Influence of nano particles of chitosan with 15% nano nitrogen on growth, yield and quality of faba bean

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ABSTRACT

The study was carried out during the two successive seasons of 2013/14 and 2014/15 at the farm of environmental studies and research institute – Sadat City University Menofiya Governorate, Egypt to study the the effect of nano particles of chitosan and chitosan with 15% nano nitrogen on growth , yield, quality of faba bean.

Significant differences were found among all treatments and control, where application of recommended dose of normal nitrogen surpassed control and all other treatments and produced the maximum values of plant height, number of leaves and branches , plant fresh weight and plant dry weight

The same trend was found concerning seed yield and its attributes , where application of recommended dose of normal nitrogen produced the maximum values of all characters ie number of pods /plant, number of seeds/pod , seed index , total weight of plant , pod weight of plant , seed yield /plant and per feddan and strow yield per plant and per feddan with significant differences with control and other chitosan 15% nano nitrogen

It is worthy to note that application of chitosan with 15% nano nitrogen caused increasing in all these traits reached to be near to the values of normal fertilization.

Concerning the chemical composition of faba bean leaves and seeds , control recorded the lowest values of NPK composition . while fertilization with normal nitrogen with recommended dose recorded the greatest vales . Gradually increases were found doe to increasing nano nitrogen up to 1.5 g / L which achieved the second rank of most values of characters .

Key words : Chitosan , Nano nitrogen , faba bean, yield, quality

ملخص العربى :

تأثير جزيئات النانو نيتروجين 15٪ المحملة مع الشيتوزان على النمو والمحصول وجودة الفول البلدى

أجريت الدراسة خلال الموسمين المتعاقبين 2014/2013 و 2015/2014 بمزرعة معهد الدراسات والبحوث البيئية - جامعة مدينة السادات بمحافظة المنوفية ، مصر لدراسة تأثير جزيئات النانو للكيتوزان والشيتوزان بنسبة 15٪. نانو النيتروجين على النمو والمحصول ونوعية فاابين.

تم العثور على اختلافات معنوية بين جميع المعاملات والضوابط ، حيث تجاوز تطبيق الجرعة الموصى بها من النيتروجين العادي السيطرة وجميع المعاملات الأخرى وأنتج القيم القصوى لارتفاع النبات وعدد الأوراق والأفرع والوزن الرطب للنبات والوزن الجاف للنبات

تم العثور على نفس الاتجاه فيما يتعلق بحاصل البذور وصفاته ، حيث أدى استخدام الجرعة الموصى بها من النيتروجين العادي إلى إنتاج القيم القصوى لجميع الصفات مثل عدد القرون / نبات ، وعدد البذور / القرون ، ودليل البذور ، والوزن الإجمالي للنبات ، ووزن القرون. من النبات وحاصل البذور / نبات والفدان ومحصول النبات النبات والفدان مع وجود اختلافات معنوية مع الكنترول وغيره من تركيزات الشيتوزان 15٪ نانو نيتروجين

وتجدر الإشارة إلى أن استخدام مادة الشيتوزان بنسبة 15٪ نانو نيتروجين تسبب في زيادة جميع هذه الصفات التي وصلت إلى ما يقرب من قيم الإخصاب الطبيعي.
فيما يتعلق بالتركيب الكيميائي لأوراق وبذور الفول ، سجلت المقارنة أقل قيم لتركيبة NPK. بينما سجل التسميد بالنيتروجين الطبيعي بالجرعة الموصى بها أكبر قيمة. تم العثور على زيادات تدريجية في زيادة النيتروجين النانوي حتى 1.5 جم / لتر والتي حققت المرتبة الثانية لمعظم قيم الصفات
الكلمات الدالة : شيتوسان ، نانو نيتروجين ، سماد نيتروجين, الفول البلدي ، صفات النمو والمحصول..

INTRODUCTION

Faba bean (*Vicia faba* L.) is a legume crop grown primarily for its edible seeds (beans). Unfortunately, production of faba bean is still limited and falls to face the increasing local consumption of the crop. However, farmers suffer from high costs of production and consequently the reduction in the net income per unit area. This is due to the strong competition between faba bean and other strategic winter season crops such as wheat and clover on the limited arable land in Nile valley and Delta. In response to rising input costs and narrowing profit margins, scientific efforts are continually looking for ways to increase land use efficiency in Egypt. The cropping system adopted by the farmer in these soils must be physically viable, sustainable, less exhaustive acceptable to farming community and most important thing is that it should be economical. Moreover, mixing species in cropping systems may lead to a range of benefits that are expressed on various space and time scales, from a short-term increase in crop yield and quality, to longer-term agro-ecosystem sustainability, up to societal and ecological benefits (Malezieux *et al*., 2009).

Several different cropping patterns are followed in the Nile Valley and Delta areas, depending on the soil type and crops. Farmers are very responsive to technology transfer, extension activities and price incentives. Accordingly, it is important to address our efforts to this fundamental issue by intercropping. Intercropping is the growing two or more crop species simultaneously in the same field area and has been widely practiced worldwide (Francis, 1986). It provides an important pathway to fix atmospheric N_2, lower the risk of crop failure or disease and increase land use efficiency (Trenbath, 1993 and Morris and Garrity, 1993). Also, it is recommended to increase total agriculture products in Egypt (Metwally, 1999).

On the other hand, onion (*Allium cepa* L.) is produced for home consumption and as income sources for many small scale farmers and commercial growers in Egypt. Onions could be consumed fresh as in green salad or in many other forms (as bulbs for cooking and pickling consumption) and use in food processing. However, more information is needed for determining the optimal spatial arrangement of intercropping onion with faba bean through the manipulation of both hill distance and ridge width; it is a general principle that if appropriate number of plants is not used in the unit of land in fact the available potential has not been used optimally. Thereby, yield of faba bean can be governed by plant density and distribution of these plants per unit area with regard to onion cultivar and its plant density as the competition for environmental resources between the two field crops must be less than exists within the same species (Vandermeer, 1989). Yield per unit area declines since yield per plant tends to decrease with further increase in the plant density' because of

competition for growth factors between adjacent plants (Silvertooth, 2001). It is known that' faba bean production is affected by different factors such as genotypes, plant distribution and plant density (Khalil *et al*., 2010 and Abd El-Rahman, 2014).

Hence, plant density is an important factor for the production of onion (Mlik, 1994). In this concern, Pakyurek *et al.* (1994) and Rizk (1997) showed that' the highest planting density produced a noticeably higher yield of good quality bulbs than the lower sowing rate. Also, Dawar *et al*. (2007) revealed that' maximum yield bulbs (7072 kg ha^{-1}) was produced at density of 80 plants/ $4m^2$'while minimum yield of bulbs (5133 kg ha^{-1}) was recorded at planting density of 40 plants/ $4m^2$. Thus, the main target of this study is to identify the influence of different ridge widths and patterns of intercropping onion with faba bean on faba bean productivity and its quality.

MATERIALS AND METHODS

The present investigation was carried out during the two successive seasons of 2017/2018 and 2018 / 2019 at the farm of Environmental studies and research institute ,University of Sadat City , Menofiya Governorate, Egypt to study the effect of nano particles of chitosan with 15% nano nitrogen on growth , yield, quality and of fababean.

Plant material

In September of both seasons, the field was cleaned, ploughed, leveled and divided into plots (10.5 m2.)Planting dates were 10 th and 14th October in both growing seasons, respectively. Fababean cultivar Sakha 4 was selected for this study,. This experiment contained nine treatments as follows :

Foliar spray with chitosan with 15% nano nitrogen at 0.5 gm /L , 1.0 gm / L and 1.5 gm / L)

Faba bean plants were sprayed three times during the growth period, after 4 , 7 and 10 weeks for chitosan .

In both seasons, all cultural practices i.e., cultivations irrigation, fertilization and pest and diseases control were done according to the recommendations of the Egyptian Ministry of Agriculture.

Seeds were harvested on June, 15th, 2016 and June, 20th, 2017 .After harvesting, plants were dried by sun.

The studied traits: At harvest, ten plants were taken randomly from each sub plot to estimate the individual traits:

a. Faba bean traits:
    1. Plant height (cm).

2. Number of branches / plant.
3. Number of pods / plant.
4. Number of seeds / plant.
5. Seed yield / plant (g).
6. 100 – Seed weight (g).
7. Seed yield / fad (ardab): it was recorded on the basis of experimental sub-plot and expressed as ardab per fad.
8. Straw yield / plant (g).
9. Straw yield (ton) / fad: it was recorded on the basis of experimental sub-plot and expressed as ton per fad.
10. Protein yield (kg/fad) = Seed protein content (%) x Seed yield (kg/fad)

1- Protein percentage :

Samples of 50 grams from faba bean seeds were air dried, then ground and the fine powder stored in brown glass bottles. All the chemical determinations were estimated in ground seeds dried at 70oC till constant weight.

The total N of faba bean seeds was determined using Microkjeldahl apparatus according to A.O.A.C. (2000). Crude protein content was calculated by multiplying total N by 6.25 for faba bean (Sadasivam and Manickam, 1997).

Statistical analysis:

The data were subjected to proper statistical analysis of variance. The treatments means were compared by using the least significant differences (L.S.D.) test at 5% levels of probability, F test was also followed to differentiate among means of studied characters as recommended by Snedecor and Cochran (1973) and by SAS 2006 Statistical analysis program, SAS User´s Guide: Statistics. SAS Institute Inc Editor, cary, NC.

RESULTS AND DISCUSSION

1. Effect of nano nitrogen chitosan on faba bean growth characters

In both seasons as well as combined analysis, all estimated traits were increased significantly by nitrogen fertilizer as compared with control (zero N) as shown in Table (2). Adding 25 kg N/fed increased plant height , number of leaves ,number of branches/plant, fresh weight of plant and dry weight of plant 9.84%,5.25 %, 2.22%, 19.69% and 24.12%, respectively, compared with the control treatment in the combined analysis. The effect of nano nitrogen (with chitosan) stimulated all mentioned growth characters and gradually increased all values up to the maximum used concentration 1.5 g/L which came at

the second rank after the recommended nitrogen dose . This may be attributed to the fact that faba bean plants could obtain its nitrogen requirements from The promoting effect of chitosan application on vegetative growth may be due to the based on how this glucosamine poly mer influences the biochemistry and molecular biology of the plant cell. The cellular targets are the plasma membrane and nuclear chromatin. Subsequent changes occur in cell membranes, chromatin, DNA, calcium,

MAP Kinase, oxidative burst, reactive oxygen species, callose pathogenesis-related (PR) genes and phytoalexins (Hadwiger, 2013). These results are in agreement with Chibu and Shibayama, (2003), Gornik *et al*. (2008), Hadwiger *et al.* (2002) in strawberry, Asghari-Zakaria.*et al*. (2009) in potato , Guan *et al.*, (2009), Algam *et al*, (2010), Ghoname *et al.*, (2010) in sweet pepper, Fawzy *et al*. (2012) in garlic , Farouk and Ramadan (2012) in cow pea, Noknoi Chookhongkha *et al*. (2012) in chili seedlings, El-Miniawy *et al*. (2013) in strawberry, Abdel-Aziz *et al.* (2016) in wheat, Malerba and Cerana, (2016) and Zayed *et al.* (2017) in bean .

Table (1) : Effect of nano particles of chitosan on vegetative characters of faba bean during

2016/2017 and 2017/2018 seasons as a combined data

Treatments	plant height (cm)	No. of leaves/ plant	No. Branches/plant	Plant fresh weight (g)	Plant dry weight (g)
	Mean	Mean	Mean	Mean	Mean
Control.	103.90	104.77	2.70	387.67	75.37
Recommended N	114.13	110.27	3.30	464.00	93.55
Nano chitosan1	108.53	108.13	3.13	356.33	69.50
Nano chitosan2	109.43	106.40	3.13	421.33	81.10
Nano chitosan3 .	109.47	103.13	3.17	446.00	85.90
Mean	109.09	106.54	3.09	415.07	81.08
LSD at 0.05	3.07	2.80	0.23	5.14	7.22

2. Effect of nano nitrogen chitosan on faba bean seed and straw yield, yield attributes characters as a combined data.

Data in Table (3) indicated that there were significant differences among treatments. Application of the recommended dose of chemical nitrogen resulted in the highest values of all studied characters i.e. number of pods ,number of seeds / pods, seed index, total weight of plant, pods weight/plant seeds yield /plant, weight seeds ton/fed, protein yield kg/fed, straw yield /plant and straw yield ton/fed with significant differences comparing to control. It is worthy to note that application of nano nitrogen 15% with chitosan caused gradually increasing in most mentioned

characters, where the maximum level of nano nitrogen 15% ranked second after the recommended dose of nitrogen

These results are in agreement with Reddy *et al.* (2000), Ghoname *et al.* (2010), Fawzy *et al*. (2012) and Van *et al.* (2013).

Table (2) : Effect of nano particles of chitosan on seed and straw yield, yield attributes characters of faba bean during 2016/2017 and 2017/2018 seasons as a combined data

Treatments	No. of pods/ plant	No.of seeds /pods	Seed index	Total weight of plant	Pods weight/plant(g)	Seeds yield /plant g	Weight seeds ton/fed	Protein yield (kg/fad)	Straw yield /plant (g))	Straw yield (ton/fad)
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Control.	2.73	2.83	77.57	94.73	36.27	19.40	1.33	332.50	58.01	8.12
Recommended N	3.83	3.37	83.70	111.10	41.95	23.23	1.63	408.33	66.38	9.29
Nano chitosan1	3.33	3.20	79.37	98.10	39.97	20.73	1.43	358.33	66.20	9.27
Nano chitosan2	3.47	3.23	81.00	98.27	41.20	20.93	1.46	365.00	64.65	9.05
Nano chitosan3 .	3.60	3.30	83.17	108.90	41.27	21.77	1.56	390.00	65.16	9.12
Mean	3.39	3.19	80.96	102.22	40.13	21.21	1.48	370.83	64.08	8.97
LSD at 0.05	0.16	0.15	2.01	3.17	1.12	1.07	0.12	8.21	1.02	NS

REFERENCES

Auffan M, Bottero JY, Wiesner MR, 2009. Chemical stability of metallic nanoparticles: A parameter controlling their potential cellular toxicity in vitro. Environ Poll 157: 1127-1133. http://dx.doi.org/10.1016/j.envpol.2008.10.002

Beadle CL, 1993. Growth analysis. In: Photosynthesis and production in a changing environment. A field and laboratory manual; Hall DC, Scurlock JMO, Bolhar-Nordenkampf HR, Leegod RC, Long SP (eds.). pp 36-46. Chapman & Hall, London.

Birbaum K, Brogioli R, Schellenberg M, Martinoia E, Stark WJ, Gunther D, 2010. No evidence for cerium dioxide nanoparticle translocation in maize plants.

Environ Sci Technol 44: 8718-8723. http://dx.doi.org/10.1021/es101685f

Boonsongrit Y, Mitrevej A, Mueller BW, 2006. Chitosan drug binding by ionic interaction. Eur J Pharm Biopharm 62: 267-274. http://dx.doi.org/10.1016/j.ejpb.2005.09.002

Chibu H, Shibayama H, 2001. Effects of chitosan applications on the growth of several crops. In: Chitin and chitosan in life science; Uragami T, Kurita K, Fukamizo T (eds). pp: 235-239. Yamaguchi, Japan.

Corredor E, Testillano PS, Coronado MJ, González-Melendi P, Fernández-Pacheco R, Marquina C, Ibarra MR, de la Fuente JM, Rubiales D, Pérez-de- Luque A, Risueño MC, 2009. Nanoparticle penetration and transport in living pumpkin plants: in situ subcellular identification. BMC Plant Biol 9: 1-11. http://dx.doi.org/10.1186/1471-2229-9-45

De Rosa MR, Monreal C, Schnitzer M, Walsh R, Sultan Y, 2010. Nanotechnology in fertilizers. Nat Nanotechnol J 5: 91. http://dx.doi.org/10.1038/nnano.2010.2

Dhoke SK, Mahajan P, Kamble R, Khanna A, 2013. Effect of nanoparticles suspension on the growth of mung (Vigna radiata) seedlings by foliar spray method. Nanotechnol Devt 3:1-5. http://dx.doi.org/10.4081/nd.2013.e1

Sun Y, Ji R, Zhu J, Wu J, Guo H, 2011. TiO2 and ZnO nanoparticles negatively affect wheat growth and soil enzyme activities in agricultural soil. J Environ Monit 13: 822-828. http://dx.doi.org/10.1039/c0em00611d

Eichert T, Kurtz A, Steiner U, Goldbach HE, 2008. Size exclusion limits and lateral heterogeneity of the stomatal foliar uptake pathway for aqueous solutes and water suspended nanoparticles. Physiol Plant 134: 151-160. http://dx.doi.org/10.1111/j.1399-3054.2008.01135.x

Feizi H, Rezvani MP, Shahtahmassebi N, Fotovat A, 2012. Impact of bulk and nanosized titanium dioxide TiO2 on wheat seed germination and seedling growth. Biol Trace Elem Res 146: 101-106. http://dx.doi.org/10.1007/s12011-011-9222-7

Fleischer A, O'Neill MA, Ehwald R, 1999. The pore size of non-graminaceous plant cell wall is rapidly decreased by borate ester cross-linking of the pectic polysaccharide rhamnogalacturon II. Plant Physiol 121: 829-838. http://dx.doi.org/10.1104/pp.121.3.829

Hasaneen MNA, Abdel-Aziz HMM, El-Bialy DMA, Omer AM, 2014. Preparation of chitosan nanoparticles for loading with NPK. Afr J Biotech 13: 3158-3164. http://dx.doi.org/10.5897/AJB2014.13699

Jia G, 2005. Cytotoxicity of carbon nanomaterials: single-wall nanotube, multi-wall nanotube, and fullerene. Environ Sci Technol 39: 1378-1383. http://dx.doi.org/10.1021/es048729l

Jinghua G, 2004. Synchrotron radiation, soft X-ray spectroscopy and nano-materials. J Nanotechnol 1: 193-225. http://dx.doi.org/10.1504/IJNT.2004.003729

Juniper BE, Cox GC, Gilchrist AJ, Williams PK, 1970. Techniques for plant electron microscopy. Blackwell Sci Publ, Oxford.

Khodakovskaya M, Dervishi E, Mahmood M, Yang X, Li Z, Fumiya W, Biris A, 2009. Carbon nanotubes are able to penetrate plant seed coat and dramatically affect seed germination and plant growth. ACS Nano 3: 3221-3227. http://dx.doi.org/10.1021/nn900887m

Lee WM, An YJ, Yoon H, Kwbon HS, 2008. Toxicity and bioavailability of copper nanopar-ticles to the terrestrial plants mung bean (Phaseolus radiatus) and wheat (Triticum aestrivum): plant agar test for water-insoluble nanoparticles. Environ Toxic Chem 27: 1915-1921. http://dx.doi.org/10.1897/07-481.1

Lei Z, Mingyu S, Xiao W, Chao L, Chunxiang Q, Liang C, Hao H, Xiaoqing L, Fashui H, 2008. Antioxidant stress is promoted by nano-anatase in spinach chloroplasts under UV-B radiation. Biol Trace Elem Res 121: 69-79. http://dx.doi.org/10.1007/s12011-007-8028-0

Liang T, Yin Q, Zhang Y, Wang B, Guo W, Wang J, Xie J, 2013. Effects of carbon nanoparticles application on the growth, physiological characteristics and nutrient accumulation in tobacco plants. J Food Agric Environ 11: 954-958.

Lin S, Reppert J, Hu Q, Hudson JS, Reid ML, Ratnikova TA, Rao AM, Luo H, Ke PC, 2009. Uptake, translocation, and transmission of carbon nanomaterials in rice plants. Small 5: 1128-1132. http://dx.doi.org/10.1002/smll.200801556

Liu AX, Lu QM, Cao YJ, 2007. Effects of composite nano-materials on rice growth. Plant Nutrit Fertil Sci 13: 344-347.

Liu AX, Liao ZW, 2008. Effects of nano-materials on water clusters. J Anhui Agric Sci 36: 15780-15781.

Liu J, Zhang YD, Zhang ZM, 2009. The application research of nano-biotechnology to promote increasing of vegetable production. Hubei Agric Sci 48: 123-127.

Lu CM, Zhang CY, Wen JQ, Wu GR, Tao MX, 2002. Research of the effect of nanometer materials on germination and growth enhancement of Glycine max and its mechanism. Soybean Sci 21: 168-172.

Ma J, Liu J, Zhang ZM, 2009. Application study of carbon nano-fertilizer on growth of winter wheat. Humic Acid 2: 14-20.

Mahmoodzadeh H, Aghili R, Nabavi M, 2013. Physiological effects of TiO2 nanoparticles on wheat (Triticum aestivum). Tech J Eng Appl Sci 3: 1365-1370. http://tjeas.com/wp-content/uploads/2013/08/1365-1370.pdf

Moore MN, 2006. Do nanoparticles present ecotoxicological risks for the health of the aquatic environment? Environ Int 32: 967-976. http://dx.doi.org/10.1016/j.envint.2006.06.014

Moosapoor N, Sadeghi SM, Bidarigh S, 2013. Effect of boher nanofertilizer and chelated iron on the yield of peanut in province guilan. Ind J Fund Appl Life Sci 3: 2231-6345.

Morgan KT, Cushman KE, Sato S, 2009. Release mechanisms for slow- and controlled-release fertilizers and strategies for their use in vegetable production. Hort Technol 19: 10-12

Nadakavukaren M, McCracken D, 1985. Botany: an Introduction to Plant Biology. West, New York.

Nair R, Varghese SH, Nair BG, Maekawa T, Yoshida Y, Kumar DS, 2010. Nanoparticulate material delivery to plants. Plant Sci 179: 154-163. http://dx.doi.org/10.1016/j.plantsci.2010.04.012

Navarro E, Baun A, Behra R, Hartmann NB, Filser J, Miao A, Quigg A, Santschi PH, Sigg L, 2008. Environmental behaviour and ecotoxicity of engineered nanoparticles to algae, plants and fungi. Ecotoxicology 17: 372-386. http://dx.doi.org/10.1007/s10646-008-0214-0

Oancea S, Padureanu S, Oancea AV, 2009. Growth dynamics of corn plants during anionic clays action. Lucrări Ştiinţifice, Seria Agronomie; 52: 212-217.

http://www.revagrois.ro/PDF/2009_1_214.pdf.

Ray S, Choudhuri MA, 1980. Regulation of flage leaf senescence in rice by nutrients and its impacts on yield. RISO 29: 9-14.

Reynolds ES, 1963. The use of lead citrate at a high pH as an electron opaque stain in electron microscopy. Cell Biol 17: 208-212. http://dx.doi.org/10.1083/jcb.17.1.208

Rico CM, Majumdar S, Duarte-Gardea M, Peralta-Videa JR, Gardea-Torresdey JL, 2011. Interaction of nanoparticles with edible plants and their possible implications in the food chain. J Agric Food Chem 59: 3485-3498. http://dx.doi.org/10.1021/jf104517j

Sartain JB, Hall WL, Littell RC, Hopwood EW, 2004. Development of methodologies for characterization of slow-released fertilizers. Soil Crop Sci Soc Fla Proc 63: 72-75.

Shi Q, Bao Z, Zhu Z, Ying Q, Qizn Q, 2006. Effects of different treatments of salicylic acid on heat tolerance, chlorophyll fluorescence, and antioxidant enzyme activity in seedlings of Cucumis sativa L. Plant Growth Regul 48: 127-135. http://dx.doi.org/10.1007/s10725-005-5482-6

Uzu G, Sobanska S, Sarret G, Munoz M, Dumat C, 2010. Foliar lead uptake by lettuce exposed to atmospheric pollution. Environ Sci Technol 44: 1036-1042. http://dx.doi.org/10.1021/es902190u

Walker R, Morris S, Brown P, Gracie A, 2004. Evaluation of potential for chitosan to enhance plant defence. Australian Government, RIRDC Report No. 4, 49 pp. http://www.peracto.com.au/publications/chitosan-evaluation.pdf.

Wang W, Tarafdar JC, Biswas P, 2013. Nanoparticle synthesis and delivery by an aerosol route for watermelon plant foliar uptake. J Nanopart Res 15: 1-13. http://dx.doi.org/10.1007/s11051-013-1417-8

Wanichpongpan P, Suriyachan K, Chandrkrachang S, 2001. Effects of chitosan on the growth of gerbera flower plant (Gerbera jamesonii). In: Chitin and chitosan in life science; Uragami T, Kurita K, Fukamizo T (eds). pp: 198-201. Yamaguchi, Japan.

Wu M, 2013. Effects of incorporation of nano-carbon into slow-released fertilizer on rice yield and nitrogen loss in surface water of paddy soil. Advance J Food

Sci Technol 5: 398-403. http://dx.doi.org/10.1109/isdea.2012.161

Xiao Q, Zhang FD, Wang YJ, 2008. Effects of slow/controlled release fertilizers felted and coated by nano-materials on nitrogen recovery and loss of crops. Plant Nutr Fertil Sci 14: 778-784.

Zheng L, Su MG, Liu C, Chen L, Huang H, Wu X, Liu XQ, Yang F, Gao FQ, Hong FH, 2005. Effect of nano-TiO2 on strength of naturally aged seeds and growth of spinach. Biol Trace Elem Res 105: 83-91. http://dx.doi.org/10.1385/BTER:104:1:083

Zhu H, Han J, Xiao JQ, Jin Y, 2008. Uptake, translocation, and accumulation of manufactured iron oxide nanoparticles by pumpkin plants. J Environ Monit 10: 713-717. http://dx.doi.org/10.1039/b805998e