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Effect of Spraying NPK-Nano Fertilizer at Two Application Times on the Growth and Yield Components of Two Bread Wheat Varieties in Two Locations.

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ABSTRACT

A field study was done during the winter seasons of 2020-2021 at the two locations, Grdarasha Research farm at College of Agricultural Engineering Sciences in Erbil and Qlyasan Agricultural Research station, College of Agricultural Engineering Sciences, University of Sulaimani The experiment included three factors, the first factor was Nano-NPK (20:20:20) spraying with 4 concentrations (0, 150, 300, and 450) µg cm^{-3}, the second factor was two periods of spraying according to Zadoks scale Z-21 and Z-43 and the third factor was two bread wheat varieties (V_1 = Adana-99 and V_2= Aras). Numerous quantitative and qualitative parameters were studied. The mentioned factors showed a positive role, the fertilization treatments of 450 µg cm^{-3} recorded the highest values of plant height (96.17 and 73.24) cm, flag leaf area (33.19 and 33.04) cm^2, number of grain $spike^{-1}$ (48.76 and 41.78), weight of grain $spike^{-1}$ (1.95 and 1.54) g, seed index (38.54 and 39.35) g, grain yield (4.93 and 4.84) t ha^{-1} and protein yield (707.28 and 609.46) kg ha^{-1} for both locations respectively. Spraying the Nano - fertilizer at the second stage had significant impact on some traits, the highest values in flag leaf area, no spikelet $spike^{-1}$, seed index, grain yield and protein yield was (30.83 and 32.17) cm^2, (17.57 and 17.60), (37.10 and 39.16) g, (4.49 and 4.34) t $ha^{-1}$and (621.86 and 533.70) kg ha^{-1}. In contrast, the second variety Aras surprised Adana-99 in most of the traits. The interaction treatments (450 mg L^{-1}x Booting stage x Aras variety**)** recorded the highest seed and protein production (5.29 and 5.71) t ha^{-1} seed yield and (763.29 and 717.27) kg ha^{-1} protein yield for both locations respectively. It is appeared from the three studied factors and their combination significant influences on most of the studied traits.

1. Introduction

Wheat (*Triticum aestivum* L.) is staple food seed crops, which ranks the first in Iraq and the world because of its strategic role in achieving food security(FAO, 2017) . Despite being among the first nations where wheat was produced, Iraq's productivity level of 1.80 t ha^{-1} is below the required level when compared to the global production of 2.76 t ha^{-1}(FAO, 2018) , as per the Agricultural Statistics Directorate (2018). In order to encourage the cultivation of this crop and increase both its quality and quantitative productivity, there must first be interest in cultivating varieties that adapt to changing environmental conditions. As a result, this topic was the focus of numerous centers and research institutions. Numerous kinds with exceptional output, outstanding quality, and good stability in the area have been accepted; they are appropriate for the environmental circumstances and their improvement.

For the best yield and quality farmers should focus on doing appropriate crop service operations. Jubail et al. (2019) referred to impact of wheat variety on yield and yield components. The use of nanomaterials or fertilizer packages, that can deliver essential elements one or more nutrients to improve plant yield and quality greater than using chemical fertilizers as mentioned by (Omidi et al., 2022)

In comparison to chemical or traditional fertilizers, which are frequently ineffective for plants after addition particularly when applied to soil with a high calcium carbonate content Nano-fertilizers are more soluble, effective, penetrate plant tissues more quickly, and have a greater representation in plant tissues. Reducing pollution, decreasing nutrient loss during fertilization, and raising output through the use of innovative technological applications are all imperative. With a size exclusion limit over 10 nm, the Nano-coated materials improve penetration through stomata(Eichert and Goldbach, 2008, Pérez-de-Luque, 2017) .Wheat growth and yield characteristics improved when N, P, and K Nano fertilizer was applied topically as obtained by Abdel-Aziz et al., (2016). Fertilizer application affects grain production according to growth stages; Al-Shammari and Noaema (2023) found substantial variances in their investigation in grain yield when fertilizer is applied during the blanket stage as opposed to the blooming stage.

This study aims to contribute to the reduction of chemical fertilizer pollutants and protect the environment because calcareous soil has low availability of N, P, and K and chemical fertilizers have low efficiencies, so this study was chosen to test the effects of NPK-Nano fertilizer spraying at different stages on plant growth properties of fine wheat.

2. Methodology:

2.1 Study locations:

Two locations were used for current study. The first one is Grdarasha research farm at College of Agricultural Engineering Sciences in Erbil, which is 415 masl. with GPS reading Latitude: 36° 4’ N and Longitude: 44° 2’. The second site was the Qlyasan Agricultural Research station, College of Agricultural Engineering Sciences, University of Sulaimani, which is situated at 35° 34′ 307″ N, 45° 21′ 992″ E, and elevation 765 masl during the winter seasons of 2020-2021. Its purpose was to investigate the effects of varying concentrations of Nano-NPK fertilizers (20:20:20) spraying with 4 concentrations (0, 150, 300, and 450) µg cm^{-3} at two times on the studied characteristics of wheat varieties. Before sowing, the soil was softened with motivator for 48 hours and plowed twice with a moldboard plow at a depth of 25 cm.

2.2. Soil Analysis:

A representative soil sample of soil samples was taken from depth 0-30 cm of the soil. The soil properties were denoted in Table 1.

Table 1. Some physio-chemical characteristics of the studied soils before planting*

Soil Properties			
Physical properties			
Soil Properties		Qlyasan	Grdarasha
Texture name		Silty clay loam	Silty clay loam
Particle Size Distribution (gram per kg)	Sand	59.68	51.80
	Silt	619.17	480
	Clay	312.15	369.46
Chemical properties			
Soil Properties		Qlyasan	Grdarasha
pH		7.42	7.65
EC dS m^{-1} at 25 °C		0.38	1.23
Organic Matter (g kg^{-1})		19.59	11.77
Total Nitrogen (g kg^{-1})		1.07	2.35
Available Phosphate (mg kg-1)		9.61	3.42
$CaCO_3$ (g kg^{-1})		215.68	312.00
Soluble Ions mmolc L^{-1}	(Ca^{+2})	2.00	1.99
	(K^{+})	0.16	0.09
	(Na^{+})	0.46	0.72
	Mg^{2+}	0.81	1.88
	HCO^{2-}	4.20	3.22
	SO_4^{2-}	0.89	0.79

*The Soil properties were analyzed in Agriculture Research Centre - Ainkawa /Erbil.

2.3 Field experiment:

A Randomized Complete Block Design (RCBD) using factorial experiment with 3 replicates, using three factors, the first factors was 4 rates of Nano-NPK that were (0 ,150, 300 and 450 µg cm^{-3}) which used at two times (S_1= 40 days after planting S_2 = 70 days after planting) and the third factor was (V_1 = Adana-99 and V_2= Aras) varietie.

The area of experiment was divided into plots each plot contains sixteen experimental units (2x2x4). The plot's area was ($1m^2$), contained 5 rows, 0.2 m spaced between rows. The recommended seed rate of 200 kg ha^{-1} was used at 11th and 13th November at Grdarasha and Qlyasan locations respectively. All other input and agronomic practices were carried out uniformly. Metrological data for both sites are shows in Table 2.

Table 2. The Meteorological data of both locations during the growing seasons*

Months	Qlyasan location			Grdarasha location		
	Temp. Cº		Rainfall mm	Temp. Cº		Rainfall mm
	Max.	Min.		Max.	Min.	
November	24.9	5.2	10.2	23.39	10.73	0.16
December	18.3	4.1	121.2	16.42	7.96	1.75
January	13.1	0	96.0	13.15	5.20	2.66
February	18.3	-6.2	138.6	14.09	6.05	2.85
March	22.7	3.5	148.2	20.55	10.71	4.59
April	26.6	7.4	65.6	24.80	13.01	1.50
May	38.5	11.7	21.0	33.95	18.85	0.30

*(Agro-Metrological Department- Sulaimani), Bakrajo and Grdarasha station.

2.4 Collecting Data:

The number of selected mature plant per experiment unit was 10 random plants at both locations to determine: Plant length (cm), flag leaf area (cm^2) using image J software (Easlon and Bloom, 2014) , number of spikelet per spike, number of grain per spike, spike weight (g), seed index (gram), seed yield (ton per hector), protein production (kilogram per hector) .The total nitrogen content was determined by the micro-Kjeldahl digestion method. Protein percent was determined according to the equation described by (Omer and Mahmood, 2024) as follow:

Protein % = $N*6.25$. then protein yield calculated according to the equation below:

Protein yield (kilogram per hector) = Seed yield kg ha^{-1} x Protein%.

2.5 Statistical analysis:

The data were submerged to statistical analyzes using SPSS program version (27). (Duncan and Duncan, 1955) was depended for multiple comparison test between mean of treatments at P-value ≤ 0.05 . Cluster analysis and principal component analysis were conducted between the interaction combination for grouping them to different classes using XLSTATE (2017).

3. Results and Discussion:

3.1. Height of plant (cm):

As shown in Table 3. a slight increment in height due to foliar application of Nano NPK the highest values (96.17 and 73.24) recorded for F_3 in both locations. The plant height was significantly responded to growth stages in Qlyasan location only with highest and lowest values (70.37 and 66.12) cm. While wheat Variety was significant in both locations with highest value (93.42 and 69.80) cm which recorded for V_2 and lowest value (90.71and 66.69) cm obtained for V_1.

The maximum plant height (97.17 and 74.92) cm was noted from the combination treatment V_2xF_3 as highest value, and the lowest values (84.83 and 62.37) obtained for V_1xF_0. The combination treatment of (S x F) had significant role on plant height, the highest values (97.00 and 75.25) recorded for F_3xS_2. the interaction V x S significantly affected the plant height, It ranged between (94.17 and 90.08) cm, and (72.75 and 65.38) V_2S_2 being the highest value and the lowest with $V_1 \times S_2$. Additionally, the results of this study unveiled that on average the mentioned interaction shows significant impact on height of plant, the highest values (98.00 and 77.81) cm obtained for ($F_3xS_2xV_2$) and the lowest values (84.00 and 60.67) cm obtained for ($F_0xS_2xV_1$) and (F_0 xS_1xV_1) for both locations respectively.

Table 3. Interaction effect of Nano-NPK foliar application at two growing stages on plant height of two wheat varieties.

Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	85.67fg	89.00def	91.33cde	94.33abc	90.71b	91.38a	
	S_2	84.00g	93.67a-d	91.67b-e	96.00abc	93.42a	92.75a	
V_2	S_1	87.67efg	91.00cde	95.67abc	96.33ab	Grdarasha		
	S_2	89.33def	93.33a-6	96.abc	98.00a			
F		86.67c	91.75b	93.67b	96.17a			
V*S		90.08b	91.33ab	92.67ab	94.17a			
V*F	84.83e	91.33cd	91.50cd	95.17ab	88.50d	92.17bc	95.83a	97.17a
S*F	86.67c	90.bc	93.50ab	95.33a	86.67c	93.50ab	93.83a	97.00a
Varieties	Stages	F0	F1	F2	F3	Varieties	stages	
V_1	S_1	60.67j	62.66hij	67.72ef	70.45cd	66.69b	66.12b	
	S_2	64.07ghi	65.82fg	69.42de	72.68bc	69.80a	70.37a	
V_2	S_1	62.05ij	64.83gh	68.53de	72.03c	Qlyasan		
	S_2	67.98[ef]	70.59cd	74.60b	77.81a			
Mean of Fertilizer		63.69d	65.98c	70.07b	73.24a			
V*S		65.38b	68.00b	66.86b	72.75a			
V*F	62.37e	64.24e	68.57bc	71.57ab	65.02de	67.71cd	71.57ab	74.92a

S*F	61.36e	63.75de	68.13c	71.24b	66.03cd	68.21c	72.01b	75.25a

Mean values followed by the same letter are not significantly different at the 5% probability level

3.2 Flag Leaf Area (cm^2):

Table 4 explains significant effects of Nano NPK fertilizer on wheat flag leaf area, the highest and lowest value (33.19 and 26.65) and (33.04 and 28.68) was recorded for (F_3 and F_0) for both locations. As with wheat varieties had a significant effect on the traits at both locations, it was noticed that V_2 (31.54 and 34.24) cm^2 exhibited superiority to V_1 (28.56 and 26.62) cm^2, as per the findings, the booting stage at Grdarasha appeared as the most suitable physiological stage for foliar Nano - NPK application to get higher greater flag leaf area 30.83 cm^2 .Furthermore, the results in the same table indicated that flag leaf area affected significantly among all possible two - factor interactions the highest values (34.74,33.34 and 32.68) cm^2 at Grdarasha recorded for (V_2 x F_3, S_2 x F_3 and V_2 x S_2) , and (37.31and 36.67) cm^2 for (V_2 x F_3 and V_2 x S_2) obtained for second location Additionally, there were significant differences between the studied interaction factors as portrait, the highest value (34.86 and 40.73) cm^2 obtained for (F_3x S_1 xV_2) and (F_3x S_2 xV_2). On the other hand, lowest values (24.47 & 22.19) cm^2 recorded for (F_0x S_1 xV_1) at both locations respectively.

Table 4. Interaction effect of Nano-NPK foliar application at two growing stages on flag leaf area (cm^2) of two wheat varieties.

Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	24.47e	26.24de	30.01a-e	31.83a-d	28.56b	29.27b	
	S_2	26.99de	27.19de	30.34a-d	31.44a-d	31.54a	30.83a	
V_2	S_1	26.51de	29.06b-e	31.17a-d	34.86a	Grdarasha		
	S_2	28.63cde	34.09abc	33.38abc	34.62ab			
F		26.65c	29.15b	31.23ab	33.19a			
V*S		28.14b	28.99b	30.40ab	32.68a			
V*F	25.73d	26.71cd	30.17bc	31.63ab	27.57cd	31.58ab	32.28ab	34.74a
S*F	25.49c	27.65bc	30.59ab	33.03a	27.81bc	30.64ab	31.86a	33.34 a
Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	22.19c	27.14abc	24.72bc	28.26abc	26.62b	28.69a	
	S_2	28.31abc	26.65abc	26.45abc	29.26abc	34.24a	32.17a	
V_2	S_1	28.42abc	29.99abc	34.89abc	33.90abc	Qlyasan		
	S_2	35.80abc	31.82abc	38.32ab	40.73a			
Mean of Fertilizer		28.68a	28.90a	31.10a	33.04a			
V*S		25.58c	27.67bc	31.8ab	36.67a			
V*F	25.25b	26.90b	25.59b	28.76ab	32.11ab	30.91ab	36.61a	37.31a
S*F	25.31a	28.56a	29.81a	31.08a	32.06a	29.24a	32.39a	35.00a

Mean values followed by the same letter are not significantly different at the 5% probability level

3.3 Number of Spikelet Spike $^{-1}$

Close examination of Table 5 showed significant impacts of Nano –NPK application at Grdarasha and Qlyasan locations on the number of spikelet spike^{-1}. The order of effectiveness being $F_3 > F_2 > F_1 > F_0$ at first location with highest and lowest values (18.42 - 16.01) spikelet spike $^{-1,}$ whilst $F_2 > F_1 > F_3 > F_0$ noted at second location with values (18.64- 16.60) spikelet spike $^{-1}$**.**

The analysis of data revealed that significant differences occurred on number of spikelet spike $^{-1}$ due to difference in wheat variety. The V_2 exhibited superiority to the V_1 variety at both locations. The V_2 variety offered (3.31- 3.31) time more number of spikelet spike $^{-1}$ compared to the other wheat varieties in both locations. Additionally, there was significant differences between growth stages, booting stage recorded 17.57and17.60 spikelet spike^{-1}at both locations respectively.

The two-factor interactions (F x V, F x S and V x S) were also found to be had significant impacts. It was also affected by the three-factor interaction (F x S x V) at both locations. The highest values were (18.72,18.60,17.90 and 19.14) spikelet spike^{-1} in the first location furthermore (19.01,18.91,18.07 and 19.41) spikelet spike^{-1} recorded for the second location illustrated in the treatment combinations (F_3 V_2), (F_3 S_2), (V_2 S_2) and ($F_3 \times S_2 \times V_2$).

Table 5. Interaction effect of Nano-NPK foliar application at two growing stages on number of spikelet spike^{-1} of two wheat varieties.

Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	14.47e	16.52cd	17.15bcd	18.20ab	16.91b	16.81b	
	S_2	16.65bcd	16.87bcd	17.37bcd	18.05abc	17.47a	17.57a	
V_2	S_1	15.90d	16.70bcd	17.22bcd	18.30ab	Grdarasha		
	S_2	17.03bcd	17.15bcd	18.29ab	19.14a			
F		16.01c	16.81b	17.51b	18.42a			
V*S		16.58b	17.24ab	17.03ab	17.90a			
V*F	15.56e	16.69cde	17.26bcd	18.13ab	16.47de	16.93cd	17.75abc	18.72a
S*F	15.18d	16.61c	17.19bc	18.25a	16.84bc	17.01bc	17.83ab	18.60a
Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	13.90g	16.33ef	17.70b-e	18.14a-d	16.83b	16.83b	
	S_2	16.57def	16.27ef	17.30b-e	18.4abc	17.61a	17.60a	
V_2	S_1	15.65f	16.83c-f	17.50b-e	18.60ab	Qlyasan		
	S_2	17.27b-e	17.12b-f	18.50ab	19.41a			
Mean of Fertilizer		16.60c	17.75b	18.64a	16.64c			
V*S		16.52b	17.13ab	17.15ab	18.07a			
V*F	15.23e	16.3de	17.5bcd	18.27ab	16.46d	16.98cd	18abc	19.01a
S*F	14.78e	16.58d	17.60bcd	18.37ab	16.92cd	16.69d	17.9abc	18.91a

Mean values followed by the same letter are not significantly different at the 5% probability level

3.4 Number of Gain Spike^{-1}

As can be seen in Table 6 levels of Nano NPK, influenced on grain number pike^{-1}**.** The F_3 recorded the highest values (48.76 and 41.78) in both locations while F_0 or control obtained the lowest value (43.44 and 34.30) grain spike^{-1}

Growth stages has different manner between the two locations, the highest value 47.59 grain in Grdarasha was obtained in tillering stages, on contrary booting stage recorded the highest value 40.12 grain in second location. From the same table, it is quite obvious that there was a significant difference between the two varieties used in the study as well as the interaction treatment between Nano fertilizer and varieties. The highest values (46.86 and 48.71) and (40.33 and 42.83) grain spike^{-1} for both locations, respectively obtained from (V_2 and V_2xF_3) while the lowest value recorded for (V_1 and V_2xF_1) and (V_1 and V_2xF_0) respectively.

The interaction between S x F, V x S and F x S x C affect significantly on this traits, at Grdarasha, the highest values for the mentioned interactions recorded at F_3S_1, V_2 S_1 and $F_3V_2S_1$ with values (50.72,49.73 and 51.30) whilst at Qlyasan location the highest values (42.96,41.68 and 44.33) grain spike^{-1} noted in F_3S_2, V_2S_2 and $F_3V_2S_2$, respectively.

Table 6. Interaction effect of Nano-NPK foliar application at two growing stages on number of grain spike^{-1} of two wheat varieties.

Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages
V_1	S_1	41.90de	42.86b-e	46.91a-e	50.13abc	44.41b	47.59a
	S_2	42.27cde	40.78e	42.92b-e	47.49a-e	46.86a	43.67b
V_2	S_1	47.54a-e	49.28a-e	50.81ab	51.30a	Grdarasha	
	S_2	42.06cde	43.13b-e	44.64a-e	46.12a-e		

F		43.44b	44.01b	46.32ab	48.76a			
V*S		45.45b	43.36b	49.73a	43.99b			
V*F	42.08bc	41.82c	44.91abc	48.81a	44.80abc	46.21abc	47.72ab	48.71a
S*F	44.72bc	46.07ab	48.86ab	50.72a	42.16c	41.95c	43.78bc	46.80ab
Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	28.81i	35.82h	37.92g	39.87def	37.09b	37.29b	
	S_2	34.84h	37.95g	39.89def	41.59bc	40.33a	40.12a	
V_2	S_1	34.96h	39.32efg	40.30cde	41.33bcd	Qlyasan		
	S_2	38.60fg	41.10bcd	42.70b	44.33a			
Mean of Fertilizer		34.30d	38.55c	40.20b	41.78a			
V*S		35.61c	38.57b	38.98b	41.68a			
V*F	31.83e	36.88d	38.90cd	40.73abc	36.78d	40.21bc	41.50ab	42.83a
S*F	31.89e	37.57cd	39.11bcd	40.6ab	36.72d	39.53bc	41.29ab	42.96a

Mean values followed by the same letter are not significantly different at the 5% probability level

3.5. Weight of Grain Spike $^{-1}$ (g)

The weight of grain per spike affected significantly by adding Nano-fertilizer Table.7 at Qlyasan location only. The highest and lowest value (1.54 and 1.04) g was recorded for F_3. As with growth stages and varieties the data revealed that there are significant differences between stages of application at Qlyasan, the highest value 1.46 g while Varieties have a significant difference at both location, the highest values (1.83 and 1.36) g was produced in plots where V_1 and V_2 was sprayed with the Nano fertilizers at both locations.

Interaction among wheat varieties and micronutrients application was also found to be significant. VF, SF and VS in second location only, maximum Weight of grain spike $^{-1}$(1.60 ,1.65 and1.51) g was recorded from V_2F_3, S_2F_3 and V_2S_2), respectively. Contrarily the lowest value (1.01,0.87 and 1.09) g was obtained for (V_1F_0, S_1F_0 and V_1S_1). Moreover, it was noticed that the interaction among the three study factors was significant at Qlyasan location only, the highest and lowest values (1.70 and 0.82) g were attained from the interaction $V_2S_2F_3$ and $V_1S_1F_0$ respectively.

Table 7. Interaction effect of Nano-NPK foliar application at two growing stages on weight of grain spike^{-1} of two wheat varieties.

Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	1.92a	1.88a	1.82a	1.73a	1.83a	1.87a	
	S_2	1.69a	1.81a	1.70a	2.11a	1.77b	1.73a	
V_2	S_1	1.90a	1.85a	1.68a	2.19a	Grdarasha		
	S_2	1.52a	1.64a	1.58a	1.77a			
F		1.76a	1.79a	1.70a	1.95a			
V*S		1.84a	1.830a	1.91a	1.63a			
V*F0	1.81a	1.84a	1.76a	1.92a	1.71a	1.74a	1.63a	1.98a
S*F	1.91a	1.86a	1.75a	1.96a	1.61a	1.72a	1.64a	1.94a
Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	0.82j	0.93i	1.22fg	1.38de	1.24b	1.15b	
	S_2	1.19gh	1.31ef	1.49c	1.60b	1.36a	1.46a	
V_2	S_1	0.91ij	1.11h	1.31ef	1.49c	Qlyasan		
	S_2	1.23fg	1.47cd	1.65ab	1.70a			
Mean of Fertilizer		1.04d	1.20c	1.42b	1.54a			
V*S		1.09b	1.4a	1.21b	1.51a			
V*F	1.01d	1.12cd	1.36b	1.49ab	1.07cd	1.29bc	1.48ab	1.60a
S*F	0.87e	1.02d	1.27c	1.44b	1.21c	1.39b	1.60a	1.65a

Mean values followed by the same letter are not significantly different at the 5% probability level

3.6. Seed Index (g):

Table 8 portray the effect of studied factors on seed index, it is clear that there are significant differences among Nano-fertilizer, growth stages and wheat varieties F_3, S_2 and V_2 recorded the highest values (38.54,37.10 and 37.73) g at first location. Whilst F_3, S_2 and V_1 with the highest value (39.35,39.16 and 38.32) g for Qlyasan. Moreover, there was a significant difference between the mean values of seed index under the interaction between varieties and Nano –NPK the highest values (39.75 and 39.64) g was obtained for V_2F_3 and V_1F_3 for both locations, respectively.

The seed index also affected by S x F, the interaction treatment S_2x F_3 display the highest value (39.53 and 40.67) at both locations while the interaction Vx S play different manner between the two locations. the highest value at Grdarasha was 38.43 obtained from V_2S_2 while at Qlyasan location V_1S_2 recorded the highest value 39.76 g.

With regard to the triple combination, viz., (Nano fertilizer, times of top dressing and varieties) on the same trait, the highest seed index mean was (40.80 and 41.45) that produced from $V_2S_2F_3$ and $V_1S_2F_3$ for both locations respectively.

Table 8. Interaction effect of Nano-NPK foliar application at two growing stages on seed index (g) of two wheat varieties.

Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	32.47e	34.40cde	35.13b-e	36.40b-e	35.18b	35.82b	
	S_2	33.80de	34.40cde	36.60b-e	38.26abc	37.73a	37.10a	
V_2	S_1	35.70b-e	36.27b-e	37.47a-d	38.70ab	Grdarasha		
	S_2	37.07a-d	37.27a-d	38.60abc	40.80a			
F		34.76c	35.58bc	36.95ab	38.54a			
V*S		34.60c	35.77bc	37.03ab	38.43a			
V*F	33.13d	34.40cd	35.87bc	37.33ab	36.38bc	36.77bc	38.03ab	39.75a
S*F	34.08c	35.33bc	36.30bc	37.55ab	35.43bc	35.83bc	37.60ab	39.53a
Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	35.52i	36.71hi	37.47fg	37.82def	38.32a	37.13b	
	S_2	36.54hi	39.80b	41.24a	41.45a	37.98b	39.16a	
V_2	S_1	36.38hi	37.15gh	37.78def	38.22cd	Qlyasan		
	S_2	37.64efg	38.17cde	38.58c	39.90b			
Mean of Fertilizer		36.52d	37.96c	38.77b	39.35a			
V*S		36.88c	39.76a	37.38c	38.57b			
V*F	36.03d	38.25abc	39.36ab	39.64a	37.01cd	37.66bc	38.18abc	39.06ab
S*F	35.95e	36.93d	37.63cd	38.02c	37.09cd	38.98b	39.91a	40.67a

Mean values followed by the same letter are not significantly different at the 5% probability level

3.7. Grain Yield (t ha^{-1})

The data which is exhibited in Table 9. show significant differences between the studied factors and their interactions. maximum grain yield was observed from F_3, S_2 and at both locations. On average F_3, F_2, F_1, F_0 recorded (4.93,4.38,4.14 and 4.09) t ha^{-1} and (4.84,4.31,3.83 and 3.48) t ha^{-1}.for both locations respectively. Furthermore, overall, it was noticed that the two factor interaction at both locations caused significant differences, the interaction of V_2xF_3 obtained the highest value (5.24 and 5.21) and (5.04 and 5.21) t ha^{-1} for the interaction treatment S_2xF_3, additionally, V_2 xS_2 gained the highest value (4.76 and 4.58) t ha^{-1}.

Furthermore, the results signified that the triple combination's affected significantly on seed yield. The best interaction which produced the highest values (5.29 and 5.71) t ha $^{-1}$ was recorded in plots where V_2 variety sprayed with F_3 at booting stage (F_3xS_2xV_2) for Grdarash and Qlyasan respectively whilst the lowest mean values (3.59 and 3.20) t ha^{-1} was achieved from the interaction treatment (F_1×S_1×V_1) and (F_0 x S_1×V_1).

Table 9. Interaction effect of Nano-NPK foliar application at two growing stages on grain yield t ha^{-1} of two wheat varieties.

Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	3.85efg	3.59g	3.73fg	4.46b-e	4.06b	4.28b	
	S_2	3.88efg	4.14c-g	4.04d-g	4.78abc	4.71a	4.49a	
V_2	S_1	4.23c-g	4.48b-e	4.73a-d	5.19a	Grdarasha		
	S_2	4.40b-f	4.35b-f	5.01ab	5.29a			
F		4.09b	4.14b	4.38b	4.93a			
V*S		3.91b	4.21b	4.66a	4.76a			
V*F	3.86d	3.87d	3.88d	4.62bc	4.31cd	4.42c	4.87ab	5.24a
S*F	4.04c	4.04c	4.23bc	4.83ab	4.14c	4.25bc	4.52abc	5.04a
Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	3.2g	3.56fg	3.93de	4.23cd	3.92b	3.90b	
	S_2	3.57fg	3.90def	4.20cd	4.72b	4.31a	4.34a	
V_2	S_1	3.32g	3.70ef	4.47bc	4.71bc	Qlyasan		
	S_2	3.78ef	4.17cd	4.65b	5.71a			
Mean of Fertilizer		3.48d	3.83c	4.31b	4.84a			
V*S		3.74b	4.1ab	4.05b	4.58a			
V*F	3.40e	3.73cde	4.07c	4.47b	3.55de	3.93cd	4.56b	5.21a
S*F	3.28f	3.63ef	4.20bc	4.47b	3.68de	4.03cd	4.43b	5.21a

Mean values followed by the same letter are not significantly different at the 5% probability level

3.8 Protein Yield (kg ha^{-1})

Data in Table 10 portray the protein yield as influenced by Nano-NPK foliar application, F_3 increased the protein yield with the order of effectiveness being $F_3 > F_2 > F_1 > F_0$ at both locations with highest and lowest values (707.28,595.56,552.45 and 530.06) and (609.46 ,535.94,468.34 and 408.68) kg ha^{-1} noted in Grdarasha and Qlyasan location. As can be seen, there was a slight increase in protein yield during booting stages which recorded the highest value (621.86 and 533.70) kg ha^{-1} at both locations. Additionally, it can be observed that the application of the two wheat varieties influenced by foliar spray of Nano- NPK at tillering and booting stages the highest value (645.42 and 536.51) kg ha^{-1} recorded for V_2 at both locations respectively, Moreover, there was a significant difference between the mean values of protein yield under the interaction between (VF,SF,VS) the highest protein yield (746.19,728.75 and 672.05) kg ha^{-1} obtained at Grdarasha ,(660.47,652.62 and 564.60) kg ha^{-1} at Qlyasan was recorded for (V_2x F_3 ,S_2x F_3 and V_2x S_2) .

The interaction among Nano-NPK, spraying times and varieties was significant on the same traits, the highest mean value (763.29and 717.27) kg ha^{-1} of protein yield for both locations was recorded from the treatment combination (F_3x S_2x V_2) while the lowest values (466.59 and 365.20) kilogram per hectare. The Dendrogram analysis in Grdarasha, grouped the interaction effect of the three treatments on the studied traits into three main clusters while in Qlyasan the Dendrogram classified

the interaction effect into four clusters Table 11and Fig 1 according to the similarity between them.

Table 12. Explain that the eigenvalue for F1 and F2 which had a great influence on variability, since their values were higher than one which was (4.72 and 1.27) in Grdarasha while in Qlyasan the eigenvalue for F_1 and F_2 only influence on variability with value (5.73 and 0.77), the other values were less than one, they can be neglected. The cumulative variability% was (67.49 and 85.59) % and (81.88 and 92.92) % for both locations respectively. After F2 and F_1 the slope of the scree plot will decrease then an approach zero (Table 12 and Figure 2), which means the effects are very low and can be neglected. The combination treatments in Figure 3 are merged and give a different explanation.

For the variables close to the center there will not be significant differences between them for example in $F_3S_2V_2$ is the closest variable to seed index and protein yield in Grdarasha and Qlyasan respectively If any of the variables are close meaning there are positive reactions between them and the other side has a negative reaction to the first one. The first two axes for the clusters were significant (eigenvalues ≤ 90) and contributed to 85.59 % and 92.92 % of total variance, and were mainly correlated to F1, F2.

Table 10. Interaction effect of Nano-NPK foliar application at two growing stages on protein yield kg ha^{-1} spikelet of two wheat varieties.

Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	487.25ef	466.59f	495.01ef	642.52bcd	547.25b	570.81b	
	S_2	496.93ef	553.08def	542.46def	694.20abc	645.42a	621.86a	
V_2	S_1	525.60def	583.51c-f	636.91bcd	729.09ab	Grdarasha		
	S_2	610.47b-e	606.60b-e	707.85ab	763.29a			
F		530.06c	552.45bc	595.56b	707.28a			
V*S		522.84c	571.67bc	618.78ab	672.05a			
V*F	492.09d	509.84d	518.74cd	668.36ab	568.04cd	595.06bc	672.38ab	746.19a
S*F	506.43d	525.05cd	565.96cd	685.81ab	553.70cd	579.84cd	625.16bc	728.75a
Varieties	Stages	F_0	F_1	F_2	F_3	Varieties	Stages	
V_1	S_1	365.20i	417.83gh	478.40ef	528.93cd	475.22b	478.02b	
	S_2	422.17gh	480.60ef	518.43de	587.97b	536.51a	533. 70a	
V_2	S_1	400.83hi	459.50fg	567.63bc	603.67 b	Qlyasan		
	S_2	446.53fg	515.43 de	579.30 b	717.27a			
Mean of Fertilizer		408.68 d	468.34 c	535.94 b	609.46 a			
V*S		447.60 c	502.30 ab	507.91 ab	564.60 a			
V*F	393.68 e	449.22cd	498.40c	558.45 b	423.68 de	487.47 c	573.47 b	660.47 a
S*F	383.02e	438.67 d	523.02bc	566.30 b	434.35 d	498.02 c	548.87bc	652.62 a

Mean values followed by the same letter are not significantly different at the 5% probability level

Table 11. Classifying the treatment combination into clusters for both locations.

Grdarasha		**Qlyasan**	
Observation	Classes	Observation	Classes
$F_0S_1V_1$	1	$F_0S_1V_1$	1
$F_1S_1V_1$	2	F_1S_1V1	2
$F_2S_1V_1$	2	$F_2S_1V_1$	3
$F_3S_1V_1$	3	$F_3S_1V_1$	3
$F_0S_2V_1$	1	$F_0S_2V_1$	2
$F_1S_2V_1$	1	$F_1S_2V_1$	3
$F_2S_2V_1$	1	$F_2S_2V_1$	3
$F_3S_2V_1$	3	$F_3S_2V_1$	3
$F_0S_1V_2$	1	$F_0S_1V_2$	2
$F_1S_1V_2$	3	$F_1S_1V_2$	3
$F_2S_1V_2$	3	$F_2S_1V_2$	4
$F_3S_1V_2$	3	$F_3S_1V_2$	4
$F_0S_2V_2$	3	$F_0S_2V_2$	2
$F_1S_2V_2$	3	$F_1S_2V_2$	3
$F_2S_2V_2$	3	$F_2S_2V_2$	4
$F_3S_2V_2$	3	$F_3S_2V_2$	4

Table 12. The eigenvalue and the variability among the wheat traits

		F1	F2	F3	F4	F5	F6	F7
Grdarasha	Eigenvalue	4.72	1.27	0.46	0.20	0.16	0.12	0.07
	Variability (%)	67.49	18.11	6.57	2.82	2.30	1.75	0.97
	Cumulative %	67.49	85.59	92.17	94.98	97.28	99.03	100.00
Qlyasan	Eigenvalue	5.73	0.77	0.20	0.14	0.09	0.04	0.02
	Variability (%)	81.88	11.04	2.90	2.06	1.24	0.62	0.26
	Cumulative %	81.88	92.92	95.83	97.88	99.12	99.74	100.00

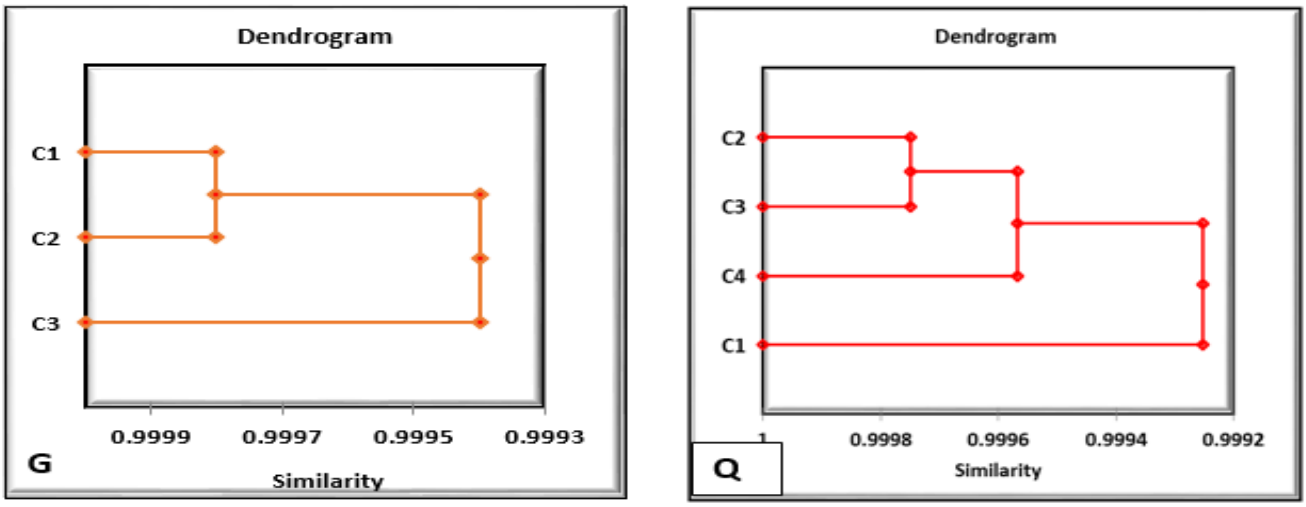

Fig 1. Dendrogram for the clusters of studied traits and the interaction combination in wheat.

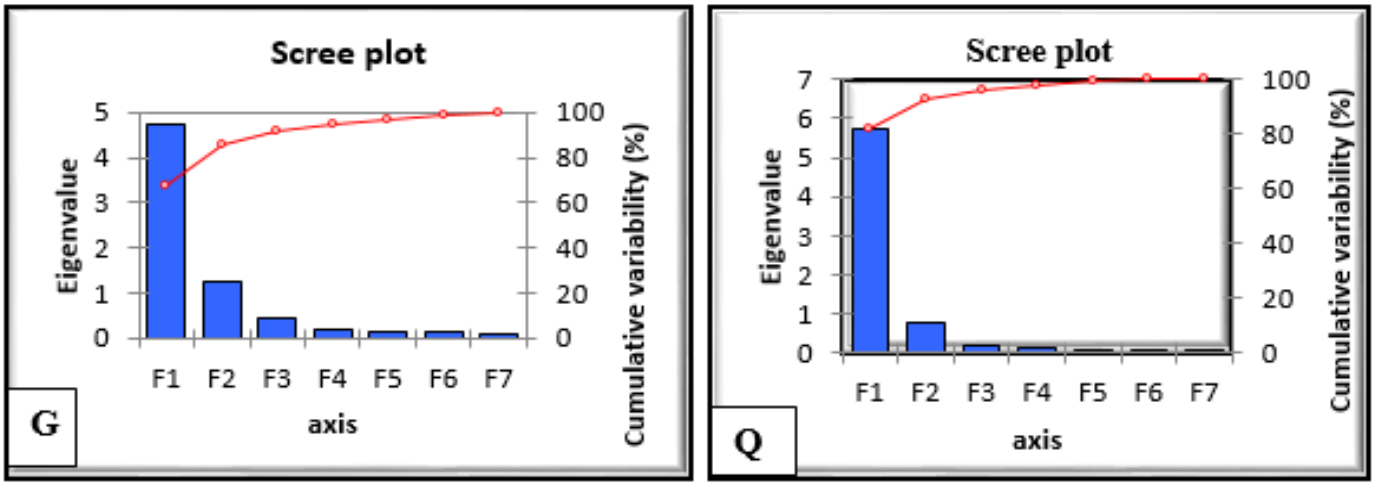

Fig 2. The decrease in slope for the scree plot after F2 and F1 for locations, respectively

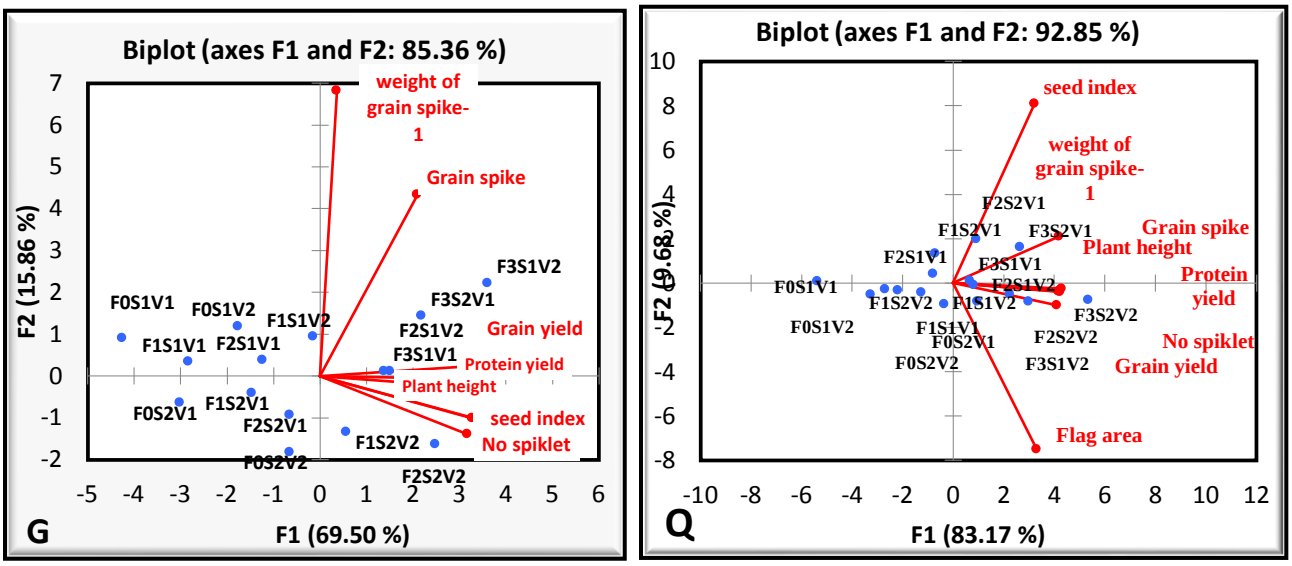

Fig 3. The vectors for the studied traits and the interaction combination of the studied treatments.

4. Discussion:

According to morphological criteria, Nano NPK significantly affected plant height; these findings concurred with those of Al-Juthery et al. (2018a). However, these findings were evident in the Qlyasan location, and they were linked to potential explanations such as an increase in enzyme activity related to cell division and elongation and the hormones production by plant as a result of an excess of the beneficial substances for plant(Al-Shammari and Noaema, 2023) . Although wheat variety was important and had the highest value in both places, the distinct genetic characteristics of the types may be connected to the diversity in plant height(Abu Dahi et al., 2009) This finding is consistent with(Hadi et al., 2020) , who found that plant height was significantly impacted by wheat variety.

According to studies conducted by (Ali and Al-Juthery, 2017) and (Singh, 2017), Nano fertilizers are improving most of growth traits (plant height, leaf area), dry matter production, chlorophyll content, and photosynthesis rate as mentioned by (Bapir and Mahmood, 2022). Nano fertilizer leads to increased production and photosynthesis translocation to different parts of the plant. Similarly, there was a significant effect of Nano -NPK on leaf area, especially in Grdarasha location, specifically F_3 and F_0. Abdel-Aziz et al., (2018) stated that Nano-Fertilizer easily absorbed by the epidermis of leaves translocated to stems which facilitated the uptake of active molecules and enhanced growth and productivity of wheat.

Additionally, the impact of Nano NPK on varieties was evident; the leaf area of V_2 was noticeably larger than that of V_1, which might be because of the cultivars' genetic makeup, this results are in harmony with the finding of (Mahmood et al.,2024). As well as the fertilizer added during the endothelium stage had time to boost cell proliferation and plant pigment content, both of which are reflected in the larger leaf area endothelium.

In regards to yield and yield components, there were significant effects of Nano NPK on the number of spikelet spike $^{-1}$ at both locations. This variation occurred on number of spikelet spike $^{-1}$ due to difference in wheat cultivars(Al-Shammari and Noaema, 2023) .There was favorable effects of Nano NPK on number of grain spike^{-1}, especially when used the highest dosage of Nano NPK (F_3), this finding was in agreement with study of Al-Juthery et al. (2018b) which found that when compared to the same quantity of 11 essential nutrients Nano-fertilizers was significantly superior to all growth parameters then yield components.

Furthermore, the significant effects of Nano

NPK on weight of grain spike $^{-1}$was promising that is due to Nano - fertilizer was easily absorbed by the epidermis of leaves and moved to stems, facilitating the uptake of active chemicals (Abdel-Aziz et al., 2018) . This may be due to the positive effect of foliar applied nitrogen, phosphorus, and potassium to sustain proper leaf nutrition as well as carbon balance, and improving photosynthetic capacity is well established (Gosavi et al., 2017) . Additionally, there was a significant difference between the mean values of seed index under the interaction between cultivars and Nano –NPK for both locations respectively. Alqasim and Al-Ghazal (2023) recommended dose of 1 g L^{-1} of Nano-fertilizer in the studied stages. Maximum grain yield was perceived from F_3, S_2 and at both locations, this may be due to the combination spraying of Nano NPK which increased the yield and yield components of wheat crop due to its stimulating role as mentioned by (Crista et al., 2012) . Foliar application of Nano-fertilizers not only improves the grain yield and protein but also have a better economics of crop (Mahmood et al., 2024) and (Rakhimova et al., 2021).

Aziz and Zrar (2021) stated in their research that foliar application with Nano-NPK increased the values of vegetative growth and yield parameters. Nano fertilizer can serve as an efficient nutrient delivery system thereby reducing the quantity of nutrients required(Singh et al., 2023). The uptick of V2 cultivar was due to increase in, no of spikelet spike^{-1} and no of grain spike^{-1}, which caused yield improving, blanket stage spraying was vastly superior for stage 2.

F_3 treatment improved the protein yield with the order of effectiveness being $F_3 > F_2 > F_1 > F_0$ at both locations. This could be because of the increase in grain yield and protein percentage as stated by Mahmood et al. (2024) . Liu and Lal (2014) mentioned that the application of Nano-fertilizer is new delivery mechanisms to improve crop productivity and that was improved in our study

Furthermore, it is evident that the two wheat varieties were applied in accordance with the findings of Hadi (2020) due to the foliar spraying of Nano-NPK at tillering and booting with V_2 at both locations, respectively. Additionally, the mean protein yield values under the interaction between (VF, SF, VS) at both locations were recorded for (V_2x F_3, S_2x F_3, and V_2x S_2), and these differences were significant. This outcome could be due to the single factors that effect on protein yield.

5. Conclusion:

The most notable findings summed up the fact that significant impact of bread wheat varieties', stages of foliar application and concentrations of Nano-NPK and their combinations on growth traits, grain and protein yield of both varieties in comparing with control treatments. the best treatments and their combination were Aras, spraying in booting stage and spraying micronutrient administration at rates of 450 mg L^{-1} NPK-Nano. In general, the highest grain yield and protein yield were improved in Grdarasha location, while the lowest values recorded from Qlyasan, it is better to recommend wider range of Nano- NPK in future studies two distinct sites by applying foliar Nano-fertilizers at varying rates at different phases.

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