Journal of Applied Sciences Research, 8(2): 686-692, 2012
ISSN 1819-544X
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

Evaluation of Nitrogen and Silicon Application for Enhancing Yield Production and Nutrient Uptake by Wheat in Clay Soil

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ABSTRACT

Silicon (Si) is a beneficial element for plant growth. It helps plant to overcome multiple stresses, alleviates metal toxicity and improve nutrient imbalance. Field experiment was conducted in two seasons (2009/2010 and 2010/2011) at Shbeen El-Knatr, El- Qualubia Governorate to study the effect of organic nitrogen (Farm yard manure) and inorganic nitrogen (Ammonium sulphate) application combined with foliar spray of silicon at a rate of 0.0, 0.2, 0.4 and 0.6 % as diatomite on the yield and chemical composition of wheat plants. Results indicated that, application of Farmyard manure (FYM), or ammonium sulphate combined with Si had significant effect on chlorophyll a and carotene as compared with the control treatment. Moreover, application of FYM as a nitrogen source alone was higher in their effects on grain and straw yield production as compare to application of ammonium sulphate. Application of FYM combined with Si significantly increased nitrogen and phosphorus content and uptake in grain and straw as compare to ammonium sulphate and control. Application of the FYM combined with 0.4 % Si as diatomite produced the highest values of grain yield, weight of 100 g grains as well as straw yield of wheat plants. The second best treatment was the application ammonium sulphte combined with 0.4 % Si as foliar spray followed by application of the FYM combined with 0.6 % Si as foliar spray. Highly significant and positive correlations were observed between grain and straw wheat yield and chlorophyll a, carotene, N, P and K uptake. The economic analysis clearly indicate that application of FYM to soil and foliar sprays of Silicon together had increased gross returns, net returns and Benefit: Cost ratio of wheat plants. This indicates that nitrogen application combined with foliar spray of silicon is important to get higher wheat yield from clay soil.

Key words: FYM, silicon, diatomite, chlorophyll, grain yield.

Introduction

Wheat (*Triticum aestivum* L.) is an important cereal crop, source of staple food and thus the most important crop in food security prospective. Besides its tremendous significance, average yield is far below than developed countries (FAO, 2010). Nitrogen is the most important plant nutrient needed to obtain high wheat yield and quality. Whereas, nitrogen is a primary constituent of proteins, chlorophyll and thus enzymes. Nitrogen fertilization management offers the opportunity for increasing wheat growth, yield and its components (Mekhemar, 2008).On the other hand, organic materials such as crop residues, farmyard manure, humic acid industrial wastes, etc., are available in abundance and reach tremendous amounts every day. Organic matter is a key component of the soil because it carries out many functions in agro-ecosystem. Organic manure is commonly applied to the soil to hence improve their physical, chemical and biological properties of many soils (Jimenez *et al.* 2002). Tawfik and Gomaa (2005) found that farmyard manure application significantly enhanced the yield and N, P and K uptake of wheat. Yaduvanshi and Sharma (2008) found that application farmyard manure with chemical amendment increased wheat yield and N, P and K uptake in grain yield. Yassen *et al.* (2010) found that application of farmyard manure residue gave a significant increase in grain and straw weight, total yield, curd protein, N, P and K content and uptake.

Diatomite is 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 waters 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 neutral and stable and will not contribute to changes in pH (Antonides, 1998).

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Silicon, (Si) an element abundantly available on earth's crust is second only to oxygen. It is the eight most abundant elements in universe. Its content in soils vary greatly and ranges from <1 to 45% by dry weight (Sommer *et al.* 2006). Silica (SiO_2) content of soils varies from less than 10% to almost 100%. Silicon dioxide (SiO_2/ silica) comprises 50-70% of the soil mass. As a consequence all plants rooting in soil contain some Si in their tissues. Silicon is considered a plant nutrient "anomaly" because it is not essential for plant growth and development. However soluble Si has enhanced the growth development and yield of many plants. The content of silica in plants is equivalent to or more than the major nutrients N, P, K supplied through fertilizers. Silicon affects plant growth, crop quality, stimulation of photosynthesis, reduction of transpiration and enhancement of plant resistance to a biotic stresses (Lu and Cao, 2001 and Raven, 2003**)**. Ghanbari-Malidarreh *et al.* (2011) concluded that if the nitrogen application was high and water supplied was available we could have silicon application until increase grain yield of rice. The purpose of this research work was to determine the effects of organic and inorganic nitrogen fertilizer applied with foliar spray of silicon as diatomite on yield and chemical composition of wheat grown in clay soil.

Materials and Method

A field experiments was conducted in seasons (2009/2010 and 2010/2011) at Shbeen El Knatr, El Qualubia Governorate to study the effect of organic and inorganic nitrogen with foliar spray of silicon as diatomite on the yield and chemical composition of wheat plants. Prior to any practices, a composite soil sample was taken from the soil surface (0-30 cm) of the experimental site, air dried, sieved by 2mm sieve and analyzed. The investigated soil characterized by: soil texture was clayey, pH 8.10, EC 1.68 dS m^{-1}, OM 2.5 %, total N 60.2 ppm, available P 8.4 ppm, available K 189.7 ppm and $CaCO_3$ 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 many other trace minerals such as titanium, boron, manganese, copper and zirconium. Some chemical properties of the investigated farmyard manure were analyzed in Table (1).

The experiments were led in a randomized complete block design with four replicates, area of each plot was 18.0 m^2 (six rows 6 m in long and 50 cm apart); the plots were separated by borders of 1.5 m in width. 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. Sources of nitrogen, one type of organic material (Farmyard manure) and the other inorganic nitrogen (Ammonium sulphate) were added. Application rate of organic matter used to depend on its content of nitrogen and the total required N (100 kg N/fed). The organic materials (Farmyard manure) were thoroughly mixed with 0–30 cm of the surface soil layer before sowing.

Table 1: Some properties of farmyard manure (FYM).

Characteristics	pH	EC dSm^{-1}	Organic matter %	Organic carbon %	Total (%)			Available micronutrient (ppm)		
					N	P	K	Fe	Zn	Mn
Farmyard manure	7.97	2.6	66.68	38.76	1.78	0.31	0.89	412	138	281

Foliar spray of silicon at three rates of 0.0, 0.2, 0.4 and 0.6 % as diatomite applied in two sprays at 4 weeks intervals. The first was after 60 days of cultivation. Basal dose of 50 kg P_2O_5 fed^{-1} and 50 kg K_2O fed^{-1} in the form of Superphosphate and potassium sulphate was added before transplanting. The experiments include nine treatments and arranged as follow:

T1: Control (without N fertilizer), T2: AS (Ammonium sulphate), T3: FYM (Farmyard manure), T4: AS + 0.2 % Si as diatomite, T5: AS + 0.4 % Si as diatomite, T6: AS + 0.6 % Si as diatomite, T7: FYM + 0.2 % Si as diatomite, T8: FYM + 0.4 % Si as diatomite and T9: FYM + 0.6 % Si as diatomite.

At the maturity stage, the plants were harvested and separated into grains and straw. Production was recorded and prepared for analysis. Samples were digested with the acid mixture. Total nitrogen, phosphorus and potassium were determined according to the method described by Faithfull (2002). Chlorophyll and carotene was also estimated according to Lichtenthalar and Wellburn (1983). The physical and chemical properties of the soil were determined according to Rebecca (2004). Harvest index = Grain yield x100 / Biological yield. Agronomic efficiency and physiological efficiency were calculated according to Buresh *et al*. (1988).

$$\text{Agronomic efficiency} = \frac{\text{Grain yield (fertilizer) - Grain yield (Control)}}{\text{Nitrogen Applied}}$$

$$\text{Physiological efficiency} = \frac{\text{Grain yield (fertilizer) - Grain yield(Control)}}{\text{N uptake (fertilizer) – N uptake (control)}}$$

All data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the Completely Randomized Design (CRD) using MSTATC computer software package according to Gomez and Gomez (1984). Least Significant Difference (LSD) method was used to test the differences between treatment means at 5% level of significance. Correlation studies were made between grain and straw yield and major and micronutrients uptake by wheat plant at harvest. The values of correlation coefficient (r) were calculated and tested for their significance at 1 and 5 %. For economic analysis, the prices of the inputs that were prevailing at the time of their use were considered for working out the cost of cultivation. Net returns per feddan were calculated by deducting cost of cultivation per feddan from gross income per feddan. Benefit cost ratio was worked out by dividing Gross return by total cost invested**.**

Results and Discussion

Chlorophyll Content:

The total chlorophyll and nutrient contents markedly differed due to Silicon and nitrogen application (Table 2). Application of 100 kg N/ fed as farm yard manure (FYM) combined with 0.4 % Si in the form of diatomite increased the chlorophyll a, carotene and N content (0.763, 0.879 mg/g fresh weight and 2.71%) followed by Application of 100 kg N/ fed as ammonium sulphate (AS) combined with 0.4 % Si (0.665, 0.816 mg/g fresh weight and 2.58%) over application of FYM or SA without Silicon and control at 70 day after sowing. The beneficial effect of applied Nitrogen gradually increased N availability in soil and furthermore taken up by plant resulting higher chlorophyll content in plants. Silicon affects plant growth, crop quality, stimulation of photosynthesis, reduction of transpiration and enhancement of plant resistance to a biotic stresses (Lu and Cao, 2001 and Raven, 2003**)**.

Table 2: Dry weight, chlorophyll, carotene and N, P and K content at 70 day of sowing (data mean of two seasons).

Treatments applied	Dry wt (g/plant)	Chlorophyll a (mg/g fr wt.)	Chlorophyll b (mg/g fr wt.)	Carotene (mg/g fr wt.)	N %	K %	P %
T1: Control (without N fertilizer)	2.51	0.333	0.260	0.576	1.79	1.23	0.072
T2: AS (Ammonium Sulphate)	3.23	0.444	0.332	0.605	2.11	1.71	0.105
T3: FYM (Farm yard Manure)	3.83	0.516	0.399	0.621	2.37	1.23	0.116
T4: AS + 0.2 % Si as Diatomite	3.87	0.483	0.343	0.724	2.18	1.89	0.111
T5: AS + 0.4 % Si as Diatomite	4.31	0.655	0.353	0.816	2.58	1.93	0.135
T6: AS + 0.6 % Si as Diatomite	4.01	0.601	0.379	0.799	2.51	2.02	0.122
T7: FY M + 0.2 % Si as Diatomite	4.23	0.712	0.324	0.656	2.27	1.80	0.117
T8: FY M + 0.4 % Si as Diatomite	5.92	0.763	0.378	0.879	2.71	1.84	0.132
T9: FY M + 0.6 % Si as Diatomite	5.22	0.632	0.409	0.811	2.15	1.85	0.107
LSD (0.05)	1.45	0.173	NS	0.193	0.639	0.706	0.060

Yield Production:

It is quite clear from the data presented in Table (3) that application of nitrogen fertilizer from different sources; inorganic fertilizer (Ammonium sulphate) and organic fertilizer (farmyard manure) were significantly increased grain, straw and weight of 100 g grain of wheat when compared with the control treatment. Results mentioned above indicate that superiority of grain and straw yield of wheat under N application might be due to the role of N in the enhancement and development of plant tissues through the synthesis of primary constituent of proteins and chlorophyll. Comparing application of nitrogen fertilizer, as (ammonium sulphate) and farmyard manure), data showed that FYM application increased grain and straw of wheat as compared with application of ammonium sulphate.

It was also clear from the obtained data that application of nitrogen fertilizer from different sources; inorganic fertilizer (Ammonium sulphate) and organic fertilizer (FYM) with foliar spray of silicon (diatomite) was significantly increased weight of 100 g of grain, grain and straw yield of wheat as compared with control treatment. Results in agreement with Singh *et al* (2006) in rice and Saeed *et al*. (2009) in wheat. They concluded that the increase in growth, dry matter and grain yield of wheat as affected by silicon application in silty loam soil.

Presented data in Table 3, also showed the effect of foliar spray of silicon as diatomite in addition to ammonium sulphate and farmyard manure fertilizers on wheat growth characters. The highest results were reached through the use of 0.4 % of silicon as diatomite in addition to FYM in weight of 100 g of grain, grain and straw yield of wheat (5.47 g, 3.83 ton fed^{-1} and 3.96 ton fed^{-1}), whereas application ammonium sulphate (AS) fertilizers with 0.4 % of silicon as diatomite were 5.38 g, 3.63 t fed^{-1} and 3.91 t fed^{-1} in weight of 100 g of grain, grain and straw yield of wheat, respectively. Ghanbari-Malidarreh *et al.* (2011) stated that silicon application to rice increased number of filled spikelet, grain, straw yield and decreased blank spikelet and harvest index.

The calculated data of agronomic efficiency (grain yield increase per unit of N-applied) and physiological efficiency (grain yield increase per additional unit of N-uptake above the control) are presented in Table 3. It was observed that the highest agronomic efficiency values were obtained with FYM (100 unit N fed^{-1}) with 0.4 % Si as Diatomite followed by AS (100 unit N fed^{-1}) with 0.4 % Si as Diatomite**.** Physiological efficiency was used to asses; whether the treatments affected the efficiency which wheat utilized plant N for the formations of grains. Generally, the treatment of FYM combined with silicon has physiological efficiency values higher than the agronomic efficiency indicated the maximum N-use efficiency due to the minimized the N-loss during the growing season.

Table 3: Effect of AS, FYM combined with Si on wheat yield (data mean of two seasons).

Treatments applied	Weight of 100 g grain	Grain yield (ton fed^{-1})	Straw yield (ton fed^{-1})	Harvest Index	Agronomic efficiency	Physiological efficiency
T1: Control (without N fertilizer)	2.73	1.75	2.73	39.1	0.00	0.00
T2: AS (Ammonium Sulphate)	4.45	2.37	3.19	42.6	6.20	22.5
T3: FYM (Farm yard Manure)	4.53	2.69	3.27	45.1	9.40	23.4
T4: AS + 0.2 % Si as Diatomite	5.12	2.75	3.64	43.0	10.0	23.5
T5: AS + 0.4 % Si as Diatomite	5.38	3.63	3.91	48.1	18.8	27.9
T6: AS + 0.6 % Si as Diatomite	5.21	2.94	3.76	43.9	11.9	25.0
T7: FY M + 0.2 % Si as Diatomite	5.22	3.44	3.65	48.5	16.9	27.3
T8: FY M + 0.4 % Si as Diatomite	5.47	3.83	3.96	49.2	20.8	26.6
T9: FY M + 0.6 % Si as Diatomite	5.35	3.51	3.86	47.7	17.6	26.6
LSD (0.05)	1.09	0.53	0.98	-	-	-

Chemical Composition:

Data presented in Table (4) and Figures 1 and 2 demonstrated that, the N content and uptake in tissues in grain, and straw of wheat were significantly increased in all tested of treatment as compared with the control treatment. These results were in accordance with those reported by Seadh and Badawi (2006) and Yassen *et al.* (2010). They stated that application of farmyard manure to the soil increased N content and uptake by grain and straw due to the beneficial effect of organic matter for improving the nutritional statue statue, particularly nitrogen. Data also, showed that increasing N content and uptake with FYM as compared to AS (Ammonium sulphate).

It was also clear from the obtained data that different nitrogen forms as ammonium sulphate and farmyard manure combined with foliar spray of silicon (0.2, 0.4 and 0.6 %) increased the N percentage as compared the control and nitrogen from. Singh *et al*. (2006) found that the application of 180 kg ha^{-1} of Silicon increased nitrogen in the grain and straw of rice. The maximum N content (2.78 % in grain and 0.88% in straw) and uptake (106.5 kg fed^{-1} in grain and 33.1 kg fed^{-1} in straw) was reported when nitrogen as FYM combined with 0.4 % of silicon. Data also, showed that N concentration tend to decrease with increasing silicon up to 0.6 %) with both ammonium sulphate and farmyard manure. Data also clearly demonstrated that increases in protein content due to foliar spray of silicon (0.2, 0.4 and 0.6 %) as diatomite under application of FYM or AS.

Application of farmyard manure increased K and P uptake in grain (35.2 and 18.4 kg fed^{-1}) and straw (104.4 and 9.39 kg fed^{-1}) of wheat respectively as compare with the control treatment. These results are in a harmony with those reported by Yaduvanshi and Sharma (2008), they found that application farmyard manure with chemical amendment increased wheat yield and P and K uptake in grain yield. Results mentioned above indicate that superiority of FYM combined with foliar spray of silicon as compared with the ammonium sulphate with foliar spray of silicon with respect to P and K uptake by wheat plants. Ma and Takahashi (2002) reported a high phosphate uptake in rice with silicon application which directly correlates the increased growth and yield. Singh *et al*. (2002) found the application of 180 kg ha^{-1} of silicon increased phosphorus in the grain and straw of rice crop.

Correlation Studies:

Correlation coefficient between yield components, chlorophyll, carotene and nutrient uptake by wheat are presented in Table 5. Chlorophyll a & b and carotene are positively and significantly correlated with grain yield (0.954**, 0.655** and 0.800**).Weight of 100 g grains showed positive and highly significant correlation with grain (0.891**) and straw (0.953**) yield of wheat plants. The results of nutrient uptake (N, P and K) are positive and significantly correlated with grain yield (0.995**, 0.975** and 0.99**) and straw yield (0.894**, 0.829** and 0.812**).

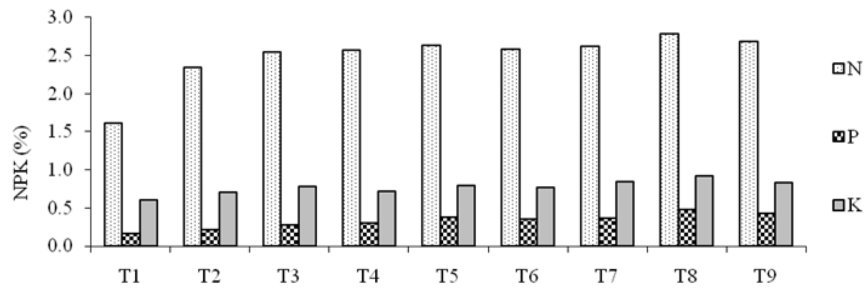

Fig. 1: N, P and K content of wheat grain.

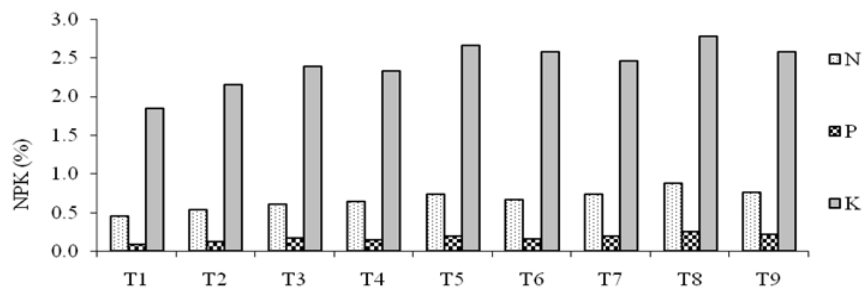

Fig. 2: N, P and K content of wheat straw.

Table 4: Effect of AS, FYM combined with silicon on protein content, N, P and K uptake by wheat plants (data mean of two seasons).

Treatments Applied	Protein (%)	Grain			Straw		
		N uptake (kg fed^{-1})	P uptake (kg fed^{-1})	K uptake (kg fed^{-1})	N uptake (kg fed^{-1})	P uptake (kg fed^{-1})	K uptake (kg fed^{-1})
T1: Control (without N fertilizer)	10.06	28.18	2.98	10.50	12.29	2.46	50.23
T2: AS (Ammonium Sulphate)	14.69	55.62	5.21	16.81	16.91	3.83	68.59
T3: FYM (Farm yard Manure)	15.88	68.33	7.53	20.98	19.95	5.56	77.83
T4: AS + 0.2 % Si as Diatomite	16.06	70.68	8.25	19.80	23.32	5.47	84.91
T5: AS + 0.4 % Si as Diatomite	16.44	84.95	12.27	25.52	28.54	7.43	104.01
T6: AS + 0.6 % Si as Diatomite	16.13	75.88	10.29	22.65	24.80	6.01	96.58
T7: FY M + 0.2 % Si as Diatomite	16.38	90.05	12.37	28.87	27.02	6.94	89.81
T8: FY M + 0.4 % Si as Diatomite	17.38	106.47	18.38	35.24	33.05	9.39	104.42
T9: FY M + 0.6 % Si as Diatomite	16.81	94.53	15.11	29.17	29.34	8.11	99.59
LSD (0.05)	3.80	9.19	2.18	4.67	5.22	1.43	NS

Table 5: Correlation between wheat yield and the studied parameters (data mean of two seasons).

	Weight of 100 grain	Grain yield	Straw yield	Chlorophyll (a)	Chlorophyll (b)	Carotene	Protein
Grain yield	0.891**						
Straw yield	0.953**	0.878**					
Chlorophyll (a)	0.796**	0.954**	0.780**				
Chlorophyll (b)	0.735**	0.655**	0.671**	0.654**			
Carotene	0.738**	0.800**	0.816**	0.787**	0.666**		
Protein	0.979**	0.882**	0.895**	0.791**	0.814**	0.687**	
N uptake by grain	0.922**	0.995**	0.894**	0.938**	0.704**	0.803**	0.921**
P uptake by grain	0.807**	0.975**	0.829**	0.941**	0.619**	0.873**	0.792**
K uptake by grain	0.839**	0.991**	0.812**	0.955**	0.633**	0.782**	0.844**

Economic Analysis:

The treatment T8 (FYM with 0.4% foliar sprays of silicon) recorded the highest gross returns (LE. 9384) followed by T5 (LE. 8894) and the highest net returns of LE. 5914 was observed in T8 followed by T5 (AS combined with 0.4 % foliar sprays of silicon) (LE. 5794). Similarly, the highest benefit: cost ratio (2.87) was observed in T5 followed by T8 (2.70). However, lowest gross returns of LE. 4288, net return LE. 1385 and benefit: cost ratio (1.46) was registered in T1 (control) in (Table 6).

The economic analysis clearly indicate that application of FYM to soil and foliar sprays of Silicon together had increased gross returns, net returns and Benefit: Cost ratio of wheat plants. The plots received FYM with 0.4 % foliar sprays of Si help to get more returns as compared to other treatments. This might be due to increased nutrient availability and uptake by plants resulted in increased growth and yield components and improved quality parameters of wheat.

Table 6: Economic of wheat as influenced by N and Si application (data mean of two seasons).

Treatments applied	Grain yield (Ton/fed)	Total cost invested (EGP/fed)	Gross Return (EGP/fed)	Net Return (EGP/fed)	Benefit: Cost ratio
T1: Control (without N fertilizer)	1.75	2930	4288	1358	1.46
T2: AS (Ammonium Sulphate)	2.37	3060	5799	2739	1.90
T3: FYM (Farm yard Manure)	2.69	3230	6591	3161	1.92
T4: AS + 0.2 % Si as Diatomite	2.75	3080	6738	3658	2.19
T5: AS + 0.4 % Si as Diatomite	3.63	3200	8894	5794	2.78
T6: AS + 0.6 % Si as Diatomite	2.94	3120	7205	4085	2.31
T7: FY M + 0.2 % Si as Diatomite	3.44	3250	8421	4971	2.44
T8: FY M + 0.4 % Si as Diatomite	3.83	3320	9384	6064	2.83
T9: FY M + 0.6 % Si as Diatomite	3.51	3290	8609	5119	2.47

EGY: Egypt Pound

Conclusion:

The obtained results showed that application of FYM in combination with foliar application of Silicon at the rate of 0.4 % produced the highest values of wheat straw and grain yields as well as nutrient content and uptake by wheat plants followed by the application of ammonium sulphate combined with Si as foliar spray. Therefore, application of FYM or AS combined with Si foliar spray is recommended for best growth and yield of wheat in clay soil.

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