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Response of two bread wheat (*Triticum aestivum* L.) varieties to foliar application of Nano fertilizers at two growing stages and its effect on their qualitative characteristics

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Abstract

This study was conducted at Sulaimani Quality Control Laboratory, Bakrajo Agricultural Research during 2022 to determine the influence of interaction treatments between four levels of Nano NPK (20:20:20) using foliar application at rates of (0, 150, 300 and 450) mg L^{-1}, two growth stages tillering and booting at two locations Sulaimani with at Qilyasan Agricultural Research Station, University of Sulaimani, located at (35° 34′ 307″ N, 45° 21′ 992″ E and elevation 765 m above sea level) and Grda-rasha, the College of Agricultural Engineering Sciences research farm, Salahaddin University of Erbil, located at (Latitude 36. 10116 N and Longitude 44.00925 E and elevation of 415 meters above sea level), during winter season of 2019-2020, on quality variation of two bread wheat varieties (Adana-99 and Aras) in terms of length (mm), width (mm), thickness (mm), protein% and hectoliter kg hl^{-1}. The highest values of bread wheat quality according to the studied characteristics of hectoliter, thickness, width and length were (78.633 kg hl^{-1}, 3.240 mm, 3.380 mm and 6.500 mm) were recorded from interaction treatments of (Aras x booting x300 mgl^{-1}), (Aras x booting x300 mgl^{-1}), (Aras x booting x150 mgl^{-1}) and (Aras x booting x control) respectively from wheat samples that taken from Sulaimani location. On the other hand, the highest grain protein of 14.633 % was obtained from interaction treatment of (Aras x tillering x300 mgl^{-1}) at Erbil location. The results indicated that the spraying x300 mgl^{-1} regarded as a best level of Nano-NPK fertilizer.

Key words: Wheat varieties, Nano NPK fertilizer, Growth stages, Protein, Hectoliter.
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Introduction

The importance of wheat is mainly due to its seed, which can be ground into flour, semolina and other flour products which constitute the basic component of bread and other products of bakery and pasta, hence it is the major source of nutrients for a large number of the world's people [1].

The quality of grain especially protein is an important element in the program of wheat breeding that affects the commercial value of wheat. The content of protein is powerfully affected by the condition of the environment, the practices of crop management [2]. Additionally, there are differences depending on fertilizer application [3].

Protein is the most vital nutrient for humans and animals as evidenced by the source of its name. The protein % in wheat grain range between 10 to 18% of total dry matter. The grain protein% is broadly utilized as the majority of vital parameters to evaluate the wheat products' baking quality and elevated cost are generally obtained with a higher protein% in bread wheat. On the other hand, the quality of baking is determined by the protein structure. The main types of protein in wheat flour are albumins, globulins, gliadin, and glutenins. Gluten proteins (gliadin and glutamines) have a vital role in determining the quality of wheat flour baking. However, the gliadins chiefly relate to the viscosity and extensibility of the dough, even as the glutenins contribute to the strength and elasticity of the dough [4]. The function of the end-use of wheat (*Triticum aestivum* L.) is associated directly with the protein content and the grain composition. The selected wheat varieties were divided into different types based on their protein% [5]. The wheat protein % is influences by rainfall, temperature, soil fertility, regimes of fertilizer management and genetic factors [6]. Promising genotypes must be chosen in order to generate market-preferred varieties to find optimum genotypes with desirable characteristics for improving grain quality [7]. Explain that foliar Nano fertilizer application are the important tools in agriculture to improve crop growth, yield and quality parameters with increase nutrient use efficiency, reduce wastage of fertilizers and cost of cultivation. [8] stated that Foliar application of Nano-fertilizers leads to significant improvement of crop productivity of wheat in semi- arid region, Moreover, the foliar application of Nano-fertilizers, *i.e.*, Nano N has direct role in increasing yield as nutrient get easily available to plant in case of foliar spray.

The nanoparticles avoid the degradation produced by the surrounding environment of the food or by the manufacturing process. The food processing issues: mixing, component stability, safety and - intrinsic food features: texture, flavor, taste masking, availability and delivery [9]. Additionally, the critical growth stage of nutrient application is one of the determinants of nutrient efficiency, they stated that tillering stage appeared to be the most physiological stage for foliar application of micronutrients. [10]. The weight test has been accepted as a measure of the physical quality of wheat and other cereals in the international trade due to its simple and expeditious measurements. All else being equal, a high-test weight variety is likely to produce more flour. Hence, this trait is used as an indicator for the evaluation of milling quality. High-quality wheat is generally above 76 kg hl^{-1}, while a value below this limit implies wheat of low quality [11]. Hectoliter weight has also been linked to grain yield, although this is strongly affected by the environment [12]. High weight test generally means good wheat grains. The main axial dimensions of grains can be used to choose sieve separators and estimate the extraction rate throughout the reduction in size. Within a plant, the dimensions of wheat grains varied greatly, and the growth rates and kernel dimensions differed. Tiny grains are regarded to have a lower potential flour yield and weaker milling characteristics. Grain size had no effect on grain properties, milling performance, or soft wheat end-user features, except that tiny grains tended to be softer. In general, as grain size decreases, flour yield and refining decline. However, [13] found that small grain is softer than large grain depending on the variety. The aims of this study is to determine the interaction effect of levels of Nano-NPK, growth stages and wheat varieties on quality of bread wheat in Iraqi Kurdistan Region.

Materials and Methods

Materials

Seeds of two bread wheat varieties (V_1 = Adanna-99 and V_2= Aras) was used as plant material for this study. Nano -NPK (**Khazra Nano Chelated NPK 20-20-20 Fertilizer) foliar application with four levels** (F_0= 0 mg L^{-1} Control, F_1=150 mg L^{-1}, F_2=300 mg L^{-1} and F_3=400 mg L^{-1}) was applied as a second factors in two growth stages (tillering and booting) as a third factors.

Location of Experiment

The current study was conducted at two locations, the first is Qilyasan Agricultural Research Station, University of Sulaimani, located at (35° 34′ 307″ N, 45° 21′ 992″ E and elevation 765 m above sea level). The second is Grda-rasha, the College of Agricultural Engineering Sciences research farm, Salahaddin University - Erbil, located at (Latitude 36. 10116 N and Longitude 44.00925 E and elevation of 415 meters above sea level).

Field Experiment

The field experiment was laid out in a Factorial Randomized Complete Block Design (RCBD) with three replicates. The first factors was two bread wheat varieties (V_1 = Adanna-99 and V_2= Aras), the second factor was two growth stages for Nano- NPK application (S_1= tillering and S_2 = booting stage) and the third factor was four levels of Nano-NPK foliar application which encompassed the following levels (F_0= 0 mg L^{-1} Control, F_1=150 mg L^{-1}, = F_2=300 mg L^{-1} and F_3=400 mg L^{-1}). Sowing was carried out during 10th and 11th November (2019-2020) in a plot with size of (1×1.5) m at rate of 160 kg ha^{-1} (according to the recommended seed rates) for both locations. All required agricultural practices were done whenever needed.

Methods of Grain analysis

The seed samples were taken after harvesting to study the quality measurement of grain bread wheat in the cereal technology lab. Sulaimani agricultural research center. Bakrajo.

Analysis of wheat Protein

Near-Infrared Reflectance Method for Protein Determination in Small Grains [14].

Hectoliter weight

Test weight, also known as hectoliter mass, is a measure of the volume of grain per unit. It is usually expressed as kilograms per hectoliter and is a good indication of grain-soundness. Millers usually use test weight as an indication of expected flour yield. To perform this analysis, 1kg clean seed is required [15].

Grain measurements

The length, width, and thickness of the grain: The three main dimensions of a wheat grain are usually measured, axial dimensions in the grain was determined by randomly measuring the length, width, and thickness of three grains [16].

Data analysis

The data were statistically analyzed according to the technique of analysis of variance (ANOVA) for randomized complete block design, the mean comparison was fulfilled according to Duncan multiple range test at the level of significant 0.05 by [17].

Results

1- Effect of varieties on bread wheat quality

The analysis of variance as announced in appendices (1 and 2) revealed that the mean square of varieties showed that not significant effect for length and width characters while highly significant for the other characters at Sulaimani location, furthermore, varieties affect significantly on all characters at Erbil location. Data in table (1) showed that varieties affected significantly on grain length, it seems that V_1 and V_2 gave the longest to the shortest values between (6.295 to 6.261) mm and (6.192 to 6.179) mm for Sulaimani and Erbil locations, respectively.

Table (1) Effect of varieties on bread wheat quality

Varieties	Length (mm)	Width (mm)	Thickness (mm)	Protein%	Hectoliter kg hl^{-1}
Sulaimani Location					
Adanna-99 (V1)	6.295 a	3.125 a	2.706 b	12.033 b	77.213 b
Araz (V2)	6.192 b	3.142 a	2.825 a	12.392 a	77.533 a
Erbil Location					
Adanna-99 (V1)	6.261 a	2.962 b	2.620 b	13.663 b	76.317 b
Araz (V2)	6.179 b	3.061 a	2.685 a	13.821 a	76.750 a

Values with different letters within columns indicate significant differences at 5% of probability according to Duncan's multiple range test.

According to the characteristics of width the results shows that there were significant differences between both varieties at Erbil location the wider to the narrower values was (3.061 to 2.962) mm, respectively. Thickness is another studied property which affected significantly, the results obtained that there were significant differences between the two varieties, the highest value recorded for V_2 2.685 mm while the lowest value obtained by V_1 2.620 mm, at Erbil location. According to characteristics of protein% which is considered the most important ingredient in wheat grain for its vital component which is considered the most important ingredient in
wheat grain for its vital component which consists of gluten the key to the bread making consists of gluten the key to the bread making and most vagaries industries so enhancing the protein% characteristics quantity and quality is a great job for baking industries in general. The results in (table 1) showed that there were significant differences between the two varieties according to Sulaimani and Erbil locations with highest and lowest values (12.392 to12.033) % and (13.821 to 13.663) % respectively.

The results for hectoliter or test weight which is consider to be an important test of wheat bread quality showed that the effect of wheat varieties on Hectoliter for both locations Sulaimani and Erbil have a significant difference which obtained from the highest to the lowest values for V_2 and V_1 (77.533 to77.2130 kg hl^{-1} and (76.750 to 76.317) kg hl^{-1} at both locations, respectively

2- Effect of growth stages for application Nano-NPK fertilizer on wheat quality.

The analysis of variance as announced in Appendices (1 and 2) revealed that the mean square of growth stages for Nano - NPK application shows that significant differences appear for hectoliter character only in Sulaimani location, while, in Erbil growth stages affect highly significant on protein % and hectoliter character, regardless of non-significant F value but there are significant differences in multiple range test. The data presented in Table (2)

Demonstrated significant differences based on the growth stages for thickness when the fertilizer was applied during the growth stages. The highest and lowest values (2.850 to 2.681) obtained for booting and tillering respectively at Sulaimani location. The same table shows significant difference on protein % in Erbil location with highest and lowest value (14.213 and 13.271) % respectively which obtained for booting and tillering stages. According to the hectoliter characters, the results shows that there were significant differences between S2 and S1 for both locations the highest and lowest values (78.038 to76.708) kg hl^{-1} and (76.929 to76.138) kg hl^{-1} respectively**.**

3- Effect of Nano – NPK fertilizer on bread wheat quality.

The analysis of variance as clarified in appendices (1 and 2) revealed that the mean square of varieties shows significant effect of Nano-NPK on all studied characters at both locations except grain width in Sulaimani, in spite of non-significant F value but there are significant differences in multiple range test.

Data in table (3) shows that F_2 recorded the highest value on grain length (6.392 and 6.343) mm in both locations while the lowest values (6.147and 6.118) mm obtained for F_4 and F_1 in Sulaimani and Erbil.

Table 2. Effect of Stage of growth for application fertilizer on bread wheat quality.

Growth Stage	Length	Width mm	Thickness mm	Protein %	Hectoliter (kg hl-1)
Sulaimani Location					
Tillering stage S1	6.202 a	3.168 a	2.681 b	12.196 a	76.708 b
Booting stage S2	6.285 a	3.099 a	2.850 a	12.229 a	78.038 a
Erbil Location					
Tillering stage S1	6.219 a	3.015 a	2.651 a	13.271 b	76.138 b
Booting stage S2	6.221 a	3.009 a	2.654 a	14.213 a	76.929 a

Values with different letters within columns indicate significant differences at 5% of probability according to Duncan's multiple range test.

Locations respectively although there are non-significant differences between F_0 and F_4. For width and thickness, F_3 recorded the highest value (3.236 and 2. 945) mm and (3.022 and 2 587) mm as the lowest value which obtained from F_4 and F_1 in Sulaimani location whilst, F_0 and F_4 at Erbil location recorded the highest value (3.143 and 2.742) mm for width and thickness, moreover the lowest values (2.949 and 2.583) mm obtained from F3 and F1, respectively for Erbil location.

The highest and lowest value in our results for protein % in both locations Sulaimani and Erbil was (12.575 to11.683) % and (14.317 to13.258) %, respectively with F_4 and F_1 treatments Moreover, the hectoliter characters was (77.783 to 76.808) and (77.367 to75.325) kg hl^{-1} for highest and lowest values respectively obtained for F_4 and F_1 at both locations respectively.

Table 3. Effect of Nano-NPK fertilizer on bread wheat quality.

Fertilizers	Length (mm)	Width (mm)	Thickness (mm)	Protein %	Hectoliter (kg hl^{-1})
slumani Location					
F_1 = 0 mg l^{-1}	6.173 ^{b}	3.102 ^{ab}	2.587 ^{b}	11.683 ^{d}	76.808 ^{c}
F_2 = 150 mg l^{-1}	6.392 ^{a}	3.174 ^{ab}	2.760 ^{ab}	12.183 ^{c}	77.275 ^{b}
F_3 =300 mg l^{-1}	6.263 ^{ab}	3.236 ^{a}	2.945 ^{a}	12.408 ^{b}	77.625 ^{a}
F_4 = 450 mg l^{-1}	6.147 ^{b}	3.022 ^{b}	2.771 ^{ab}	12.575 ^{a}	77.783 ^{a}
Erbil location					
F_1 = 0 mg l^{-1}	6.118 ^{d}	3.143 ^{a}	2.583 ^{b}	13.258 ^{d}	75.325 ^{d}
F_2 = 150 mg l^{-1}	6.343 ^{a}	2.968 ^{b}	2.658 ^{ab}	13.492 ^{c}	76.467 ^{c}
F_3 =300 mg l^{-1}	6.161 ^{c}	2.949 ^{b}	2.628 ^{b}	13.900 ^{b}	76.975 ^{b}
F_4 = 450 mg l^{-1}	6.258 ^{b}	2.988 ^{b}	2.742 ^{a}	14.317 ^{a}	77.367 ^{a}

Values with different letters within columns indicate significant differences at 5% of probability according to Duncan's multiple range test.

4 –Effect of interaction between Varieties and growth stages

Analysis of variance as announced in appendices (1 and 2) revealed that the mean square of varieties showed that non-significant effect for width and hectoliter characters at Sulaimani location, while non- significant effect for thickness and hectoliter, and highly significant effect for length, thickness and highly significant protein% in Sulaimani and length, and protein in Erbil location.

Data in table (4) indicated that there were significant differences according to interaction effect of varieties and stage of growth on bread wheat quality in term of all characteristics for both locations except width in Sulaimani and thickness in Erbil location in spite of non-significant F value but there is significant differences in multiple range test. Length character recorded the highest and lowest values e (6.327 to 6.281) and (6.078 to and V_1

S_2) at both locations. 6.158) mm from the interaction treatments of (V_1 S_1)

Width character that there were significant differences obtained from the highest to the lowest values (3.165 to 2.864), with V_1 S_2 and V_1 S_1 at Erbil location, while thickness characters in Sulaimani recorded the highest to the lowest values (2.991 to 2.659) from the interaction treatments V_2 S_2 and V_1 S_2. Protein % affected significantly with the interaction between wheat varieties and growth stages the highest to the lowest values (12.508 to 11.883) % for the interaction treatments (V_1S_2 and V_1S_1)at Sulaimani location and (14.217 to 13.108) was recorded for (V_2 S_1 and V_1S_1) at Erbil location.

The hectoliter character varied from as low as (76.517 and 75.908) kg hl^{-1} under the interaction treatment V_1S_1 for both locations to as high as (78.167 and 77.133) under the interaction treatment V_2 S_2 for both locations.

Table 4. Effect of the interaction between Varieties and stage of growth on wheat bread quality

Variety x Growth stages	Length (mm)	Width (mm)	Thickness (mm)	Protein %	Hectoliter(kg hl-1)
			Sulaimani Locations		
V_1 S_1	6.327 [a]	3.171 [a]	2.703 [b]	11.883 [d]	76.517 [d]
V_1 S_2	6.078 [b]	3.165 [a]	2.659 [b]	12.508 [a]	76.900 [c]
V_2 S_1	6.264 [a]	3.079 [a]	2.709 [b]	12.183 [c]	77.908 [b]
V_2 S_2	6.307 [a]	3.118 [a]	2.991 [a]	12.275 [b]	78.167 [a]
			Erbil locations		
V_1 S_1	6.281 [a]	2.864 [d]	2.608 [a]	13.108 [c]	75.908 [d]
V_1 S_2	6.158 [d]	3.165 [a]	2.693 [a]	13.433 [b]	76.367 [c]
V_2 S_1	6.242 [b]	3.060 [b]	2.633 [a]	14.217 [a]	76.725 [b]
V_2 S_2	6.200 [c]	2.958 [c]	2.676 [a]	14.208 [a]	77.133 [a]

Values with different letters within columns indicate significant differences at 5% of probability according to Duncan's multiple range test.

5- Effect of interaction between varieties and Nano- NPK fertilizer

The analysis of variance as revealed in appendices (1 and 2) depicts that the mean square of the interaction between varieties and Nano fertilizer levels, showed that non-significant effect for all characters with the exception of hectoliter at Sulaimani location, while non- significant effect for length and protein%, and highly significant effect for width and hectoliters and significant effect for thickness at Erbil location but there is significant differences in multiple range test among all characteristics at both locations.

Among the two factor interactions, the interaction between (V × F) affected bread wheat quality significantly at both locations as presented in Table 5, the results show significant differences recorded from the highest to the lowest values for length, width, thickness, protein and hectoliter.

The grain length obtained (6.443 to 6.052) mm with V_1 F_1 and V_2 F_3, respectively at Sulaimani location and (6.388 to 6.065 mm) with V1F1 and V_2 F_0, respectively at Erbil location. The presented result in the same table for grain width shows the highest and lowest values (3.315 to 2.988) mm obtained for the interaction treatment V_2 F_2 and V_1 F_3, respectively at Sulaimani location and (3.235 to 2.888) with the interaction V_2 F_0 and V_1F_1, respectively at Erbil location. Furthermore the characteristic of thickness produced (3.065 to 2.558) from V_2 F_2 and V_2 F_0, respectively at Sulaimani location while (2.755 to 2.513) with V_2 F_3 and V_1 F_2, at Erbil location, further more protein characters recorded (12.717 to 11.450) with V_2 F_3 and V_1 F_0, at Sulaimani location and (14.367 to 13.200)% with V_2 F_3 and V_2 F_0, respectively at Erbil location, while hectoliter recorded (78.017 to76.750) kg hl^{-1} with V_2 F_3 and V_2 F_0, respectively at Sulaimani location and (77.700 to75.683) kg hl^{-1} with V_2 F_3 and V_1 F_0,respectively at Erbil location.

Table (5) Effect of the interaction of Varieties and rate of Nano fertilizers on wheat bread quality

Varieties x Nano - NPK	Length (mm)	Width (mm)	Thickness (mm)	Protein%	Hectoliter(kg hl^{-1})
Sulaimani Location					
$V_1 F_0$	6.255 abc	3.215 ab	2.615 bc	11.450 f	76.867 de
$V_1 F_1$	6.443 a	3.140 ab	2.780 abc	12.000 e	77.083 cd
$V_1 F_2$	6.242 abc	3.157 ab	2.825 abc	12.250 d	77.350 bc
$V_1 F_3$	6.242 abc	2.988 b	2.605 c	12.433 c	77.550 b
$V_2 F_0$	6.092 bc	2.988 b	2.558 c	11.917 e	76.750 e
$V_2 F_1$	6.340 a	3.208 ab	2.740 bc	12.367 c	77.467 b
$V_2 F_2$	6.285 ab	3.315 a	3.065 a	12.567 b	77.900 a
$V_2 F_3$	6.052 c	3.055 ab	2.937 ab	12.717 a	78.017 a
Erbil Location					
$V_1 F_0$	6.172 cd	3.050 b	2.603 bcd	13.317 bc	74.967 f
$V_1 F_1$	6.388 a	2.888 c	2.637 abcd	13.417 bc	76.417 d
$V_1 F_2$	6.178 cd	2.892 c	2.513 d	13.650 b	76.850 c
$V_1 F_3$	6.307 b	3.018 b	2.728 ab	14.267 a	77.033 bc
$V_2 F_0$	6.065 e	3.235 a	2.563 cd	13.200 c	75.683 e
$V_2 F_1$	6.298 b	3.047 b	2.678 abc	13.567 b	76.517 d
$V_2 F_2$	6.143 d	3.007 b	2.742 ab	14.150 a	77.100 b
$V_2 F_3$	6.208 c	2.957 bc	2.755 a	14.367 a	77.700 a

Values with different letters within columns indicate significant differences at 5% of probability according to Duncan's multiple range test.

6-The effect of interaction between growth stages and Nano –NPK fertilizers.

The interaction effects for growth stages and levels of Nano–NPK fertilizers caused significant differences on bread wheat quality, it is evident from table (6) that the highest and lowest grain length (6.450 to 6.048) mm obtained from $S_2 F_1$and $S_1 F_3$, at Sulaimani location, and (6.368 to 6.083) mm with $S_2 F_1$ and $S_1 F_0$, additionally the values for grain width was (3.287 to 2.858) for the interaction treatments $S_2 F_2$ and $S_2 F_3$ and (3.202 to 2.928) mm recorded from $S_2 F_0$ and $S_2 F_1$ for both locations respectively. According to the presented data, grain thickness recorded (3.067 to 2.570) mm by the interaction between $S_2 F_2$ and $S_1 F_3$, at Sulaimani location and (2.752 to 2.540) mm with $S_1 F_3$ and $S_1 F_0$, at Erbil location respectively. The protein% recorded (14.567 to 12.600) % from $S_2 F_3$ and S_1F_0 at Erbil location .and (12.650 to11.600) % with the interaction treatment S_1F_3 and $S_1 F_0$, at Sulaimani location respectively. Whereas the interaction treatments $S_2 F_3$ recorded the highest grain hectoliter (78.533 to77.783) while the lowest value (76.233 and 74.833) kg hl^{-1} obtained from S_1F_0 respectively, for both locations.

Table 6. Effect of the interaction between growth stages and Nano NPK on wheat quality

Growth stages x Nano NPK	Length (mm)	Width (mm)	Thickness (mm)	Protein %	Hectoliter (kg hl^{-1})
Sulaimani Location					
S_1 F_0	6.168 ^{bc}	3.137 ^{a}	2.585 ^{b}	11.600 ^{g}	76.233 ^{f}
S_1 F_1	6.333 ^{ab}	3.165 ^{a}	2.747 ^{ab}	12.083 ^{e}	76.617 ^{e}
S_1 F_2	6.258 ^{abc}	3.185 ^{a}	2.823 ^{ab}	12.450 ^{bc}	76.950 ^{d}
S_1 F_3	6.048 ^{c}	3.185 ^{a}	2.570 ^{b}	12.650 a	77.033 ^{d}
S_2 F_0	6.178 ^{bc}	3.067 ^{ab}	2.588 ^{b}	11.767 ^{f}	77.383 ^{c}
S_2 F_1	6.450 ^{a}	3.183 ^{a}	2.773 ^{ab}	12.283 ^{d}	77.933 ^{b}
S_2 F_2	6.268 ^{abc}	3.287 ^{a}	3.067 ^{a}	12.367 ^{cd}	78.300 ^{a}
S_2 F_3	6.245 ^{abc}	2.858 ^{b}	2.972 ^{a}	12.500 ^{b}	78.533 ^{a}
Erbil Location					
S_1 F_0	6.083 ^{f}	3.083 ^{b}	2.540 ^{b}	12.600 ^{f}	74.833 ^{g}
S_1 F_1	6.318 ^{b}	3.007 ^{bc}	2.672 ^{ab}	12.933 ^{e}	76.100 ^{e}
S_1 F_2	6.183 ^{cd}	2.948 ^{c}	2.640 ^{ab}	13.483 ^{d}	76.667 ^{d}
S_1 F_3	6.292 ^{b}	3.020 ^{bc}	2.752 ^{a}	14.067 ^{bc}	76.950 ^{c}
S_2 F_0	6.153 ^{de}	3.202 ^{a}	2.627 ^{ab}	13.917 ^{c}	75.817 ^{f}
S_2 F_1	6.368 ^{a}	2.928 ^{c}	2.643 ^{ab}	14.050 ^{bc}	76.833 ^{cd}
S_2 F_2	6.138 ^{e}	2.950 ^{c}	2.615 ^{ab}	14.317 ^{ab}	77.283 ^{b}
S_2 F_3	6.223 ^{c}	2.955 ^{c}	2.732 ^{a}	14.567 ^{a}	77.783 ^{a}

Values with different letters within columns indicate significant differences at 5% of probability according to Duncan's multiple range test.

7-Interaction effect of Varieties, growth stages, Nano–NPK on quality

Data in table (7) indicated that the interaction among the three studied factors Varieties, growth stages and Nano –NPK foliar application had a positive effect on bread wheat quality. Grain length recorded from the highest to the lowest values (6.500 to 5.827) mm with V_2 S_2 F_1 and V_1 S_2 F_3, at Sulaimani location and (6.443 to 5.970) mm with V_2 S_1F_1 and V_1 S_2 F_0, at Erbil location, the grain width recorded (3.380 to 2.787) mm with V_2 S_2 F_2 and V_2 S_1 F_3, respectively at Sulaimani location and (3.323 to 2.780) mm with V_1 S_2 F_0 and V_1 S_1F_2, respectively at Erbil location, while grain thickness recorded (3.240 to 2.350) mm with V_2 S_2 F_3 and V_1 S_2 F_0, respectively at Sulaimani location and (2.833 to 2.467) mm withV_2 S_2 F_3 and V_1 S_1 F_2, respectively at Erbil location, grain protein % recorded (12.867 to 11.133)% with V_1 S_2 F_3 and V_1 S_1 F_0, respectively at Sulaimani location, (14.633 to12.533)% with V_2 S_1 F_3 and V_1 S_1 F_0, respectively at Erbil location additionally, grain hectoliter recorded (78.633 and 78.167) kg hl^{-1} with V_2 S_2 F_3 as a highest value and the interactions V_1 S_1 F_0 recorded the lowest value (76.233 and to74.367) kg hl^{-1} at both locations location while Erbil location recorded (78.167 to74.367) kg hl^{-1} with V_2 S_2 F_3 and $V_1S_1F_0$.

Table 7. Effect of Varieties, growth stages, Nano –NPK on wheat quality.

Varieties x Growth Stages x Nano - NPK	Length mm	Width mm	Thickness mm	Protein %	Hectoliter kg hl^{-1}
Sulaimani Location					
$V_1 S_1 F_0$	6.267 ^{ab}	3.177 ^{abc}	2.820 $^{a-d}$	11.133 ^{h}	76.233 ^{f}
$V_1 S_1 F_1$	6.487 ^{a}	3.197 ^{abc}	2.793 $^{a-d}$	11.767 ^{g}	76.500 ^{ef}
$V_1 S_1 F_2$	6.283 ^{ab}	3.120 ^{abc}	2.693 ^{bcd}	12.200 ^{ef}	76.667 ^{ef}
$V_1 S_1 F_3$	6.270 ^{ab}	3.190 ^{abc}	2.507 ^{cd}	12.433 ^{cd}	76.667 ^{ef}
$V_2 S_1 F_0$	6.243 ^{ab}	3.253 ^{ab}	2.410 ^{d}	11.767 ^{g}	77.500 ^{d}
$V_2 S_1 F_1$	6.400 ^{ab}	3.083 ^{abc}	2.767 $^{a-d}$	12.233 ^{e}	77.667 ^{cd}
$V_2 S_1 F_2$	6.200 ^{ab}	3.193 ^{abc}	2.957 ^{abc}	12.300 ^{de}	78.033 ^{bc}
$V_2 S_1 F_3$	6.213 ^{ab}	2.787 ^{c}	2.703 ^{bcd}	12.433 ^{cd}	78.433 ^{ab}
$V_1 S_2 F_0$	6.070 ^{bc}	3.097 ^{abc}	2.350 ^{d}	12.067 ^{f}	76.233 ^{f}
$V_1 S_2 F_1$	6.180 ^{ab}	3.133 ^{abc}	2.700 ^{bcd}	12.400 ^{d}	76.733 ^{e}
$V_1 S_2 F_2$	6.233 ^{ab}	3.250 ^{ab}	2.953 ^{abc}	12.700 ^{b}	77.233 ^{d}
$V_1 S_2 F_3$	5.827 ^{c}	3.180 ^{abc}	2.633 ^{cd}	12.867 ^{a}	77.400 ^{d}
$V_2 S_2 F_0$	6.113 ^{bc}	2.880 ^{bc}	2.767 $^{a-d}$	11.767 ^{g}	77.267 ^{d}
$V_2 S_2 F_1$	6.500 ^{a}	3.283 ^{ab}	2.780 $^{a-d}$	12.333 ^{d}e	78.200 ^{ab}
$V_2 S_2 F_2$	6.337 ^{ab}	3.380 ^{a}	3.177 ^{ab}	12.433 ^{cd}	78.567 ^{a}
$V_2 S_2 F_3$	6.277 ^{ab}	2.930 ^{bc}	3.240 ^{a}	12.567 ^{bc}	78.633 ^{a}
$V_2 S_2 F_0$	6.160 ^{fgh}	3.147 ^{bcd}	2.597 ^{bcd}	13.733 ^{d}	76.067 ^{f}
$V_2 S_2 F_1$	6.293 ^{cd}	2.897 ^{fgh}	2.603 ^{bcd}	14.033 ^{cd}	76.900 ^{cd}
$V_2 S_2 F_2$	6.140 ^{h}	2.897 ^{fgh}	2.670 $^{a-d}$	14.567 ^{ab}	77.400 ^{b}
$V_2 S_2 F_3$	6.207 ^{efg}	2.890 ^{fgh}	2.833 ^{a}	14.500 ^{abc}	78.167 ^{a}
Erbil Location					
$V_1 S_1 F_0$	**6.197 $^{e-h}$**	**2.843 ^{gh}**	**2.550 ^{bcd}**	**12.533 ^{g}**	**74.367 ^{h}**
$V_1 S_1 F_1$	6.333 ^{bc}	2.817 ^{h}	2.590 ^{bcd}	12.767 ^{efg}	76.067 ^{f}
$V_1 S_1 F_2$	6.220 ^{ef}	2.780 ^{h}	2.467 ^{d}	13.233 ^{e}	76.533 ^{e}
$V_1 S_1 F_3$	6.373 ^{b}	3.017 ^{def}	2.827 ^{a}	13.900 ^{d}	76.667 ^{de}
$V_2 S_1 F_0$	6.147 ^{gh}	3.257 ^{ab}	2.657 $^{a-d}$	14.100 ^{bcd}	75.567 ^{g}
$V_2 S_1 F_1$	6.443 ^{a}	2.960 ^{fg}	2.683 ^{abc}	14.067 ^{bcd}	76.767 ^{de}
$V_2 S_1 F_2$	6.137 ^{h}	3.003 ^{ef}	2.560 ^{bcd}	14.067^{bcd}	77.167^{bc}
$V_2 S_1 F_3$	6.240 ^{de}	3.020 ^{def}	2.630 $^{a-d}$	14.633 ^{a}	77.400 ^{b}
$V_1 S_2 F_0$	5.970 ^{i}	3.323 ^{a}	2.530 ^{cd}	12.667^{fg}	75.300 ^{g}
$V_1 S_2 F_1$	6.303 ^{c}	3.197 ^{bc}	2.753 ^{ab}	13.100 ^{ef}	76.133 ^{f}
$V_1 S_2 F_2$	6.147 ^{gh}	3.117 ^{cde}	2.813 ^{a}	13.733 ^{d}	76.800 ^{de}
$V_1 S_2 F_3$	6.210 ^{efg}	3.023 ^{def}	2.677 $^{a-d}$	14.233 $^{a-d}$	77.233 ^{b}
$V_2 S_2 F_0$	6.160 ^{fgh}	3.147 ^{bcd}	2.597 ^{bcd}	13.733 ^{d}	76.067 ^{f}
$V_2 S_2 F_1$	6.293 ^{cd}	2.897 ^{fgh}	2.603 ^{bcd}	14.033 ^{cd}	76.900 ^{cd}
$V_2 S_2 F_2$	6.140 ^{h}	2.897 ^{fgh}	2.670 $^{a-d}$	14.567 ^{ab}	77.400 ^{b}
$V_2 S_2 F_3$	6.207 ^{efg}	2.890 ^{fgh}	2.833 ^{a}	14.500 ^{abc}	78.167 ^{a}

Values with different letters within columns indicate significant differences at 5% of probability according to Duncan's multiple range test.

8- Effect of the locations on wheat bread quality.

The analysis of variance as announced in Appendix (3) revealed that the mean square of varieties showed that non-significant effect for length and highly significant for all characters with the exception of significant effect for thickness characters for both locations. Data in table (8) indicated that there were significant differences regarding the effect of location for characteristics in term of hectoliter, protein, thickness and width which obtained from the

highest to the lowest. Grain width, thickness and hectoliter value was (3.133 to 3.012), (2.766 to2.653) mm and (77.373 to 76.533) kg hl^{-1} for Sulaimani and Erbil location, respectively while the Grain protein% value recorded, (13.742 to 12.213) % for Erbil and Sulaimani location, respectively Sulaimani and Erbil location

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Table 8. Effect of the locations. on wheat bread quality.

Locations	Length (mm)	Width (mm)	Thickness (mm)	Protein %	Hectoliter (kg hl^{-1})
Sulaimani	6.244 [a]	3.133 [a]	2.766 [a]	12.213 [b]	77.373 [a]
Erbil	6.220 [a]	3.012 [b]	2.653 [b]	13.742 [a]	76.533 [b]

Values with different letters within columns indicate significant differences at 5% of probability according to Duncan's multiple range test.

Discussion

The differences between the two varieties in these traits may be due to their differences in the relative performance of each genotype, the results of variety differences are in agreement with those whom reported by [18]. The recent results are in parallel with the previous findings that the studied die mention can influenced by environment, these results were in agreement with [19]. the significant differences in protein % of our result between the two varieties was in harmony with [20] whom reported that bread wheat quality is grouped based on Protein content as very low (6.0 %), low (9.1- 11.5%), medium (11.6-13.5 %), high (13.6-15.5 %), very high (15.6-17.5) %, and extra high 17.6 %. The differences between varieties in hectoliters character was in agreement with the results reported by [21]and [22] noted that TGW and HLW parameters are affected by genotypes.

High protein values can be related to the low-test weight, which is primarily determined by varieties and can be influenced positively or adversely by late sowing dates, nitrogen deficit, water availability, and high humidity during the filling stage [23]. The differences in protein and hectoliters between the two growth stages was in harmony with similar results obtained by [23 and 24]. From the results it shows that the response of wheat varieties was differed according to Nano fertilizer levels, these data are in agreement with those whom reported by [25 and 26], and (27) stated that Hectoliter and seed index these parameters are heavily affected by environmental factors such as soil nutrient levels, amount of rainfall, and number of sunny days. The interaction between (V and S) and its effect on thickness was depicts by [21]. [28] explain the same results of our data according to hectoliter characters and effect of (V x S.) interaction treatments. Significant effects of (V x F) on bread wheat quality shows that the response of wheat varieties were different due to different genotypes, these results are in agreement with researchers whom reported by [29 and 30]. The value of hectoliter is consistent with the U.S. grading system's standard hectoliter weight of more than 77.23kg hl^{-1} for wheat [31] The differences from the interaction treatment growth stages and fertilizers on hectoliter was in harmony with the researchers whom reported by [30]. Foliar nourishment guarantees the availability of nutrients to crops so that the higher yield can be obtained. among major nutrients, nitrogen plays a vital role in increasing the crop yield. The application of proper amount of nitrogen is considered a key factor to obtain abundant quantity of wheat. Foliar application of nitrogen has more effects on yield and quality of wheat as it incurs minimum losses [32]. The three factor interactions differed significantly for all agronomic parameters due to their genetic background [33]. Wheat quality was influenced by various factors: environment., management, and their interactions among those factors [34].

Appendix 1: Mean Squares of Variance Analysis for Some quality characters of wheat in Sulaimani Location

		Mean squares				
S.O.V	d.f	Length(mm)	Width (mm)	Thickness (mm)	Protein %	Hectoliter (kg hl^{-1})
V	1	$0.128^{n.s}$	$0.003^{n.s}$	0.169**	1.541**	1.235**
S	1	$0.083^{n.s}$	$0.057^{n.s}$	$0.342^{n.s}$	$0.013^{n.s}$	21.200**
F	3	0.147*	$0.103^{n.s}$	0.257**	1.803**	2.241**
V S	1	0.255*	$0.006^{n.s}$	0.319**	0.853**	$0.047^{n.s}$
V F	3	$0.033^{n.s}$	$0.084^{n.s}$	$0.116^{n.s}$	$0.019^{n.s}$	0.269*
S F	3	$0.025^{n.s}$	$0.103^{n.s}$	0.107 **	0.093**	$0.062^{n.s}$
V S F	3	$0.030^{n.s}$	$0.044^{n.s}$	0.110^{**}	0.061**	$0.092^{n.s}$
Error	32	0.029	0.045	0.062	o.007	0.065
Total	47					

Appendix 2: mean squares of variance analysis for some quality characters of bread wheat in Erbil location.

		Mean squares				
S.O.V	d.f	Length (mm)	Width (mm)	Thickness (mm)	Protein %	Hectoliter (kg hl-1)
V	1	0.082**	0.118**	0.049**	0.301*	2.253**
S	1	$0.000^{n.s}$	$0.000^{n.s}$	$0.000^{n.s}$	10.641**	7.521**
F	3	0.122**	0.094**	0.054**	2.607**	9.416**
VS	1	0.020**	0.488**	0.005^{ns}	0.333*	0.007^{ns}
VF	3	0.003^{ns}	0.037**	0.040*	0.196^{ns}	0.279**
SF	3	0.014**	0.024**	0.009^{ns}	0.378**	0.073^{ns}
VSF	3	0.017**	0.027**	0.059**	0.039^{ns}	0.056^{ns}
Error	32	0.001	0.005	0.012	0.072	0.032
Total	47					

Appendix 3: mean squares of the variance analysis for some quality characters of bread wheat in both locations

		Mean squares				
S.O.V	d.f	Length (mm)	Width (mm)	Thickness (mm)	Protein %	Hectoliter (kg hl^{-1})
L	1	$0.014^{n.s}$	0.355**	0.307*	56.120**	16.918**
Error	94	0.029	0.041	0.059	0.338	0.775
Total	95					

Conclusion

Based on the above results, it can be concluded that application of different rate of foliar Nano-fertilizers at different stages for application for two bread wheat varieties had a greater role in enhancing grain quality, significant variation among varieties was detected in response to quality characteristics to foliar Nano fertilizer application (rate of 450 mg l^{-1}) at two different growth stages for application at two different locations. Regarding the wheat quality varieties was the main factor which had the greatest impact on four quality characteristics, Hectoliter, protein, thickness and width. The two bread wheat varieties which used in our study displayed a wide range in physical, chemical, test quality.

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استجابة صنفين من قمح الخبز (*Triticum aestivum* L) للرش الورقي للأسمدة النانوية في مرحلتي نمو وتأثير ذلك على صفات الجودة

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الخلاصة

أجريت هذه الدراسة في مختبر السيطرة النوعية بمركز بحوث بكرجو الزراعية في السليمانية خلال عام 2022 لتحديد تأثير المعاملات العاملية بين أربعة مستويات من السماد النانوني NPK (20:20:20) باستخدام الرش الورقي بمستويات (0 و 150 و 300 و 450) ملغم لتر$^{-1}$، خلال مرحلتي نمو (التفرعات و البطان) والتمهيد في موقعين السليمانية وأربيل على اختلاف جودة صنفين من قمح الخبز (ادنة 99 وأراس) من حيث الطول (مم) ، العرض (مم) ، السمك (مم) ، البروتين٪ و الهكتوليتر kg hl^{-1} سجلت أعلى قيم لجودة قمح الخبز وفقا للصفات المدروسة الهكتوليتر والسمك والعرض والطول (78.633 كغم هكتوليتر $^{-1}$ و3.240 مم و3.380 مم و6.500 مم) من المعاملات العاملية (صنف اراس x مرحلة البطان 300x ملغم لتر$^{-1}$) و (صنف اراس x مرحلة البطان 300x ملغم لتر$^{-1}$) و(صنف اراس x مرحلة البطان 150x ملغم لتر$^{-1}$) وصنف اراس x مرحلة البطان 0x ملغم لتر$^{-1}$) على التوالي من عينات القمح المأخوذة من موقع السليمانية. ومن ناحية أخرى، تم الحصول على أعلى بروتين للحبوب بنسبة 14.633٪ من المعاملات العاملية (صنف اراس x مرحلة التفرعات 300x ملغم لتر$^{-1}$) من موقع اربيل .

الكلمات المفتاحية : اصناف الحنطة ، سماد NPK النانوى، مراحل النمو، البروتين، الهكتوليتر.