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Impact of Different Mineral Nitrogen Levels, Zeolite Amendment and Potassium Silicate on Wheat Growth and Productivity

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ABSTRACT

This study investigates the potential to reduce the recommended mineral nitrogen dose (NRD) for wheat without compromising yield by utilizing zeolite amendment and potassium silicate spraying. The experiment included main plot treatments of 100%, 80%, and 60% NRD (ammonium nitrate, 33%N). Subplots incorporated zeolite at a rate of 1.2 ton fed^{-1} (applied or not), and sub-subplots involved potassium silicate spraying at 0.0, 750, and 1000 mg L^{-1}. Key measurements included plant height, fresh and dry weights, leaf area, chlorophyll content, grain and straw yield, carbohydrates, protein content, and soil NPK levels. Results demonstrated that applying zeolite with 80% NRD and potassium silicate at 1000 mg/L outperformed the traditional 100% NRD application in terms of plant growth and yield parameters. Additionally, the zeolite amendment significantly enhanced soil NPK availability. These findings suggest that reducing the NRD to 80% when combined with zeolite and potassium silicate can maintain or even improve wheat productivity while enhancing soil fertility. Generally, integrating zeolite amendments and optimal potassium silicate application can effectively reduce nitrogen fertilizer usage without reducing wheat yield. Future research should focus on long-term impacts and the economic feasibility of this approach.

Keywords: Zeolite ,Potasium silicate, Wheat

INTRODUCTION

Wheat is a staple crop essential for global food security, necessitating optimized agricultural practices to ensure high yield and sustainability (El-Shamy *et al.* 2022). Traditionally, achieving optimal wheat production has relied heavily on the application of mineral nitrogen fertilizers (El-Sherpiny and Faiyad, 2023; Gamal *et al.* 2024). However, excessive use of these fertilizers poses environmental risks, including soil degradation, water pollution, and increased greenhouse gas emissions. Sustainable agricultural practices seek to reduce these risks by optimizing fertilizer use without compromising crop yields (Ahmed *et al.* 2017). Zeolite, a naturally occurring mineral, has shown promise in improving soil nutrient retention and enhancing plant growth (Ippolito *et al.* 2011). Its high cation exchange capacity allows for better retention of nutrients, potentially reducing the need for high fertilizer inputs. It improves soil quality by enhancing nutrient retention and availability, which helps in reducing nutrient leaching and ensuring a more consistent supply of essential minerals to plants (Szatanik-Kloc *et al.* 2021). Zeolite's ability to absorb and slowly release nutrients like ammonium, potassium, and calcium can lead to more efficient fertilizer use and improved plant growth. Additionally, its porous nature helps in maintaining soil moisture, which is particularly beneficial in drought-prone areas (Jarosz *et al.* 2022). By enhancing soil structure and fertility, zeolite supports healthier root development and overall plant vitality. These properties make zeolite a valuable amendment in sustainable farming practices, as it contributes to higher crop yields while reducing the dependency on chemical fertilizers (Elseedy *et al.* 2023). Fig 1 shows the zeolite structure.

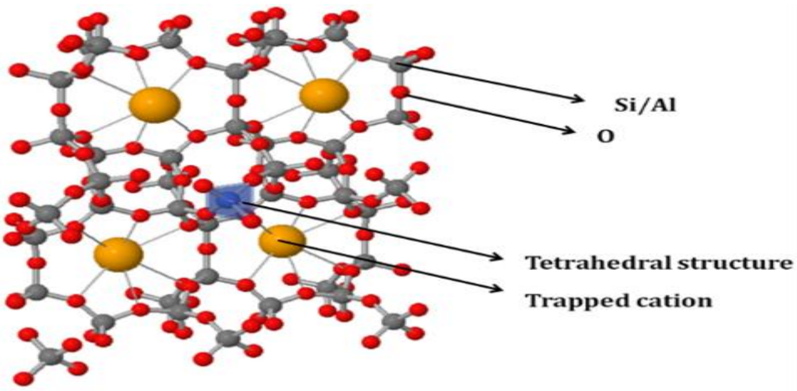

Fig 1. Zeolite structure (C.F. Mondal *et al.* 2021)

Additionally, potassium silicate has been identified as a beneficial foliar spray, enhancing plant resistance to stress and improving growth metrics. Potassium silicate is an important agricultural input known for its multiple benefits

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to plant health and growth (El-Sherpiny *et al.* 2022). It enhances the structural integrity of plants by depositing silica in cell walls, which strengthens tissues and improves resistance to biotic and abiotic stresses. This increased resilience helps plants withstand pest attacks, diseases, and environmental stresses such as drought and salinity (Soliman *et al.* 2022). Additionally, potassium silicate promotes photosynthesis by improving the leaf's light-capturing efficiency, leading to better growth and higher yields. It also plays a crucial role in nutrient uptake, particularly of essential minerals like nitrogen, phosphorus, and potassium, thereby optimizing the overall nutrient balance in plants. This makes potassium silicate a valuable tool in sustainable agriculture, as it supports plant health and productivity while potentially reducing the need for other chemical inputs (Seadh *et al.* 2024).

This study investigates the combined effects of reduced mineral nitrogen doses, zeolite amendment, and potassium silicate application on wheat growth and yield. Specifically, the study seeks to:

1. Assess the impact of various nitrogen rates (100%, 80%, and 60% of the recommended dose) on wheat growth and yield.
2. Evaluate the effectiveness of zeolite amendment in enhancing soil nutrient availability and wheat performance.
3. Investigate the role of potassium silicate spraying at different rates (0.0, 750, and 1000 mg L^{-1}) on plant growth parameters and yield.
4. Identify the optimal combination of treatments that supports sustainable wheat production with reduced nitrogen input.

By achieving these objectives, the study aims to contribute to the development of more sustainable and environmentally friendly wheat cultivation practices.

MATERIALS AND METHODS

A field experiment was conducted at a private farm located in Met Antar village, Talkha district, El-Dakahlia Governorate, Egypt. The study utilized a split-split-plot design with three replications to assess the efficacy of reducing nitrogen recommended doses (NRD) through soil addition of zeolite amendment and potassium silicate spraying across the agricultural seasons of 2022/23 and 2023/24. Main plot treatments consisted of three levels of nitrogen recommended doses: 100%, 80%, and 60% NRD using ammonium nitrate (33%N). Subplots were treated with or without zeolite at a rate of 1.2 ton fed^{-1} (applied before sowing during soil preparation), while sub-subplots received potassium silicate spraying at concentrations of 0.0, 750, and 1000 mg L^{-1}. Each sub-subplot measured 2 × 1 meters. Seeds of the Sakha 96 variety were sown on November 13^{th}. Irrigation was performed seven times throughout the growing period. Nitrogen fertilization was split into two equal doses according to the studied treatments. The first dose was applied before the second irrigation event, while the second dose was added before the third irrigation event. Phosphorus fertilization was applied as calcium superphosphate (6.6%P) during soil preparation, while potassium fertilization was done using potassium sulphate (38%K) before the third irrigation event, following the guidelines of the Ministry of Agriculture and Soil Reclamation (MASR). Potassium silicate treatments were sprayed three times at 2-week intervals, with the first application occurring 35 days after sowing. Weed, insect, and fungal disease control measures were implemented according to the guidelines of MASR. Harvesting was conducted on May 4^{th} of each season. The soil characteristics prior to sowing indicated a predominantly clay texture, with clay comprising 50%, followed by silt at 30%, and fine sand at 17 %. The content of coarse sand was recorded at 3%. The soil was classified as clayey based on its textural class. Water holding capacity (WHC) was measured at 36 %, indicating the soil's ability to retain moisture. The electrical conductivity (EC) was determined to be 3.6 dSm^{-1}, and the pH level was 8.100. Organic matter content was measured at 1.2%, contributing to soil fertility. Nutrient analysis revealed available nitrogen at 40.02 $mgkg^{-1}$, available phosphorus at 7.13 $mgkg^{-1}$ and available potassium at 204.78 mg kg^{-1}. The initial soil was analysed according to Peverill, (1999). The zeolite used in the study exhibited an electrical conductivity (EC) of 2.5 dSm^{-1}. Its cation exchange capacity (CEC) was recorded at 160 cmol kg^{-1}, indicating its ability to retain and exchange cations. The zeolite composition consisted of 63% SiO_2 and 12% AlO_3, suggesting a high silica content and aluminum oxide content, respectively.Various growth and yield parameters were assessed at different growth stages throughout the experiment. At 70 days from sowing, measurements were taken for plant height, fresh and dry weights, leaf area and chlorophyll content. Additionally, carotene content was determined using ethanol (95%) via spectrophatometer,the method described by Lichtenthaler *et al.* (1987). Leaf nutrient content, encompassing nitrogen, phosphorus, and potassium, was assessed using the methodology detailed by Reuter and Robinson, (1997). Upon harvest, various parameters were measured, including spike length and weight , weight of 1000 grains, number of grains, grain, straw yield and biological yield , and harvest index (%). Grain quality parameters such as nitrogen, phosphorus, potassium, carbohydrates and protein were also determined according to the AOAC (2000) guidelines. The available nitrogen (N), phosphorus (P), and potassium (K) levels were determined using specific methods. Available nitrogen content was assessed through a kjeldahl method described by Bremner, (1960). Available phosphorus was determined using spectrophotometer (Olsen method), as outlined by Koralage *et al.* (2015). Available potassium content was measured according to flamphotometer method, described by Angelova *et al.* (2021). These methods are commonly employed in soil nutrient analysis and provide accurate assessments of the available NPK levels in the soil.The collected data were subjected to analysis of variance (ANOVA) using the methodology described by Gomez and Gomez (1984). Statistical analysis was conducted using the CoStat computer software package (Version 6.303, CoHort, USA, 1998–2004). The significance of differences between means was determined using the least significant difference (LSD) test at a 5% probability level.

RESULTS AND DISCUSSIONS

1. Growth parameters and chemical consistent in straw at 70 days from sowing

Data in Table 1 show the impact of different mineral nitrogen levels, zeolite amendment and potassium silicate on growth parameters, including plant height, fresh and dry weights leaf area, of wheat at 70 days after sowing during the season of 2022/23 and 2023/24, while the data of Table 2 show the impact of the same treatments on leaves chlorophyll, carotene, N, P, K contents of wheat at 70 days after sowing during the season of 2022/23 and 2023/24.

Higher nitrogen levels significantly increased plant height, with 100% NRD showing the greatest height (102.94 cm in 2022/23, 106.06 cm in 2023/24) and 60% NRD the least (81.95 cm in 2022/23, 85.19 cm in 2023/24). Similarly, fresh weight (41.90 g/plant in 2022/23, 43.17 g/plant in 2023/24) and dry weight (13.74 g/plant in 2022/23, 14.43 g/plant in 2023/24) were highest with 100% NRD. The highest leaf area was also observed with 100% NRD (126.03 cm²/plant in 2022/23, 129.75 cm²/plant in 2023/24). Zeolite amendment significantly increased plant height (99.16 cm in 2022/23, 102.85 cm in 2023/24) compared to without zeolite (87.56 cm in 2022/23, 90.56 cm in 2023/24).Fresh weight (40.27 g/plant in 2022/23, 41.76 g/plant in 2023/24) and dry weight (12.80 g/plant in 2022/23, 13.44 g/plant in 2023/24) were also higher with zeolite. Leaf area was significantly larger with zeolite (120.25 cm²/plant in 2022/23, 124.67 cm²/plant in 2023/24).Higher potassium silicate levels (1000 mg/L) led to the greatest plant height (95.04 cm in 2022/23, 98.56 cm in 2023/24). Fresh (39.74 g/plant in 2022/23, 41.21 g/plant in 2023/24) and dry weight (12.46 g/plant in 2022/23, 13.09 g/plant in 2023/24) increased with higher potassium silicate. Leaf area increased with higher potassium silicate levels (117.82 cm²/plant in 2022/23, 122.14 cm²/plant in 2023/24).

The combination of 100% NRD and zeolite showed the highest plant height, fresh weight, dry weight, and leaf area compared to lower nitrogen levels or without zeolite. The combination of 100% NRD, zeolite, and 1000 mg/L potassium silicate showed the highest values across all growth parameters. Also, the data demonstrated that applying zeolite with 80% NRD and potassium silicate at 1000 mg/L outperformed the traditional 100% NRD application in terms of plant growth.

Table 1. Impact of different mineral nitrogen levels, zeolite amendment and potassium silicate on growth parameters of wheat at 70 days after sowing during the season of 2022/23 and 2023/24

Treatments			Plant height cm		Fresh weight g/plant		Dry weight g/plant		Leaf area cm^2/plant	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
main										
100% of NRD			102.94a	106.06a	41.90a	43.17a	13.74a	14.43a	126.03a	129.75a
80% of NRD			94.55b	98.21b	40.18b	41.68b	12.78b	13.41b	121.40b	126.35b
60% of NRD			81.95c	85.19c	35.30c	36.70c	9.62c	10.09c	101.76c	105.81c
LSD at 5%			0.66	0.66	0.06	0.07	0.13	0.10	1.24	1.24
Sub										
Without zeolite			87.56b	90.56b	38.04b	39.35b	11.33b	11.89b	112.75b	116.87b
With zeolite			99.16a	102.85a	40.27a	41.76a	12.80a	13.44a	120.25a	124.67a
LSD at 5%			0.53	0.75	0.30	031	0.06	0.08	0.72	0.59
Sub sub										
Without spraying			91.44c	94.67c	38.67c	40.03c	11.69c	12.26c	115.15c	119.47c
Potassium silicate (750 mgL^{-1})			93.60b	96.88b	39.05b	40.43b	12.04b	12.65b	116.52b	120.70b
Potassium silicate (1000 mgL^{-1})			95.04a	98.56a	39.74a	41.21a	12.46a	13.09a	117.82a	122.14a
LSD at 5%			0.64	0.61	0.35	0.36	0.12	0.09	1.11	1.15
Interaction										
100% of NRD	Without zeolite	Without spraying	93.44	96.43	39.65	40.92	12.68	13.32	120.16	123.54
		Potassium silicate (750 mgL^{-1})	96.80	99.69	40.15	41.40	13.00	13.66	121.77	125.47
		Potassium silicate (1000 mgL^{-1})	97.75	100.71	40.72	41.94	13.03	13.67	121.99	125.34
	With zeolite	Without spraying	107.56	110.86	42.27	43.54	14.31	14.98	128.67	132.81
		Potassium silicate (750 mgL^{-1})	110.61	113.61	43.18	44.39	14.49	15.25	131.01	134.86
		Potassium silicate (1000 mgL^{-1})	111.48	115.06	45.44	46.85	14.91	15.69	132.59	136.47
80% of NRD	Without zeolite	Without spraying	86.87	89.51	38.38	39.57	11.66	12.19	114.66	119.64
		Potassium silicate (750 mgL^{-1})	87.53	90.07	38.91	40.04	12.07	12.74	117.11	121.59
		Potassium silicate (1000 mgL^{-1})	88.87	92.56	39.40	41.06	12.48	13.14	118.00	123.42
	With zeolite	Without spraying	99.67	103.73	41.36	43.01	13.10	13.75	125.66	131.08
		Potassium silicate (750 mgL^{-1})	102.61	107.34	41.41	43.32	13.78	14.41	126.32	131.25
		Potassium silicate (1000 mgL^{-1})	105.59	110.00	42.04	43.81	13.91	14.62	128.46	133.47
60% of NRD	Without zeolite	Without spraying	78.09	81.23	34.87	36.27	8.77	9.21	99.72	103.50
		Potassium silicate (750 mgL^{-1})	78.99	82.06	35.06	36.43	8.91	9.31	100.16	104.15
		Potassium silicate (1000 mgL^{-1})	79.70	82.73	35.20	36.53	9.34	9.78	101.15	105.17
	With zeolite	Without spraying	83.01	86.25	35.51	36.90	9.60	10.08	102.05	106.24
		Potassium silicate (750 mgL^{-1})	85.04	88.53	35.56	37.02	10.02	10.54	102.72	106.87
		Potassium silicate (1000 mgL^{-1})	86.83	90.31	35.62	37.04	11.07	11.62	104.74	108.94
LSD at 5%			1.56	1.49	0.86	0.88	0.28	0.22	2.72	2.82

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

The impact of different mineral nitrogen levels, zeolite amendment, and potassium silicate application on chlorophyll, carotene, nitrogen (N), phosphorus (P), and potassium (K) contents of wheat leaves at 70 days after sowing during the 2022/23 and 2023/24 seasons is summarized in Table 2. The 100% NRD treatment resulted in the highest chlorophyll content (41.58 SPAD in 2022/23 and 43.39 SPAD in 2023/24).The 80% NRD treatment had a slightly lower chlorophyll content (40.19 SPAD in 2022/23 and 41.04 SPAD in 2023/24).The 60% NRD treatment showed the lowest chlorophyll content (36.61 SPAD in 2022/23 and 37.51 SPAD in 2023/24). Carotene content was highest in the 100% NRD treatment (0.287 mg.g⁻¹ in 2022/23 and 0.299 mg.g⁻¹ in 2023/24). It decreased with the 80% NRD treatment (0.269 mg.g⁻¹ in 2022/23 and 0.280 mg.g⁻¹ in 2023/24).The lowest carotene content was observed in the 60% NRD treatment (0.228 mg.g⁻¹ in 2022/23 and 0.237 mg.g⁻¹ in 2023/24).The highest nitrogen content was found in the 100% NRD treatment (3.45% in 2022/23 and 3.49% in 2023/24).The 80% NRD treatment showed a moderate decrease (3.26% in 2022/23 and 3.31% in 2023/24).The 60% NRD treatment had the lowest nitrogen content (2.77% in 2022/23 and 2.80% in 2023/24).The 100% NRD treatment also had the highest phosphorus content (0.339% in 2022/23 and 0.353% in 2023/24). Phosphorus content was lower in the 80% NRD treatment (0.325% in 2022/23 and 0.338% in 2023/24).The 60% NRD treatment exhibited the lowest phosphorus content (0.286% in 2022/23 and 0.298% in 2023/24).Potassium content was highest in the 100% NRD treatment (2.94% in 2022/23 and 3.00% in 2023/24).It decreased with the 80% NRD treatment (2.74% in 2022/23 and 2.79% in 2023/24).The lowest potassium content was found in the 60% NRD treatment (2.32% in 2022/23 and 2.37% in 2023/24).

Zeolite amendment significantly increased chlorophyll content (40.54 SPAD in 2022/23 and 41.81 SPAD in 2023/24) compared to no zeolite (38.43 SPAD in 2022/23 and 39.55 SPAD in 2023/24). Carotene content was higher with zeolite amendment (0.275 mg.g⁻¹ in 2022/23 and 0.286 mg.g⁻¹ in 2023/24) than without (0.248 mg.g⁻¹ in 2022/23 and 0.259 mg.g⁻¹ in 2023/24).Nitrogen content increased with zeolite amendment (3.31% in 2022/23 and 3.35% in 2023/24) compared to no zeolite (3.02% in 2022/23 and 3.06% in 2023/24). Phosphorus content was higher with zeolite amendment (0.329% in 2022/23 and 0.343% in 2023/24) than without (0.305% in 2022/23 and 0.318% in 2023/24).Potassium content increased with zeolite amendment (2.83% in 2022/23 and 2.89% in 2023/24) compared to no zeolite (2.51% in 2022/23 and 2.56% in 2023/24).

Table 2. Impact of different mineral nitrogen levels, zeolite amendment and potassium silicate on leaves chlorophyll, carotene, N, P, K contents of wheat at 70 days after sowing during the season of 2022/23 and 2023/24

Treatments			Chlorophyll SPAD		Carotene mg.g^{-1}		N %		P %		K %	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
main												
100% of NRD			41.58a	43.39a	0.287a	0.299a	3.45a	3.49a	0.339a	0.353a	2.94a	3.00a
80% of NRD			40.19b	41.04b	0.269b	0.280b	3.26b	3.31b	0.325b	0.338b	2.74b	2.79b
60% of NRD			36.61c	37.51c	0.228c	0.237c	2.77c	2.80c	0.286c	0.298c	2.32c	2.37c
LSD at 5%			0.70	0.36	0.004	0.003	0.05	0.06	0.004	0.004	0.03	0.02
Sub												
Without zeolite			38.43b	39.55b	0.248b	0.259b	3.02b	3.06b	0.305b	0.318b	2.51b	2.56b
With zeolite			40.54a	41.81a	0.275a	0.286a	3.31a	3.35a	0.329a	0.343a	2.83a	2.89a
LSD at 5%			0.40	0.22	0.002	0.004	0.03	0.03	0.005	0.004	0.02	0.01
Sub sub												
Without spraying			39.13b	40.28b	0.256c	0.266c	3.11c	3.15c	0.313c	0.326c	2.61c	2.66c
Potassium silicate (750 mgL^{-1})			39.45b	40.60b	0.261b	0.272b	3.17b	3.22b	0.316b	0.329b	2.67b	2.72b
Potassium silicate (1000 mgL^{-1})			39.86a	41.15a	0.268a	0.279a	3.22a	3.26a	0.323a	0.336a	2.74a	2.79a
LSD at 5%			0.37	0.40	0.002	0.002	0.03	0.03	0.002	0.002	0.03	0.03
Interaction												
100% of NRD	Without zeolite	Without spraying	40.41	42.12	0.268	0.279	3.22	3.27	0.323	0.336	2.68	2.74
		Potassium silicate (750 mgL^{-1})	40.76	42.53	0.273	0.285	3.31	3.36	0.325	0.340	2.72	2.77
		Potassium silicate (1000 mgL^{-1})	40.79	42.56	0.278	0.290	3.34	3.36	0.329	0.343	2.83	2.89
	With zeolite	Without spraying	42.08	43.90	0.294	0.306	3.58	3.63	0.349	0.363	3.07	3.13
		Potassium silicate (750 mgL^{-1})	42.68	44.40	0.300	0.312	3.61	3.66	0.353	0.367	3.14	3.19
		Potassium silicate (1000 mgL^{-1})	42.77	44.80	0.308	0.322	3.66	3.70	0.357	0.371	3.21	3.27
80% of NRD	Without zeolite	Without spraying	38.62	39.47	0.249	0.259	3.02	3.05	0.306	0.318	2.52	2.57
		Potassium silicate (750 mgL^{-1})	38.71	39.57	0.254	0.264	3.09	3.14	0.307	0.320	2.55	2.60
		Potassium silicate (1000 mgL^{-1})	39.49	40.34	0.262	0.272	3.15	3.19	0.320	0.333	2.64	2.69
	With zeolite	Without spraying	41.27	42.30	0.281	0.292	3.42	3.48	0.338	0.352	2.88	2.93
		Potassium silicate (750 mgL^{-1})	41.50	42.37	0.286	0.297	3.43	3.51	0.339	0.354	2.91	2.97
		Potassium silicate (1000 mgL^{-1})	41.91	42.75	0.291	0.303	3.54	3.61	0.347	0.362	2.99	3.06
60% of NRD	Without zeolite	Without spraying	35.46	36.21	0.211	0.219	2.66	2.69	0.274	0.286	2.13	2.18
		Potassium silicate (750 mgL^{-1})	35.58	36.43	0.218	0.227	2.71	2.75	0.277	0.288	2.25	2.30
		Potassium silicate (1000 mgL^{-1})	36.00	36.69	0.225	0.235	2.73	2.77	0.283	0.296	2.28	2.32
	With zeolite	Without spraying	36.92	37.69	0.231	0.241	2.77	2.79	0.287	0.299	2.37	2.41
		Potassium silicate (750 mgL^{-1})	37.48	38.29	0.238	0.248	2.85	2.89	0.296	0.308	2.43	2.49
		Potassium silicate (1000 mgL^{-1})	38.22	39.74	0.244	0.254	2.88	2.92	0.301	0.313	2.49	2.54
LSD at 5%			0.91	0.98	0.006	0.004	0.07	0.08	0.005	0.005	0.06	0.07

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

The highest chlorophyll content was achieved with 1000 mg/L potassium silicate spraying (39.86 SPAD in 2022/23 and 41.15 SPAD in 2023/24), followed by 750 mg/L (39.45 SPAD in 2022/23 and 40.60 SPAD in 2023/24), and no spraying (39.13 SPAD in 2022/23 and 40.28 SPAD in 2023/24). Carotene content was highest with 1000 mg/L potassium silicate spraying (0.268 mg.g⁻¹ in 2022/23 and 0.279 mg.g⁻¹ in 2023/24), followed by 750 mg/L (0.261 mg.g⁻¹ in 2022/23 and 0.272 mg.g⁻¹ in 2023/24), and no spraying (0.256 mg.g⁻¹ in 2022/23 and 0.266 mg.g⁻¹ in 2023/24).The highest nitrogen content was observed with 1000 mg/L potassium silicate spraying

(3.22% in 2022/23 and 3.26% in 2023/24), followed by 750 mg/L (3.17% in 2022/23 and 3.22% in 2023/24), and no spraying (3.11% in 2022/23 and 3.15% in 2023/24).Phosphorus content was highest with 1000 mg/L potassium silicate spraying (0.323% in 2022/23 and 0.336% in 2023/24), followed by 750 mg/L (0.316% in 2022/23 and 0.329% in 2023/24), and no spraying (0.313% in 2022/23 and 0.326% in 2023/24).The highest potassium content was achieved with 1000 mg/L potassium silicate spraying (2.74% in 2022/23 and 2.79% in 2023/24), followed by 750 mg/L (2.67% in 2022/23 and 2.72% in 2023/24), and no spraying (2.61% in 2022/23 and 2.66% in 2023/24).

The combination of 100% NRD and zeolite showed the highest chlorophyll, carotene, nitrogen, phosphorus, and potassium contents in wheat leaves compared to lower nitrogen levels or without zeolite. The combination of 100% NRD, zeolite, and 1000 mg/L potassium silicate showed the highest values across all leaves chemical constitutes. Also, the data demonstrated that applying zeolite with 80% NRD and potassium silicate at 1000 mg/L outperformed the traditional 100% NRD application in terms of leaves chemical constituents.

Yield and Grain Quality

Table 3 presents the effects of different mineral nitrogen levels, zeolite amendment, and potassium silicate on wheat yield components, including spike length, spike weight, weight of 1000 grains, and the number of grains per spike. Table 4 highlights the impact of these treatments on wheat yield metrics such as grain yield, straw yield, biological yield, and harvest index. Table 5 examines the influence of the same treatments on wheat grain quality, measuring the percentages of nitrogen, phosphorus, potassium, carbohydrates, and protein.

The highest values for all the aforementioned traits were recorded with 100% NRD, followed by 80% NRD, and then 60% NRD. Additionally, the highest values were observed with zeolite amendment compared to the control group. Furthermore, the values increased progressively with higher levels of potassium silicate, from 0.0 to 750 mg/L, and then to 1000 mg/L.

Regarding the interaction effects, the results indicate that the highest values were achieved with the treatment combining 100% NRD and zeolite, especially when supplemented with 1000 mg/L potassium silicate. The lowest values across these yield components were observed with the 60% NRD treatment without zeolite and potassium silicate. Additionally, the data demonstrated that applying zeolite with 80% NRD and 1000 mg/L potassium silicate outperformed the traditional 100% NRD application in terms of all the aforementioned traits.

Table 3. Impact of different mineral nitrogen levels, zeolite amendment and potassium silicate on yield components of wheat at 70 days after sowing during the season of 2022/23 and 2023/24

Treatments			Spike length cm		Spike weight g		Weight of 1000 grain g		No. grain/spike	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
main										
100% of NRD			19.13a	19.45a	5.51a	5.68a	49.47a	51.57a	32.11a	32.78a
80% of NRD			18.25b	18.49b	4.99b	5.19b	47.95b	48.93b	29.12b	29.71b
60% of NRD			14.96c	15.18c	3.46c	3.60c	46.17c	47.30c	22.78c	23.83c
LSD at 5%			0.28	0.18	0.05	0.03	0.88	0.76	0.59	0.72
Sub										
Without zeolite			16.70b	16.93b	4.20b	4.36b	47.12b	48.48b	25.52b	26.15b
With zeolite			18.23a	18.53a	5.14a	5.32a	48.62a	50.09a	30.67a	31.56a
LSD at 5%			0.15	0.09	0.02	0.03	0.28	0.49	0.94	0.68
Sub sub										
Without spraying			17.22c	17.48b	4.52c	4.68c	47.56b	48.92b	27.28b	28.06b
Potassium silicate (750 mgL^{-1})			17.37b	17.63b	4.65b	4.82b	47.80b	49.14b	27.94b	28.61b
Potassium silicate (1000 mgL^{-1})			17.80a	18.08a	4.84a	5.02a	48.25a	49.80a	29.06a	29.89a
LSD at 5%			0.13	0.17	0.04	0.05	0.44	0.46	0.70	0.91
Interaction										
100% of NRD	Without zeolite	Without spraying	17.78	18.04	4.76	4.91	47.90	49.79	27.67	28.00
		Potassium silicate (750 mgL^{-1})	17.97	18.26	4.94	5.08	48.41	50.48	28.33	28.67
		Potassium silicate (1000 mgL^{-1})	18.59	18.85	5.30	5.45	48.76	50.86	29.67	30.00
	With zeolite	Without spraying	19.96	20.33	5.97	6.16	50.11	52.19	35.33	35.67
		Potassium silicate (750 mgL^{-1})	20.06	20.44	6.01	6.21	50.13	52.19	35.67	36.33
		Potassium silicate (1000 mgL^{-1})	20.39	20.79	6.10	6.28	51.48	53.87	36.00	38.00
80% of NRD	Without zeolite	Without spraying	17.25	17.50	4.24	4.42	46.62	47.63	25.00	26.00
		Potassium silicate (750 mgL^{-1})	17.37	17.60	4.41	4.59	46.79	47.74	26.00	26.33
		Potassium silicate (1000 mgL^{-1})	17.68	17.93	4.59	4.79	47.65	48.78	27.33	27.67
	With zeolite	Without spraying	18.88	19.13	5.49	5.71	48.76	49.89	31.67	32.00
		Potassium silicate (750 mgL^{-1})	19.16	19.43	5.66	5.89	48.97	49.92	32.33	33.00
		Potassium silicate (1000 mgL^{-1})	19.46	19.79	5.82	6.05	49.06	49.98	34.00	34.67
60% of NRD	Without zeolite	Without spraying	14.40	14.58	3.10	3.22	45.77	46.82	21.00	22.33
		Potassium silicate (750 mgL^{-1})	14.47	14.67	3.15	3.27	46.08	47.20	22.00	22.67
		Potassium silicate (1000 mgL^{-1})	14.79	14.98	3.34	3.48	46.08	47.04	22.67	23.67
	With zeolite	Without spraying	15.07	15.32	3.52	3.66	46.20	47.18	23.00	24.33
		Potassium silicate (750 mgL^{-1})	15.18	15.39	3.73	3.88	46.42	47.31	23.33	24.67
		Potassium silicate (1000 mgL^{-1})	15.87	16.12	3.92	4.08	46.47	48.27	24.67	25.33
LSD at 5%			0.32	0.42	0.11	0.12	1.10	1.11	1.71	2.22

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 4. Impact of different mineral nitrogen levels, zeolite amendment and potassium silicate on yield of wheat at 70 days after sowing during the season of 2022/23 and 2023/24

Treatments			Grain yield(ton/hectare)		straw yield (ton/hectare)		Biological yield(ton/hectare)		Harvest index %	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
main										
100% of NRD			6.20a	6.51a	8.52a	8.96a	14.72a	15.47a	42.08a	42.06a
80% of NRD			5.74b	6.02b	8.04b	8.43b	13.78b	14.45b	41.62b	41.65b
60% of NRD			4.65c	4.88c	6.82c	7.16	11.47c	12.04c	40.50c	40.49c
LSD at 5%			0.09	0.06	0.13	0.02c	0.22	0.07	0.01	0.23
Sub										
Without zeolite			5.21b	5.47b	7.48b	7.85b	12.69b	13.32b	41.00b	41.00b
With zeolite			5.86a	6.16a	8.13a	8.54a	13.99a	14.70a	41.82a	41.83a
LSD at 5%			0.05	0.03	0.08	0.06	0.13	0.09	0.01	0.14
Sub sub										
Without spraying			5.41c	5.69c	7.66c	8.05c	13.07c	13.74c	41.30c	41.31a
Potassium silicate (750 mgL^{-1})			5.55b	5.83b	7.78b	8.17b	13.33b	13.99b	41.56b	41.56a
Potassium silicate (1000 mgL^{-1})			5.65a	5.93a	7.97a	8.37a	13.62a	14.30a	41.38a	41.37a
LSD at 5%			0.05	0.06	0.07	0.07	0.13	0.09	0.01	n.s
Interaction										
100% of NRD	Without zeolite	Without spraying	5.73	6.03	8.08	8.48	13.81	14.51	41.50	41.58
		Potassium silicate (750 mgL^{-1})	5.82	6.10	8.14	8.55	13.95	14.66	41.69	41.64
		Potassium silicate (1000 mgL^{-1})	5.92	6.21	8.35	8.78	14.28	14.98	41.49	41.43
	With zeolite	Without spraying	6.39	6.71	8.73	9.14	15.12	15.86	42.27	42.34
		Potassium silicate (750 mgL^{-1})	6.61	6.94	8.84	9.34	15.45	16.29	42.76	42.63
		Potassium silicate (1000 mgL^{-1})	6.71	7.05	8.98	9.44	15.70	16.50	42.77	42.75
80% of NRD	Without zeolite	Without spraying	5.28	5.53	7.32	7.70	12.60	13.23	41.89	41.80
		Potassium silicate (750 mgL^{-1})	5.38	5.68	7.54	7.89	12.92	13.57	41.65	41.87
		Potassium silicate (1000 mgL^{-1})	5.44	5.71	7.99	8.40	13.43	14.12	40.51	40.47
	With zeolite	Without spraying	6.04	6.35	8.42	8.86	14.46	15.21	41.75	41.75
		Potassium silicate (750 mgL^{-1})	6.14	6.42	8.51	8.90	14.65	15.33	41.92	41.91
		Potassium silicate (1000 mgL^{-1})	6.29	6.63	8.61	9.03	14.90	15.66	42.23	42.33
60% of NRD	Without zeolite	Without spraying	4.36	4.58	6.53	6.87	10.90	11.45	40.04	40.03
		Potassium silicate (750 mgL^{-1})	4.45	4.65	6.62	6.92	11.07	11.57	40.22	40.19
		Potassium silicate (1000 mgL^{-1})	4.50	4.70	6.73	7.05	11.23	11.76	40.04	40.00
	With zeolite	Without spraying	4.67	4.91	6.90	7.25	11.57	12.16	40.36	40.39
		Potassium silicate (750 mgL^{-1})	4.90	5.16	7.02	7.39	11.91	12.55	41.10	41.12
		Potassium silicate (1000 mgL^{-1})	5.01	5.27	7.14	7.51	12.15	12.78	41.25	41.22
LSD at 5%			0.13	0.14	0.18	0.18	0.31	0.23	0.02	0.81

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 5. Impact of different mineral nitrogen levels, zeolite amendment and potassium silicate on grain quality of wheat at 70 days after sowing during the season of 2022/23 and 2023/24

Treatments			N %		P %		K %		Carbohydrates %		Protein %	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
main												
100% of NRD			2.20a	2.30a	0.266a	0.279a	2.42a	2.54a	67.51a	69.50a	12.66a	13.20a
80% of NRD			2.04b	2.08b	0.246b	0.258b	2.26b	2.37b	66.40b	69.12a	11.74b	11.97b
60% of NRD			1.48c	1.51c	0.202c	0.212c	1.76c	1.85c	62.91c	65.41b	8.49c	8.69c
LSD at 5%			0.03	0.05	0.004	0.003	0.02	0.01	1.01	0.66	0.15	0.28
Sub												
Without zeolite			1.77b	1.82b	0.222b	0.233b	2.00b	2.10b	64.59b	66.96b	10.19b	10.48b
With zeolite			2.05a	2.11a	0.255a	0.268a	2.30a	2.41a	66.65a	69.12a	11.78a	12.13a
LSD at 5%			0.01	0.05	0.002	0.004	0.01	0.01	0.60	0.32	0.06	0.15
Sub sub												
Without spraying			1.85c	1.90c	0.232c	0.244c	2.09c	2.19c	65.19ab	67.62ab	10.64c	10.95c
Potassium silicate (750 mgL^{-1})			1.91b	1.96b	0.238b	0.251b	2.15b	2.26b	65.59b	68.00b	11.00b	11.30b
Potassium silicate (1000 mgL^{-1})			1.97a	2.03a	0.245a	0.257a	2.21a	2.32a	66.08a	68.49a	11.31a	11.67a
LSD at 5%			0.02	0.03	0.002	0.001	0.02	0.02	0.49	0.65	0.12	0.25
Interaction												
100% of NRD	Without zeolite	Without spraying	2.02	2.10	0.238	0.251	2.21	2.32	65.87	67.76	11.62	12.08
		Potassium silicate (750 mgL^{-1})	2.11	2.20	0.246	0.258	2.27	2.39	66.06	68.05	12.13	12.63
		Potassium silicate (1000 mgL^{-1})	2.14	2.23	0.256	0.269	2.31	2.43	66.57	68.37	12.29	12.80
	With zeolite	Without spraying	2.27	2.37	0.280	0.293	2.53	2.65	68.09	70.31	13.05	13.63
		Potassium silicate (750 mgL^{-1})	2.32	2.41	0.286	0.301	2.56	2.70	69.10	71.22	13.32	13.86
		Potassium silicate (1000 mgL^{-1})	2.36	2.47	0.290	0.305	2.62	2.76	69.34	71.26	13.55	14.18
80% of NRD	Without zeolite	Without spraying	1.84	1.88	0.223	0.233	2.12	2.23	64.97	67.79	10.56	10.81
		Potassium silicate (750 mgL^{-1})	1.87	1.91	0.229	0.242	2.14	2.24	65.25	67.84	10.75	10.96
		Potassium silicate (1000 mgL^{-1})	1.99	2.03	0.232	0.244	2.18	2.29	65.37	68.31	11.42	11.67
	With zeolite	Without spraying	2.18	2.23	0.262	0.275	2.36	2.48	67.40	70.24	12.54	12.82
		Potassium silicate (750 mgL^{-1})	2.20	2.24	0.267	0.279	2.39	2.50	67.57	70.28	12.63	12.86
		Potassium silicate (1000 mgL^{-1})	2.23	2.27	0.274	0.288	2.44	2.55	68.10	70.83	12.82	13.03
60% of NRD	Without zeolite	Without spraying	1.29	1.32	0.186	0.195	1.52	1.60	61.95	64.21	7.42	7.57
		Potassium silicate (750 mgL^{-1})	1.32	1.35	0.192	0.201	1.59	1.66	62.37	64.85	7.59	7.76
		Potassium silicate (1000 mgL^{-1})	1.37	1.40	0.196	0.205	1.68	1.76	62.92	65.42	7.88	8.03
	With zeolite	Without spraying	1.50	1.53	0.206	0.217	1.80	1.89	62.85	65.43	8.63	8.78
		Potassium silicate (750 mgL^{-1})	1.66	1.69	0.211	0.222	1.95	2.05	63.20	65.78	9.55	9.70
		Potassium silicate (1000 mgL^{-1})	1.72	1.79	0.220	0.231	2.05	2.15	64.18	66.75	9.89	10.29
LSD at 5%			0.05	0.11	0.006	0.003	0.05	0.06	1.20	1.60	0.29	0.61

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

2.Soil properties at harvest stage

Table 6 presents the impact of different mineral nitrogen levels, zeolite amendment, and potassium silicate on available soil NPK levels at the harvest stage over two consecutive seasons. The table displays measurements of nitrogen (N), phosphorus (P), and potassium (K) in mg/kg of soil.The data suggests that the effect of potassium silicate on soil NPK levels was not statistically significant, as indicated by the lack of significant differences among treatments with varying concentrations of potassium silicate. Conversely, the effect of zeolite amendment appears to be significant, leading to noticeable increases in the soil's content of available nitrogen, phosphorus, and potassium. This suggests that zeolite application positively influenced the soil's nutrient availability, potentially enhancing nutrient uptake by wheat plants during the growth period.Overall, while potassium silicate did not demonstrate a substantial impact on soil NPK levels, zeolite proved to be a beneficial soil amendment, contributing to enhanced nutrient availability in the soil. This underscores the importance of considering various soil amendments and their effects on nutrient dynamics when managing agricultural systems.

Table 6. Impact of different mineral nitrogen levels, zeolite amendment and potassium silicate on available soil NPK at harvest stage during the season of 2022/23 and 2023/24

Treatments			N $mgkg^{-1}$		P $mgkg^{-1}$		K $mgkg^{-1}$	
			1st	2nd	1st	2nd	1st	2nd
main								
100% of NRD			45.76a	47.15a	9.12c	9.61c	218.65c	227.75c
80% of NRD			43.94b	45.74b	9.86b	10.05b	225.41b	233.48b
60% of NRD			42.59c	44.15c	10.48a	10.39a	231.14a	239.50a
LSD at 5%			0.41	0.47	0.23	0.11	0.54	2.18
Sub								
Without zeolite			43.26b	44.85b	9.35b	9.35b	215.35b	223.55b
With zeolite			44.98a	46.57a	10.29a	10.70a	234.85a	243.77a
LSD at 5%			0.25	0.27	0.13	0.10	1.68	1.18
Sub sub								
Without spraying			44.31a	45.90a	9.94a	10.14a	226.94a	235.70a
Potassium silicate (750 mgL^{-1})			44.12a	45.79ab	9.85ab	10.05a	225.16ab	234.00a
Potassium silicate (1000 mgL^{-1})			43.93a	45.46b	9.67b	9.88b	223.21b	231.28b
LSD at 5%			n.s	0.44	0.21	0.10	2.00	2.23
Interaction								
100% of NRD	Without zeolite	Without spraying	45.44	46.89	8.76	8.96	210.76	219.12
		Potassium silicate (750 mgL^{-1})	45.44	46.79	8.77	8.94	209.34	217.74
		Potassium silicate (1000 mgL^{-1})	44.93	46.21	8.63	8.80	208.80	217.36
	With zeolite	Without spraying	46.45	47.84	9.58	10.54	227.82	238.08
		Potassium silicate (750 mgL^{-1})	46.26	47.77	9.47	10.43	227.83	237.30
		Potassium silicate (1000 mgL^{-1})	46.06	47.39	9.48	9.96	227.36	236.91
80% of NRD	Without zeolite	Without spraying	42.64	44.33	9.40	9.58	216.83	225.58
		Potassium silicate (750 mgL^{-1})	42.28	44.04	9.29	9.49	214.83	224.67
		Potassium silicate (1000 mgL^{-1})	42.21	43.94	9.01	9.23	214.74	222.07
	With zeolite	Without spraying	45.67	47.63	10.62	10.82	239.68	247.35
		Potassium silicate (750 mgL^{-1})	45.60	47.60	10.53	10.74	236.76	244.81
		Potassium silicate (1000 mgL^{-1})	45.59	47.50	10.37	10.61	230.25	237.85
60% of NRD	Without zeolite	Without spraying	42.18	43.87	10.33	9.77	224.22	231.38
		Potassium silicate (750 mgL^{-1})	42.21	44.11	10.22	9.69	220.49	228.17
		Potassium silicate (1000 mgL^{-1})	41.99	43.49	9.77	9.66	218.15	225.83
	With zeolite	Without spraying	43.47	44.82	10.96	11.17	242.34	252.67
		Potassium silicate (750 mgL^{-1})	42.91	44.39	10.82	11.02	241.69	251.30
		Potassium silicate (1000 mgL^{-1})	42.79	44.19	10.79	11.04	239.95	247.65
LSD at 5%			1.04	1.07	0.52	0.23	4.90	5.46

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Nitrogen is a crucial nutrient for plant growth, playing a vital role in numerous physiological processes (Sanchez-Bragado *et al.* 2017). It is a key component of amino acids, the building blocks of proteins, and is also found in nucleic acids, chlorophyll, and ATP. As a major constituent of chlorophyll, nitrogen is directly involved in photosynthesis, enabling plants to convert sunlight into energy. This is why adequate nitrogen levels are associated with higher chlorophyll content, which in turn enhances photosynthetic efficiency and overall plant productivity (Fradgley *et al.* 2021). Nitrogen deficiency can lead to reduced chlorophyll production, resulting in pale, yellow leaves (chlorosis) and stunted growth. Conversely, sufficient nitrogen availability promotes vigorous vegetative growth, increased leaf area, and higher biomass accumulation (Kubar *et al.* 2022; Hnizil *et al.* 2024). This study's findings that the 100% NRD treatment led to the highest chlorophyll, carotene, and nutrient contents in wheat leaves underscore the importance of optimal nitrogen supply for maximizing plant health and productivity.

Zeolite is a naturally occurring mineral with a high cation exchange capacity (CEC), which allows it to adsorb and retain nutrients, including nitrogen, in the soil (Ippolito *et al.* 2011). This property makes zeolite an effective soil amendment for improving nutrient availability and reducing nitrogen leaching (Szatanik-Kloc *et al.* 2021). By holding onto nitrogen ions, zeolite ensures a more steady supply of this essential nutrient to plants, especially during critical growth stages (Jarosz *et al.* 2022). The zeolite's ability to enhance soil's physical and chemical properties can lead to improved water retention and root penetration, further aiding in efficient nutrient uptake (Elseedy *et al.* 2023). The significant improvements in chlorophyll, carotene, nutrient contents and yield traits observed in the zeolite-amended treatments in this study are consistent with previous research showing that zeolite can enhance nitrogen use efficiency and overall plant performance.

Potassium silicate plays a multifaceted role in enhancing plant performance. As a source of both potassium and silicon, it contributes to improved plant health and stress tolerance (El-Sherpiny *et al.* 2022). Potassium is essential for various physiological processes, including enzyme activation, osmoregulation, and stomatal function, which are crucial for maintaining water balance and photosynthetic efficiency (Soliman *et al.* 2022). Silicon, on the other hand, is known to fortify plant cell walls, improving structural integrity and resistance to biotic and abiotic stresses. Silicon enhances plants' ability to withstand diseases, pests, and environmental stresses such as drought and salinity. Additionally, silicon can stimulate antioxidant defense mechanisms, thereby reducing oxidative damage in plants (Seadh *et al.* 2024).

In this study, the highest values for plant growth performance, chlorophyll, carotene, nutrient contents, yield and its components were achieved with the combined application of 100% NRD, zeolite, and 1000 mg/L potassium silicate. This suggests that potassium silicate not only supplements essential nutrients but also enhances the overall efficiency of nutrient utilization and stress resilience, leading to superior plant growth and development. The combination of 100% NRD and zeolite showed the highest plant growth performance, chlorophyll, carotene, nutrient contents, yield and its components, indicating that optimal nitrogen supply, along with zeolite amendment, can significantly enhance wheat growth and nutrient accumulation. Furthermore, the addition of 1000 mg/L potassium silicate to this combination resulted in the highest overall values for all measured parameters, highlighting the synergistic effects of these treatments. Interestingly, the data also demonstrated that applying zeolite with 80% NRD and potassium silicate at 1000 mg/L outperformed the traditional 100% NRD application in terms of growth parameters, leaf chemical constituents and yield. This suggests that integrating zeolite and potassium silicate can potentially reduce the need for high nitrogen inputs while still achieving superior plant performance. The obtained results are in harmony with those of Jakkula and Wani, (2018); Abdel Fatah and Khalil, (2020); Rodrigues *et al.* (2021).

CONCLUSION

The study concludes that integrating zeolite amendment and potassium silicate application can significantly reduce the required dose of mineral nitrogen fertilizer without compromising wheat yield. Specifically, applying zeolite in conjunction with 80% of the recommended nitrogen dose and spraying potassium silicate at 1000 mg/L yielded better results than using the full recommended nitrogen dose alone. This approach not only maintains high productivity but also enhances soil nutrient content, particularly NPK levels, thus promoting long-term soil health. Based on these findings, it is recommended that farmers adopt the use of zeolite and potassium silicate to optimize fertilizer usage, reduce environmental impact, and sustain crop yields. Future research should explore the long-term economic and environmental benefits of this practice, as well as its applicability to other crops and varying agricultural conditions.

REFERENCES

Abdel Fatah, E. M., & Khalil, S. R. (2020). Effect of zeolite, potassium fertilizer and irrigation interval on yield and quality of sugar beet in sandy soil. Journal of Plant Production, 11(12), 1569-1579.

Ahmed, M., Rauf, M., Mukhtar, Z., & Saeed, N. A. (2017). Excessive use of nitrogenous fertilizers: an unawareness causing serious threats to environment and human health. Environmental Science and Pollution Research, 24, 26983-26987.

Angelova, L., Genova, N., Stoyanova, S., Surleva, O., Nekov, I. H., Ilieva, D., & Surleva, A. (2021). Comparative study of soil test methods for determination of plant available potassium in Bulgarian arable soils. *Аналитика и контроль*, *25*(3), 182-192.

AOAC, (2000).″ Official Methods of Analysis‶. 18th Ed. Association of Official Analytical Chemists, Inc., Gaithersburg, MD, Method 04.

Bremner, J. M. (1960). Determination of nitrogen in soil by the Kjeldahl method. *The Journal of Agricultural Science*, *55*(1), 11-33.

Elseedy, M., Mohammed, R. Y., El-Sherpiny, M. A., & Taha, A. A. (2023). Enhancing crop resilience to drought stress: Antitranspirants, zeolite and water conservation strategies for strategic crop productivity. Journal of Soil Sciences and Agricultural Engineering, 267-274.

El-Shamy, M. A., El-Naqma, K. A., & El-Sherpiny, M. A. (2022). Possibility of using clover residues, green manures as a partial substitute of mineral nitrogen fertilizer to wheat plants grown on normal and saline soils. Journal of Global Agriculture and Ecology, 14(4), 51-63.

El-Sherpiny, M. A., & Faiyad, R. (2023). Enhancing wheat productivity under salinity conditions via composts made from agricultural by-products and sorbitol sugar. Asian Journal of Plant and Soil Sciences, 8(1), 71-84.

El-Sherpiny, M. A., Kany, M. A., & Ibrahim, N. R. (2022). Improvement of performance and yield quality of potato plant via foliar application of different boron rates and different potassium sources. Asian Journal of Plant and Soil Sciences, 7(1), 294-304.

Fradgley, N. S., Bentley, A. R., & Swarbreck, S. M. (2021). Defining the physiological determinants of low nitrogen requirement in wheat. Biochemical Society Transactions, 49(2), 609-616.

Gamal, R., Abou-Hadid, A. F., Omar, M. E. D., & Elbana, M. (2024). Does climate change affect wheat productivity and water demand in arid regions? case study of Egypt. Journal of Agriculture and Food Research, 101181.

Gomez, K. A. and Gomez, A. A. (1984). "Statistical procedures for agricultural research". John Wiley and Sons, Inc., New York.pp:680.

Hnizil, O., Baidani, A., Khlila, I., Nsarellah, N., & Amamou, A. (2024). Assessing the impact of nitrogen fertilization, variety selection, year and their interaction on wheat yield and yield components. Nitrogen, 5(2), 266-287.

Ippolito, J. A., Tarkalson, D. D., & Lehrsch, G. A. (2011). Zeolite soil application method affects inorganic nitrogen, moisture, and corn growth. Soil science, 176(3), 136-142.

Jakkula, V. S., & Wani, S. P. (2018). Zeolites: Potential soil amendments for improving nutrient and water use efficiency and agriculture productivity. Scientific Reviews & Chemical Communications, 8(1), 1-15.

Jarosz, R., Szerement, J., Gondek, K., & Mierzwa-Hersztek, M. (2022). The use of zeolites as an addition to fertilisers–A review. Catena, 213, 106125.

Koralage, I. S. A., Silva, N. R. N., & De Silva, C. S. (2015). The determination of available phosphorus in soil: a quick and simple method.

Kubar, M. S., Alshallash, K. S., Asghar, M. A., Feng, M., Raza, A., Wang, C., ... & Alshamrani, S. M. (2022). Improving winter wheat photosynthesis, nitrogen use efficiency, and yield by optimizing nitrogen fertilization. Life, 12(10), 1478.

Lichtenthaler, H. K. (1987). Chlorophyll fluorescence signatures of leaves during the autumnal chlorophyll breakdown. *Journal of Plant Physiology*, *131*(1-2), 101-110.

Mondal, M., Biswas, B., Garai, S., Sarkar, S., Banerjee, H., Brahmachari, K. & Hossain, A. (2021). Zeolites enhance soil health, crop productivity and environmental safety. Agronomy, 11(3): 448.

Peverill, K. I. (1999). Soil analysis: an interpretation manual. CSIRO publishing.

Reuter, D., & Robinson, J. B. (Eds.). (1997). Plant analysis: an interpretation manual. CSIRO publishing.

Rodrigues, M. Â., Torres, L. D. N. D., Damo, L., Raimundo, S., Sartor, L., Cassol, L. C., & Arrobas, M. (2021). Nitrogen use efficiency and crop yield in four successive crops following application of biochar and zeolites. Journal of Soil Science and Plant Nutrition, 21(2), 1053-1065.

Sanchez-Bragado, R., Serret, M. D., & Araus, J. L. (2017). The nitrogen contribution of different plant parts to wheat grains: exploring genotype, water, and nitrogen effects. Frontiers in Plant Science, 7, 215227.

Seadh, S., Abdel-Moneam, M. A., El-Sherpiny, M. A., & Mohamed, A. I. A. (2024). Enhancing Sugar Beet Performance under Water Scarcity Via Spraying Boron and Potassium Silicate: A Field Trial under Egyptian Conditions. Journal of Plant Production, 15(4), 145-152.

Soliman, M. A., El-Sherpiny, M. A., & Khadra, A. B. (2022). Improvement of performance and productivity of potato plants via addition of different organic manures and inorganic potassium sources. Asian Journal of Plant and Soil Sciences, 7(1), 331-341.

Szatanik-Kloc, A., Szerement, J., Adamczuk, A., & Józefaciuk, G. (2021). Effect of low zeolite doses on plants and soil physicochemical properties. Materials, 14(10), 2617.

تأثير مستويات مختلفة من النيتروجين المعدني والزيوليت وسيليكات البوتاسيوم على نمو وإنتاجية القمح

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الملخص

تبحث هذه الدراسة في إمكانية تقليل الجرعة الموصى بها من النيتروجين المعدني (NRD) للقمح دون المساس بالمحصول من خلال الإضافة الأرضية للزيوليت والرش الورقي بسيليكات البوتاسيوم. تضمنت التجربة معاملات القطع الرئيسية وكانت ١٠٠٪، ٨٠٪، و٦٠٪ من الجرعه الموصي بها من النيتروجين المعدني (نترات الأمونيوم، ٣٣٪ نيتروجين). القطع الفرعية اشتملت على الزيوليت بمعدل ١,٢ طن فدان-١ (تم التطبيق او لم يتم)، وتضمنت القطع المنشقه الثانية رش سيليكات البوتاسيوم بمعدل ٠,٠، ٧٥٠، و١٠٠٠ ملجم لتر-١. وشملت القياسات الرئيسية ارتفاع النبات، والأوزان الطازجة والجافة، والمساحة الورقية، ومحتوى الكلوروفيل، ومحصول الحبوب والقش، والكربوهيدرات، ومحتوى البروتين، ومستويات NPK في التربة. أظهرت النتائج أن استخدام الزيوليت مع السماد النيتروجيني بنسبه ٨٠٪ من NRD وسيليكات البوتاسيوم عند ١٠٠٠ ملجم لتر-١ يتفوق على التطبيق التقليدي للسماد النيتروجيني بنسبه ١٠٠٪من NRD من حيث نمو النبات والإنتاجية. بالإضافة إلى ذلك، أدى الزيوليت إلى زيادة النيتروجين والفسفور والبوتاسيوم المتاح في التربة بشكل كبير. تشير هذه النتائج إلى أن تقليل NRD إلى ٨٠٪ عند دمجها مع الزيوليت كإضافة ارضيه وسيليكات البوتاسيوم كرش ورقي يمكن أن يحافظ على إنتاجية القمح أو حتى يحسنها مع تعزيز خصوبة التربة. بشكل عام، دمج الزيوليت والتطبيق الأمثل لسليكات البوتاسيوم يمكن أن يقلل بشكل فعال من استخدام الأسمدة النيتروجينية دون تقليل إنتاجية القمح. يجب أن تركز الأبحاث المستقبلية على التأثيرات طويلة المدى والجدوى الاقتصادية لهذا النهج.