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ARTICLE

Effect of Integrated Nano-Fertilizer Spray and Vermicompost in Growth and Quality of Corn Yield

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ABSTRACT

A field experiment was conducted to investigate the effect of integrated nano-fertilizer spray and vermicompost in growth and quality of corn yield in calcareous soil at College of Agricultural Engineering Sciences/University of Baghdad/Iraq during the autumn season of 2022 using Split Split Plot Design in a randomized complete block design with three replicates. Main plots were designated to two types of vermicompost (local and imported). The secondary plots were assigned to vermicompost added to the soil at three levels of 0, 10 and 20 Mg ha^{-1}. The third plots were assigned to nano-fertilizer containing N, P, K, Zn, Fe and Mn at 0, 50, 100 and 150 mg L^{-1} sprayed on plant at 20, 40 and 60 days after planting. The results showed a significant effect of local vermicompost achieving available nitrogen and phosphorus in the soil as 43.31 mg N kg^{-1} soil and 19.25 mg P kg^{-1} soil. In the leaves, nitrogen was 3.86%, potassium 4.54%, iron 174.22 mg Fe kg^{-1} and Zinc was 73.53 mg Zn kg^{-1}, grain yield was 165.48 Mg ha^{-1}. Adding vermicompost to the soil at 20 Mg ha^{-1} achieving in available nitrogen in the soil of 43.74 mg N kg^{-1} soil, available phosphorus of 19.72 mg P kg^{-1} soil and available potassium of 196.93 mg K kg^{-1} soil. In the leaves, nitrogen was 4.37%, phosphorus was 0.44%, potassium 4.87%, iron was 182.63 mg Fe kg^{-1}, zinc was 73.70 mg Zn kg^{-1} and grain yield was 168.43 Mg ha^{-1}. Spraying nano-fertilizer on the plant at 150 mg L^{-1} achieved In the leaves, nitrogen 4.28%, phosphorus of 0.46%, potassium of 5.10%, iron of 204.83 mg Fe kg^{-1}, zinc of 89.28 mg Zn kg^{-1} and manganese of 234.07 mg Mn kg^{-1} and grain yield was 172.88 Mg ha^{-1}.

Keywords: Macronutrient; Micronutrient; Vermicompost; Corn

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1. Introduction

Most Iraqi soils have a high soil pH, making them alkaline, and a high content of carbonate minerals and low organic carbon content. This increased the availability of micro-nutrients and reduced efficiency of micro-nutrient fertilizers, as these nutrients are prone to adsorption and sedimentation, which leads to its insufficiency to meet the plant's requirements [1].

Micronutrients are essential for activating the photosynthesis, contributing to the formation of chlorophyll, affecting proteins synthesis, and are essential for oxidation and reduction processes, and important for enzymes involved in the respiration process, these significantly affects crop production and quality. It was necessary to use fertilizers as an alternative to traditional fertilizers to supply nutrients for plant growth and productivity while maintaining soil health and environmental cleanliness. Nano fertilizers which are effective, the technology of using Nano fertilizers is still being used experimentally in Iraq, but several countries surrounding Iraq have made significant advancements in using this technology [2].

Vermicompost is used as a fertilizer to eliminate heavy metals when worms are introduced into waste, proving effective in removing these contaminants [3–5]. Bottinelin et al. [6] discovered that vermicompost contains various enzymes that enhance the activity of organisms, including peroxidase, protease, amylase, inverts, cellulose, phosphatase, dehydrogenase, and urease enzymes. Khalifa et al. [7] indicated that the interaction between the application of vermicompost and irrigation levels resulted in the highest yield of barley grains and biological yield. Additionally, it contributed to increased water productivity when lower water levels were used and improved some studied physical and chemical properties of the soil. Similarly, Ramazanoglu [8] found that adding four levels of vermicompost to the soil (2, 4, 6, and 8 tons/ha) significantly enhanced soil enzyme activity in wheat fields and increased the availability and uptake of several macro and micronutrients from the soil. Moreover, Al-Maamori et al. [9] demonstrated that applying three levels of vermicompost alongside mineral fertilization for potato plants helped reduce soil pH, increase organic matter content in the soil, and enhance nutrient concentrations absorbed by the plants.

Corn (*Zea mays* L.) is one of strategic grain crops in global production in many countries of the world, including Iraq. It is used in energy and biofuel production and in the feed industry, and it has a high nutritional value, as starch and oil are extracted from it. It contains protein, vitamin A, B1 and B2 [10]. Despite this, the production rate is still low relative to global production, so it is necessary to provide means that lead to increasing the production.

The aim is to study the effect of spraying with Nano fertilizer and adding vermicompost to the soil on the availability of N, P, K in soil and N, P, K, Fe, Zn and Mn in the plant and growth, yield and quality of corn.

2. Materials and Methods

During the autumn season of 2022 a field experiment was conducted at the College of Agricultural Engineering Sciences, University of Baghdad, Iraq to study the effect of integrated nano-fertilizer spray on the plant and vermicompost in growth and quality of Corn yield. The experiment followed a randomized complete block design (RCBD) using Split Split Plot arrangement. Soil samples were collected to analyze chemical, physical and fertility properties (**Table 1**). The main plots were assigned to two types of vermicompost (local and imported) symbolized as T_1 and T_2 respectively. The secondary plots were assigned to vermicompost at 0, 10 and 20 Mg ha^{-1} symbolized as V_0, V_1, and V_2 respectively. The third plots were assigned to nano-fertilizer containing N, P, K, Zn, Fe and Mn at rates 0, 50, 100 and 150 mg L^{-1} symbolized as F_0, F_1, F_2 and F_3 respectively which was sprayed on plant at 20, 40 and 60 days after planting.

Corn (Bohoth 106 variety) was sown in 3 × 3 m plots, each consisting of four rows with dimensions of 3 m in length and 0.75 m width with a separation distance of 1 m between each unit, the spacing between plants was 25 cm. Nitrogen was applied as urea at 200 kg N ha^{-1}. Phosphorus was applied as superphosphate at 60 kg P ha^{-1} and potassium was applied as potassium sulfate at 120 kg K ha^{-1}.

Table 1. Physical, chemical and fertility characteristics of soil.

EC	pH	O.M	$CaCO_3$	CEC	N	P	K	Fe	Zn	Mn	Texture
ds m^{-1}		%	g kg^{-1} Soil	c mol c kg^{1}	mg kg^{-1} Soil						
1.98	7.37	1.22	288.05	16.74	57.03	16.68	184.17	3.19	2.37	2.11	Silty loam

3. Results and Discussion

3.1. Available Nitrogen

Results of **Table 2** indicate a significant effect of local vermicompost to the soil, as T_1 achieved available nitrogen 43.31 mg N kg^{-1} soil relative to imported vermicompost T_2 which achieved 37.98 mg N kg^{-1} soil. Results of the same table showed a significant effect of adding vermicompost to the soil, as V_2 achieved available nitrogen 43.74 mg N kg^{-1} soil relative to V_0 which achieved 36.75 mg N kg^{-1} soil, this is ascribed to the role of vermicompost in reducing pH and enhancing the nutrients availability, such as nitrogen, as well as the organic acids resulting from the decomposition of vermicompost by soil organisms, including nitrogen-fixing bacteria and fungi that secrete growth hormones such as cytokinin, gibberellin, and auxin, by secreting mucus substances suitable for the microorganisms activity, these acids containing active groups, compete for adsorption surfaces, thereby reducing the nutrients interaction on stabilization surfaces and increasing the nitrogen availability. Adding vermicompost works to enrich soil with microscopic organisms such as nitrogen-fixing bacteria and fungi which play a crucial role in increasing nitrogen availability[11, 12]. There was no significant effect of nano-fertilizers on available nitrogen. The interaction between vermicompost and nano-fertilizers on available nitrogen, as $T_1V_2F_2$ achieved 49.61 mg N kg^{-1} soil relative to $T_0V_0F_0$ which achieved 37.24 mg N kg^{-1} soil.

Table 2. Effect of Spray Nano-fertilizer and Vermicompost on Available Nitrogen.

	Nano-Fertilizer mg L^{-1}					
	Vermicompost Mg ha^{-1}	F_0	F_1	F_2	F_3	T * V
T_1	V_0	37.24	39.12	38.47	37.45	38.07
	V_1	44.12	46.58	43.69	44.58	44.74
	V_2	47.92	45.68	49.61	45.32	47.13
T_2	V_0	35.69	36.41	33.96	35.71	35.44
	V_1	38.93	37.45	38.23	37.95	38.14
	V_2	40.19	39.84	41.02	40.39	40.36
LSD			2.81			1.93
						Average
F*T	T_1	43.16	43.79	43.92	42.38	43.31
	T_2	38.27	37.9	37.73	38.01	37.98
LSD			2.04			0.86
						Average
F* V	V_0	36.57	37.76	36.21	36.47	36.75
	V_1	41.52	42.01	40.96	41.26	41.44
	V_2	44.05	42.76	45.31	42.85	43.74
LSD			1.27			0.91
Average		40.71	40.84	40.83	40.19	
LSD			N.S			

3.2. Available Phosphorus

Results of **Table 3** indicate a significant effect of adding local vermicompost to the soil, as T_1 achieved available phosphorus 19.25 mg P kg^{-1} soil relative to imported vermicompost T_2 which achieved 17.90 mg P kg^{-1} soil. There was a significant effect of adding vermicompost to the soil, as V_2 achieved available phosphorus 19.72 mg P kg^{-1} soil relative to V_0 which achieved 16.95 mg P kg^{-1} soil, this is ascribed to added vermicompost contains a phosphorus, furthermore the impact of compost fertilization in enhancing phosphorus availability when it decomposes (25, 48), in addition to the impact of vermicompost in the creation of carbonic acid when decomposed by microorganisms, which led to lowering soil pH and release phosphorus from compounds and release them into soil solution, since Iraqi soils are considered calcareous soils, and thus it will increase of the forms of orthophosphate ($H_2PO_4^{-2}$), this will lead to a reduction in phosphorus deposition, this is consistent with[13, 14]. There was a significant effect of spraying nano-fertilizers on available phosphorus as F_2 achieved 19.08 mg P kg^{-1} soil relative to F_0 which achieved 17.53 mg P kg^{-1} soil, this is ascribed to small size of the nano particles, which allows them to penetrate the leaves more effectively and increase nutrients uptake, which is reflected in increased respiration and increased CO_2 secretion, which combines with water to form carbonic acid, lowering soil pH and dissolving phosphorus-bearing minerals, increasing their release and availability in the soil, this is agree with[15]. The interaction between vermicompost and nano-fertilizers on available phosphorus, as $T_1V_2F_3$ achieved of 21.51 mg P kg^{-1} soil relative to $T_0V_0F_0$ which achieved of 15.76 mg P kg^{-1} soil.

Table 3. Effect of spray nano-fertilizers and vermicompost on available phosphorus.

		Nano-Fertilizer mg L^{-1}				
	Vermicompost Mg ha^{-1}	**F_0**	**F_1**	**F_2**	**F_3**	**T * V**
T_1	V_0	15.76	18.13	17.92	17.47	17.32
	V_1	18.90	19.72	19.89	20.12	19.65
	V_2	19.82	20.48	21.39	21.51	20.80
T_2	V_0	15.82	16.76	17.35	16.39	16.58
	V_1	17.52	18.74	18.90	18.69	18.46
	V_2	17.41	18.62	19.02	19.58	18.65
LSD			0.91			0.48
						Average
F*T	T_1	18.16	19.44	19.73	19.70	19.25
	T_2	16.91	18.04	18.42	18.22	17.90
LSD			0.59			0.34
						Average
F* V	V_0	15.79	17.44	17.63	16.93	16.95
	V_1	18.21	19.23	19.39	19.40	19.06
	V_2	18.61	19.55	20.20	20.54	19.72
LSD			0.55			0.29
Average		17.53	18.74	19.07	18.96	
LSD			0.23			

3.3. Available Potassium

Results of **Table 4** show no significant effect of adding vermicompost (local and imported) to the soil on available potassium. There was a significant effect of adding vermicompost, as V_2 achieved available potassium 196.93 mg K kg^{-1} soil relative to V_0 which achieved 179.96 mg K kg^{-1} soil, this is ascribed to vermicompost releases potassium into soil as its organic matter decomposes, this enhancing the potassium availability[12, 16, 17]. There was a significant effect of spraying nano-fertilizers on available potassium as F_3 achieved 195.45 mg K kg^{-1} soil relative to F_0 which achieved 184.29 mg K kg^{-1} soil, this is ascribed to the impact of nano-fertilizers for microelements in enhancing chlorophyll, which causes to an enhanced photosynthesis process, plant growth and increases root respiration and the release of CO_2. When it interacts with water, it forms carbonic acid, which works to dissolve potassium from its minerals, transforming it into available for the plant[18]. The interaction between vermicompost and nano-fertilizers on available potassium, as $T_1V_2F_3$ achieved 213.52 mg K kg^{-1} soil relative to $T_0V_0F_0$ which achieved 173.69 mg K kg^{-1} soil.

Table 4. Effect of Spray Nano-fertilizer and Vermicompost on Available Potassium.

		Nano-Fertilizer mg L^{-1}				
	Vermicompost Mg ha^{-1}	**F_0**	**F_1**	**F_2**	**F_3**	**T * V**
T_1	V_0	173.69	182.4	179.6	185.3	180.24
	V_1	186.78	188.95	190.83	200.86	191.85
	V_2	190.73	194.16	197.62	213.52	199.00
T_2	V_0	179.50	183.91	181.90	173.40	179.67
	V_1	189.4	190.25	194.71	198.19	193.13
	V_2	185.64	198.61	193.71	201.45	194.85
			5.62			3.91
						Average
F*T	T_1	183.73	188.50	189.35	199.89	190.37
	T_2	184.84	190.92	190.10	191.01	189.22
			2.96			N.S
						Average
F* V	V_0	176.59	183.15	180.75	179.35	179.96
	V_1	188.09	189.60	192.77	199.52	192.49
	V_2	188.18	196.38	195.66	207.48	196.93
			3.48			2.57
Average		184.29	189.71	189.72	195.45	
LSD			1.97			

3.4. Nitrogen in Ieaves

Results of **Table 5** indicate a significant effect of adding local vermicompost to the soil, as T_1 achieved concentration of nitrogen in the leaves 3.86% relative to imported vermicompost T_2 gave 3.73%. There was a significant effect of adding vermicompost to the soil, as V_2 achieved concentration of nitrogen in the leaves 4.37% relative to V_0 gave 3.14%, this is attributed to the crucial roles of nutrients in vermicompost and their involvement in the physiological and biological processes, and this enhanced the plants efficiency and capacity to uptake nutrients necessary for its growth. Moreover the function of organic matter in reducing nutrient loss through washing or through the formation of chelating compounds released during the decomposition of added organic, which contributes to enhancing nitrogen availability and increasing it's in the leaves [19]. There was a significant effect of spraying nano-fertilizer on nitrogen in the leaves as F_3 achieved 4.28% relative to F_0 which gave 3.08%, this is ascribed to nano fertilizers offer an increased surface area for facilitating various metabolic reactions, which enhanced photosynthesis, in addition to the importance of foliar nutrition in supplying plants with their nutrient needs such as nitrogen and increasing its concentration in the plant. This results agree with [20–22]. The interaction between vermicompost and nano-fertilizer on nitrogen, as $T_1V_2F_3$ achieved 4.89% relative to $T_0V_0F_0$ which achieved of 2.02%.

3.5. Phosphorus in Leaves

Results of **Table 6** show that adding vermicompost (local and imported) had no significant effect on phosphorus. There was a significant effect of adding vermicompost to the soil, as V_2 achieved phosphorus 0.44% relative to V_0 which gave 0.36%, This is ascribed to the decomposition of vermicompost releases nutrients into the soil solution in the rhizosphere, and then they are uptake by the plant, in addition to forming an amount of organic acids and natural chelates that can contribute to increasing phosphorus in leaves. As well as the impact of vermicompost in enhancing the activity of microorganisms in the soil and supplying it with carbon and energy, it then works to dissolve compounds containing phosphorus and release it in a way that is available for uptake by the plant [23–25]. There was a significant effect of spraying nano-fertilizer on phosphorus as F_3 achieved 0.46% relative to F_0 which gave 0.31%, this is ascribed to nano fertilizers sprayed on the shoots facilitate absorption by the plant, which improves plant growth and increases the absorption of nutrients, including phosphorus, this is agree with [21, 26, 27]. The interaction between vermicompost and nano-fertilizers on concentration of phosphorus in the leaves, as $T_1V_2F_3$ achieved 0.52% relative to $T_0V_0F_0$ which gave 0.29%.

Table 5. Effect of Spray Nano-fertilizers and Vermicompost on Nitrogen in Leaves.

		Nano-Fertilizer mg L^{-1}				
	Vermicompost Mg ha^{-1}	**F_0**	**F_1**	**F_2**	**F_3**	**T * V**
T_1	V_0	2.02	3.25	3.69	3.79	3.18
	V_1	3.29	3.96	4.01	4.57	3.95
	V_2	3.94	4.23	4.79	4.89	4.46
T_2	V_0	2.14	3.12	3.43	3.69	3.09
	V_1	3.23	3.74	3.94	4.34	3.81
	V_2	3.91	4.56	4.21	4.45	4.28
			0. 87			0. 39
						Average
F*T	T_1	3.08	3.81	4.16	4.41	3.86
	T_2	3.09	3.80	3.86	4.16	3.73
			0. 56			0. 31
						Average
F* V	V_0	2.08	3.18	3.56	3.74	3.14
	V_1	3.26	3.85	3.97	4.45	3.88
	V_2	3.92	4.39	4.50	4.67	4.37
			0. 43			0. 29
Average		3.08	3.81	4.01	4.28	
LSD			0. 21			

Table 6. Effect of spray nano-fertilizer and vermicompost on phosphorus in leaves.

		Nano-Fertilizer mg L^{-1}				
	Vermicompost Mg ha^{-1}	**F_0**	**F_1**	**F_2**	**F_3**	**T * V**
T_1	V_0	0.29	0.38	0.42	0.47	0.39
	V_1	0.26	0.41	0.48	0.46	0.40
	V_2	0.34	0.45	0.47	0.52	0.44
T_2	V_0	0.23	0.34	0.38	0.39	0.33
	V_1	0.38	0.47	0.39	0.46	0.42
	V_2	0.37	0.45	0.46	0.48	0.44
			0.05			0.02
						Average
F*T	T_1	0.29	0.41	0.45	0.48	0.41
	T_2	0.32	0.42	0.41	0.44	0.40
			0.03			N.S
						Average
F* V	V_0	0.26	0.36	0.40	0.43	0.36
	V_1	0.32	0.44	0.43	0.46	0.41
	V_2	0.35	0.45	0.46	0.50	0.44
			0.04			0.02
Average		0.31	0.41	0.43	0.46	
LSD			0.01			

3.6. Potassium in Leaves

Results of **Table 7** indicate a significant effect of adding local vermicompost to the soil, as T_1 achieved concentration of potassium in the leaves 4.54% relative to imported vermicompost T_2 which gave 4.28%. There was a significant effect of adding vermicompost to the soil, as V_2 achieved concentration of potassium in the leaves 4.87% relative to V_0 which gave 3.80%, this is ascribed to vermicompost fosters the reproduction of microorganisms. These microorganisms release organic acids and growth-promoting hormones like gibberellins and auxins, and enhance potassium availability, leading improved potassium uptake by plants [2]. There was a significant effect of spraying nano-fertilizer on concentration of potassium in the leaves as F_3 achieved of 5.10% relative to

F_0 which gave 3.65%, this is ascribed to that nano-fertilizers improving growth of plant. Iron increases grain germination and helps the root to grow and absorb nutrients [28], and zinc essential impact in regulating stomata functions by maintaining the potassium content [29, 30]. The interaction between vermicompost and nano-fertilizers on concentration of potassium in the leaves, as $T_1V_2F_3$ achieved 6.34% relative to $T_0V_0F_0$ which achieved of 3.25%.

Table 7. Effect of spray nano-fertilizer and vermicompost on potassium in leaves.

		Nano-Fertilizer mg L⁻¹				
	Vermicompost Mg ha⁻¹	**F_0**	**F_1**	**F_2**	**F_3**	**T * V**
	V_0	3.25	4.12	3.98	4.73	4.02
T_1	V_1	3.69	4.52	4.93	5.39	4.63
	V_2	3.78	4.62	5.23	6.34	4.99
	V_0	2.97	3.64	3.83	3.91	3.58
T_2	V_1	3.98	4.21	4.82	5.01	4.50
	V_2	4.23	4.57	4.94	5.27	4.75
			0.91			0.76
						Average
F*T	T_1	3.57	4.42	4.71	5.48	4.54
	T_2	3.72	4.14	4.53	4.73	4.28
			0.45			0.34
						Average
	V_0	3.11	3.88	3.90	4.32	3.80
F* V	V_1	3.83	4.36	4.87	5.2	4.56
	V_2	4.00	4.59	5.08	5.80	4.87
			0.48			0.39
Average		3.65	4.28	4.62	5.10	
LSD			0.35			

3.7. Iron in Ieaves

Results of **Table 8** indicate a significant effect of adding local vermicompost to the soil, as T_1 achieved iron 174.22 mg Fe kg^{-1} relative to imported vermicompost T_2 which achieved of 165.27 mg Fe kg^{-1}. There was a significant effect of adding vermicompost to the soil, as V_2 achieved iron 182.63 mg Fe kg^{-1} relative to V_0 which achieved of 156.67 mg Fe kg^{-1}, this is ascribed to vermicompost releases nutrients to plant, including iron, which enhance the iron availability in the rhizosphere. Additionally, vermicompost enhances microbial activity in the soil, which can contribute to converting iron from its unavailable form to available form [31]. There was a significant effect of spraying nano-fertilizer on iron as F_3 achieved 204.83 mg Fe kg^{-1} relative to F_0 which achieved 135.13 mg Fe kg^{-1}, this is ascribed to spraying iron increases its absorption into plant tissues, and small size of nanoparticles allows them to easily penetrate pores of plant leaf. Nano-chelated iron fertilizers offer distinct advantages like superior absorption, heightened production, improved photosynthesis, and a larger leaf surface area, thus increasing iron concentration, results is agree with [14, 32, 33]. The interaction between vermicompost and nano-fertilizers on concentration of iron in the leaves, as $T_1V_2F_3$ achieved 237.85 mg Fe kg^{-1} relative to $T_0V_0F_0$ which achieved of 110.56 mg Fe kg^{-1}.

3.8. Zinc in Leaves

Results of **Table 9** show a significant effect of adding local vermicompost, as T_1 achieved zinc 73.53 mg Zn kg^{-1} relative to imported vermicompost T_2 which achieved of 71.44 mg Zn kg^{-1}. There was a significant effect of adding vermicompost to the soil, as V_2 achieved zinc 73.70 mg Zn kg^{-1} relative to V_0 which achieved 69.74 mg Zn kg^{-1}, this is ascribed to vermicompost adds organic materials rich in nutrients, including zinc, which increases the availability of zinc, in addition to vermicompost decomposition produces organic acids that decrease soil pH and enhanced zinc availability and its uptake by the plant [34]. There was a significant effect of spraying nano-fertilizer on zinc as F_3 achieved of 89.28 mg Zn kg^{-1} relative to F_0 which achieved 52.85 mg Zn kg^{-1}, this is ascribed to the effect of spray nano-zinc led to enhanced zinc. In addition, addition of other microelements encourages the uptake of zinc as a result of improving the shoot and root systems, and then an increase in the demand for nutrients, including zinc, The results are consistent with[35–39]. The interaction between vermicompost and nano-fertilizers on concentration of zinc in the leaves, as $T_2V_2F_3$ achieved 94.93 mg Zn kg^{-1} relative to $T_0V_0F_0$ which achieved of 51.36 mg Zn kg^{-1}.

Table 8. Effect of spray nano-fertilizers and vermicompost on iron in leaves.

		Nano-Fertilizer mg L^{-1}				
	Vermicompost Mg ha^{-1}	**F_0**	**F_1**	**F_2**	**F_3**	**T * V**
T_1	V_0	110.56	157.42	163.78	210.31	160.51
	V_1	143.91	167.94	184.19	198.40	173.61
	V_2	150.81	190.12	175.43	237.85	188.55
T_2	V_0	117.23	146.59	168.13	179.39	152.83
	V_1	138.51	158.72	171.28	196.63	166.28
	V_2	149.80	163.68	186.97	206.42	176.71
			19.63			10.27
						Average
F*T	T_1	135.09	171.82	174.46	215.52	174.22
	T_2	135.18	156.33	175.46	194.14	165.27
			13.71			7.81
						Average
F* V	V_0	113.89	152.00	165.95	194.85	156.67
	V_1	141.21	163.33	177.73	197.51	169.94
	V_2	150.30	176.90	181.20	222.13	182.63
			12.08			6.37
Average		135.13	164.07	174.96	204.83	
LSD			5.64			

Table 9. Effect of spray nano-fertilizers and vermicompost on zinc in leaves.

		Nano-Fertilizer mg L^{-1}				
	Vermicompost Mg ha^{-1}	**F_0**	**F_1**	**F_2**	**F_3**	**T * V**
T_1	V_0	51.36	64.89	73.69	81.37	67.82
	V_1	53.94	74.90	76.98	93.68	74.87
	V_2	49.78	67.92	80.36	88.50	71.64
T_2	V_0	54.39	70.69	71.25	90.28	71.65
	V_1	57.39	65.97	82.37	86.94	73.16
	V_2	50.28	73.70	84.17	94.93	75.77
			6.07			4.81
						Average
F*T	T_1	51.69	69.23	77.01	87.85	71.44
	T_2	54.02	70.12	79.26	90.71	73.53
			4.23			2.14
						Average
F* V	V_0	52.87	67.79	72.47	85.82	69.74
	V_1	55.66	70.43	79.67	90.31	74.02
	V_2	50.03	70.81	82.26	91.71	73.70
			3.59			2.69
Average		52.85	69.67	78.13	89.28	
LSD			3.08			

3.9. Manganese in Leaves

Results of **Table 10** show that there was no significant effect of vermicompost (local and imported) to the soil on manganese in the leaves. There was a significant effect of spraying nano-fertilizer on manganese as F_3 achieved 234.07 mg Mn kg^{-1} relative to F_0 which achieved 103.80 mg Mn kg^{-1}, this is ascribed to nano manganese sprayed on the plants increased manganese, the activity of manganese occurs at the stage of oxygen liberation when the water molecule is split in light reactions, which enabled the movement of electrons from water to chlorophyll within photosystem [40], this agree with [21, 41]. The interaction between vermicompost and nano-fertilizers on concentration of manganese in the leaves, as $T_2V_2F_3$ achieved 243.61 mg Mn kg^{-1} relative to $T_0V_0F_0$ which achieved 96.54 mg Mn kg^{-1}.

Table 10. Effect of spray nano-fertilizer and vermicompost on manganese in leaves.

		Nano-Fertilizer mg L^{-1}				
	Vermicompost Mg ha^{-1}	F_0	F_1	F_2	F_3	T * V
T_1	V_0	96.54	135.98	178.21	231.69	160.60
	V_1	92.38	143.61	167.38	240.69	161.01
	V_2	110.28	147.95	174.91	221.96	163.77
T_2	V_0	97.63	138.24	169.47	236.82	160.54
	V_1	115.72	153.17	170.39	229.70	167.24
	V_2	110.26	139.26	171.82	243.61	166.23
			10.41			8.76
						Average
F*T	T_1	99.73	142.51	173.50	231.44	161.79
	T_2	107.87	143.55	170.56	236.71	164.67
			7.36			N.S
						Average
F* V	V_0	97.08	137.11	173.84	234.25	160.57
	V_1	104.05	148.39	168.88	235.19	164.13
	V_2	110.27	143.60	173.36	232.78	165.00
			6.24			N.S
Average		103.80	143.03	172.03	234.07	
LSD			5.13			

3.10. Dry Weight

Results of **Table 11** indicate a significant effect of adding local vermicompost to the soil, as T_1 achieved dry weight 165.48 gm plant^{-1} relative to imported vermicompost T_2 which achieved of 164.00 gm plant^{-1}. There was a significant effect of adding vermicompost to the soil, as V_2 achieved dry weight 168.43 gm plant^{-1} relative to V_0 which achieved 160.43 gm plant^{-1}, this is ascribed to the role of vermicompost in enhancing soil fertility and nutrients availability in it, in addition to providing soil with nutrients it contains, which leads to increased penetration of roots into soils and enhanced efficiency of uptake of water and nutrients, the results is agree with (34). There was a significant effect of spraying nano-fertilizer on the plant on dry weight as F_3 achieved of 172.88 gm plant^{-1} relative to F_0 which achieved 155.47 gm plant^{-1}, this is ascribed to adding nano fertilizers enhance the proline accumulation, amino acids, nutrients absorption, enzyme activity and antioxidants, such as catalase, peroxidase, glutathione dismutase, nitrate reductase, which ultimately leads to improving the plant's tolerance to severe climate changes [42, 43]. The interaction between vermicompost and nano-fertilizers on dry weight, as $T_1V_2F_3$ achieved 178.36 gm plant^{-1} relative to $T_0V_0F_0$ which achieved 149.18 gm plant^{-1}.

3.11. Grain Yield

The results of **Table 12** show a significant effect of adding local vermicompost to the soil, as T_1 achieved grain yield 8.01 Mg ha^{-1} relative to imported vermicompost T_2 which gave 6.86 Mg ha^{-1}.

Table 11. Effect of spray nano-fertilizer and vermicompost on dry weight.

		Nano-Fertilizer mg L^{-1}				
	Vermicompost Mg ha^{-1}	**F_0**	**F_1**	**F_2**	**F_3**	**T * V**
T_1	V_0	149.18	161.47	166.43	168.58	161.41
	V_1	153.63	165.65	169.27	174.23	165.69
	V_2	158.28	167.87	172.91	178.36	169.35
T_2	V_0	150.19	153.59	164.57	169.47	159.45
	V_1	159.75	158.31	170.17	171.94	165.04
	V_2	161.84	163.79	169.68	174.73	167.51
			3.28			2.32
						Average
F*T	T_1	153.69	164.99	169.53	173.72	165.48
	T_2	157.26	158.56	168.14	172.04	164.00
			1.97			0.87
						Average
F* V	V_0	149.68	157.53	165.50	169.02	160.43
	V_1	156.69	161.98	169.72	173.08	165.36
	V_2	160.06	165.83	171.29	176.54	168.43
			2.81			0.93
Average		155.47	161.78	168.83	172.88	
LSD			0.79			

Table 12. Effect of Spray Nano-fertilizer and Vermicompost on Grain Yield.

		Nano-Fertilizer mg L^{-1}				
	Vermicompost Mg ha^{-1}	**F_0**	**F_1**	**F_2**	**F_3**	**T * V**
T_1	V_0	5.82	6.46	6.84	7.01	6.53
	V_1	6.61	6.85	9.73	10.77	8.49
	V_2	7.48	7.07	9.90	11.57	9.00
T_2	V_0	4.46	5.93	5.81	7.62	5.96
	V_1	6.08	6.54	7.76	8.33	7.17
	V_2	6.09	7.07	7.92	8.69	7.44
			1.32			0.71
						Average
F*T	T_1	6.63	6.80	8.82	9.78	8.01
	T_2	5.54	6.51	7.16	8.21	6.86
			0.781			0.35
						Average
F* V	V_0	5.14	6.20	6.32	7.32	6.24
	V_1	6.35	6.80	8.83	9.73	7.97
	V_2	6.78	6.96	8.83	9.95	8.09
			0.83			0.43
Average		6.09	6.65	7.99	9.00	
LSD			0.38			

There was a significant effect of adding vermicompost to the soil, as V_2 achieved grain yield 8.09 Mg ha^{-1} relative to V_0 which achieved 6.24 Mg ha^{-1}, this is ascribed to vermicompost plays a crucial impact in enhancing soil properties, this facilitates root penetration and nutrient uptake, which reflects positively on the yield, these results agreed with [44–46]. There was a significant effect of spraying nano-fertilizer on grain yield as F_3 achieved of 9.00 Mg ha^{-1} relative to F_0 which achieved 6.09 Mg ha^{-1}, this is ascribed to nano fertilizers increase crop productivity by delivering nutrients directly to the plant, especially by containing micronutrients that have impact in increasing Essential processes [28], this agree with [47–51]. The interaction between adding vermicompost and nano-fertilizer on grain yield, as $T_1V_2F_3$ achieved

11.57 Mg ha^{-1} relative to $T_0V_0F_0$ which achieved 5.82 Mg ha^{-1}.

4. Conclusions

Results showed a significant effect of using nano-fertilizer and vermicompost on growth and quality of corn yields in calcareous soil, adding local vermicompost at 20 Mg ha^{-1} increasing the available N, P and K in soil, improving the concentration of nutrients in leaves. Additionally, spraying of nano-nutrients at 150 mg L^{-1} enhancing iron, zinc and manganese in the plant, which had a significant effect on the dry weight and grain yield of corn. Overall, the combined strategy of using vermicompost and nano-fertilizers can be effective in enhancing growth and yield of corn in calcareous soils.

Author Contributions

Conceptualization, A.J.H.A.-T.; methodology, A.J.H.A.-T. and F.W.A.; fieldwork, A.J.H.A.-T. and F.W.A.; laboratory analyses, F.W.A.; writing—original draft preparation, A.J.H.A.-T. and F.W.A.; writing—review and editing, A.J.H.A.-T. and F.W.A. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

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