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RESEARCH ARTICLE

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The effect of phosphorus fertilizer types and varieties on growth and yield of Sorghum [*Sorghum bicolor* (L.) Moench].

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ABSTRACT

The field experiment was carried out during autumn growing season (2023) in Daquq district / Kirkuk governorate located in north-eastern Iraq at a latitude 35.28°N, and a longitude of 23.44°E. The study aimed to compare the effect of conventional and nano phosphorus fertilizer on the growth and yield of Sorghum varieties. The study established according to Randomized Complete Block Design (R.C.B.D) in split plots system, the main plots include three levels of conventional and nano phosphorus fertilizer as a first factor (100kg ha-1 conventional phosphorus, 5kg ha-1 nano-phosphorus and 10kg ha-1 nano- phosphorus). This was used as a ground application, where conventional phosphorus fertilizer was applied once at planting, and nano-phosphorus fertilizer was added in two doses, the first at planting and the second at flowering. The secondary plots included six genotypes of Sorghum (Bohoth, Giza, J, Enqadh, Rabih, and Lio). The results showed that: Nano phosphorus fertilizer 10kg ha-1 record high values in all studied traits except in chlorophyll index for flag leaf and grain phosphorus percentage Giza variety had significant influence in traits of (flag leaf area, total grain yield., and grain phosphorus percentage). While J variety had significant impact in (yield efficiency). 1000 grains weight was highest for Buhouth variety The interaction between (10kg ha-1 nano phosphorus fertilizer and Giza variety) by giving the highest means in traits of flag leaf area and the total grain yield. Interaction between (10kg ha-1 nano phosphorus fertilizer and J variety) record significant values in traits, grains number per panicle and yield efficiency. While the highest 1000 grain weight recorded by the interaction between 10kg ha-1 nano phosphorus and Bohoth variety treatment. Significant ratio of phosphorous in the grains where observed in the interaction between 10kg ha-1 nano phosphorus and Lio variety..

***Keywords*: Sorghum, varieties, conventional phosphorus, nano, growth traits and yield.**

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Monech] belongs to the Poaceae family, it is an important common cereal crop in different regions of the world [1]. It comes in fifth place in the world after wheat, rice, corn and barley crops in terms of cultivated area and production, production capacity of any crop, apart from its specifications, depends on crop management which applied according to the correct scientific basics and providing nutrients, especially macro elements, including phosphorus. Iraqi soils characterized by a high soil reaction degree, which reduces macro elements availability, especially phosphorus [2]. Phosphorus deficiency problem is usually common in many regions of the world, especially in the soils of arid and semi-arid areas, and keeping appropriate level of phosphorus in plant tissues improve the activity and root system growth which increase its saturation and enhance plant shoot system which leads to early ripening [3].

For many years, scientists focused on introducing some modern technologies in agriculture, including using nano-fertilizers. Their goal was increasing the plant's benefit from the mineral as a result of their characteristics that characterize its molecules due to their small diameter, which increases their chemical effectiveness and provides a bigger surface area for reactions [4]. As well as the speed of their absorption and diffusion within The plant system, as it is considered a suitable mechanism for transporting elements to the plant targeted parts by exploiting the porous surfaces of the plant parts, which may increase the efficiency of their use by the plant and compensate nutrient deficiency that plant needs [5] . The differences among genotypes make them show clear differences in growth characteristics and production, and the interaction of genetic factors with the environment will show its effect on the phenotypic characteristics and productivity. All these factors contribute to determining the variability of these characteristics [6]. This study conducted to compare the effect of nano-fertilizer phosphorus with conventional through the influence on growth and yield of Sorghum and to examine the response of several varieties of Sorghum to nano-phosphorus to determine the best level of nano-phosphorus with the best variety performance of Sorghum under the dominant environmental conditions in the study area.

Materials and methods

A field experiment was carried out during the autumn season (2023) at Daquq district in Kirkuk governorate, with the aim of comparing the effect of conventional and nano-phosphorus fertiliser on the growth, yield and quality of Sorghum varieties. The experimental land was prepared, where it plowed twice perpendicularly by disc plough. After ploughing harrow been used for breaking up and smoothing out the soil surface and prepared for planting. Soil samples were taken at a depth of (0-30) cm and the soil properties are presented in Table (1).

Table (1) Soil physical and chemical properties of the experiment soil for previous two seasons before planting

Analysis type		2023 growing season	Unit
Soil pH		7.10	
Soil Electrical conductivity		0.66	dS m^{-1}
Water Electrical conductivity		34.2	dS m^{-1}
Total Dissolved Solids (TDS)		907	ppm
Available phosphorus		2.37	mg kg^{-1}
Available nitrogen		8.41	mg kg^{-1}
Available potassium		198.67	mg kg^{-1}
Organic matter		0.82	%
Soil proportion	Sand	23	%
	Silt	32	%
	Clay	45	%
Texture			Sandy clay

The experimental land divided into three replicates, each one divided into three main plots which placed with phosphorus fertilizer levels as the first factor (100 kg P_2O_5 ha^{-1} traditional phosphorus, 5 kg ha^{-1} nano phosphorus, and 10 kg ha^{-1} nano phosphorus) applied as soil additions. The traditional phosphorus fertilizer was applied once at planting, while the nano phosphorus fertilizer was applied in two doses: the first at planting and the second at flowering. The subplots included six genetic varieties of sorghum: Bohoth, Giza, J, Enqadh, Rabih, and Lio .I got varieties from the University of Tikrit / College of Agriculture. Each main plot was divided into six secondary plots which occupied with six varieties of Sorghum, thus the total experimental unit's number was (3 6× ×3 = 54). Each replicate contained 18 experimental units, which include five lines with a length of 3 m and a distance between the lines 0.70 m and between a plant and another 0.20 m. The field fertilized with 200 kg N ha^{-1} by using urea fertilizer (46% N) added in three equal doses at planting, elongation stage and the beginning of flowering. The seeds were planted on 15/7/2023 at 2-3 cm depth, where 2-3 seeds were placed in each seedbed. Weeds were controlled manually whenever needed and use 10% granulated diazinon pesticide with an average of 4 kg ha^{-1} to control corn stem borer (*Sesamia cretica*). The crop was irrigated whenever needed using the irrigation system with a fixed sprinkler. After flowering was completed, the plant panicles were covered with paper bags to prevent birds attacking.

Traits which assessed were days number from planting till 50% flowering, plant height, flag leaf area, flag leaf chlorophyll content, panicle length, grains per panicle, 300 grains weight (g), grain yield (t ha^{-1}), yield efficiency and grains phosphorus percentage). The data were statistically analyzed according to complete random block design (R.C.B.D) in split plot system and then the differences between the means were compared by using the Duncan Multi-Range Test at a significant level of 0.05 using [7]

Results and discussion

1. **Days number from planting till 50% flowering (day)**

Growth period from germination till flowering gives a correct idea about early varieties because they are less affected by environmental factors than other growth stages [8]. It is noted from Table (2) that this trait is not significantly affected by phosphorus fertilization levels, with significant differences between the varieties and their interaction with fertilizer applications. The results showed that Bohoth variety was significantly earlier in reaching the stage of 50% flowering by 86.44 days, and did not differ significantly from the variety (Giza and G) where they record an average of (87.22 and 87 days) respectively. In contrast to the Lio variety was significantly late by 87.55 days. This can be attributed to the variation of varieties in the required period for flowering and the difference in their genetic background. As there are varieties with early, medium and late flowering, these results are consistent with the findings of [9], [10], [11] and [12]. It is also noticed from Table (2) that the interaction between the nano-fertilizer treatment 10 kg ha^{-1} with the Bohoth and J variety was significantly earliest in reaching this stage with an average of 85.0 days, while the interaction between conventional fertilizer 100 kg P2O5 ha^{-1} with the Lio variety was significantly late by an average of 89.0 days.

Table (2) Effect of phosphorus fertilization and varieties and their interactions on days number from planting till 50% flowering (day) for Sorghum

Varieties	Phosphorus fertilization level kg ha^{-1}			Varieties average
	P_2O_5 kg100 (Conventional)	(Nano) 5	(Nano) 10	
Bohoth	87.33 b-e	87.00 b-e	85.00 g	86.44 b
Giza	87.66 b-e	86.66 c-f	86.00 efg	86.77 b
J	88.00 abc	86.66 c-f	85.00 g	86.55 b
Inqath	88.33 ab	86.66 c-f	86.66 c-f	87.22 ab
Rabeh	87.66 a-d	88.00 abc	85.33 fg	87.00 ab
Lio	89.00 a	87.33 b-e	86.33 d-g	87.55 a

Phosphorus average	88.00 a	87.05 a	85.72 a

Means with different letters have significant difference according to the Duncan's multiple range test at 0.05

2. Plant height (cm)

This trait influence by genetic and environmental factors, where the stem grows vertically by Internode elongation, it appears from Table (3) that there are significant differences between fertilizer applications and varieties and the interaction between them for plant height. Phosphorus nano-fertilizer treatments 10 and 5 kg ha^{-1} had significant by recording 140.31 and 140.98 cm respectively. Compared to conventional phosphorus fertilizer treatment, which gave the lowest value of plant height amounted 129.27 cm. This may be due to the positive effect of phosphorus nano-phorus in most of the vital processes within the plant and cell division as it enters the composition of the living nuclear material in the plant and the availability of the nano- phosphorus mineral in the soil and increase the absorption levels by the plant leads to improve its growth due to the role of this element in the spread of roots and cell division and increase their numbers and provide the necessary energy for photosynthesis [13]. For the varieties, Bohoth recorded the highest rate of plant height by 154.53 cm, while the Giza variety recorded the lowest value by 130.60 cm. The reason for the difference between varieties in plant height may be due to their difference in genetic background, their ability to respond to environmental conditions, and their reflection on elongation increase and cell divisions. These results are consistent with [14]. For the interaction between the study factors levels, the interaction between phosphorus nano-fertilizer 10 kg ha^{-1} and the Bohoth variety which gave the highest average of plant height 160.20 cm, while the lowest recorded by interaction between conventional phosphorus fertilizer and Giza variety amounted by 120.80 cm.

Table (3) Effect of phosphorus fertilization and varieties and their interactions on Sorghum plant height (cm)

Varieties	Phosphorus fertilization level kg ha^{-1}			Varieties average
	P_2O_5 kg 100 (Conventional)	(Nano) 5	(Nano) 10	
Bohoth	150.53 bc	152.86 b	160.20 a	154.53 a
Giza	120.80 k	131.20 hi	139.80 ef	130.60 d
J	127.40 ij	136.74 fg	147.00 cd	137.05 b
Inqath	123.20 jk	138.55 ef	134.70 fgh	132.15 cd
Rabeh	121.20 k	143.60 de	136.40 fg	133.73 c
Lio	132.50 ghi	139.50 ef	127.80 ij	133.27 cd
Phosphorus average	129.27 b	140.31 a	140.98 a	

Means with different letters have significant difference according to the Duncan's multiple range test at 0.05

3. Flag leaf Chlorophyll content index

Chlorophyll is one of the most important compounds found in plants, which has the ability to absorb light and convert part of it into chemical energy that is stored in plants in the form of carbohydrates and is considered a source of life [15]. Table (4) shows that there are significant differences between fertilizer applications and varieties and their interactions on chlorophyll content index in the flag leaf. 5 kg ha^{-1} Phosphorus nano-fertilizer gave the highest rate by 46.30, and did not differ significantly from 10 kg ha^{-1} phosphorus nano-fertilizer treatment, which gave a rate of 45.27, compared to the treatment of conventional phosphorus fertilizer, which gave the lowest rate of 42.94. This illustrates the important role of the nano- phosphorus element and its complete utilization to promote growth and roots extension, which improves plants ability to absorb nutrients, resulting in an increase the amount of absorbed nitrogen and this reflected positively in plants growth [16]. Increased chlorophyll content in the flag leaf is consistent with the results [17]. For varieties, J variety recorded the highest rate of chlorophyll content index in flag leaf 48.73. On the other hand, Giza variety recorded the lowest value 41.90, and the difference between the varieties in their leaves chlorophyll content may be mainly due to the genetic variation between them. In addition to the different responses to the growth factors, and this corresponds to what found by [18] and [11]. For the interaction between studied factors levels, the interaction between phosphorus nano-fertilizer 5 kg ha^{-1} and class J treatment gave the highest average 50.13 of flag leaf chlorophyll content index, while the lowest average recorded by the interaction between phosphorus nano-fertilizer 10 kg ha^{-1} and Giza variety which amounted by 38.87.

Table (4) Effect of phosphorus fertilization and varieties and their interactions on Sorghum flag leaf chlorophyll content index

Varieties	Phosphorus fertilization level kg ha^{-1}			Varieties average
	P_2O_5 kg 100 (Conventional)	(Nano) 5	(Nano) 10	
Bohoth	43.86 c-f	46.19 a-d	44.80 b-e	44.95 b
Giza	41.26 def	45.57 a-d	38.87 f	41.90 c
J	45.87 a-d	50.13 a	50.02 ab	48.73 a
Inqath	39.99 ef	47.51 abc	47.58 abc	45.03 b

Rabeh	44.61	b-e	43.47	c-f	43.18	c-f	43.75 bc
Lio	42.09	c-f	44.75	b-e	47.19	abc	44.67 bc
Phosphorus average	42.95	b	46.27	a	45.27	a	

Means with different letters have significant difference according to the Duncan's multiple range test at 0.05

4. Flag leaf area (cm^2)

The results in Table (5) shows that there are significant differences between fertilizer applications and varieties and their interaction on flag leaf area. Where the treatment of phosphorus nano-fertilizer 10 kg ha^{-1} gave the highest value 335.58 cm^2, compared to 5 kg ha^{-1} nano-fertilizer which gave the lowest rate 264.70 cm^2. The presence of sufficient quantities of available phosphorus for the plant increases the process of light-dependent reaction and electron transferring rate in photosynthesis process, which leads to an increase in the number of Cells. In addition to the lack of RNA formation as a result of incomplete processing with phosphorus has an effect on protein formation and when there is a lack of protein formation, vegetative growth also decreases, so the plant has a small size and a small leaf area and has limited root growth and thin stems [19]. These results agree with [20]. Varieties showed significant differences between them, where Inqath variety record significant value of flag leaf area 315.67 cm^2. Which did not differ significantly from the varieties (Bohoth, Giza and Lio), which gave (304.95, 310.18 and 305.80) cm^2 respectively. In contrast, J variety recorded the lowest rate 261.95 cm^2. The reason behind the variation in flag leaf area for the varieties may be due to the difference in the nature of the genetic background which affects by environmental factors, this conclusion agreed with the findings of [21] and [22]. It is also noted from the interaction between phosphorus fertilization input and variety the interaction between nano-phosphorus 10 kg ha^{-1} and Giza variety treatment gave the highest average of flag leaf area 394.12 cm^2. Which did not differ significantly from Lio variety with the same fertilizer treatment, which gave an average of 390.15 cm^2. While the lowest average was recorded by the interaction between the conventional phosphorus fertilizer and the variety Rabeh amounted to 204.61 cm^2.

Table (5) Effect of phosphorus fertilization and varieties and their interactions on Sorghum flag leaf area

Varieties	Phosphorus fertilization level kg ha^{-1}						Varieties average
	P_2O_5 kg 100 (Conventional)		(Nano) 5		(Nano) 10		
Bohoth	340.80	b	270.97	de	303.10	c	304.95 a
Giza	309.52	c	276.68	d	394.12	a	310.18 a
J	250.05	ef	269.85	de	344.32	b	261.97 b
Inqath	309.97	c	245.92	f	265.95	def	315.67 a
Rabeh	204.61	g	265.87	def	315.82	c	262.10 b
Lio	265.35	def	258.90	def	390.15	a	305.80 a
Phosphorus average	280.05	b	264.70	c	335.58	a	

Means with different letters have significant difference according to the Duncan's multiple range test at 0.05

5. Panicle length (cm)

Results in Table (6) showed a significant effect of phosphorus fertilization and interaction between studied factors panicle length (cm). While the studied varieties did not differ significantly among themselves for this trait, the treatment of nano-phosphorus fertilizer 10 kg ha^{-1} gave the highest value 25.28 cm, compared to the conventional phosphorus fertilizer, which gave the lowest 23.45 cm and the level of phosphorus nano-fertilizer 5 kg ha^{-1}, which averaged 23.92 cm, and it seems that the increase in the panicle length occurred as a result of the basic role played by available phosphorus for plants nutrition, which means increasing the availability of dry matter and then increasing plant height (3), leaves number per plant and leaf area, which reflected positively in increasing panicle length. It noted from the same table that interaction between 10 kg ha^{-1} phosphorus nano-fertilizer and two varieties (Bohoth and Rabeh) gave the highest average of panicle length 25.23 and 25.86 cm respectively. While the interaction between conventional phosphorus fertilizer and the Lio variety gave the lowest average 22.46 cm.

Table (6) Effect of phosphorus fertilization and varieties and their interactions on Sorghum panicle length (cm)

Varieties	Phosphorus fertilization level kg ha^{-1}						Varieties average
	P_2O_5 kg 100 (Conventional)		(Nano) 5		(Nano) 10		
Bohoth	23.53	abc	23.66	abc	24.53	abc	23.51 a
Giza	23.53	abc	23.96	abc	25.33	ba	24.27 a
J	23.53	abc	24.33	abc	24.93	abc	24.26 a
Inqath	23.93	abc	24.40	abc	25.93	a	24.75 a
Rabeh	23.73	abc	24.26	abc	25.86	a	24.62 a
Lio	22.46	c	22.93	bc	25.13	abc	23.51 a

Phosphorus average	23.45 b	23.92 b	25.28 a	

Means with different letters have significant difference according to the Duncan's multiple range test at 0.05

6. Grains per panicle (seeds panicle^{-1})

This trait considered one of yield basic components, and this characteristic is determined at the stage when the competition between plant parts is intensive. So grains number is the most associated characteristic of the plant yield [23]. There are significant differences between fertilizer applications and varieties and their interaction between them as shown in Table (7). Both treatments of phosphorus nano-phosphorus fertilizer 5 and 10 kg ha^{-1} were significantly by giving the highest rate of 2455.83 and 2504.44 seeds panicle^{-1}) respectively. While, conventional phosphorus fertilizer treatment gave the lowest rate of grains number per panicle 2275.11. The reason for this linked to the effect of nano-phosphorus fertilizer in increasing flag leaf area (Table 5) and flag leaf chlorophyll content (Table 4), which may have led to an increase in photosynthesis, their transport and accumulation in the plant reproductive parts and reduce competition between them, which positively affected the increase in the percentage of fertilized florets and thus an increase in grains number per panicle. As well as the significant increase of nano-phosphorus 10 kg ha^{-1} in panicle length (Table 6) [24] and [13]. Varieties showed significant differences in grains per panicle, where Giza and Bohoth recorded the highest significant rate of seeds per panicle amounted by (2518.56 and 2511.89 grains panicle^{-1}). On the other hand, Lio variety recorded the lowest rate 2256.67 grains panicle^{-1}, and did not differ significantly from the Rabeh variety, which recorded an average 2284.89 grains panicle^{-1}. The reason for the difference between the varieties may be due to the nature of genetic background and good utilizing of environmental conditions for growing. As grains panicle^{-1} is related to genetic factors and it is greatly affected by environmental conditions. This is in consistent with findings of [25] and [11]. For the interaction between phosphorus fertliser and variety levels, the interaction between 10 kg ha^{-1} phosphorus nano-fertilizer and Bohoth variety record significant average of seeds per panicle 2677.67. While the lowest average was recorded by the interaction between conventional phosphorus fertilizer and the Lio variety amounted by 2042.80 grains panicle^{-1}

Table (7) Effect of phosphorus fertilization and varieties and their interactions on Sorghum grains per panicle (grains panicle^{-1})

Varieties	Phosphorus fertilization level kg ha^{-1}			Varieties average
	P_2O_5 kg 100 (Conventional)	(Nano) 5	(Nano) 10	
Bohoth	2274.00 hi	2584.00 ab	2677.67 a	2511.89 a
Giza	2402.00 d-g	2535.67 bc	2618.00 ab	2518.56 a
J	2375.67 e-h	2461.00 cde	2430.00 c-f	2422.22 b
Inqath	2323.67 f-i	2504.00 bcd	2602.00 ab	2476.56 ab
Rabeh	2233.33 i	2293.00 ghi	2328.33 f-i	2284.89 c
Lio	2042.00 j	2357.33 e-h	2370.67 e-h	2256.67 c
Phosphorus average	2275.11 b	2455.83 a	2504.44 a	

Means with different letters have significant difference according to the Duncan's multiple range test at 0.05

7. 1000 grain weight (g)

The results of Table (8) show that there are significant differences between fertilizer applications and varieties and their interactions on 1000 grain weight. 10 kg ha^{-1} of nano-phosphorus fertilizer had significant influence by giving 32.94 g, compared to conventional phosphorus fertilizer, which gave the lowest rate of 1000 grain weight 27.27 g. This may be due to the fact that the increase in the amount of available phosphorus in the soil which provided by nano-fertilizer was reflected on root system improvement, which leads to an increase in the absorbed amount of nutrients and their delivery to the plant vegetative parts, which led to an increase in the shoot system, especially increasing leaf area (Table 6). And thus improved (source) and increased food transported to the grain [26] on similar results.

Varieties also showed significant differences, where Bohoth variety recorded the highest rate of 1000 grain weight amounted by 31.33 g. In contrast to the record of Rabeh variety which had lowest rate 29.11 g. Perhaps the genetic background of Bohoth variety had high efficiency in redistributing the products of the photosynthesis process from the vegetative parts to the reproductive parts of the plant, which reflected in increasing grain weight, this result is consistent with the findings of [10], [27] and [11]. It is noted from the same table for the interaction of 10 kg ha^{-1} phosphorus nano-fertilizer and Bohoth variety had significant impact on 1000 grain weight 36.0 g. while the lowest average was recorded by the interaction between conventional phosphorus fertilizer and Lio variety 25.33 g.

Table (8) Effect of phosphorus fertilization and varieties and their interactions on Sorghum 1000 grain weight (g)

Varieties	Phosphorus fertilization level kg ha^{-1}			Varieties average
	P_2O_5 kg 100 (Conventional)	(Nano) 5	(Nano) 10	
Bohoth	28.00 ef	30.00 cde	36.00 a	31.33 a
Giza	27.00 fg	29.00 def	32.00 bc	29.33 c
J	29.00 def	31.00 bcd	32.33 bc	30.77 ab

Inqath	27.33 fg	28.66 def	33.00 b	29.66 bc
Rabeh	27.00 fg	28.00 ef	32.33 bc	29.11 c
Lio	25.33 g	29.33 def	32.00 bc	28.88 c
Phosphorus average	27.27 c	29.33 b	32.94 a	

Means with different letters have significant difference according to the Duncan's multiple range test at 0.05

8. Total grain yield (t ha^{-1})

The results of Table (9) show that there are significant differences between fertilizer applications and varieties and their interaction on total grain yield. Where 10 kg ha^{-1} phosphorus nano-fertilizer gave significant amount of total grain yield of 6.84 t ha^{-1}, which did not differ significantly from the treatment of 5 kg ha^{-1} phosphorus nano-fertilizer 6.67 t ha^{-1}. While conventional phosphorus fertilizer gave the lowest rate 5.95 t ha^{-1} of total grain yield. The reason of recording high grain yield by 10 kg ha^{-1} phosphorus nano-fertilizer may be due to involving this treatment in increasing yield components, like grains per panicle (Table 7) and 1000 grain weight (Table 8), which led to high total grain yield compared to conventional phosphorus fertilizer, which gave the lowest rate of yield components, these results agreed with [28].

Varieties showed significant differences, where Giza and J record highest rate of total grain yield (7.60 and 7.32 t ha^{-1}) respectively. On the other hand, Rabeh variety records the lowest average 5.49 t ha^{-1}. The reason for the difference between varieties in grain yield can be attributed to the difference in the number of grains per panicle (Table 7). These results are consistent with the obtained results by [29], [10] and [30].

It is noted from the same table that there is a significant impact of interaction between 10 kg ha^{-1} phosphorus fertilizer and (Giza and G) varieties. Where the highest average of grain yield was (8.82 and 8.81 t ha^{-1}) respectively. While the lowest average recorded by the interaction between conventional phosphorus fertilizer and Rabeh amounted by 5.08 t ha^{-1}.

Table (9) Effect of phosphorus fertilization and varieties and their interactions on Sorghum total grain yield (t ha^{-1})

Varieties	Phosphorus fertilization level kg ha^{-1}			Varieties average
	P_2O_5 kg 100 (Conventional)	(Nano) 5	(Nano) 10	
Bohoth	5.47 fg	5.89 efg	5.82 efg	5.72 cd
Giza	6.55 b-e	7.42 b	8.82 a	7.60 a
J	5.79 efg	7.36 bc	8.81 a	7.32 a
Inqath	6.37 c-f	6.29 def	5.88 efg	6.18 bc
Rabeh	5.08 g	5.84 efg	5.56 efg	5.49 d
Lio	6.47 b-f	7.21 bcd	6.15 ef	6.61 b
Phosphorus average	5.95 b	6.67 a	6.84 a	

Means with different letters have significant difference according to the Duncan's multiple range test at 0.05

9. Yield efficiency (g m^{-2})

The results of Table (10) indicate to significant differences between the fertilizer applications and varieties and their interactions on yield efficiency. Where 10 kg ha^{-1} nano-phosphorus fertilizer gave the highest average 1.17 g cm^{-2} of yield efficiency, which did not differ significantly from 5 kg ha^{-1} nano-fertilizer, which gave an average of 1.14 g cm^{-2}, compared to conventional phosphorus fertilizer, which gave the lowest rate of 1.04 g cm^{-2}. This may be occurred due to the significant effect of nano-phosphorus fertilizer treatment in total grain yield (9), which reflected positively on yield efficiency.

For varieties, J variety record highest rate of yield efficiency of 1.24 g cm^{-2}, which did not differ significantly from Giza variety, which gave an average of 1.23 g cm^{-2}. On the other hand, Rabeh variety recorded the lowest average trait of yield efficiency 0.97 g cm^{-2}. The reason for significant performance of (Giza and J) varieties on yield efficiency is due to their effects in total grain yield (Table 9). The varieties vary in leaf area production, as well as in the grain yield production per unit of same leaf area. And the efficiency of leaves and vegetative parts in photosynthesis, when two genetic backgrounds are equal in the production of the same paper area, but their yield may differ due to their difference in the leaves arrangement within shoot system. As well as the thickness of the leaf and chlorophyll content and other factors that may affect the production of photosynthetic products for grains growth.

The interaction between 10 kg ha^{-1} nano-phosphorus fertilizer and J variety gave the highest average of yield efficiency 1.48 g cm^{-2}, while the lowest average was recorded by the interaction between conventional phosphorus fertilizer and the Rabeh variety amounted by 0.88 g cm^{-2}.

Table (10) Effect of phosphorus fertilization and varieties and their interactions on Sorghum yield efficiency (g cm^{-2})

Varieties	Phosphorus fertilization level kg ha^{-1}			Varieties average
	P_2O_5 kg 100 (Conventional)	(Nano) 5	(Nano) 10	

Bohoth	0.95 ef	1.02 c-f	1.10 b-e	1.02 cd
Giza	1.08 c-f	1.30 ab	1.31 ab	1.23 a
J	1.00 def	1.23 bc	1.48 a	1.24 a
Inqath	1.15 b-e	1.11 b-e	1.02 c-f	1.09 bc
Rabeh	0.88 f	0.98 ef	1.05 c-f	0.97 d
Lio	1.17 b-e	1.22 bcd	1.03 c-f	1.14 ab
Phosphorus average	1.04 b	1.14 a	1.17 a	

Means with different letters have significant difference according to the Duncan's multiple range test at 0.05

10. Grain phosphorus percentage (%):

The results in Table (11) show that there are no significant differences between 10 and 5 kg ha^{-1} nano-phosphorus fertilizer which gave the highest rate by (3.07 and 3.05%). But they were significantly higher than conventional phosphorus fertilizer treatment, which gave the lowest mean of phosphorus percentage 2.39%. The reason for this may be attributed to available nano-phosphorus in the soil and high its absorption by plant roots. As well as the role of nano-phosphorus in improving plant growth, plant height, chlorophyll content in flag leaf and flag leaf area (Table 3, 4, 5 and 6) thus increasing phosphorus concentration in plant tissues and then moving to grains [31] and [32].

For the varieties, Giza variety performed significantly by recording the highest average of grain phosphorus 3.13%. On the other hand, Rabeh had the lowest average 2.43%. The reason for high phosphorus concentration in grains is due to the increased in absorbed amount by varieties, as the varieties vary in their phosphorus absorption, this pointed by [33] and [34].

It also noted from the same table for the interaction between phosphorus fertliser and variety levels, that the interaction between 10 kg ha^{-1} phosphorus fertilizer and Lio variety gave the highest average of grain phosphorus 3.56%. While the lowest average was recorded by the interaction between conventional phosphorus fertilizer and Bohoth variety amounted to 2.13%.

Table (11) Effect of phosphorus fertilization and varieties and their interactions on Sorghum grain phosphorus percentage (%)

Varieties	Phosphorus fertilization level kg ha^{-1}			Varieties average
	P_2O_5 kg 100 (Conventional)	(Nano) 5	(Nano) 10	
Buhoth	2.13 f	3.44 ab	3.24 abc	2.94 ab
Giza	2.59 c-f	3.31 ab	3.49 ab	3.13 a
J	2.43 def	3.24 abc	2.29 ef	2.66 bc
Inqath	2.39 def	2.97 a-d	3.24 abc	2.87 ab
Rabeh	2.21 ef	2.60 c-f	2.50 def	2.43 c
Leo	2.58 c-f	2.82 b-e	3.56 a	2.99 ab
Phosphorus average	2.39 b	3.06 a	3.07 a	

Means with different letters have significant difference according to the Duncan's multiple range test at 0.05

Conclusions

According to the results which found in the current study, it can be concluded:

1. Complete nano-fertilizer with 10 kg ha^{-1} recommended due to improved most of growth characteristics and yield which studied and did not differ significantly from 5 kg ha^{-1} fertilizer in total grain yield and significantly higher from conventional phosphorus fertilizer in most studied characteristics except for grain protein percentage and protein yield.
2. Increasing phosphorus content of Sorghum grains by using phosphorus nano-fertilizer compared to using conventional phosphorus fertilizer.
3. Conventional phosphorus fertilizer could be reduced by 20 times when using 5 kg ha^{-1} nano- phosphorus fertilizer as a ground application.

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تأثير السماد الفسفور التقليدي و النانوي في نمو وحاصل أصناف الذرة البيضاء

[*Sorghum bicolor* (L.) Moench]

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الخلاصة:

نفذت التجربة الحقلية في الموسم الخريفي (2023) في قضاء داقوق في محافظة كركوك الواقعة شمال شرق العراق على دائرة عرض °35.28 درجة شمالاً ، وخط طول °23. 44 درجة شرقاً ، بهدف دراسة مقارنة لتأثير سماد الفسفور التقليدي و النانوي في نمو وحاصل أصناف من الذرة البيضاء، بأستخدام تصميم القطاعات العشوائية الكاملة ***(R.C.B.D)*** بترتيب الالواح المنشقة ، إذ تضمنت الالواح الرئيسية ثلاث مستويات من سماد الفسفور التقليدي و النانوي كعامل اول (100 كغم هـ −1 فسفور التقليدي و 5 كغم هـ ***1***− فسفور النانوي و 10 كغم هـ −1 فسفور النانوي) استخدمت كإضافة أرضية،اذ اضيفت سماد الفسفور التقليدي بدفعة واحدة عند الزراعة وأُضيفت سماد الفسفور النانوي بدفعتين الاولى عند الزراعة والثانية عند التزهير، بينما تضمنت الالواح الثانوية ستة تراكيب وراثية من محصول الذرة البيضاء وهي (بحوث و جيزة و جي و إنقاذ و رابح و ليو) واظهرت النتائج ما يلي*:*

تفوق معاملة سماد فسفور النانوي 10 كغم هـ−1 في جميع الصفات المدروسة عدا صفة دليل الكلوروفيل لورقة العلم والنسبة المئوية للفسفور في الحبوب تفوق صنف جيزة في الصفات(مساحة ورقة العلم حاصل الحبوب الكلي نسبة المئوية للفسفور في الحبوب)، اما صنف جي فقد تفوق في الصفة (كفاءة الحاصل) ، اما الصفة وزن 1000 حبة فقد تفوق بها الصنف بحوث *.*

تميزت التداخل بين (معاملة سماد الفسفور النانوي 10 كغم هـ−1 و صنف جيزة) بإعطاء أعلى متوسطات في صفات مساحة ورقة العلم وحاصل الحبوب الكلي، و تفوقت (معاملة سماد الفسفور النانوي 10 كغم هـ−1 مع الصنف جي) في الصفات عدد حبوب الدالية و كفاءة الحاصل حيث أعطت أعلى متوسط لهذه الصفات ، اما صفات وزن 1000 حبة فقد تفوق بها مع معاملة سماد الفسفور النانوي 10 كغم هـ−1 مع الصنف بحوث ، كما تفوقت معاملة سماد الفسفور النانوي 10 كغم هـ−1 مع الصنف ليو في صفة نسبة الفسفور في الحبوب.

كلمات المفتاحية : ذرة بيضاء ،اصناف ،فسفور تقليدي ،نانوي ،صفات النمو و حاصل.