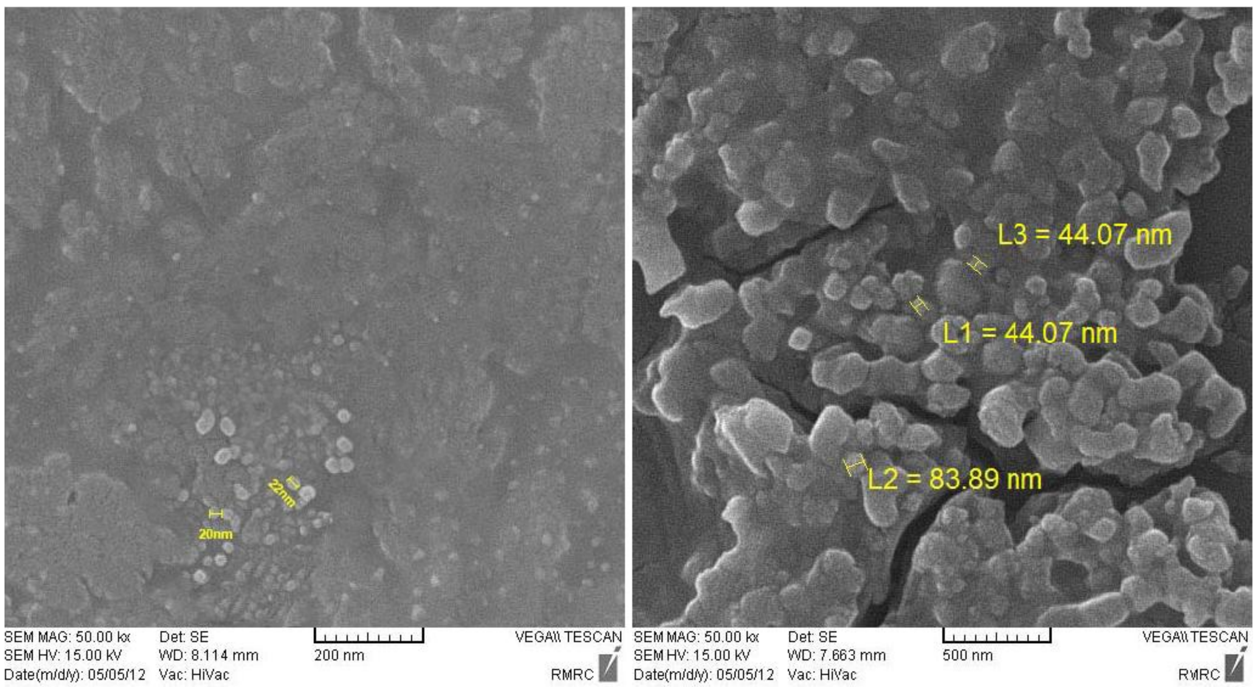

Figure 1 : SEM of NNC (left) and SNNC (right) (Khazra company, 2013)

form[25], soil nitrate was measured from the planting time to the end of the growing season, on a monthly time step, from the depths of 15, 30, 45 and 60 cm. Soil samples after extraction were analyzed in the laboratory. Determination of nitrate leaching was conducted with collecting drainage water samples after irrigation. Measurements were carried out by using a spectrophotometer at a wavelength of 400 micrometers[26].

The yield was measured using the weight of potato by balance with precision ± 0.01 g in lysimeters area. To evaluate the experimental design, the treatments included U, SCU, NNC and SNNC in 3 levels of nitrogen was performed based on a factorial experiment in CRD with 3 replications. Data analysis was performed using SPSS and SAS softwares.

RESULTS

To determine the physical and chemical characteristics of the soil before planting, soil samples from lysimeter were taken. The samples were air-dried and passed through a sieve of 2 mm. The physical and chemical properties of the soil and chemical properties of water were prepared in TABLE 1.

Based on results of TABLE 1, textured soil is sandy loam, electrical conductivity of irrigation water and soil extract are 0.73 and 1.7 dsm^{-1}, respectively, which is suitable for agricultural crops.

Figure 2 presents mean effects of fertilizer treatments different levels on soil nitrate concentration and leaching

TABLE 1 : The physical and chemical properties of soil and irrigation of water

Amount	Unit	Parameter	Characteristic	Amount	Unit	Parameter	Characteristic
0.93	Meq/L	Na^+	Water chemical	60		sand	
1.9		Mg^{2+}		21	%	silt	Soil physical
4.5		Ca^{2+}		19		clay	
4.3		CO_2^{2+}		37	Meq/L	Na^+	Soil chemical
1.8		Cl^-		28		Mg^{2+}	
1.23		SO_4^{2-}		140		Ca^{2+}	
0.52	--	SAR		42		CO_2^{2+}	
0.73	dSm^{-1}	EC		132		Cl^-	
8.3	--	pH		31		SO_4^{2-}	
				4.04	--	SAR	
				1.7	dSm^{-1}	EC_e	
				7.4	--	pH	

during the potato growing season. The vertical axis is the nitrate concentration (mg/l) and the horizontal axis is average of three nitrogen levels in four fertilizer treatments including NNC, SNNC, SCU and U. In each case, different letters in each column indicate significant differences at the 5% level between amount concentrations.

As seen from Figure 2, with increasing nitrogen levels in all four fertilizer treatments, soil nitrate concentration and leaching nitrate increased. Comparison of soil nitrate during the potato growing season showed that the highest level of soil nitrate was in third level of each four fertilizer treatments. So that by reducing input nitrogen, soil nitrate available to plants has also declined. Nitrate in the soil during the crop growth period indicated better nutrition of the plant, which will be gradually delivered to the plant. The highest soil nitrate content during the study was at third level of nitrogen for NCS treatment (16.41 mg/lit) and the lowest at first level of nitrogen for U fertilizer (8.65 mg/lit) was registered. Also Figure 2 indicated the average of soil nitrate concentration during the potato growing season in NC, NCS, SCU and U fertilizers was 10.55, 12.42, 11.85 and 9.56 mg/l, respectively. These results revealed that the soil nitrate in NC, NCS and SCU fertilizers were 10.36, 29.92 and 23.95 percentage, respectively and more than U fertilizer which is reasonable according to low rate of leaching in slow released fertilizers than other fertilizers. The leaching value of slow released fertilizers in each of 3 nitrogen levels was less than U fertilizer. This result is consistent with El-Gindy et al.[10]. They found that performance of slow released fertilizers was better than U fertilizer, due to high residual effect of nitrogen in potato cultivation. Also Figure 2 proved that the difference between the nitrate leaching values in all three nitrogen levels of treatments was significant at the 5% level. The highest and lowest nitrate leaching belong to the third level of U (670.78 mg/l) and the second level of SNNC (220.8 mg/l), respectively. With increasing input nitrogen levels, nitrate leaching value increased. Increased value of nitrate leaching was due to increased value of input nitrogen. Similar results have been reported by Bahmani et al.[4] which is consistent

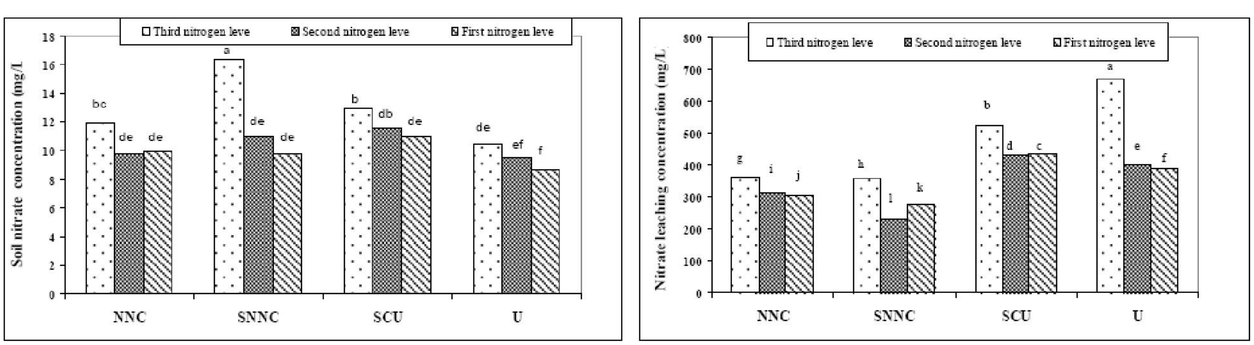

Figure 2 : Mean nitrogen concentration in leaching and soil

with the results of Figure 2. Mean nitrate leaching of three nitrogen levels in NC, NCS, SCU and U were 326.94, 288.4, 463.97 and 486.24 mg/l, respectively. The results also showed that the use of slow released fertilizers causes nitrate leaching reduction, also low nitrate leaching in Nano-Chelate fertilizers. Ryan and Hariq[35] reported nitrate leaching of slow released fertilizers such as SCU is little which is consisted with results of this study. Cui et al.[8] believes increasing the surface to volume in nano-particles and Sikoa and Szmiat[37] believes chelating properties (the grafted nanoparticles) causes less nitrate leaching. Less leaching of nutrients from the soil, in addition to less pollution of soil and water, is economic. According to a study in Canada, the use of Nano fertilizers can prevent $ 2,000 million capital loss because low efficiency of other fertilizers[24].

The effects of soil nitrate different levels in fertilizer treatments during different times of sampling are shown in Figure 3.

Figure 3 showed that with increasing nitrogen levels in all four fertilizer treatments, nitrate to time (ie 4.52 mg/l in table) before fertilization was increased. On the other hand, Figure 3 indicated soil nitrate in the first

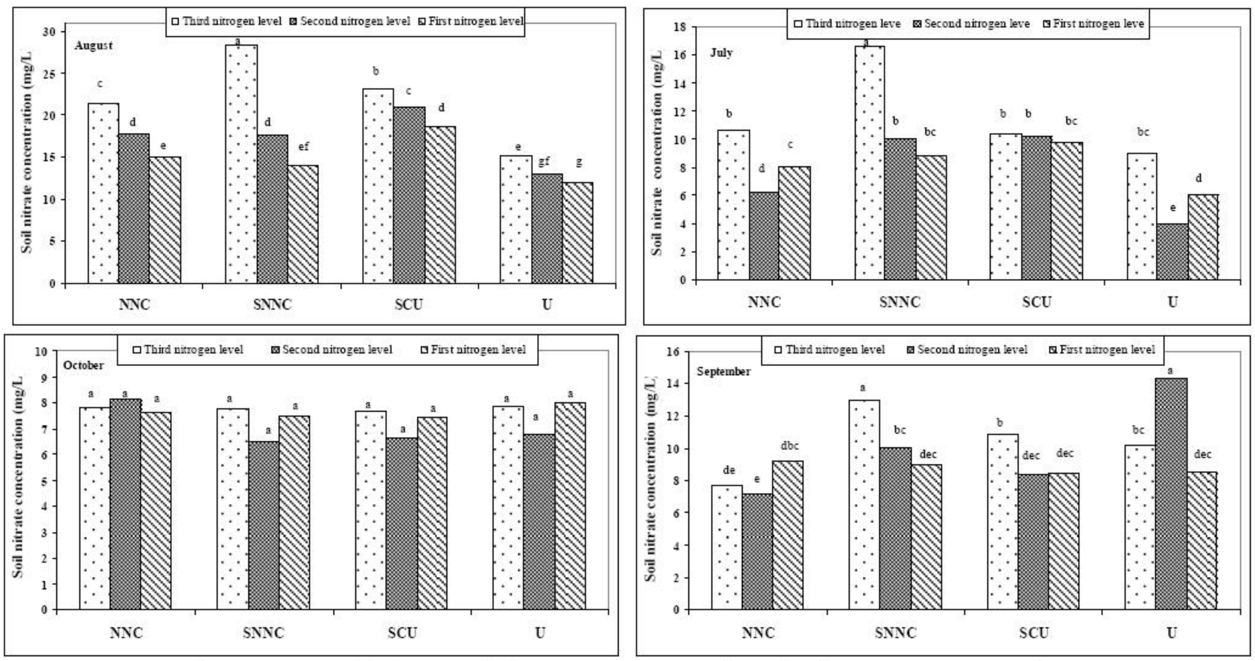

Figure 3 : Variations of nitrate concentration during potato growing

two months of the growing season has increased due to fertilization and in final two months of the growing season is reduced due to lack of fertilization and the use of nitrate by the plant. Increased soil nitrate in the first month is due to fertilizer of the first stage (July) and in the second month is due to fertilizer of the second stage and residual nitrate from first stage. Most often, nitrate in the soil profile is observed in higher levels of nitrogen than the lower levels. The soil nitrate in the first three month is more than the last month due to primary growth and development of potato. In the last month (October) soil nitrate is reduced due to the final growth of production and soil nitrate uptake during the previous stages. Also there were no significant differences between treatments soil nitrate in each of three nitrogen levels.

To investigate variation of nitrate in different depths, the effects of treatments on different nitrate levels in four depths of 15, 30, 45 and 60 cm were measured and were given in Figure 4.

Figure 4 illustrates the difference in nitrate distribution in the soil profile by the application of fertilizers. This difference could be due to the different structure of each fertilizers. As shown in Figure 4, the least amount of nitrate occurred in the soil surface of SNNC, SCU and U treatments but in NNC fertilizer minimum value was achieved in the lower depths. These results are consistent with reports of Bahmani et al.[4] and Nabipoor et al.[27]. They stated that with U fertilizer, soil nitrate increased in the soil profile from the surface to the soil

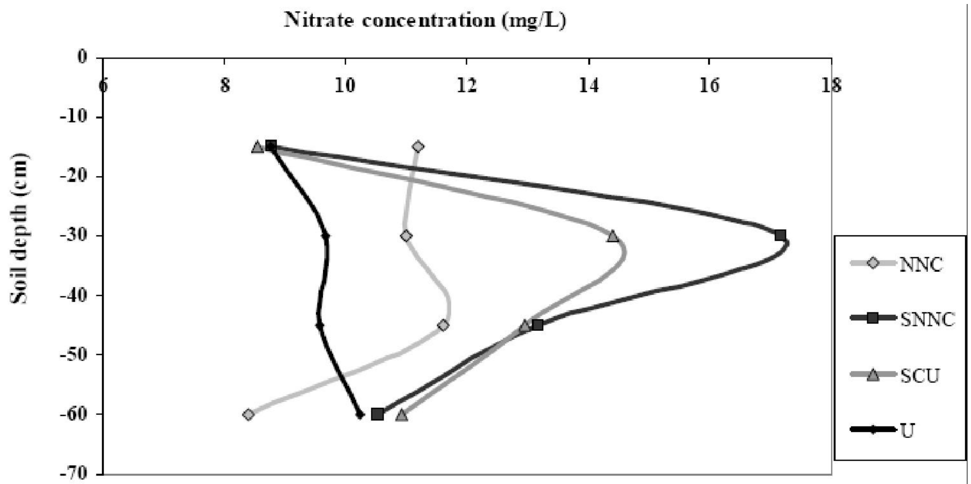

Figure 4 : Variations of nitrate concentration in soil depth under NNC, SNNC, SCU and U application

depth. Moreover Figure 4 proved the reverse behavior in soil nitrate distribution in both U and NC fertilizers and was similar to behavior in two sulfur fertilizers (SNNC and SCU). This could be due to a combination of two elements SNNC and SCU (nitrogen and sulfur), which is the same in both treatments. Although their structure is quite different and this difference is evident in the amount of nitrate measured at different depths of soil. In two SNNC and SCU treatments, the highest nitrate concentrations was at 30 cm depth and with increasing soil depth to 60 cm, was decreased. According to study of Mohhamadi and Faeznia[21], the root system of the potato in 30 cm layer accumulates, therefore it is expected that maximum nitrogen uptake by plants occurs in this depth, which leads to the increase yield. Nitrate in the lower depths usually occurs in the form of leaching, which is not available for the root. The maximum nitrate concentration in NNC treatment is 45 cm depth but the minimum nitrate concentration is visible at 60 cm depth. The low nitrate in 60 cm depth of soil profile indicates a decrease in nitrate leaching and it's losses. This result is in agreement with the results of Figure 2. The nitrate concentrations in U treatment have increased at a depth of 60 cm. This result showed lack of nitrogen in the deep root development and high nitrate leaching, which is in agreement with the study of Nabipoor et al.[27]. They reported the high rate of U nitrate leaching in the soil profile. To study the effect of nitrate movement in the soil profile on the yield, potato yield was measured. Mean potato yield of treatments according to different levels of nitrogen was given in Figure 5.

Figure 5 revealed that the highest yield of potato was in the second level of nitrogen in the SNNC treatment (58.61 ton/ha) that had no significant difference with the third level of nitrogen in the NNC treatment. The lowest yield was observed in the third level of nitrogen in U treatment equivalent to 31.05 ton/ha. In U treatment with increasing levels of input nitrogen, the yield is decreased linearly. This result could be due to increased nitrate leaching by increasing levels of nitrogen, which is in agreement with the results of Figure 2. Cases of reduced yields due to high nitrogen are given in results of Guarda et al.[13] on wheat and by less nitrogen physiological efficiency in rice yield and environmental pollution in study of Jiang et al.[14]. However, the yield in NNC treatment increased significantly with increasing nitrogen fertilizer. This indicates the NNC treatment compared to urea, converting nitrogen to protein and other materials in order to increase yield have well performed. In other words, NNC by slowly releasingnitrogen, has provided food security in the growing season and the final yield has increased[28,36]. While nitrogen in U treatment increased not only yield, but also nitrate leaching (as a negative trait). Thus, in NNC treatment, concerns related to product quality and environmental health with increased fertilizer is less. The mean yield of three nitrogen levels in NNC, SNNC, SCU and U treatments were 50.24, 52.71, 51.97 and 36.46 ton/ha, respectively, which represents the highest yield of potato in the sulfur treatments. This result is consistent with the results of Figure 3. These results are based on the effect of high nitrate availability on the root system of plants on potato yield. In other words, high levels of nitrate in 30 cm depth in both NCS and SCU treatments and that the accumulation of potato roots is in this depth, led to greater production of product. Consumption of SNNC fertilizer treatments caused an 4.9% yield increase compared to NNC, and SCU treatment which led to a 42.5% yield increase of potatoes compared to U treatment. On the other hand, the element sulfur as a nutrient in fertilizers has improved plant nutrition and is looking to increase yield. But overall, priority of potato yield belongs to SNNC, SCU, NNC and U treatments. Madani et al.[18] stated the potential potato yield can reach more than 100 ton/ha but yields of over 40 ton/ha is desirable. Since the yield of all 3 treatment of NC, NCS and SCU are more than 40 ton/ha, therefore NNC, SNNC and SCU fertilizers can be recommended over U fertilizer. Furthermore, the low nitrate leaching also approved this recommendation. This result is in agreement with studies of DeRosa et al.[9] and Barmaki et al.[5] based on increased yield by Nano fertilizer application, and El-Gindy et al.[10], Lotfollahi et al.[17], Malakouti et al.[17], and Malakouti et al.[19] and Fun et al.[11] based on increased yield by SCU application. However in some studies with the SCU application, yields declined such as study of Babaakbari Sara[3] (2005) in wheat cultivation. In this study the yield of the SCU treatment was significantly lower than U application. Gascho and Snyder[12] reported the application of SCU in primary growth stages of sugarcane, increased its growth however yield was less than ammonium sulfate fertilizer application. Nourgholi poor et al. (2008) investigated the effect of different sources of nitrogen fertilizer on yield and quality of wheat and expressed SCU cannot supply the nitrogen requirements of winter wheat and cannot substitute U or ammonium nitrate. These studies indicate further research requirements in other products.

TABLE 2 presents the statistical analysis of fertilizer treatments in different levels of nitrogen on yield, nitrate leaching and soil nitrate.

Based on the variance analysis table, the effect of fertilizer on potato yield, soil nitrate and nitrate leaching is significant at 1% level. Similarly, the effect of input nitrogen level and the effect of interaction type × level are similar to the effect of fertilizer. The results of the analysis TABLE 3 illustrated that the use of each different level of nitrogen fertilizer treatments had significant effects on traits. This indicates the importance of the type and amount of fertilizer in potato cultivation, which

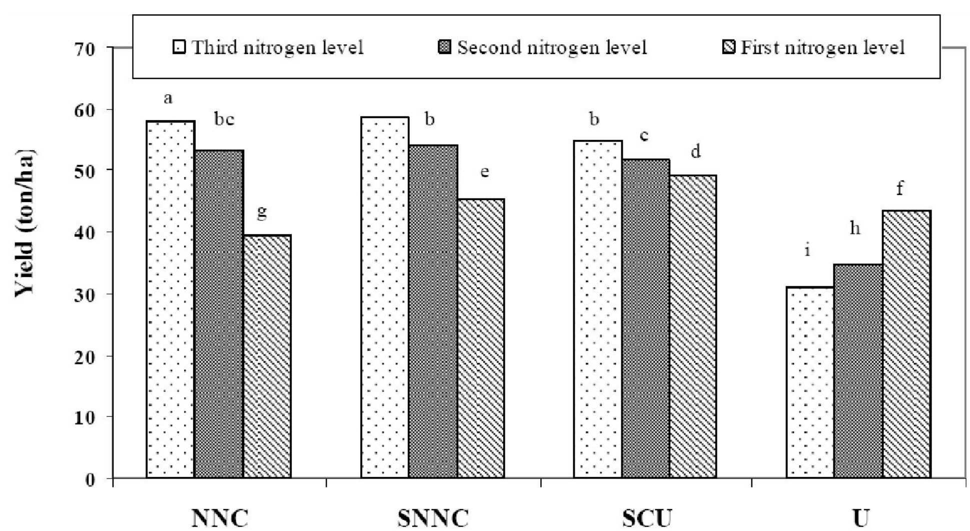

Figure 5 : Mean potato yield in fertilizer treatments in nitrogen different levels

TABLE 2 : The variance analyzed of yield, soil nitrate and nitrate leaching

CV (%)	Fertilizer×Level		Nitrogen level (1, 2, 3)		Fertilizer (NC,NSC,SCU, U)		S.O.V
	df	MS	df	MS	df	MS	
9.01	6	4.92**	2	31.86**	3	14.92**	Soil nitrate
0.99	6	10501.3**	2	68965.01**	3	87073.29**	Nitrate leaching
2.09	6	161.26**	2	71.073**	3	527.74**	Yield

should be selected with consideration of economic and environmental factors. So that, based on the results obtained in this study with the purpose of access to the most yield preferred type of fertilizer, SNNC, SCU, NNC and U, respectively, while with attention to nitrate leaching and its effects on human and the environmental health, priority of fertilizers were SNNC, NNC, SCU and U, respectively. Since there was no significant difference between yield of the SCU and NNC treatments, the use of Nano-Chelate fertilizers is recommended. Thus, nanotechnology has been successful in increasing food production and to minimize costs and protect the environment which has also confirmed in report of Chinnamuthu and Boopathi[6].

CONCLUSIONS

Considering that a higher yield with the least adverse environmental effects is considered in the third millennium, therefore the use of suitable fertilizer is in agreement with more production. The use of nanotechnology in agriculture in recent years has attracted much attention. In this study, the reduction of nitrate leaching and increasing potato yield with emphasis on less soil and water pollution in 3 nitrogen levels of NNC, SNNC, SCU and U were studied. The results showed that the slow released fertilizers reduced nitrate leaching and increased plant available nitrogen in the soil during the potatoes growing season. Meanwhile, the potato yield with slow released fertilizers was considerably more than U fertilizer. So that, NNC application, reduced nitrate leaching 33% compared to U fetilizer. This number in SNNC and SCU fertilizers were 41% and 6%, respectively. In contrast, the potato yield with use of NNC, SNNC and SCU fertilizers were 38%, 45% and 43%, respectively more than U treatment. Comparison of different levels of nitrogen also indicated that low nitrogen levels in slow released fertilizers was better than high levels of U fertilizer, which is economical. Since, the results of this study obtained in greenhouse for potato, repeating this research in field conditions for other products is also recommended.

REFERENCES

[1] Y.Abbasi1, A.Liaghat, F.Abbasi; Evaluation of Nitrate Deep Leaching under Maize Furrow Fertigation. Journal of Water and Soil., **26(4)**, 842-853 **(2012)**.

[2] K.Akhlaghi; Formulation and manufacture of sealants for use in the production process sulfur-coated urea. Iran Petrochemical Conference. NPC. 23, 24 July. Tehran, **(2008)**.

[3] M.Babaakbari Sara; Nitrogen efficiency in two calcareous soils with different textures in Karaj wheat lands. MSc Thesis, Faculty of Agriculture, Tarbiat Modarres University, Tehran, **(2005)**.

[4] O.Bahmani, S.Boroomand Nasab, M.Behzad, A.Naseri; Evaluation of potential nitrate and ammonium leaching under deficit irrigation in soil profile. Iranian Journal of Irrigationand Drainage, **1(3)**, 37-44 **(2009)**.

[5] S.Barmaki, M.Modares, V.Mehdizadeh; The application of nanotechnology in order to optimize the use of chemical fertilizers with emphasis on nano fertilizers. The first Congress of the fertilizer challenge. 1, 2 March. Tehran, **(2010)**.

[6] C.R.Chinnamuthu, P.Boopathi; Nanotechnology and agroecosystem. Madras Agricultural Journal, **96**, 17-31 **(2009)**.

[7] H.Cui, C.Sun, Q.Liu, J.Jiang, W.Gu; Applications of nanotechnology in agrochemical formulation, perspectives, challenges and strategies. Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences, Beijing. China, 1-6 **(2006)**.

[8] M.R.DeRosa, C.Monrea, M.Schnitzer, R.Walsh, Y.Sultan; Nanotechnology in fertilizers. Nature Nanotechnology, **5**, 91-92 **(2010)**.

[9] A.M.El-Gindy, M.H.Mahmoud, A.H.El-Guibali; Response of plant to slow release fertilizers under drip irrigation systems. Annals of Agricultural Science (Cairo), **1**, 197-212 **(2000)**.

[10] X.Fan, F.Li, F.Lin, D.Kumar; Fertilization with a new type of coated urea: evaluation for nitrogen efficiency and yield in winter wheat. Plant Nutr., **25**, 853-865 **(2004)**.

[11] G.J.Gascho, G.H.Snyder; Sulfur-coated fertilizers for sugarcane: I. Plant response to sulfur-coated urea. Soil Science Society of American Journal, **40**, 119-122 **(1976)**.

[12] G.Guarda, S.Padovan, G.Delogu; Grain yield, nitrogen use efficiency and baking quality of old and modern Italian bred-wheat cultivars grown at different nitrogen levels. European J. of Agron, **21**, 181-192 **(2004)**.

[13] L.G.Jiang, D.F.Dong, X.Q.Gan, S.Q.Wei; Photosynthetic efficiency and nitrogen distribution under different nitrogen management and relationship with physiological N-use efficiency in three rice genotypes. Plant.Soil, **271**, 321-328 **(2005)**.

[14] A.Johnson; Agriculture and nanotechnology. Ward and Dutta, University of Wisconsin-Madison, **(2006)**.

[15] Y.S.Kim, F.Reid, A.Hansen, Q.Zhang; On-field crop stress detection system using multi-spectral imaging sensor. Agri. and Biosys.Eng., **1(2)**, 88-94 **(2000)**.

[16] M.Lotfollahi, M.J.Malakouti, H.Safari; Nitrogen efficiency using SCU in light textured soil in Karaj. New methods of feeding wheat (Collection of articles of Malekooti et al.). Publications Sana, Tehran, 751-759 **(2004)**.

[17] H.Madani, A.Farhadi, A.R.Pazaki, M.Changizi; Effect of different nitrogen levels and zeolite on the quantitative and qualitative characteristics of potato Agria in Arak. New Findings in Agriculture, **3(4)**, 379-391 **(2009)**.

[18] M.J.Malakouti, A.Bybordi, M.Lotfollahi, A.A.Shahabi, K.Siavoshi, R.Vakil, J.Ghaderi, J.Shahabifar, A.Majidi, A.R.Jafarnajadi, F.Dehghani, M.H.Keshavarz, M.Ghasemzadeh, R.Ghanbarpouri, M.Dashadi, M.Babaakbari, N.Zaynalifard; Comparison of complete and sulfur coated urea fertilizers with pre-plant urea in incearsing grain yield and nitrogen use effeciency in wheat. K.Agri.Sci. and Technol., **10**, 173-183 **(2008)**.

[19] M.J.Malakouti, Z.Khademi, Z.Khoogar; New techniques for wheat nutrition. Department Agronomy, Ministry of Agriculture. Publications Sana. Tehran, **(2004)**.

[20] M.J.Malakouti, P.Keshavarz, N.Karimian; Diagnosis and recommend the best fertilizer for sustainable agriculture. Seventh Edition, with thoroughly. publication of Tarbiat Modarres University, Tehran, **(2008)**.

[21] R.W.Miller, D.T.Gardiner; Soils in our environment. 9th Edition, Prentice Hall, Upper Saddle River, New Jersey, USA., 642 **(2001)**.

[22] A.R.Mohhamadi, F.Faeznia; Effects of water stress on growth and yield of two potato cultivars. Research Report, Agricultural Research Center, Semnan, Shahrood, **(2001)**.

[23] C.M.Monreal; Nanofertilizers for Increased N and P Use Efficiencies by Crops. In: Summary of Information Currently Provided to MRI Concerning Applications for Round 5 of the Ontario Research Fund-Research Excellence Program, 12-13 **(2010)**.

[24] S.H.Mousavi Fazl, F.Faeznia; Effect of different moisture regimes and nitrogen on the yield and nitrate concentrations in potato tubers. Iranian Journal of Soil Research, **22(2)**, 243-250 **(2008)**.

[25] R.L.Mulvaney; Nitrogen-inorganic forms. In: D.L.Sparks, (Ed); Methods of soil analysis—Part 3. Chemical methods—SSSA Book Series No. 5. Soil Science Society of America and American Society of Agronomy, Madison, 1123–1184 **(1996)**.

[26] M.Nabipoor, H.Emami, A.R.Astaraee; Effect of nitrate fertilizer source, and irrigation on nitrate leaching, and its distribution in the soil profile. The first national conference of water management in agriculture. 30, 31 May. Institute of Soil and Water research, **(2012)**.

[27] M.Naderi, A.Danesh-Shahraki; Nanofertilizers and Their Role in Sustainability of Agriculture. The 1st Iranian Fertilizer Challenges Congress. Half a Century of the Fertilizer Consumption. 1, 2 March. Tehran, **(2010)**.

[28] M.Naderi, A.Danesh-Shahraki; The application of nanotechnology in the formulation optimization of chemical fertilizers. Journal of Nano, **106(4)**, 20-22 **(2011)**.

[29] F.Nourgholi Poor, Y.R.Bagheri, M.Lotfollahi; Soil Genesis in the Lands of Islamic Azad University of Khoraskan (Isfahan). Journal of Research in Agricultural Science, **4(2)**, 120-129 **(2009)**.

[30] M.Peyvandi, H.Parande, M.Mirza; Comparison of Nano Fe Chelate with Fe Chelate Effect on Growth Parameters and Antioxidant Enzymes Activity of Ocimum Basilicum. New Cell Mol.Biotech J., **1/4**, 89-99 **(2011)**.

[31] M.Peyvandi, M.Mirza, Z.Kamali Jamakani; The Effect of Nano Fe Chelate and Fe Chelate on the Growth and Activity of some Antioxidant. New Cellular & Molecular Biotechnology Journal, **2(5)**, 25-32 **(2011)**.

[32] G.M.Pierzynski, J.T.Sims, G.F.Vance; Soils and environmental quality. 3rd Edition, Taylor & Francis, Boca Raton, USA, **(2005)**.

[33] M.Rahimizadeh, A.Kashani, A.Zare Faizabadi, A.Koocheki, M.Nassiri Mahallati; Investigation of nitrogen use efficiency in wheat-based double cropping systems under different rate of nitrogen and return of crop residue. EJCP, **3(3)**, 125-142 **(2010)**.

[34] J.Ryan, S.N.Hariq; Crop and laboratory evaluation of nitrogen release from sulfur coated urea

asmocote. Lebanese, Science Collection, **2(1)**, 5-15 **(1986)**.

[35] A.Shaviv; Controlled Release of Fertilizers. IFA International Workshop on Enhanced-Efficiency Fertilizers, 28-30 June 2005, Frankfurt, Germany **(2005)**.

[36] L.Sikoa, P.A.K.Szmiat; Nitrogen sources, mineralization rates and plant nutrient benefits from compost. In: Stoffella et al., (Ed); Compost Utilization in Horticultural Cropping Systems, CRC Press, USA, **(2001)**.

[37] A.H.Ziaeyan, P.Keshavarz; Increasing Nitrogen Use Efficiency in Potato by Application of Slow Release. N-Fertilizers. Iranian Journal of Soil Research, **24(2)**, 107-115 **(2010)**.

[38] F.Zvomuya, C.J.Rosen, M.P.Russelle, S.C.Gupta; Nitrate Leaching and Nitrogen Recovery Following Application of Polyolefin-Coated Urea to Potato. J.Plant.Nutri., **20**, 989-1001 **(2002)**.