

Effect of Nitrogen Levels, Diatomite and Potassium Silicate Application on Yield and Chemical Composition of Wheat (*Triticum aestivum* L.) Plants

Doaa M. Abou Basha, S.A.A. EL Sayed and H.I. El-Aila

Department of Plant Nutrition, National Research Center, Dokki, Giza, Egypt

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Abstract: A field experiments were conducted two winter seasons of 2010/2011 and 2011/2012 in the private farm, Shebeen El Kanater Qalubia Governorate, Egypt to study the effect of three levels of nitrogen fertilizers with two type of foliar application of silicon (diatomite and potassium silicate) on yield and chemical composition of wheat plants. Data showed that increasing the levels of nitrogen with diatomite and potassium silicate as foliar application increased fresh, dry weight, chlorophyll a, b, carotenoids and N, P, K content of wheat plants at 70 days after planting (DAP). The addition of 100 kg N/feddan (one feddan=0.42ha) with 5% potassium silicate resulted in a remarkable effect on all parameters as compared with control. It was observed that the application of 150 kg N/fed+ 5% diatomite increased the biological yield, crop and harvest index than the addition of 50 or 100 kg N/fed + 5% K₂SiO₄. While, addition of 100kg N/fed + 5% K₂SO₄ was more pronounced effect on biological yield, crop and harvest index than any treatments. It was noticed the addition of 100 kg N/fed with 5% K₂SiO₄ as foliar application had a remarkable effect on total and uptake- NPK and protein as compared with 50 or 150 kg N/fed with K₂SiO₄ as foliar application.

Key words: Chemical composition • Diatomite • Grain yield • Nitrogen • Potassium silicate • Wheat (*Triticum aestivum* L.)

INTRODUCTION

Silicon is one of the most commonly occurring chemical elements in nature. In spite of high silicon concentration in different soil types, it is not an indispensable element for the growth and development of higher plant. Yet, recent research has proved that supplementary application of silicon positively influences many aspects of plant growth. It is a well-known fact that silicon is involved in plant tolerance against many stress factors: It increases manganese and heavy metal as well as resistance against pathogens like fungi or herbivorous insects Error! Reference source not found [1]. Numerous studies give evidence that silicon acts in different plant species, although the main object of silicon research seems to be gamins, with special focus on rice. There have also been records documenting the above-mentioned role of silicon in ornamental plants, for example roses [2] and poinsettia [3]. One of the most important facts is that silicon in the soil helps plants

survive in the conditions of water shortage, as well as, drought resistance associated with silicon is explained by decreasing transpiration in cells with higher silicon concentration [4]. All of these may influence plant development, for example shoot growth, flowering or fruit production [5]. Additional treatment with silicon seems to be justified in modern horticulture, as soilless media based on peat substrate are mainly used during plant production. Diatomite a naturally occurring siliceous sedimentary mineral compound from microscopic skeletal remains of unicellular algae-like plant called diatoms. These plants have been part of the earth's ecology since prehistoric times with diatoms inhibiting both fresh and salt water for a very long period of time. Diatomite improve the physical structure of the soil (It helps to break up heavy clay based soils as well as retain moisture in light or sandy soils), helps retain moisture for longer periods, enhances movement of water to the root zone and provides a slow release of nutrients (it acts as a fertilizer carrier). The porosity of diatomite

contributes to its ability to draw water, while moving water and nutrients laterally throughout the medium, making diatoms pebbles ideal for hydroponics. Diatomite is pH natural and stable and will not contribute to change in pH [6, 7].

The aim of this study was to assess the effect of foliar application of silicon as (diatomite of potassium silicate) on yield and chemical composition of wheat plants.

MATERIALS AND METHODS

A field experiments were conducted during two winter seasons of 2010/2011 and 2011/2012 in the private farm, Shebeen El Kanater Qalyubia Governorate, Egypt to study the effect of three levels of nitrogen fertilizer with two type of foliar application of silicon (diatomite and potassium silicate) on yield and chemical composition of wheat plants. Soil sample was taken from the soil surface (0-30 cm) of the experimental site, air dried, sieved by 2 mm sieve and physical and chemical properties of the soil were determined according to Rebecca [8] soil texture was clay, pH 8.10, EC 1.68 dS/m, OM 2.5%, total N 60.2 ppm, available P 8.4 ppm, available K 189.7 ppm and CaCO₃ 2.10%. The diatomite are mined and ground up to render a powder that looks and feels like talcum powder to us. Diatomite is characterized by 3.4% magnesium, 33.7% silicon, 19.0% calcium, 5.1% sodium, 2.9% iron and other trace minerals such as titanium, boron, manganese, copper and zirconium. The experiment was laid out in a randomized complete block design with four replicates, plot area was 18.0 m² (six rows 6 m in long and 50 cm apart): the plots were separated by borders of 1.5 m in width. Seeds of wheat (*Triticum aestivum* L.) cv. Sakha 92 were planted on the last week of November at a rate of 100 kg N/fed in both seasons. Nitrogen fertilizer was added at the rate of 50,100 and 150kg N/fed (one feddan=0.42ha) in the form of ammonium nitrate (33.5% N) after 20, 50 and 80 days after planting (DAP). Foliar spray of 5% diatomite and 5% potassium silicate was applied at 60, 90 and 120 DAP Basal dose of 50kg P₂O₅/fed and 50kg K₂O /fed in the form of super phosphate and potassium silicate was added before transplanting. The experiments include ten treatments and arranged as follow:

1- Control (without fertilizer),	6- 100 kg N/fed + 5% diatomite
2- 50 kg N/fed (as AN)	7- 150 kg N/fed + 5% diatomite
3- 100 kg N/fed (AN)	8- 50 kg N/fed + 5% K ₂ SiO ₄
4- 150 kg N/fed (AN)	9- 100 kg N/fed + 5% K ₂ SiO ₄
5- 50 kg N/fed +5% diatomite	10- 150 kg N/fed + 5% K ₂ SiO ₄

At 70 and 125 DAP a random sample from each plot was taken for determined the fresh and dry weight (g/plant). Photosynthetic pigments (Chlorophyll a, b and carotenoids as mg/g. fw) were estimated according to Lichetoenthalar and Wellburn [9]. At harvest time (125 DAP) plants of one square meter from each plot were taken from the inner three rows for determining the grain yield (t/fed.), straw yield (t/fed.), biological yield(t/fed) and 100-grain weight (g). Harvest and crop index were also calculated according to Buresh *et al.* [10] as follows:

Harvest index (HI) = Grain yield (t/fed)/ biological (grain +straw) in t/fed x 100

Crop index (CI) = Grain yield (t/fed)/ straw yield (t/fed) x 100

Total nitrogen, phosphorus and potassium in grain were determined according to the method described by Faithfull [11]. The protein percentage in the grain was calculated by multiplying N% x 5.75.

Statistical Analysis: All data were statistical analyzed according to the technique of analysis of Variance (ANOVA) for the completely Randomized design (CRD) using MSTATC software package according to Gomez and Gomez [12]. Least significant Difference (LSD) was used compare the differences between treatments means at the level 5% probability.

RESULTS AND DISCUSSION

Fresh and Dry weight, Chlorophyll and NPK Contents: Data presented in Table 1 indicated the application of different nitrogen fertilizers without diatoms or potassium silicate increased fresh and dry weight, chlorophyll a, b and carotenoids, as well as, N, P and K contents in straw as compared control in 70 DAP. However, application of 150 kg N/fed in combination with 5% diatomite resulted in a remarkable effect on fresh, dry weight and chlorophyll a comparison with 150 kg N/fed without diatomite. Concerning the application of potassium silicate as foliar application in combination with the different levels of nitrogen, data in Table 1 also indicated that the treatment of 100 kg N/fed + 5% K₂SiO₄ was more pronounced effect on fresh, dry weight; chlorophyll a, b, carotenoids, N, P and K content in 70 DAP. These increases estimated by 40.06%, 48.91%, 51.54%, 43.26%, 35.41%, 43.44%, 20.0%, 38.71% for the fresh and dry weight, chlorophyll a, b,

Table 1: Effect of nitrogen levels, diatomite and potassium silicate application on fresh and dry weight, chlorophyll a, b, carotenoids N, P and K content at 70 DAP (Average of two seasons)

Treatments	Fresh weight (g/plant)	Dry weight (g/plant)	Chlorophyll a (mg/g fw)	Chlorophyll b (mg/g fw)	Carotenoids (mg/g fw)	Macronutrients (%)		
						N	P	K
Control No fertilizer	11.23	1.12	0.213	0.107	0.237	0.98	0.067	0.94
50 Kg N/ fed	16.83	2.50	0.543	0.225	0.484	1.79	0.105	1.46
100 Kg N/ fed	17.67	3.04	0.646	0.261	0.695	1.94	0.108	1.52
150 Kg N fed ¹	17.91	3.67	0.89	0.332	0.751	2.10	0.127	1.85
50 Kg N/ fed + 5% diatoms	18.30	3.61	0.844	0.344	0.695	2.35	0.112	1.46
100 Kg N/ fed + 5% diatoms	19.50	3.91	0.927	0.354	0.835	2.62	0.124	1.80
150 Kg N/ fed + 5% diatoms	19.49	4.72	1.09	0.402	0.919	3.19	0.131	2.02
50 Kg N/ fed + 5% K ₂ SiO ₄	21.25	4.63	1.009	0.348	0.751	2.51	0.116	1.63
100 Kg N/ fed + 5% K ₂ SiO ₄	29.48	5.95	1.333	0.460	1.076	3.43	0.135	2.48
150 Kg N/ fed + 5% K ₂ SiO ₄	27.75	5.42	1.094	0.417	0.892	2.49	0.127	2.01
LSD 0.05	2.11	0.94	0.49	0.029	0.0119	0.68	NS	NS

Table 2: Effect of nitrogen levels, diatomite and potassium silicate application on wheat yield and some yield components (Average of two seasons).

Treatments	100 grains weight (g)	Grain yield (ton/ fed)	Straw (ton/ fed)	Biological yield (ton/fed)	Crop index	Harvest index
Control No fertilizer	2.06	0.88	1.52	2.4	57.89	36.67
50 Kg N/ fed	3.87	1.98	3.59	5.57	55.15	35.55
100 Kg N/ fed	4.78	2.59	4.63	7.22	55.94	35.87
150 Kg N fed ¹	4.91	3.00	4.75	7.75	63.16	38.71
50 Kg N/ fed + 5% diatoms	5.00	3.16	4.71	7.87	67.09	40.15
100 Kg N/ fed + 5% diatoms	5.21	3.25	4.82	8.07	67.43	40.27
150 Kg N/ fed + 5% diatoms	5.42	3.38	4.85	8.23	69.69	41.07
50 Kg N/ fed + 5% K ₂ SiO ₄	5.19	3.21	4.62	7.83	69.48	41.00
100 Kg N/ fed + 5% K ₂ SiO ₄	5.65	3.72	4.91	8.63	75.76	43.11
150 Kg N/ fed + 5% K ₂ SiO ₄	5.36	3.50	4.74	8.24	73.84	42.48
LSD 0.05	1.51	0.94	1.38	1.79	NS	NS

carotenoids and N, P and K content respectively comparison to 100 kg N/fed alone. This result may be due to the favorable effects of silicon on wheat plants seem to originate from reinforcement of the cell walls due to deposition of Si in form amorphous silica (SiO₂H₂O) [13,14]. For instance, Si increased the thickness and the roughness of wheat leaves thus improving light reception, which results in enhanced yield [15]. Accumulation of Si by some plant species may be equal to or higher than some macronutrients such as P, K, Mg, Ca and S [14]. Even where no Si was added into the nutrient solution, the levels of Si in the roots and leaves of zinnia and zucchini were higher than those of Ca, P, K and Mg.

Grain Yield and Grain Index: Data in Table 2 illustrated that grain yield (ton/fed) was significantly affected by different levels of nitrogen with or without diatomite or potassium silicate. The results revealed that applied diatomite or potassium silicate combination with levels of nitrogen increased the grain yield and weight of 100 grains, in comparison with the control or nitrogen alone. Data in Table 2 also indicated that application of 150 kg N/fed with diatomite increased grain yield and 100 grains weight, compared with 50 or 100 kg N/fed in combination with diatomite. However, applied of 100 kg N/fed with potassium silicate was more pronounced effect on 100 grains weight, grain and compared to the other treatments. These increases may be due to the effects of

silicon fertilizers on plants as follows 1) The direct influence through soil fertility and 2) The direct influence on the plants [16, 17] stated that silicon application to rice increased number of filled spikelet, grain, straw yield and decreased blank spikelet and harvest index.

Biological and Straw Yield, Crop and Harvest Index: Biological and straw yield, crop and harvest index are presented in Table 2. Application of nitrogen rates singly or in combination with diatomite and/or potassium silicate significantly increased the biological and straw yields, compared to the control. However, application of diatomite or K₂SiO₄ as foliar application in combination with different nitrogen levels increased crop and harvest index than the addition of nitrogen levels alone. It was observed that the application of 150 kg N/fed + 5% diatomite increased the biological and straw yield, crop and harvest index than the addition of 50 or 100 kg N/fed + 5% K₂SiO₄. While, the addition of 100 kg N/fed + 5% K₂SiO₄ was more pronounced effect on biological yield, crop and harvest index than the other treatments. These results may be attributed that Si plays an active role in the biochemical processes of plant and also may plays an important role in the intercellular synthesis of organic compounds [18]. The available silicon in the sap may constitute between 0.5– 8.0 % of the total Si in the plant, it is likely to play an active role in the biochemical processes of the plant [19].

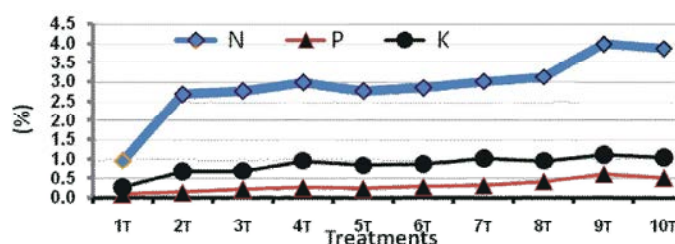


Fig. 1: Effect of nitrogen levels, diatomite and potassium silicate application on grain content of macronutrient percentage (Average of two seasons)

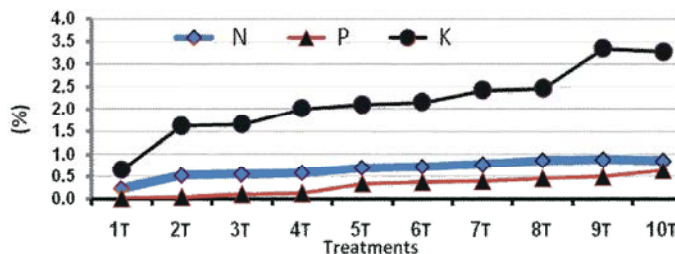


Fig. 2: Effect of nitrogen levels, diatomite and potassium silicate application on straw content of macronutrient percentage (Average of two seasons)

Table 3: Effect of FYM, diatomite and potassium silicate application on macronutrient uptake (kg/fed) (Average of two sessions).

Treatments	Nitrogen uptake (mg/ kg)		Phosphorus uptake (mg/ kg)		Potassium uptake (mg/ kg)		Protein (%)
	Grain	Straw	Grain	Straw	Grain	Straw	
Control No fertilizer	9.45	2.17	0.89	0.20	2.56	6.50	6.00
50 Kg N/ fed	64.32	12.57	3.12	1.20	16.32	39.12	16.75
100 Kg N/ fed	68.33	13.57	5.43	2.71	17.02	40.95	17.31
150 Kg N fed ¹	81.73	15.85	7.11	3.55	26.24	54.94	18.69
50 Kg N/ fed + 5% diatoms	95.10	24.03	7.90	11.67	28.84	72.10	17.31
100 Kg N/ fed + 5% diatoms	98.13	24.79	9.64	12.74	29.95	74.02	17.81
150 Kg N/ fed + 5% diatoms	104.52	26.74	10.76	13.54	35.42	84.03	18.81
50 Kg N/ fed + 5% K ₂ SiO ₄	107.40	29.59	14.41	15.78	32.94	84.75	19.56
100 Kg N/ fed + 5% K ₂ SiO ₄	138.32	30.46	21.15	16.99	38.83	116.13	24.94
150 Kg N/ fed + 5% K ₂ SiO ₄	135.45	29.75	17.85	22.40	36.40	114.80	24.19
LSD 0.05	6.52	0.98	1.18	0.69	1.17	2.14	NS

Chemical Composition: Figs. 1 and 2 illustrated the application of ammonium nitrate with or without diatomite or potassium silicate as foliar application on total-NPK in grains and straw of wheat plants as compared to control. Data in Table 3 showed that the application of ammonium nitrate with or without diatomite or potassium silicate as foliar application on NPK-uptake and protein in grains and straw of wheat plants. Results indicated that the addition of ammonium nitrate at any levels of nitrogen without diatomite or potassium silicate increased N, P, K-uptake and protein in grain and straw of wheat plants as compared to control. It was noticed that the addition of 150 kg N/fed increased N, P, K -uptake and protein as compared to 50 or 100 kg N/fed of ammonium nitrate without the addition of diatomite or potassium silicate as foliar application.

Data also showed that the addition of ammonium nitrate with diatomite as foliar application stimulate N, P, K-uptake and protein in grains and straw of wheat plants.

It was revealed that increasing levels of nitrogen up to 150 kg N/fed with 5% diatomite as foliar application increased N, P, K-uptake and protein in grains and straw of wheat plants. The addition of 150 kg N/fed with diatomite as foliar application improved NPK -uptake in grains by about 21.8, 33.9 and 20.3 as compared to the addition of 150 kg Nfed¹ ammonium nitrate alone. It was observed that the addition of potassium silicate had more pronounced effect on NPK-uptake and protein in grains and straw of wheat plants as compared to all treatments. It was noticed the addition of 100 kg N/fed with 5% K₂SiO₄ as foliar application had a remarkable effect on NPK-uptake and protein as compared to 50 or 150 kg N/fed with K₂SiO₄ as foliar application. The percentage rates of increasing were 24.4, 49.1 & 8.7 in grains as compared to 150 kg N/fed with diatomite. This phenomenon may be attributed to plant can use only about 30% of applied phosphate fertilizer, if leaching is low. The mixture of active Si with P fertilizer can increase

the efficiency of P fertilization by 40– 60 % [20]. Also Si interaction with potassium varies, depending on the anion in the fertilizer [21]. Transpiration decrease if the chloride salt is used yet increases if the sulphate salt is used so there is greater uptake and deposition of Si for the latter K fertilizer. Importantly, Si-rich amendments are recommended for the reduction in leaching of nitrogen, phosphorus and potassium based fertilizers [15]. Silicon increased nitrogen and phosphate levels in the grain and straw of rice, suggests that silicon in lesser amounts can be beneficial in increasing grain yield and growth of cereal crops [22].

REFERENCES

1. Reynolds, O.L., M.G. Keeping and J.H. Meyer, 2009. Silicon-augmented resistance of plants to herbivorous insects: a review. *Annals of Applied Biology*, 155: 171-186.
2. Gillman, J.H., D.C. Zlesak and J.A. Smith, 2003. Applications of potassium silicate decrease black sot infection in *Rosa* hybrid. *Meipelta*. (Fuschia Me idland). *HortSci.*, 38: 1144-1147.
3. Mc Avoy, R.J. and B.B. Bible, 1996. Silica sprays reduce the incidence and severity of bract necrosis in poinsettia. *HortSci.*, 31(7): 1146-1149.
4. Gao, X., C. Zou, L. Wang and F. Zhang, 2006. Silicon decreases transpiration rate and conductance from stomata of maize plant. *J. Plant Nutr.*, 29: 1637-1647.
5. Regina D. and W. Katarzyna, 2011. The effect of silicon foliar application on the development of seasonal ornamental plants. *Acta Agrotanica*, 64(4): 99-106.
6. Antonides, L.E., 1998 *Diatomite: U.S. Geological Survey Mineral Commodity Summaries*, pp: 56-57.
7. Hellal, F.A., R.M. Zeweny and A.A Yassen, 2012. Evaluation of Nitrogen and Silicon Application for Enhancing Yield Production and Nutrient Uptake by Wheat in Clay Soil. *J. of Applied Sciences Research*, 8(2): 686-692.
8. Rebecca, B., 2004. *Soil Survey Methods Manual*. Soil Survey Investigations Report. No 42 Natural Resources Conservation Services.
9. Lichetoenthaler, H.K. and A.R. Wellburn, 1983. Determination of total carotenoids and chlorophyll a and b of leaf extracts in different solvents. *Biochem. Soc. Trans.*, 11: 591-952.
10. Buresh, R.J., S.K. Datta, J.L. Padilla and T.T. Chua, 1988. Potential of inhibitors for increasing response of low land rice to urea fertilization. *Agron. J.*, 80: 947-952.
11. Faithfull, N.T., 2002. *Methods in Agriculture. Chemical Analysis. A practical Handbook*. CABI Publishing, pp: 84-95.
12. Gomez, K.A. and A.A. Gomez, 1984. *Statistical Procedures for Agriculture Research*. 2nd Ed. John Wiley and Sons Inc. New York.
13. Lnanaga, S. and A. Okasaka, 1995. Calcium and silicon binding compounds in cell walls of rice shoots. *Soil Sci. Plant Nutr.*, 41: 103-110.
14. Epstein E., 1999. Silicon. *Annual Review of Plant Physiology and Plant Molecular Biology*, 50: 641-664.
15. Savvas, D., G. Manos, A. Kotsiras and S. Souvaliotis, 2002. Effects of silicon and nutrient-induced salinity on yield, flower quality and nutrient uptake of gerbera grown in a closed hydroponic system. *J. Appl. Bot.*, 76: 153-158.
16. Matichenkov and Calvert, 1999. (Silicon fertilizers for citrus in florid). *Proc. Fla. State Hort. Soc.*, 112: 5-8.
17. Ghanbari-Malidarreh, A., A. Kashani, G. Nourmohammadi, H.R. Mobasser and S.V. Alavi, 2011. Evaluation of silicon application and nitrogen rates on yield, yield components in rice (*Oryza sativa* L.) in two irrigation systems. *American-Eurasian J. Agric. and Environ. Sci.*, 10(4): 532-543.
18. Matichenkov, V.V., E.A. Bocharnikova, A.A. Kosobryukhov and K.Y. Biel, 2008. Mobile forms of silicon in plants. *Doklady (Proceedings) Biological Sciences*, 418: 39-40.
19. French-Monar, R.D., F.A. Rodrigues, G.H. Korndorfer and L.E. Datnoff, 2010. (Silicon suppresses phytophthora blight development on bell pepper). *J. Physiopathology*, 58: 554-560.
20. Matichenkov, V.V., V.M. Dyakov and E.A. Bocharnikova, 1997. The complex silicon phosphate fertilizer. Russian Patent Registration No.97121543.
21. Guevel, M.H., J.G. Menzies and R. R. Belanger, 2007. Effect of root and foliar applications of soluble silicon on powdery mildew control and growth of wheat plants. *European Journal of Plant Pathology*, 119: 429-436.
22. Singh, K., R. Singh, J.P. Singh, Y. Singh and K.K. Singh, 2006. Effect of level and time of silicon application on growth, yield and its uptake by rice (*Oryza sativa*). *Indian J. Agric. Sci.*, 76(7): 410-413.