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Responses of Two Red Cabbage Hybrids to Nano NPK and Zinc Fertilizers (*Brassica oleracea* L. var. capitata rubra)

Mohamed Ahmed Ahmed[1], Sanaa M.S. Rasheed[2], Pashtiwan J. M. Zeebaree[1] & Warhel N. A[1]

[1] Dept. of Horticulture, Technical College of Akre, Duhok Polytechnic University, Iraq

[2] Dept of Horticulture, College of Agriculture engineering science, University of Duhok, Iraq

Correspondence: Warhel N. A, Dept. of Horticulture, Technical College of Akre, Duhok Polytechnic University, Iraq.

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Abstract

The experiment was indicated in the field condition at protected cultivation Department/ in Zakho Technical Institute/Dohuk Polytechnic University, Kurdistan Region/Iraq, during the winter growing season (2021-2022), which aimed to investigate the effectiveness three levels of nano NPK (0, 1 and 2 g l^{-1}) and three level of Zinc fertilizers (0, 2 and 4 g l^{-1}) on growth and yield of two red Cabbage hybrids (*Brassica oleracea* L. var. capitata rubra) plants. Results showed that the Zeina hybrid plants superior to Tropicana hybrid in all parameter weight of plants, number of Leaves per Head, Weight of head, head circumstances, head length and total yield. While the plants treated with and 1 g l^{-1} nano NPK fertilizers had significantly influenced on number of leaves per head, weight of plants, weight of head, head circumstance, total yield, when compared with control. Additionally, increased concentrations of nano NPK fertilizers sprayed on plants to 2 g l^{-1} caused a significantly increase of weight of head and stem diameters. Furthermore, the plants sprayed with 4 g l^{-1} Zinc fertilizers had significantly affected on number of leaves per head, weight of head, stem diameter and total yield. Whereas, head weight and length of head significantly increased when plants treated with 2 g l^{-1} Zinc fertilizers. Further research is needed to investigate whether the other cabbage cultivar and higher concentrations nano NPK and Zinc fertilizers than used in this research will give the better parameters.

Keywords: Cabbage, Tropicana, Zeina, hybrids, Nano NPK, Zinc fertilizers

1. Introduction

Cabbage *Brassica oleracea* L. var. capitata rubra. is one of major winter leafy vegetable which belong to Brassicaceae family. It is well grown in cool humid weather and grown for the leafy head grown a row and the end bud. The leaves were used row or in pickle or cooked. Cabbage crop can be grown in middle region of Iraq especially in Baghdad region in large scale (Hasan & Solaiman, 2012). The area cultivated with cabbage in Iraq (1187.5 ha) with a productivity of (12.725 ton ha^{-1}). The productivity of cabbage in Iraq is very low when compared with other countries (Al-Ubaidy *et al*., 2019).

Nano fertilizers 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. Nano fertilizers provide more surface area for different metabolic reactions in the plant which increase rate of photosynthesis and produce more dry matter and yield of the crop (Singh, *et al*., 2017; Mandal, 2021; & Shilpa, *et al*., 2022). The uptake, distribution, and accumulation of nano fertilizers in crops depend on a number of parameters, and these factors greatly depend on both internal and extrinsic factors as well as the exposure route. The two most significant inherent elements influencing the effectiveness of nanoparticle applications are particle size and surface coating (Zulfiqar *et al.,* 2019). Ajirloo *et al*., (2015) showed that spraying tomato plants with nano NPK fertilizers improved the quantity of fruits, weight, diameter of fruits, plant height, and stem diameter.

Zinc as a plant nutrient, has the strongest impact on yield and quality of vegetable crops, it's important for the formation and activity of chlorophyll and in the functioning of several enzymes and the growth hormone Auxin, the form of zinc available to plants is the Zn^{2+} ion and deficiency can occur on alkaline soils and sandy soils low in organic matter (Gupta, 1990). Zinc application is less expensive but can give higher profits than other nutrients (Solanki *et al*., 2010). In recent years, an increased frequency of zinc deficiency has been observed in

crops and Zn may become a factor limiting yield and quality of crops, Zinc deficiency is observed mainly due to high crop yield, therefore, higher rate of zinc removed by crops and lesser use of zinc containing fertilizers. The farmers of the area, by and large, use N, P and K fertilizers in vegetable crops and as a consequence, deficiency of zinc is increasing (Alloway, 2009). Singh & singh, 2017) showed that the application of zinc up to 6 kg ha^{-1} Zn significantly increased the edible head yield and dry matter production of cabbage over control.

Cabbage as a leafy vegetable has the potential to contain greater Zn concentrations than cereal seeds, legume seeds, root or tuber crops (White & Broadley, 2011). Thus, cabbage has greater biofortification (strategy to increase human dietary Zn intakes by increasing Zn concentrations in edible produce) potential, since mineral element composition in leaves of different cabbage genotypes is not affected by their colored (Barker *et al*., 2017). The present study was aimed to investigate the improvement of cabbage growth and yield in Iraq generally in Kurdistan area, when fertilized plants by nano NPK and Zinc fertilizers along one season of implantation to increase productivity of two red Cabbage hybrids.

2. Materials and Methods

2.1 Study Location and Soil Preparation

The experimental study was carried out in the field condition at Protected Cultivation Department/ in Zakho Technical Institute/Dohuk polytechnic University, Kurdistan Region/ Iraq, during the growing season (2021-2022), In latitude (37.15 ° N, 42.68 ° E). Several samples were taken randomly from different sites inside the flied at the depth of (0-30) cm. The samples were air dried and then sieved using 2.0 mm sieve for analysis of some chemical and physical properties of the soil as illustrated in Table 1.

Table 1. Some physical and chemical characteristics of the soil in the land experiment

Analysis Report			
	Characteristics	**Measuring units**	**Test**
1	**Sand**	**(%)**	**38.6**
2	**Silt**	**(%)**	**24.1**
3	**Clay**	**(%)**	**37.3**
4	**Texture**	**----------**	**Sandy clay loam**
5	**Total – N**	**(%)**	**1.238**
6	**Available phosphorus**	**(%)**	**2.129**
7	**Available potassium**	**(%)**	**25.137**
8	**$CaCO_3$**	**%**	**14.8**
9	**Organic matter**	**(%)**	**1.941**
10	**pH**	**1:1**	**7.05**
11	**Ec conductivity**	**($ds.m^{-1}$)**	**0.126**

The analysis was carried out in soil laboratory, College of Agricultural Engineering Sciences, Duhok.

2.2 Field Preparation

The land was well ploughed and the soil softening was done, then organic manure (decomposed animal manure) was added to the soil one month before transplanting Furthermore, plowing of land was done again to mix the organic matter into the soil surface. Then the land was leveled. The area was divided into 3 blocks, the distance between the plants on a line about 40 cm and between the rows about 60 cm, each experimental unit consisted of 10 plants.

2.3 Seedling Production and Cultural Practices

Two cabbage hybrid cultivars namely (Tropicana and Zeina F1) seed was sown in trays on 15 September 2021, and transplanted at 14 October 2021 in to the land area, at a distance of 40 cm between plants and 60 cm

between rows. Drip irrigation system of the field was done after planting. Agricultural practice was similarity done in all experimental study by farmer including weeding, disease control and irrigation.

2.4 Experimental Treatments Design and Data Analysis

The experiment was comprised the effect of two cabbage hybrids plants (Tropicana and Zeina F1), three levels of Nano NPK (0, 1 and 2 g l^{-1}) and three level of Zinc fertilizers (0, 2 and 4 g l^{-1}). The treatments were arranged in split-split plot system. The main-plot (2 cultivar) and the sub-plots would be three levels of nano NPK fertilizers and in sub-sub-plot would be the three level of Zinc fertilizers, going to randomly arranged in a Randomized Complete Block Design (RCBD), 18 treatments were be involved in this trail (2×3×3=18) with three replications (54 experimental units), The fertilizers spray first was one month after transplanting and repeated three-time interval 10 days between them. The results were analyzed statistically by using Duncan multiple range test at 5 % level (SAS, 2013).

2.5 Experimental Measurements

For data collection five plants will be selected randomly from each experimental units to measure: Weight of plant (kg), Number of Leaves per Head, Weight of Head (gm), Head circumstances (cm), Length of Head (cm), Stem Diameter (cm) and Total yield (ton ha^{-1}).

3. Results

3.1 Weight of Plant (kg)

The results in Table 2 showed that used planting Zeina hybrid plants caused a significant increase in weight of plant which reached 1.31 kg with increased percentage reached to 50.57 % compared with Tropicana hybrid plants. In addition, spraying nano NPK fertilizers at 2 g l^{-1} showed a significantly increased in weight of plant 1.28 kg compared with control 0.83 kg. Moreover the plants sprayed with any concentrations of Zinc fertilizers studied did not cause a significant difference in the weight of plants.

The results showed that using Zeina hybrid plants interacted with 2 g l^{-1} nano NPK fertilizers gave a significantly highest values 1.60 and 1.37 kg respectively, whereas the lowest values 0.69 kg recorded with the interaction between Tropican hybrid plants and 0 g l^{-1} of nano NPK fertilizers respectively. In addition to that the interaction between the red cabbage hybrid plant and Zinc fertilizers showed a significantly increase in weight of plants, the highest value reached 1.36 kg for using Zeina hybrid plants interacted with fertilized plant with 2 g l^{-1} of Zinc fertilizers compared with the other interactions. The third dual interaction the plant which sprayed with 2 g l^{-1} nano NPK and 4 g l^{-1} of zinc fertilizers record the highest significant value of weight of plants reached 1.49 kg compared with the least value 0.57 kg for the treatment 0 g l^{-1} for both nano NPK and Zinc fertilizers.

Table 2. Effect of hybrids, nano NPK and Zn fertilizers and their interactions on weight of plant (kg) of Red Cabbage plants

Hybrids	Nano NPK (g l^{-1})	Zinc (g l^{-1})			Hybrid * Nano NPK	Hybrids
		0	2	4		
Tropicana	0	0.56^{f}	0.86^{d-f}	0.65^{fe}	0.69^{b}	0.87^{b}
	1	1.02^{c-f}	1.05^{c-f}	0.84^{d-f}	0.97^{b}	
	2	0.58^{f}	0.98^{c-f}	1.32^{a-d}	0.96^{b}	
Zeina	0	0.58^{f}	1.20^{a-d}	1.12^{b-e}	0.96^{b}	1.31^{a}
	1	1.60^{ab}	1.26^{a-d}	1.25^{a-d}	1.37^{a}	
	2	1.51^{a-c}	1.64^{ab}	1.66^{a}	1.60^{a}	
Zinc fertilizers		0.97^{a}	1.16^{a}	1.14^{a}	Nano NPK	
Hybrids * Zinc	Tropicana	0.72^{b}	0.96^{b}	0.94^{b}		
	Zeina	1.23^{a}	1.36^{a}	1.34^{a}		
Nano NPK * Zinc	0	0.57^{d}	1.03^{c}	0.89^{cd}	0.83^{b}	
	1	1.31^{ab}	1.16^{a-c}	1.05^{c}	1.17^{a}	
	2	1.04^{c}	1.31^{ab}	1.49^{a}	1.28^{a}	

Means with same letter for each factor and interactions are not significantly different at 5% level based on DMRT.

The triple interactions among the red cabbage hybrid, nano NPK and zinc fertilizers clarified that the using Zeina hybrid plants which sprayed with 2 g l^{-1} nano NPK, 4 mg l^{-1} Zinc fertilizers, gave the highest value of weight of plants 1.66 kg compared with the least value 0.56 kg for the Tropicana hybrid plants which sprayed with 0 g l^{-1} for both nano NPK and Zinc fertilizers.

3.2 Number of Leaves per Head

Results in Table 3 indicated that the using Zeina hybrid plants caused a significantly increased in number of leaves reached 69.59 leaf $head^{-1}$ compared with Tropicana hybrid plants which reached 58.81 leaf $head^{-1}$. On the other hand, spraying nano NPK fertilizers at 1 g l^{-1} showed a significantly increased in number of leaves 67.94 leaf $plant^{-1}$ compared with control reached 61.67 leaf $plant^{-1}$. Whereas, fertilized plants with Zinc fertilizers at 4 g l^{-1} caused a significantly increase in number of leaves which reached 67.72 leaf $head^{-1}$ respectively, compared with 62.00 leaf $head^{-1}$ for plant sprayed with 2 g l^{-1} Zinc fertilizers.

The interaction between Zeina hybrid plants and spraying any concentration of nano NPK fertilizers caused a significantly increase number of leaves which reached 68.67, 69.33, and 70.78 leaf $head^{-1}$ respectively, so is the case for Tropicana hybrid plants which also recorded significantly increase number of leaves which reached 65.11 leaf $plant^{-1}$ interacted with 1 g l^{-1} nano NPK fertilizers compared with the control. Additionally, spraying Zeina hybrid plants interacted with 4 g l^{-1} of zinc fertilized recorded significantly increase number of leaves which reached 73.33 leaf $head^{-1}$ compared with the lowest number of leaves for the Tropicana hybrid plants that not treated with Zinc fertilized which reached 56.44 leaf $head^{-1}$. In reverse, the third dual interaction between nano NPK and Zinc fertilizers indicated that the plants which sprayed with nano NPK at 1 g l^{-1} and 4 g l^{-1} Zinc fertilizers gave the highest significant value of number of leaves reached 72.67 leaf $head^{-1}$ in comparison with the lowest value 57.50 leaf $head^{-1}$ for 0 g l^{-1} nano NPK and 2 g l^{-1} Zinc fertilizers.

The triple interactions among red cabbage hybrid plant, nano NPK and Zinc fertilizers factors indicated that the using Zeina hybrid plant sprayed with 1 g l^{-1} nano NPK, 4 g l^{-1} Zinc fertilizers, gave the highest value of numbers of leaves reaching 78.00 leaf $head^{-1}$ compared with the lowest value 51.00 leaf $head^{-1}$ for the Tropicana hybrid plants which sprayed with 0 g l^{-1} for both nano NPK and Zinc fertilizers, With increasing percentage reached to 52.94 % than the least value.

Table 3. Effect of hybrids, nano NPK and Zn fertilizers and their interactions on Number of Leaves per Head of Red Cabbage plants

Hybrids	Nano NPK (g l^{-1})	Zinc (g l^{-1})			Hybrid * Nano NPK	Hybrids
		0	2	4		
Tropicana	**0**	51.00^{e}	52.33^{de}	60.67^{b-e}	54.67^{b}	
	1	62.33^{b-e}	65.67^{a-e}	67.33^{a-d}	65.11^{a}	58.81^{b}
	2	56.00^{c-e}	55.67^{c-e}	58.33^{b-e}	56.67^{b}	
Zeina	**0**	73.67^{ab}	62.67^{a-e}	69.67^{a-c}	68.67^{a}	
	1	66.33^{a-e}	68.00^{a-c}	78.00^{a}	70.78^{a}	69.59^{a}
	2	68.00^{a-c}	67.67^{a-d}	72.33^{ab}	69.33^{a}	
Zinc		62.89^{ab}	62.00^{b}	67.72^{a}		
Hybrids * Zinc	**Tropicana**	56.44^{c}	57.89^{c}	62.11^{bc}		**Nano NPK**
	Zeina	69.33^{ab}	66.11^{ab}	73.33^{a}		
Nano NPK * Zinc	**0**	62.33^{ab}	57.50^{b}	65.17^{ab}	61.67^{b}	
	1	64.33^{ab}	66.83^{ab}	72.67^{a}	67.94^{a}	
	2	62.00^{b}	61.67^{b}	65.33^{ab}	63.00^{ab}	

Means with same letter for each factor and interactions are not significantly different at 5% level based on DMRT.

3.3 Weight of Head (g)

The results in Table 4 exposed that planting Zeina hybrid cabbage plant caused a significantly increased in the weight of head reaching 684.37 g compared with 546.89 g for Tropicana hybrid plants. Additionally, increased concentrations of nano NPK fertilizers on plants to 1 and 2 g l^{-1} caused a significantly increase weight of head to 656.44 and 634.33 g respectively, compared with 556.11 g for control, with increase percentage 18.04 %. Whereas, spraying red cabbage hybrid plants with Zinc fertilizers at 4 g l^{-1} increased this characteristic significantly to 651.56 g when compared with the control which reached 583.83 g.

The results of the interaction between the red hybrid cabbage plants and nano NPK fertilizers showed that using Zenia hybrid interacted with 1 g l^{-1} nano NPK concentration of gave a significant highest values 758.89 g respectively, compared with lowest value 530.11 g for treatments Tropicana hybrid interact with 2 g l^{-1} respectively. The dual interactions between the hybrid cabbage plant and Zinc fertilizers showed that using Zeina hybrid plants which sprayed with Zinc fertilizers at 4 g l^{-1} which gave highest value reached 749.56 g in comparison with the least value of 536.44 g for Tropicana hybrid plants interacted with 0 g l^{-1} of Zinc fertilizers. In addition to that, the interaction between 1 g l^{-1} nano NPK and 2 g l^{-1} Zinc fertilizers gave the highest value of weight head 709.33 g compared with least value of 503.50 g for plants sprayed with 0 g l^{-1} nano NPK and 2 g l^{-1}Zinc fertilizers.

The triple interactions among the hybrid cabbage plants, nano NPK and zinc fertilizers clarified that the using Zeina hybrid plants which sprayed with 2 g l^{-1} for nano nano NPK and 4 g l^{-1} Zinc fertilizers gave the highest value of weight of head reached 838.67 g respectively, compared with the least value 494.67 g for the Tropicana hybrid plants which sprayed with 1g l^{-1} nano NPK and 0 g l^{-1} of Zinc fertilized.

Table 4. Effect of hybrids, nano NPK and Zn fertilizers and their interactions on Weight of Head (g) of Red Cabbage plant

Hybrids	**Nano NPK (g l^{-1})**	**Zinc (g l^{-1})**			**Hybrid * Nano NPK**	**Hybrids**
		0	**2**	**4**		
Tropicana	**0**	598.33^{c-e}	511.67^{d-e}	559.67^{c-e}	556.56^{b}	546.89^{b}
	1	494.67^{e}	594.33^{c-e}	573.00^{c-e}	554.00^{b}	
	2	516.33^{d-e}	546.00^{c-e}	528.00^{c-e}	530.11^{b}	
Zeina	**0**	534.67^{c-e}	495.33^{e}	637.00^{b-e}	555.67^{b}	684.37^{a}
	1	679.33^{a-d}	824.33^{a}	773.00^{ab}	758.89^{a}	
	2	679.67^{a-d}	697.33^{a-c}	838.67^{a}	738.56^{a}	
Zinc		583.83^{b}	611.50^{ab}	651.56^{a}	**Nano NPK**	
Hybrids * Zinc	**Tropicana**	536.44^{d}	550.67^{dc}	553.56^{dc}		
	Zeina	631.22^{bc}	672.33^{ab}	749.56^{a}		
Nano NPK * Zinc	**0**	566.50^{bc}	503.50^{c}	598.33^{a-c}	556.11^{b}	
	1	587.00^{bc}	709.33^{a}	673.00^{ab}	656.44^{a}	
	2	598.00^{a-c}	621.67^{ab}	683.33^{ab}	634.33^{a}	

Means with same letter for each factor and interactions are not significantly different at 5% level based on DMRT.

3.4 Head Circumstances (cm)

The result in Table 5 indicated that significant differences occurred between the two red cabbage hybrids plants in terms of head circumstances, the Zeina hybrid had 9.22 cm superior to Tropicana hybrid plants reached 8.30cm. Furthermore, Fertilizing plants with 1 g l^{-1} of nano NPK significantly increased head circumstances to 9.94 cm when compared with control respectively. In addition, spraying plants to Zinc fertilizers at 2 g l^{-1} showed a significantly increased in head circumstances 9.07 cm compared with control 8.37 cm.

Table 5. Effect of hybrids, nano NPK and Zn fertilizers and their interactions on Head circumstances (cm) on Red Cabbage plant

Hybrids	Nano NPK (g l^{-1})	Zinc (g l^{-1})			Hybrid * Nano NPK	Hybrids
		0	2	4		
Tropicana	0	9.67^{a-d}	9.00^{be}	8.00^{d-f}	8.89^{b}	8.37^{b}
	1	8.67^{b-e}	10.00^{a-c}	8.17^{c-f}	8.94^{b}	
	2	7.77^{ef}	6.73^{fg}	7.33^{e-g}	7.28^{c}	
Zeina	0	6.00^{g}	8.33^{b-f}	8.77^{b-e}	7.70^{c}	9.22^{a}
	1	10.17^{ab}	11.17^{a}	11.47^{a}	10.93^{a}	
	2	7.97^{d-f}	9.20^{b-e}	9.90^{a-c}	9.02^{b}	
Zinc		8.37^{b}	9.07^{a}	8.94^{ab}	Nano NPK	
Hybrids * Zinc	Tropicana	8.70^{bc}	8.58^{c}	7.83^{c}		
	Zeina	8.04^{c}	9.57^{ab}	10.04^{a}		
Nano NPK * Zinc	0	7.83^{d}	8.67^{b-d}	8.38^{c-d}	8.29^{b}	
	1	9.42^{a-c}	10.58^{a}	9.82^{ab}	9.94^{a}	
	2	7.87^{d}	7.97^{d}	8.62^{bd}	8.15^{b}	

Means with same letter for each factor and interactions are not significantly different at 5% level based on DMRT.

The interaction between the hybrid cabbage plants and nano NPK fertilizers affected significantly this characteristic; the highest value of head circumstances reached 10.93 cm for Zeina hybrid plants interacted with sprayed plants to 1 g l^{-1} nano NPK fertilizers whereas the lowest head circumstances reached 7.28 cm for Tropicana hybrid interacted with 2 g l^{-1} nano NPK fertilizers. The dual interaction between the hybrid cabbage plants and zinc fertilizers showed that the Zeina hybrid plant interacted with 4 g l^{-1} Zinc fertilizers caused a significantly increase in head circumstance to 10.04 cm compared with the least value 7. 83 cm for Tropicana hybrids plants interacted with 4 g l^{-1} Zinc fertilizers. Additionally, the third dual interaction between 1g l^{-1} nano NPK and 2 g l^{-1} Zinc fertilizers gave the highest value of head circumstances 10.58 cm compared with least value of 7.83 cm for plants sprayed with 0 g l^{-1} for both nano NPK and Zinc fertilizers.

The triple interactions among the three factors studied indicated that the Zeina hybrids plants which interacted with 1 g l^{-1} nano NPK and 4 g l^{-1} Zinc fertilizers gave the highest value of this characteristic to 11.47 cm when compared with the lowest value reached 6.00 cm for Zeina hybrid plants interacted with 0 g l^{-1} for both nano NPK and Zinc fertilizers.

3.5 Length of Head (cm)

Results in Table 6 indicated that significant differences occurred between the two red cabbage hybrids plants in terms of length of head, the Zeina hybrid plants had 11.89 cm superior to Tropicana hybrid plants reached 10.91 cm. On the other hand, treated cabbage hybrid plants with spraying any concentrations of nano NPK studied did not cause significant differences between them. While spraying plants with 2 g l^{-1} of Zinc fertilizers significantly increased length of head to 11.95 cm when compared with control which reached 10.98 cm.

The significantly highest value of this trait was 12.32 cm when Zeina hybrid plants treated with 2 g l^{-1} nano NPK, whereas the lowest value reached 10.48 cm for the Tropicana hybrid plants treated with 2 g l^{-1} nano NPK fertilizers. The dual interaction between the hybrid cabbage plants and Zinc fertilizers showed that the Zeina hybrid plant interacted with 2 g l^{-1} Zinc fertilizers caused a significantly increase in length of head to 13.01 cm compared with the least value 10.89 cm for Tropicana hybrids plants interacted with 2 g l^{-1} Zinc fertilizers. Additionally, the third dual interaction between 1 g l^{-1} nano NPK and 2 g l^{-1} Zinc fertilizers gave the highest value of length of head to 12.20 cm compared with least value of 10.58 cm for plants sprayed with 0 g l^{-1} for both nano NPK and Zinc fertilizers.

The triple interactions among red cabbage hybrid plant, nano NPK and Zinc fertilizers factors indicated that the Zeina hybrid plants sprayed with 2 g l^{-1} for both nano NPK and Zinc fertilizers, gave the highest value of length of head reaching 13.3 cm when compared with the lowest value reached 10.00 cm.

Table 6. Effect of hybrids, nano NPK and Zn fertilizers and their interactions on Length of Head (cm) on Red Cabbage plant

Hybrids	Nano NPK (g l^{-1})	Zinc (g l^{-1})			Hybrid * Nano NPK	Hybrids
		0	2	4		
Tropicana	0	11.17^{c-f}	11.00^{d-f}	11.73^{b-d}	11.30^{b}	10.91^{b}
	1	10.60^{d-f}	11.33^{c-e}	10.97^{d-f}	10.97^{bc}	
	2	11.10^{c-f}	10.33^{ef}	10.00^{f}	10.48^{c}	
Zeina	0	10.00^{f}	12.67^{ab}	11.00^{d-f}	11.22^{b}	11.89^{a}
	1	10.67^{d-f}	13.07^{a}	12.67^{ab}	12.13^{a}	
	2	12.33^{a-c}	13.30^{a}	11.33^{c-e}	12.32^{a}	
Zinc		10.98^{b}	11.95^{a}	11.28^{b}		
Hybrids * Zinc	Tropicana	10.96^{c}	10.89^{c}	10.90^{c}	Nano NPK	
	Zeina	11.00^{c}	13.01^{a}	11.67^{b}		
Nano NPK * Zinc	0	10.58^{b}	11.83^{a}	11.37^{ab}	11.26^{a}	
	1	10.63^{b}	12.20^{a}	11.82^{a}	11.55^{a}	
	2	11.72^{a}	11.82^{a}	10.67^{b}	11.40^{a}	

Means with same letter for each factor and interactions are not significantly different at 5% level based on DMRT.

3.6 Stem Diameter (cm)

Results in Table 7 showed that the using Zeina hybrid plants caused a significant increase in weight of plant which reached 3.11 kg with increased percentage reached to 21.01 % compared with Tropicana hybrid plants. Additionally, increased concentrations of nano NPK fertilizers on plants to 1 and 2 g l^{-1} caused a significantly increase stem diameter to 3.00 and 2.92 cm respectively, compared with 2.59 cm for control. Moreover, increased concentrations of Zinc fertilizers to spraying plants to 2 and 4 g l^{-1} caused a significantly increase stem diameter to 3.07 and 3.02 cm respectively, compared with 2.42 cm for control.

The results of the interaction between the hybrid cabbage plants and nano NPK fertilizers showed that using Zenia hybrid interacted with 1 g l^{-1} nano NPK fertilizers gave a significant highest values 3.29 cm respectively, compared with lowest value 2.41 cm for treatments Tropicana hybrid interacted with 0 g l^{-1} of nano NPK fertilizers. The dual interactions between the hybrid cabbage plant and Zinc fertilizers showed that planting Zeina hybrid plants sprayed with zinc fertilizers at 2 g l^{-1} gave the highest value which reached 3.38 cm in comparison with the least value 2.10 cm for Tropicana hybrid plants interacted with 0 g l^{-1} of Zinc fertilizers. In addition to that, the third dual interaction between 2 g l^{-1} nano NPK and 2 g l^{-1} Zinc fertilizers gave the highest value of stem diameter 3.27 cm compared with least value of 2.05 for plants sprayed with 0 g l^{-1} both nano NPK and Zinc fertilizers.

Table 7. Effect of hybrids, nano NPK and Zn fertilizers and their interactions on Stem Diameter (cm) on Red Cabbage plant

Hybrids	Nano NPK (g l^{-1})	Zinc (g l^{-1})			Hybrid * Nano NPK	Hybrids
		0	2	4		
Tropicana	0	1.30^{f}	2.80^{c-e}	3.13^{b-d}	2.41^{c}	2.57^{b}
	1	2.30^{e}	2.50^{e}	2.83^{c-e}	2.54^{bc}	
	2	2.70^{de}	2.70^{de}	2.83^{c-e}	2.74^{b}	
Zeina	0	2.80^{c-e}	2.70^{de}	2.83^{c-e}	2.78^{b}	3.11^{a}
	1	2.83^{c-e}	3.60^{ab}	3.43^{ab}	3.29^{a}	
	2	2.60^{de}	3.83^{a}	3.33^{a-c}	3.26^{a}	
Zinc		2.42^{b}	3.02^{a}	3.07^{a}		
Hybrids * Zinc	Tropicana	2.10^{d}	2.67^{c}	2.93^{bc}	Nano NPK	
	Zeina	2.74^{c}	3.38^{a}	3.20^{ab}		
Nano NPK * Zinc	0	2.05^{e}	2.75^{b-d}	2.98^{a-c}	2.59^{b}	
	1	2.57^{d}	3.05^{ab}	3.13^{ab}	2.92^{a}	
	2	2.65^{cd}	3.27^{a}	3.08^{ab}	3.00^{a}	

Means with same letter for each factor and interactions are not significantly different at 5% level based on DMRT.

The triple interactions among the hybrid cabbage plants, nano NPK and Zinc fertilizers clarified that the using Zeina hybrid plants which sprayed with 2 g l^{-1} for both nano NPK and Zinc fertilizers gave the highest value of stem diameter reached 3.83 cm compared with the least value 1.30 cm for the Tropicana hybrid plants which sprayed with 0 g l^{-1} for both nano NPK and Zinc fertilized.

3.7 Total Yield (ton ha^{-1})

The results in Table 8 indicated that used Zeina hybrid cabbage plant caused a significantly increased in total yield reaching 25.09 ton ha^{-1} compared with 20.05 ton ha^{-1} for Tropicana hybrid plants. Additionally, increased concentrations of nano NPK fertilizers on plants to 1 and 2 g l^{-1} caused a significantly increase total yield to 24.07 and 23.26 ton ha^{-1} g respectively, compared with 20.39 ton ha^{-1} for control, with increase percentage 18.04 %. Whereas, spraying the red cabbage hybrid plants with Zinc fertilizers at 4 g l^{-1} increased this characteristic significantly to 23.89 ton ha^{-1} when compared with the control which reached 21.4 ton ha^{-1}.

Table 8. Effect of hybrids, nano NPK and Zn fertilizers and their interactions on total yield (ton.ha^{-1}) on Red Cabbage plant

Hybrids	Nano NPK (g l^{-1})	Zinc (g l^{-1})			Hybrid * Nano NPK	Hybrids
		0	2	4		
Tropicana	0	21.94^{c-e}	18.76^{de}	20.52^{c-e}	20.41^{b}	20.05^{b}
	1	18.14^{e}	21.79^{c-e}	21.01^{c-e}	20.31^{b}	
	2	18.93^{de}	20.02^{c-e}	19.36^{c-e}	19.44^{b}	
Zeina	0	19.60^{c-e}	18.16^{e}	23.36^{b-e}	20.37^{b}	25.09^{a}
	1	24.91^{a-d}	30.23^{a}	28.34^{ab}	27.83^{a}	
	2	24.92^{a-d}	25.57^{a-c}	30.75^{a}	27.08^{a}	
Zinc		21.41^{b}	22.42^{ab}	23.89^{a}		
Hybrids * Zinc	Tropicana	19.67^{d}	20.19^{cd}	20.30^{cd}	Nano NPK	
	Zeina	23.14^{bc}	24.65^{ab}	27.48^{a}		
Nano NPK * Zinc	0	20.77^{bc}	18.46^{c}	21.94^{a-c}	20.39^{b}	
	1	21.52^{bc}	26.01^{a}	24.68^{ab}	24.07^{a}	
	2	21.93^{a-c}	22.79^{ab}	25.06^{ab}	23.26^{a}	

Means with same letter for each factor and interactions are not significantly different at 5% level based on DMRT.

The results of the interaction between the hybrid cabbage plants and nano NPK fertilizers showed that using Zenia hybrid interact with 1 g l^{-1} nano NPK fertilizers gave a significant highest values 27.73 ton ha^{-1} respectively, compared with lowest value 19.44 ton ha^{-1} for treatments Tropicana hybrid interact with 2 g l^{-1} nano NPK respectively. The dual interactions between the hybrid cabbage plant and Zinc fertilizers showed that using Zeina hybrid plants which sprayed with zinc fertilizers at 4 g l^{-1} gave highest value which reached 27.48 ton ha^{-1} in comparison with the least value of 19.67 for Tropicana hybrid plants interacted with 0 g l^{-1} of Zinc fertilizers. In addition to that, the interaction between 1 g l^{-1} nano NPK and 2 g l^{-1} Zinc fertilizers gave the highest value of weight head to 26.01 ton ha^{-1} compared with least value to18.46 ton ha^{-1} for plants sprayed with 0 g l^{-1} nano NPK and 2 g l^{-1} Zinc fertilizers.

The triple interactions among the hybrid cabbage plants, nano NPK and zinc fertilizers clarified that the using Zeina hybrid plants which sprayed with 2 g l^{-1} for nano NPK and 4 g l^{-1} Zinc fertilizers gave the highest value of weight of head reached 30.75 ton ha^{-1} respectively, compared with the least value 18.14 ton ha^{-1} for the Tropicana hybrid plants which sprayed with 1g l^{-1} nano NPK and 0 g l^{-1} of Zinc fertilized.

4. Discussion

Zeina hybrid is a superior when compared to Tropicana hybrid in all parameters. These results could be explained may be due refer to the cultivar differ in their potential growth and productivity, and this depends mainly on the physiological processes controlled by the interaction of both genetic and environmental variance. The reason of this diversification can be attributed to the adaptability of genes and to morphological characteristics, and physiological factors during the growth period of the crop (Olaniyi *et al.,* 2010), The result was in conformity with the finding of (Olaniyi & Ojetayo 2011) who illustrated in a study of two cabbage varieties (Copenhagen market and F1 Milor) that the Copenhagen market produced better head yield than F1 Milor varieties, (Saeed, 2022) who illustrated in a study of two cabbage hybrid that the fireball F1 superior to Zeina hybrid in (number of leaves, wight of head kg, total yield and marketable yield ton ha^{-1}).

Spraying red cabbage hybrid plants with 1 g l^{-1} of nano NPK fertilizers produced significant increases in number of leaves per head, weight of head, head circumstance, total yield, when compared with control as shown in Tables 3, 4, 5, and 8). Additionally, increased concentrations of nano NPK fertilizers sprayed on plants to 2 g l^{-1} caused a significantly increase of weight of plant and stem diameters as shown in Tables 2 and 7. The enhancement effect of nano fertilizers on these studied characteristics may be attributed to the fact that it has a dimension ranging from 30 to 40 nm which is able to hold numerous ions because of their high surface area and

slowly release them in a timely manner to cope with crop demand. Moreover, their slow release and super sorbent phosphatic and nitrogenous fertilizers (Lal, 2008). The increase in the preceding plant vegetative growth parameters may be attributable to the element's increased availability at lower dosages when compared to conventional nitrogen sources; a lack of nitrogen may restrict plant growth Echer *et al.* (2012) found a comparable linear rise in plant fresh weight in Swiss chard. This increment may be due to high essentiality of N as a component of amino acids, proteins, nucleic acids, pigments and many enzymes (Marschner, 1995). These findings support the investigation of (Al-Jubouri & Abdulrahman, 2023) they reported that plant height, number of outer and inner leaves of head, and leaf area was increased by spraying 2 g l^{-1} nano NPK fertilizers on cabbage plants. So, nitrogen is critical for growth and development of plants, especially during cell division and cell enlargement phase of growth. This positive effect of nano fertilizers may also due to increasing the photosynthetic rates and the assimilation rates, which is leading to increase the most vegetative parameters and increased the heads yield (Saleh et al., 2010). Phosphorus is considered as an important macronutrient plant, making up about 0.2 % of a plants dry weight. It is one component of key molecules such as nucleic acids, phospholipids and ATPs. It is involved in several plant functions, including controlling enzyme reactions, regulation of metabolic pathways, energy transfer, photosynthesis and transformation of carbohydrates as well as formation of protein leading to increases in vegetative growth parameters (Marschner, 1995). Potassium is directly involved in enzyme activation; maintenance of water status, energy relations, and translocation of assimilates. It has an important role in protein synthesis. It has also a main role in regulating cellular turgid pressure to avoid wilting, which in turn controls the stomata opening and hence greatly enhances drought tolerance (McCarty, 2005). The enzyme responsible for synthesis of starch (starch synthetase) is activated by potassium element. Thus, with inadequate K, the level of starch declines while soluble carbohydrates and N compounds accumulate (Patil, 2011). The cause of this outcome could also be a physical and chemical characteristics of the culture medium had a major impact on how readily available air, nutrients, and water are to plants. As a result, the physical characteristics of the medium were crucial to increase plant development and output, Two of the most vital nutrients for crop production are nitrogen and calcium carbonate due to their chemical characteristics, which play crucial roles in plant cell architecture and metabolism and affect both the quantity and quality of secondary metabolites (Babalar *et al*., 2010; & Hassan, 2012), the medium used in the cultivation, Table 2 provided the appropriate conditions for good growth and obtaining the best yield, as noted from the obtained results. Nutrition plays a key role in plant growth and development; increases nutrients will stimulate plants to grow and increase their yield (Aziz *et al*., 2010; & Zheljazkov *et al*., 2011). The results of present study agreed with results when compared to previous studies. (Ajirloo *et al*, 2015) on Tomato plant, (Muhemed & mijwel, 2020) on cucumber plants, and (Abdulhameed *et al*., 2021) on cabbage plants.

Treated red cabbage hybrid plants with 2 g l^{-1} of Zinc fertilizers produced significant increases in head circumstance, length of head when compared with control as shown in Tables 5 and 6. Additionally, increased concentrations of Zinc fertilizers sprayed on plants to 4 g l^{-1} caused a significantly increase of number of leaves per head, weight of head, stem diameters and total yield as shown in Tables 3, 4, 7 and 8. This result can be explained as an improvement in growth characteristics due to the application of zinc through foliar micronutrients, which may have enhanced photosynthesis and other metabolic activities and ultimately led to an increase in biological processes like cell elongation and cell division (Hatwar *et al*., 2003). Additionally, zinc an influences the activities of hydrogenase and carbonic anhydrase, stabilizes ribosomal fractions, and contributes to the creation of cytochrome (Tisdale *et al*., 1984). These findings support the investigation of (Taheri *et al*., 2020) they reported that with the foliar application of zinc and boron @ 1%, on cabbage plants the head weight, head diameter, head thickness, yield, hole plant weight, Stem length, and stem diameters significantly increased. Or may be due to plant enzymes activated by Zinc are involved in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, regulation of auxin synthesis and pollen formation (Marschner, 1995). However the regulation and maintenance of the gene expression required for the tolerance of environmental stresses in plants are Zinc dependent (Cakmak, 2000). However, Zinc seems to affect the capacity for water uptake and transport in plants and also reduce the adverse effects of short periods of heat and salt stress (Kasim, 2007; Disante *et al*., 2010; Peck & McDonald, 2010; & Tavallali *et al*., 2010). Zn is necessary for the synthesis of tryptophan, a precursor to IAA, and it also actively participates in the creation of auxin, a crucial growth hormone. (Alloway, 2004 & Brennan, 2005). Additionally, zinc is necessary for cellular membrane integrity in order to maintain the structural orientation of macromolecules and ion transport networks. The maintenance of membranes is aided by its interaction with phospholipids and the sulphydryl groups of membrane proteins (Kabata-Pendias &Pendias, 2001 & Dang, 2010). Or may be due to a positive correlation appeared between all vegetative parameter as shown in Table (9), expected the length of head had a negative

correlation with head circumstance which reached (r= 20.03-). The result was in conformity with the finding of (Kasturikrishana & Ahlawat, 2000) on pea plants, and (Hou & Shang, 2006) on cabbage plants.

Table 9. correlation relation between all studies characters

Characters	Plant weight	No. of leaves per head	Weight of head	Head circumstance	Length head	Stem diameter
No. of leaves per head	41. 74**					
Weight of head	30. 20*	36. 27**				
Head circumstance	27. 70*	60. 76**	44. 02**			
Length head	39. 00**	40. 45**	41. 88**	23. 03-		
Stem diameter	27. 40*	49. 43**	26. 05*	29. 47*	32. 85**	
Total yield	41. 75**	100.00**	36. 28**	60. 76**	40. 44**	49. 44**

**Significant at probability level (0.01)

*Significant at probability level (0.05)

5. Conclusion

To conclude, the results gained from this experiment exposed that the effects of three studied factors (two red cabbage hybrids, Nano NPK and Zn fertilizers) were affected on cabbage vegetative growth and yield quantitative characters. The Zeina hybrid has superiority over the Tropicana hybrid in all parameters. However, spraying a nano NPK fertilizer at a dosage of 2 g l^{-1} was found to significantly improve most of the tested indicators, which were all measures of plant growth. Whereas most of the measured characteristics improved dramatically after being sprayed with a Zinc fertilizers of 4 g l^{1}. It appears that using that levels gave the best growth and development results on red cabbage hybrids. Further research is needed to investigate whether the higher concentrations than used in this research will give the better parameters.

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