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Compost and Biostimulants versus Mineral Nitrogen on Productivity and Grain Quality of Two Wheat Cultivars

Mohamed Abbas [1], Hashim Abdel-Lattif [2], Ramadan Badawy [2], Mustafa Abd El-Wahab [2] and Mohamed Shahba [1,*]

[1] Natural Resources Department, Faculty of African Postgraduate Studies, Cairo University, Giza 12613, Egypt; msaelsarawy@cu.edu.eg
[2] Agronomy Department, Faculty of Agriculture, Cairo University, Giza 12613, Egypt; hashemlatif@agr.cu.edu.eg (H.A.-L.); elbadawy.w@agr.cu.edu.eg (R.B.); mostafahasan@agr.cu.edu.eg (M.A.E.-W.)
* Correspondence: shahbam@cu.edu.eg; Tel.: +20-1099415131

Abstract: To reduce the environmental pollution, this study was designed to test the effect of using compost and biostimulants as total or partial replacement for mineral nitrogen on productivity and grain quality of two wheat cultivars. Two field experiments were conducted in the Desert Experimental Station, Cairo University located at Wadi El-Natroon, Egypt during two successive seasons (2016/2017 and 2017/2018). A split-split-plot design in a randomized complete block arrangement was used. Four fertilizer treatments (100% mineral nitrogen as control, 100% compost, 75% compost + 25% mineral nitrogen and 50% compost + 50% mineral nitrogen). Four levels of biostimulants foliar applications (control, 0.75 L ha^{-1}, 1.13 L ha^{-1} and 1.5 L ha^{-1}). Treatments were tested on two wheat cultivars (Egyptian cultivar, Gemmiza-10 and Nigerian cultivar, LacriWhit-4). Results indicated that, the treatment of 50% compost + 50% mineral nitrogen fertilizer along with 1.5 L ha^{-1} of biostimulants (VIUSID® agro) significantly increased the grain yield of both wheat cultivars, LacriWhit-4 and Gemmiza-10 (4.44- and 4.53-ton ha^{-1}, respectively). The increase of grain yield was 0.9- and 1.36-ton ha^{-1}, respectively. The treatment of 100% compost significantly increased protein, crude fiber, total sugars, Mg and Mn contents in grain while the treatment of 100% mineral nitrogen fertilizer significantly increased ash, total phenols, P and Ca contents in grain. Replacing nitrogen fertilization with compost significantly increased ether extract and carbohydrates content of the Nigerian cultivar grains while N, K and Fe contents were increased in the grains of both tested cultivars. The foliar application of biostimulants (VIUSID® agro) at different levels significantly increased protein, carbohydrates, total sugars, P, K, Ca, Cu and Zn contents. It can be concluded that replacing mineral nitrogen fertilizer with a combination of compost and mineral nitrogen (50% compost + 50% mineral nitrogen) along with 1.5 L ha^{-1} of biostimulants (VIUSID® agro) is recommended for the enhancement of productivity and grain quality of wheat while reducing environmental pollution.

Keywords: yield; VIUSID® agro; protein; carbohydrates; macronutrients and micronutrients

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1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important staple cereal food crops worldwide especially in Egypt. It is grown around the world under different conditions [1] and provides about 30% of the calories needed by the world population [2]. Wheat grains contain essential nutrients such as proteins, lipids, and carbohydrates. It is also used as a source of bioactive compounds for medical industry such as alkaloids, flavonoids, terpenoids glycosides, steroids, tannins and saponin [3,4].

The European Biostimulant Industry Council defines a plant biostimulant as a material which contains substance(s) and/or microorganisms and can stimulate natural processes to benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and/or improve crop quality, independently of its nutrient content. In addition, biostimulants have been applied in crop production because they can enhance plant growth and improve the efficiency of plant nutrients [5,6]. Biostimulants (VIUSID® agro) is a growth enhancer that improves crop growth and yield [7]. VIUSID® agro enhanced crop production of soybean, radish tomato, bean, maize, tobacco, coffee, faba, and wheat crops [8–14]. Biostimulants reduced the amount of chemicals used in agriculture and plant protection [15].

Higher soil organic matter content enhances the yield of cereals [16]. Agegnehu and Bekele [17] reported a significant increase in soil pH, total nitrogen and organic matter content, cation exchange capacity and exchangeable cations due to the application of organic fertilization. Kwadwo et al. [18] found an increase in soil organic matter and available nutrients as a result of organic fertilizers application. Bayu et al. [19] reported that organic manure increases soil organic matter and improved soil fertility status. Organic matter helps to retain nutrient cations at exchange sites, promotes soil structure, and improves the water-holding capacity [20].

The integration of organic and inorganic sources may improve and sustain crop yields without degrading soil fertility status [21]. The application of organic manure in combination with mineral fertilizer increased crop growth and productivity due to the improvement of soil physical conditions, soil fertility and the availability of nutrients [22]. Abd El-Gawad and Morsy [23] concluded that the integration of organic and inorganic fertilizers was better than using organic or inorganic fertilizer separately. In addition, organic manures applied in integration with the inorganic fertilizers gave higher yield than sole chemical fertilizers [24]. A combination of both organic and inorganic fertilizers enhanced carbon storage in soils and reduced emissions from mineral nitrogen fertilizer and contributed to high crop productivity [25]. The combination of nitrogen fertilizer at 50% of the recommended dose with bio-organic fertilizers could be positively effective in wheat production [21,22,26]. Chen et al. [27] suggested that inorganic plus organic fertilizer can increase wheat yield and its stability by improving soil fertility and reducing vulnerability to climate change. Tahir et al. [28] indicated that organic matter along with recommended dose of synthetic fertilizers could be helpful in increasing the grain yield of wheat. Akhtar et al. [29] indicated that the combined use of compost and chemical fertilizer could be more effective to increase the wheat yield on sustainable basis than the chemical nitrogen fertilizer alone.

The long-term application of chemical fertilizers decreases soil microorganism, increase pollution, and disturbs the soil ecological balance [30,31]. Nitrate represents the main agricultural pollutants that pose concern for the environment [32]. The application of N-rich fertilizers to crops, may increase the nitrate concentration [33]. Increasing application rate of nitrogen fertilizers reduces nitrogen use efficiency and enhance fertilizer losses through ammonium volatilization, denitrification, leaching, and runoff, which may generate environmental risks [34]. Maucieri et al. [35] indicated the importance of combining mineral fertilizers with organic ones to maximize cereals yield. Getachew et al. [36] indicated that the application of inorganic or organic fertilizers alone did not cause a sustainable increase in yields. Applying organic fertilizers as partial or full replacement for mineral fertilizers is a way to manage nutrients in a cost-effective way [37].

The objective of the present study was to determine the effect of compost and biostimulants as total or partial mineral nitrogen fertilization replacement on grain yield and quality of two wheat cultivars (Egyptian cultivar, Gemmiza-10 and Nigerian cultivar, LacriWhit-4).

2. Materials and Methods

2.1. Experimental Site

Two field experiments were conducted in the Desert Experimental Station, Faculty of Agriculture, Cairo University in Wadi El-Natroon, El-Beheira Governorate, Egypt (Latitude, 30°32′30″–30°33′0″ N; longitude, 29°57′15″–29°58′15″ E; altitude, 45 m above sea level) during the two successive seasons of 2016/2017 and 2017/2018. Monthly mean temperature values decreased gradually from 21.4 and 22.7 °C in November to 15.4 and 13.9 °C in January in 2016/2017 and 2017/2018 seasons, respectively. The maximum relative humidity was 62.3 and 60.3% during February and January in both years, respectively. The maximum amount of rainfall was 91.7- and 40.98-mm during April and January in the first and second seasons, respectively (Table 1).

Table 1. Mean monthly climatic data at the experimental location in Wadi El-Natroon during 2016/2017 and 2017/2018 seasons *.

Month	2016/2017			2017/2018		
	Temperature (°C)	Relative Humidity (%)	Rainfall (mm)	Temperature (°C)	Relative Humidity (%)	Rainfall (mm)
October	27.9	29.9	0.6	26.4	28.7	1.2
November	21.4	23.3	30.23	22.7	25.0	20.86
December	19.3	21.2	50.08	16.5	18.5	8.69
January	15.4	59.5	5.68	13.9	60.3	40.98
February	16.9	62.3	12.93	15.6	54.0	11.6
March	20.9	50.0	0.32	21.5	43.3	1.27
April	24.7	41.0	91.07	26.2	38.3	5.63

* Data obtained from the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Egypt.

Soil samples were collected randomly at 0–30 cm depth. Soil samples were air-dried, ground gently, and sieved through a 2 mm sieve to obtain the fine soil particles. Samples were mixed and analyzed in the Laboratories of the Faculty of Agriculture, Cairo University, Giza, Egypt. Soil physical and chemical properties were assessed. Moreover, irrigation water samples were collected for analysis. Soil physical analysis was conducted according to Klute [38] and chemical analysis was performed according to Page et al. [39]. The experimental site soil was classified as sandy loam (Table 2). The soil pH was 7.21 and 7.54 and electrical conductivity (EC) was 5.12 and 5.43 dS m^{-1} in the 2016/17 and 2017/18 seasons, respectively. Chemical analysis of irrigation water was performed according to Cottenie et al. [40]. The water pH was 7.5 and 7.8 and EC was 4.16 and 4.26 dSm^{-1} in 2016/2017 and 2017/2018 seasons, respectively (Table 3).

Table 2. Soil properties at the experimental site during 2016/2017 and 2017/2018 seasons.

Soil Analysis	2016/2017	2017/2018
	Physical properties	
Sand (%)	93.75	92.77
Silt (%)	4.55	5.20
Clay (%)	1.70	2.08
Texture class	Sandy loam	Sandy loam
	Chemical properties	
pH $_{(1:1)}$	7.54	7.21
EC $_{(1:1)}$ (dS m^{-1})	5.12	5.43
Organic matter (%)	0.57	0.63
Total $CaCO_3$ (%)	3.89	5.08
Available N (mg kg^{-1})	7.01	8.43
Available P (mg kg^{-1})	1.77	2.31
Available K (mg kg^{-1})	153	176
Irrigation system	Sprinkler irrigation	Sprinkler irrigation

Table 3. Chemical properties of irrigation water at the experimental site during 2016/2017 and 2017/2018 seasons.

Season	pH	EC (dS m^{-1})	Ions Concentration meq L^{-1}						
			HCO_3^-	CL^-	SO_4^-	Ca^{++}	Mg^{++}	Na^+	K^+
2016/17	7.8	4.16	2.8	30.5	9.0	3.9	4.3	33.3	0.64
2017/18	7.5	4.26	3.2	29.1	7.9	5.3	4.6	32.5	0.55

2.2. Experimental Design and Treatments

Two wheat cultivars (Gemmiza-10 and LacriWhit-4) were used, Nigerian cultivar LacriWhit-4 was obtained from the National Agricultural Seeds Council, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria and the Egyptian cultivar Gemmiza-10 was obtained from Wheat Research Department, Field Crops Research Institute, Agricultural Research Centre, Egypt. The compost was obtained from Quesna Agricultural Development Company, Egypt and incorporated at the rates of 12-ton ha^{-1} before sowing. The biostimulants (VIUSID® agro) were provided from Catalysis, Spain.

A split-split-plot design in a randomized complete block arrangement was used with three replications. Main plots were allotted to the four fertilizer treatments (100% minerals "control", 100% compost, 75% compost + 25% mineral nitrogen and 50% compost + 50% mineral nitrogen), The biostimulant concentrations [control (0.0 L ha^{-1}), low (0.75 L ha^{-1}), medium (1.13 L ha^{-1}) and high (1.5 L ha^{-1})], were assigned to sub-plots and cultivars were assigned to sub-sub-plot. Each sub-sub-plot consists of 16 rows of 0.20 m in width and 4.0 m in length. The experimental plot area was 12 m^2. A buffer zone of 1 m was planned between experimental plots. Each main plot was surrounded with a wide ridge (1.5 m) to avoid interference of the foliar applications. The composition of VIUSID® agro and compost are presented in Tables 4 and 5. The ratios of N, P and K were presented as percentages of the kilogram. Quantitatively they were 250,130 and 300 kg/ha, respectively (Table 5).

Table 4. Chemical composition of VIUSID® agro used during 2016/2017 and 2017/2018 seasons.

* Components	%	Components	%
Potassium phosphate	5.00	Calcium pantothenate	0.115
Malic acid	4.60	Pyridoxal	0.225
Glucosamine	4.60	Folic acid	0.05
Arginine	4.15	Cyanocobalamin	0.0005
Glycine	2.35	Monoammonium glycyrrizinate	0.23
Ascorbic acid	1.15	Zinc sulphate	0.115

* Components were subjected to a molecular activation process, according to Catalysis, http://www.catalysisagro.com/ accessed on 20 March 2014 [7].

Table 5. Chemical and physical properties of organic amendment during 2016/2017 and 2017/2018 seasons.

Components	2016/2017	2017/2018
Moisture content (%)	25.00	24.00
pH $_{(1:10)}$	7.00	7.1
EC $_{(1:10)}$ (ds/m)	2.65	2.70
Total Nitrogen (%)	2.15	2.20
Ammoniacal Nitrogen—NH_4^+ (%)	0.45	0.49
Nitrate Nitrogen—NO_3^- (%)	0.029	0.024
Organic Matter (%)	1.671	1.686
Organic Carbon (%)	38.90	38.85
Ash (%)	32.8	32.8
C:N Ratio	1:18	1:18
Total Phosphorus (P_2O_5) (%)	1.09	1.07
Total Potassium (%)	2.55	2.50
No weed seeds or nematodes were detected		

2.3. Cultural Practices

Seeds were sown on the first week of October in both seasons. Seeds were sown in drilling by hand. Calcium super phosphate fertilizer (15.5% P_2O_5) at the rate of 112.5 kg P_2O_5 ha^{-1} was applied during seedbed preparation. Nitrogen was added at the rate of 225 kg N ha^{-1} for control (100% nitrogen fertilization as recommended dose) in the form of ammonium nitrate (33.5% N). Potassium sulphate (48% K_2O) was applied at the rate of

125 kg K_2O ha^{-1}. Application of N and K fertilizers was done at 20 days from planting and repeated for 10 times with equal doses at 8 days interval. The control treatment (0.0 L ha^{-1}) was sprayed with an equal amount of distilled water for comparison. VIUSID® agro doses were sprayed at morning time (10:00–12:00 a.m.) by a hand sprayer on a dry and sunny day. All doses of VIUSID® agro were applied in three equal intervals at 45, 60 and 75 days after sowing. Cultural practices were conducted according to the recommendation of the Agricultural Research Center (ARC), Egyptian Ministry of Agriculture.

2.4. Data Collection

Agronomic Characteristics

Plant height (cm), number of tillers per plant, spikes length (cm), spike weight per plant (g), number of grains per spike and grain index (g) were recorded for twenty selected plants from the inner ridges of each plot at harvest time. Grain yield in kg was weighed from one square meter of each experimental unit and then adjusted into ton ha^{-1}.

2.5. Grain Quality Characteristics

2.5.1. Preparation of Samples

Grains were manually removed and dried at 65 °C to a constant weight, ground and stored in polyethylene bags in dark at 4 °C for chemical analysis.

2.5.2. Chemical Composition of Grain

Protein (total nitrogen content as estimated by the Kjeldahl's method × 5.75), ash and fibre percentages were determined according to A.O.A.C. [41]. Carbohydrate content of grains (on dry basis) was calculated according to Fraser and Holumes [42] as follows: carbohydrates = 100 − (ash + ether extract + protein + fiber). Total sugar content was determined according to Moore and Stein [43]. Total phenols were estimated using the folinciocalteou colorimetric method according to Swain and Hillis [44].

2.5.3. Macro and Micronutrients Composition of Grain

Two grams of sample was burned at 550 °C. The ashes were dissolved in 100 mL 1 M HCl. Nitrogen (N) was determined using micro Kjeldahel method as described by Jones et al. [45]. Phosphorus (P) was determined spectrophotometerically using stannous chloride method according to A.O.A.C. [41]. Potassium (K) was determined by flame photometer (BWBI). Perkin Elmer (Model 3300, Wellesley, MA, USA) Atomic Absorption Spectrophotometer was used to quantify the contents of theses minerals, Calcium (Ca), zinc (Zn), iron (Fe), magnesium (Mg), manganese (Mn), sodium (Na), and copper (Cu) were carried out on the grains where samples were digested as recommend by Piper [46] and as described in Association of Official Agricultural Chemists, A.O.A.C. [41].

2.6. Statistical Analysis

Normal data distribution assumption was tested using SPSS v. 17.0 [47] software packages according to the Shapiro and Wilk method [48]. The two seasons' data were tested for homogeneity using Bartlett's [49] test of homogeneity and it was found to be homogeneous, and as a result, data of both seasons were combined for analysis. The combined ANOVA was carried out according to Snedecor and Cochran [50], to estimate the main effects of the different sources of variation and their interactions. F-test was used to test treatment significance at 5% probability level using "MSTAT-C" software package [51]. Mean separation was done using least significant difference (LSD) test when significant differences were found.

3. Results

3.1. Agronomic Characteristics

Since there was no significant difference between seasons, data for the two seasons were pooled together. Significant differences among replacement of mineral nitrogen fertilization with compost, VIUSID® agro levels, and between cultivars in agronomic traits were found (Table 6). Replacement of mineral nitrogen fertilizer with compost resulted in a significant difference in the all-agronomic traits except the number of tillers per plant. The foliar application of VIUSID® agro levels significantly enhanced agronomic traits. The interaction between nitrogen fertilizer replacement with compost and VIUSID® agro levels was significant in the all-agronomic traits except spike length and number of grains per spike in both wheat cultivars. Results indicated a significant interaction among replacement of mineral nitrogen fertilizer with compost, VIUSID® agro and cultivars and all of the agronomic characteristics were affected except for the number of tillers plant^{-1} (Table 6).

Table 6. Effect of different levels of compost and foliar application of VIUSID® agro on agronomic characteristics of two wheat cultivars.

Treatments	VIUSID® (L Ha^{-1})	Genotypes	Plant Height (cm)	No. of Tillers Plant^{-1}	Spike Length (cm)	Spike Weight (g)	No. of Grains Spike^{-1}	Grain Index (g)	Yield ha^{-1} (ton)
100% nitrogen fertilization	Control	Gemmiza-10	94.60	2.87	10.67	2.07	33.84	42.03	3.08
		LacriWhit-4	103.4	2.60	12.21	2.20	39.53	37.59	3.63
	0.75	Gemmiza-10	96.90	3.12	10.69	2.02	34.76	39.65	2.92
		LacriWhit-4	103.2	3.38	12.62	2.39	39.87	41.08	3.80
	1.13	Gemmiza-10	93.8	2.73	11.46	2.07	35.52	39.53	3.25
		LacriWhit-4	106.0	4.30	13.15	2.20	40.72	36.37	3.87
	1.5	Gemmiza-10	93.50	2.73	12.00	2.29	36.55	43.17	3.70
		LacriWhit-4	111.0	3.77	13.07	2.32	41.14	38.04	3.88
100% compost	Control	Gemmiza-10	102.1	3.13	11.90	2.04	34.68	40.14	3.14
		LacriWhit-4	111.9	2.78	13.47	1.99	40.82	32.55	3.33
	0.75	Gemmiza-10	102.1	3.00	12.23	2.27	36.99	42.67	3.39
		LacriWhit-4	111.7	3.37	14.43	2.29	42.50	36.23	3.81
	1.13	Gemmiza-10	104.1	2.50	12.08	2.25	37.15	41.57	3.69
		LacriWhit-4	108.7	2.85	14.93	2.21	42.59	34.69	4.07
	1.5	Gemmiza-10	106.3	2.60	12.74	2.38	37.66	43.85	4.04
		LacriWhit-4	115.5	3.77	14.85	2.63	44.19	40.94	4.15
75% compost + 25% nitrogen fertilization	Control	Gemmiza-10	108.1	3.12	11.91	2.17	36.57	40.65	2.87
		LacriWhit-4	116.6	3.55	14.44	2.12	42.42	33.07	4.04
	0.75	Gemmiza-10	106.6	2.98	12.28	2.06	37.42	37.18	3.20
		LacriWhit-4	114.4	3.12	14.93	2.33	43.78	35.79	3.79
	1.13	Gemmiza-10	107.9	3.50	12.48	1.76	38.35	29.75	3.41
		LacriWhit-4	115.0	3.80	15.27	2.60	43.95	40.73	4.24
	1.5	Gemmiza-10	113.2	3.12	13.10	2.16	39.35	37.09	3.67
		LacriWhit-4	116.0	3.38	15.52	2.60	45.82	38.90	4.23
50% compost + 50% nitrogen fertilization	Control	Gemmiza-10	109.6	3.17	11.74	2.15	37.31	39.33	3.67
		LacriWhit-4	115.8	2.87	15.31	2.24	44.04	33.92	4.00
	0.75	Gemmiza-10	111.3	3.63	12.08	2.22	37.82	39.95	3.89
		LacriWhit-4	115.7	2.73	15.72	2.36	44.97	35.38	4.03
	1.13	Gemmiza-10	109.1	4.17	12.40	2.27	38.76	40.04	4.23
		LacriWhit-4	112.5	2.73	16.24	2.65	46.00	39.65	4.41
	1.5	Gemmiza-10	115.4	3.78	12.54	2.36	39.61	41.11	4.44
		LacriWhit-4	117.2	3.12	16.37	2.75	47.51	39.70	4.53
	LSD p = 0.05		2.83	0.59	ns	0.12	ns	2.30	0.04

ns: not significant.

Results indicated a positive effect of combining mineral nitrogen and organic sources. The treatment of 50% compost + 50% mineral nitrogen fertilizer and the treatment of 1.5 L ha^{-1} of VIUSID® agro achieved the highest values of plant height (115.4 and 117.2 cm), number of tillers plant^{-1} (4.17 and 4.30), spike length (12.54 and 16.37 cm), spike weight (2.36 and 2.75 g), number of grains per spike (39.61 and 47.51), grain index (41.11 and 39.70 g) and grain yield (4.44 and 4.53 ton ha^{-1}) for the Egyptian cultivar Gemmiza-10 and for the Nigerian cultivar LacriWhit-4, respectively (Table 6). Results also indicated that the treatment of 50% compost + 50% mineral nitrogen fertilizer and the treatment of 1.5 L ha^{-1} of biostimulants (VIUSID® agro) significantly increased the grain yield of both cultivars. Cultivar LacriWhit-4 increased by 0.9-ton ha^{-1} and cultivar Gemmiza-10 increased by 1.36-ton ha^{-1}, compared to the control.

3.2. Grain Chemical Contents

Analysis of variance indicated significant differences among treatments, and between cultivars in chemical contents of grains (Table 7). The treatment of 100% compost significantly increased protein, crude fiber and total sugars. The mineral nitrogen fertilizer significantly increased ash and total phenols contents. The substitution of nitrogen fertilization with compost significantly increased ether extract, carbohydrates of Nigerian cultivar. The foliar application of biostimulants (VIUSID® agro) at different levels significantly increased protein, carbohydrates and total sugars contents in both cultivars (Table 7). Gemmiza-10 and LacriWhit-4 cultivars achieved a higher ash content (2.36 and 3.06 g/100 g, respectively) under mineral nitrogen fertilizer without foliar application of biostimulants (VIUSID® agro). Both cultivars achieved the highest protein contents (7.75 and 8.23 g/100 g, respectively) when sprayed with high level of VIUSID® agro (1.5 L ha^{-1}) under 100% compost. Gemmiza-10 and LacriWhit-4 cultivars achieved the highest ether extract content (2.07 and 2.57 g/100 g, respectively) under the treatment of 50% compost + 50% mineral nitrogen fertilizer without application of VIUSID® agro. The treatment of 100% compost without application of VIUSID® agro achieved the highest crude fiber content (3.25 and 2.99 g/100 g) of Gemmiza-10 and LacriWhit-4 cultivars, respectively. Cultivars Gemmiza-10 and LacriWhit-4 achieved higher carbohydrates content (89.76 and 89.14 g/100 g, respectively) under the treatment of mineral nitrogen fertilizer with compost (75% compost + 25% mineral nitrogen fertilizer) without application of VIUSID® agro and under the treatment of 50% compost + 50% mineral nitrogen fertilizer with moderate dose of VIUSID® agro (1.13 L ha^{-1}). Under the treatment of 100% compost, Gemmiza-10 and LacriWhit-4 cultivars achieved the highest total sugar content (23.95 and 32.91 mg/100 g, respectively), with low dose of VIUSID® agro (0.75 L ha^{-1}). Under mineral nitrogen fertilizer without application of VIUSID® agro, the Egyptian and the Nigerian cultivars achieved the highest total phenols content (2.44 and 3.19 mg gallic acid/100 g, respectively).

Table 7. Effect of different levels of compost, foliar application of VIUSID® agro and two wheat cultivars on chemical composition of grain (g/100 g).

Treatments	VIUSID® (L Ha^{-1})	Genotypes	Ash	Crude Protein	Ether Extract	Crude Fiber	Carbohydrate	Total Sugar *	Total Phenols **
100% nitrogen fertilization	Control	Gemmiza-10	2.63	4.51	1.84	2.81	88.21	23.94	2.44
		LacriWhit-4	3.06	5.63	2.19	2.24	86.88	24.44	3.19
	0.75	Gemmiza-10	2.52	4.88	1.06	2.76	88.78	18.51	2.31
		LacriWhit-4	2.27	5.92	2.17	2.35	87.30	23.02	3.19
	1.13	Gemmiza-10	2.35	5.27	1.32	2.60	88.46	15.70	2.24
		LacriWhit-4	2.60	6.31	1.00	2.50	87.59	20.34	2.14
	1.5	Gemmiza-10	1.97	5.93	1.35	2.26	88.50	22.10	1.95
		LacriWhit-4	2.76	6.56	1.34	2.76	86.60	27.01	2.17
100% compost	Control	Gemmiza-10	2.75	5.97	1.80	3.25	86.23	17.55	1.97
		LacriWhit-4	2.81	4.91	1.86	2.99	87.44	28.44	1.88
	0.75	Gemmiza-10	1.78	6.16	1.42	1.99	88.66	23.95	2.22
		LacriWhit-4	2.65	5.44	2.08	2.77	87.06	32.91	2.56
	1.13	Gemmiza-10	2.06	6.58	0.79	2.46	88.11	16.11	2.10
		LacriWhit-4	2.63	7.75	2.38	2.85	84.40	20.98	2.23
	1.5	Gemmiza-10	2.30	7.75	1.67	2.52	85.76	15.19	2.44
		LacriWhit-4	2.65	8.23	1.91	2.75	84.46	22.54	2.32
75% compost + 25% nitrogen fertilization	Control	Gemmiza-10	2.09	5.08	0.79	2.28	89.76	18.12	2.10
		LacriWhit-4	2.45	5.16	1.80	2.48	88.12	21.73	1.71
	0.75	Gemmiza-10	2.35	5.72	0.71	2.61	88.61	17.79	2.20
		LacriWhit-4	2.71	5.68	1.99	2.79	86.84	26.89	2.17
	1.13	Gemmiza-10	2.05	5.94	1.59	2.12	88.31	16.81	2.05
		LacriWhit-4	2.86	6.84	2.22	2.99	85.09	18.70	2.22
	1.5	Gemmiza-10	2.00	6.83	1.62	2.19	87.36	15.04	2.15
		LacriWhit-4	3.06	7.16	2.35	3.21	84.22	20.36	2.21
50% compost + 50% nitrogen fertilization	Control	Gemmiza-10	1.90	5.68	2.07	2.11	88.25	15.33	2.20
		LacriWhit-4	2.15	6.36	2.57	2.24	86.68	20.17	2.20
	0.75	Gemmiza-10	2.15	5.94	1.87	2.35	87.70	14.89	2.14
		LacriWhit-4	2.45	6.85	2.57	2.58	85.56	15.39	2.21
	1.13	Gemmiza-10	2.16	6.04	0.58	2.42	88.79	17.80	2.35
		LacriWhit-4	1.10	6.17	2.42	1.18	89.14	18.59	2.31
	1.5	Gemmiza-10	2.48	6.00	0.54	2.75	88.24	17.58	2.18
		LacriWhit-4	2.78	7.20	2.14	2.91	84.97	23.74	1.96
	LSD $p = 0.05$		0.05	0.08	0.16	0.10	0.15	1.37	0.29

* Total sugar (mg/100 g) ** Total phenols: (mg gallic acid/100 g).

3.3. Macro and Micronutrients Composition of Grain

Analysis of variance indicated significant differences among treatments and between cultivars in grains macro and micronutrients contents (Tables 8 and 9). However, the treatment of 100% compost significantly increased Mg, Mn, contents in grain of both cultivars and Na content in the Egyptian cultivar. The treatment of 100% mineral fertilization significantly increased P, Ca, Cu, and Zn contents in the grains of both cultivars but Na content was increased only in the Nigerian cultivar. The replacement of mineral nitrogen fertilizer with compost significantly increased N, K and Fe contents while foliar application of biostimulants (VIUSID® agro) at different levels significantly increased P, K, Ca, Cu and Zn contents in grains of both cultivars (Tables 8 and 9).

Table 8. Effect of different levels of compost, foliar application of VIUSID® agro and two wheat cultivars on macronutrient contents of grain (mg/kg).

Treatments	VIUSID® (L ha^{-1})	Genotypes	N *	P	K	Ca
100% nitrogen fertilization	Control	Gemmiza-10	871	2548	3068	9055
		LacriWhit-4	1226	4921	4140	2506
	0.75	Gemmiza-10	897	2347	3116	8880
		LacriWhit-4	980	6664	3611	2112
	1.13	Gemmiza-10	944	2769	2978	10,423
		LacriWhit-4	1277	6835	6068	2009
	1.5	Gemmiza-10	1063	4140	2349	10,112
		LacriWhit-4	886	6996	4980	1667
100% compost	Control	Gemmiza-10	1113	2918	4185	8280
		LacriWhit-4	1420	5838	5077	1361
	0.75	Gemmiza-10	1117	3058	2016	4614
		LacriWhit-4	1019	4546	5367	2056
	1.13	Gemmiza-10	1153	2939	3286	7779
		LacriWhit-4	923	4191	5161	1882
	1.5	Gemmiza-10	1470	3001	3551	4431
		LacriWhit-4	1491	3630	5244	3824
75% compost + 25% nitrogen fertilization	Control	Gemmiza-10	2198	3041	2340	4511
		LacriWhit-4	2132	2989	5865	3824
	0.75	Gemmiza-10	1266	3306	2591	4105
		LacriWhit-4	1269	2883	5582	3430
	1.13	Gemmiza-10	896	3330	2161	3032
		LacriWhit-4	1266	2697	5263	3305
	1.5	Gemmiza-10	1012	3183	2179	3893
		LacriWhit-4	1390	2529	5892	3883
50% compost + 50% nitrogen fertilization	Control	Gemmiza-10	1088	3132	3046	2816
		LacriWhit-4	1097	3185	5290	4318
	0.75	Gemmiza-10	1511	3226	2332	2522
		LacriWhit-4	1352	2967	6155	3890
	1.13	Gemmiza-10	1023	2895	3358	2471
		LacriWhit-4	1141	3364	4530	3603
	1.5	Gemmiza-10	1051	3556	4962	2935
		LacriWhit-4	1442	3023	6634	2988
LSD $p = 0.05$			107.7	152.2	506.0	364.3

* N: mg/100 g.

Table 9. Effect of different levels of compost, foliar application of VIUSID® agro and two wheat cultivars on micronutrient contents of grain (mg/kg).

Treatments	VIUSID® (L ha^{-1})	Genotypes	Fe	Mg	Mn	Na	Cu	Zn
100% nitrogen fertilization	Control	Gemmiza-10	17.43	1385	39.24	2297	11.79	43.16
		LacriWhit-4	46.78	2455	17.18	2348	11.63	46.14
	0.75	Gemmiza-10	13.84	1287	28.00	1833	13.85	42.22
		LacriWhit-4	38.77	2299	13.85	5948	7.85	33.53
	1.13	Gemmiza-10	19.29	1737	43.11	1669	10.55	43.87
		LacriWhit-4	37.90	2486	23.53	1486	10.89	59.11
	1.5	Gemmiza-10	18.08	1623	41.22	2277	18.26	104.50
		LacriWhit-4	31.22	2455	20.12	3096	13.54	57.68
100% compost	Control	Gemmiza-10	21.79	2422	90.68	3048	16.83	72.94
		LacriWhit-4	23.06	2243	24.57	2657	11.01	55.24
	0.75	Gemmiza-10	19.83	1742	47.59	1517	14.57	83.54
		LacriWhit-4	32.34	2556	36.61	2384	10.65	45.72
	1.13	Gemmiza-10	19.15	1813	46.95	1730	14.39	45.08
		LacriWhit-4	30.04	2596	28.41	2212	10.14	42.39
	1.5	Gemmiza-10	17.68	1768	34.41	2118	14.79	41.24
		LacriWhit-4	72.65	1630	29.35	2029	9.13	44.68
75% compost + 25% nitrogen fertilization	Control	Gemmiza-10	19.51	1721	30.29	1864	11.02	48.74
		LacriWhit-4	79.49	1532	21.96	1678	9.19	51.85
	0.75	Gemmiza-10	20.74	1830	41.20	2048	11.25	42.94
		LacriWhit-4	68.20	1746	23.45	1877	10.66	51.20
	1.13	Gemmiza-10	21.80	1947	33.61	2056	13.89	46.47
		LacriWhit-4	83.95	1850	22.91	2033	11.69	55.31
	1.5	Gemmiza-10	18.33	1706	21.97	2178	10.39	46.24
		LacriWhit-4	75.63	1930	31.55	1778	10.51	50.27
50% compost + 50% nitrogen fertilization	Control	Gemmiza-10	20.66	1782	27.38	1741	12.80	48.08
		LacriWhit-4	63.73	1716	17.16	1979	13.54	48.02
	0.75	Gemmiza-10	19.59	1896	17.31	1455	11.42	44.50
		LacriWhit-4	57.83	1890	30.22	2096	12.51	44.10
	1.13	Gemmiza-10	14.89	1499	19.36	1888	9.68	38.27
		LacriWhit-4	78.31	1797	36.24	2224	12.12	57.67
	1.5	Gemmiza-10	19.31	1935	24.93	2369	9.51	43.13
		LacriWhit-4	69.53	1762	28.07	1993	12.07	53.02
	LSD $p = 0.05$		2.08	159.7	4.51	106.7	2.44	5.09

The treatment of 25% compost + 75% mineral nitrogen fertilizer without the application of VIUSID® agro resulted in the highest content of N (2198 and 2132 mg/100 g) in the Egyptian and the Nigerian cultivars, respectively. Cultivars Gemmiza-10 and LacriWhit-4 achieved the highest P content (4140 and 6996 mg/kg, respectively) under the treatment of 100% mineral nitrogen fertilizer with the application of the high dose of VIUSID® agro (1.5 L ha^{-1}). Under the treatment of mineral nitrogen fertilizer with compost (50%/50%) combined with the application of VIUSID® agro (1.5 L ha^{-1}), Gemmiza-10 and LacriWhit-4 cultivars attainted the highest values of K (4962 and 6634 mg/kg, respectively). The highest contents of Ca (10,423 and 2506 mg/kg) were observed in Gemmiza-10 and LacriWhit-4 cultivars under the treatment of 100% mineral nitrogen fertilizer along with the application of VIUSID® agro (1.13 L ha^{-1}) and (0.0 L ha^{-1}), respectively (Table 8).

Looking closely at the micronutrient contents, Gemmiza-10 and LacriWhit-4 cultivars achieved the highest contents of Fe (21.80 and 83.95 mg/kg, respectively) under the treatment of 25% compost + 75% mineral nitrogen fertilizer without the application of VIUSID® agro. Furthermore, Gemmiza-10 cultivar achieved the highest contents of Mg, Mn and Na (2422, 90.68 and 3048 mg/kg, respectively) under the treatment of 100% compost. In addition, it achieved the highest values of Cu and Zn (18.26 and 104.50 mg/kg, respectively) under the treatment of 100% mineral nitrogen fertilizer plus the application of the high level of VIUSID® agro (1.5 L ha^{-1}). The cultivar LacriWhit-4 achieved the highest values of Mg and Mn (2556 and 36.61 mg/kg, respectively) under the treatment of 100% compost plus the application of the low level of VIUSID® agro (0.75 L ha^{-1}). In addition, it achieved the highest contents of Na, Cu and Zn (5948, 13.54 and 59.11 mg/kg, respectively) under the treatment of 100% mineral nitrogen fertilization along with 0.75, 1.5 and 1.13 L ha^{-1} of VIUSID® agro, respectively (Table 9).

4. Discussion

Chemical fertilizers are one of the most important agricultural environmental pollutants. It is well known that organic fertilizers are insufficient to sustain good crop yields and support soil fertility [52]. Accordingly, compost mixed with chemical fertilizers not only improves the efficiency of the fertilization processes but also reduces the use of chemical fertilizers and environmental pollution [53]. Applying organic fertilization to soils as partial or full substitutes for mineral fertilizers is stimulated by a desire to manage crop production in a cost-effective way [37]. Getachew et al. [36] pointed out that the sole application of either organic or inorganic fertilizer was not enough for a sustainable increase in crop yields.

Our findings assured the beneficial and synergistic effects of 50% compost and 50% of recommended dose of mineral nitrogen fertilizer along with biostimulants (VIUSID® agro) on wheat growth, yield, and quality of grains. These combinations significantly increased the grain yield of wheat cultivars. In agreements with our findings, Abbas et al. [13] reported a positive effect of plant compost and biostimulants (VIUSID® agro) on faba bean yield. Tahir et al. [28] indicate that organic matter along with mineral fertilizers could be helpful in increasing the grain yield of wheat. The improved wheat productivity due to the integration between organic and mineral fertilizers has been reported by numerous authors, Sarwar, [16]; Agegnehu et al. [21]; Abd El-Gawad and Morsy [23]; Chen et al. [27] and Zemichael and Dechassa [22]. Compost along with mineral nitrogen fertilizer significantly improved the plant height, number of tillers per plant, number of spikelet $spike^{-1}$ and grain yield of wheat [29]. However, Maucieri et al. [35] reported that organic fertilization with compost represents a valid replacement for mineral fertilization in wheat. Furthermore, Kany et al. [54] (2016) indicated that the application of organic fertilizers produced the highest values of wheat agronomic traits and yield.

In the present investigation, replacement of mineral nitrogen fertilizer with a combination of compost and mineral nitrogen (50% compost + 50% mineral nitrogen fertilizer) increased grain yield of the studied cultivars. This may be attributed to the positive effect of compost as an organic amendment on soil properties, i.e., soil pH, total nitrogen and organic matter content, cation exchange capacity, enhanced contents of soil organic matter, plant available nutrients, improved soil fertility status, enhanced soil capacity for moisture retention, promoted soil structure, and improved soil water-holding capacity [17–20,55]. Higher yield due to the application of organic manure and mineral fertilizer can be a result of improved root growth and better nutrient uptake that favor improved growth and delayed leaves senescence [56]. The increase in yield could be a result of a better overall performance that results from induced cell division, expansion of cell wall, better meristematic activity, higher photosynthetic efficiency, and more efficient regulation of water intake into the cells [57,58]. It was found that the combined application of mineral fertilizers and organic manure resulted in optimum wheat yield as well as improved soil physico-chemical properties for sustainable production of wheat crop [22]. However, Mohamed et al. [59] obtained high wheat productivity with a complete replacement of chemical fertilizers with organic and biofertilizers.

It was found that foliar application of the biostimulant VIUSID Agro® at different levels significantly increased the grain yield, protein, carbohydrates, total sugars, P, K, Ca, Cu and Zn contents. The biostimulant VIUSID® agro contains many compounds such as amino acids, potassium phosphate, calcium pantothenate, zinc sulphate and ascorbic acid. This complicated structure is the reason behind the ability of the compounds of VIUSID

Agro® to promote and activate the cell metabolism, by increasing the plant's physiological activity [60]. Biostimulants has been applied in crop production because they can enhance plant growth, enhance photosynthesis, and improve the efficiency of plant nutrients uptake [5–7]. Biostimulants (VIUSID® agro) is a well-known growth enhancer that improves water and nutrient use efficiency of crops and stimulates plant development [7,61–63]. Biostimulants have been reported to improve crop yields of wheat [64], increase minerals uptake and improve nutrient use efficiency for both macro- and micronutrients [65,66].

Our results showed that the treatment of 100% compost significantly increased protein, crude fiber, total sugars, Mg, Mn contents in grain. The 100% mineral fertilization significantly increased ash, total phenols, P and Ca contents in grain. The replacement of nitrogen fertilization with compost significantly increased ether extract, carbohydrates of the Nigerian cultivar and N, K and Fe contents in grains of both cultivars. In addition, grains starch contents, crude protein, and moisture contents were improved when mineral nitrogen was combined with organic fertilizers at 75:25 ratios followed by 50:50 ratio [67]. Furthermore, the addition of organic and inorganic fertilizers to the soil improves the availability of both macro-and micronutrients, which are very vital for plant various metabolic activities including protein synthesis, and carbohydrates synthesis for a continuous growth and development [68,69]. However, some authors indicated that the organic farming does not get enough nutrients, and additional supply of chemical fertilizers is needed for better grains quality [70–72]. Our results revealed that replacing mineral nitrogen with compost and/or compost plus VIUSID® agro applications induced higher nutrient content as compared with mineral nitrogen fertilization. Compost has a high content of macronutrients (N, P, and K), ash and organic matter. Plant compost has a positive effect on soil properties as it can release N, P, and K in the rhizosphere zone. Compost increases the availability and content of nutrients such as nitrogen, phosphorus and potassium in the soil and grain ionic contents. In agreement with our findings, Mohamed et al. [59] indicated that compost application improved macro and micronutrients availability compared with inorganic fertilization. However, Azad et al. [73] found that the recommended dose of mineral fertilizers significantly increased the contents of N, P, K and S in the grains of wheat. Bulut et al. [74] found no significant increase in Cu, Fe, Mn, Se, Zn, Cd, Co, Cr, Ni and Pb contents in wheat grains because of organic fertilization, while the lowest contents were resulted with the usage of chemical fertilizers. It is hard to correlate the grain nutrient contents with a specific factor. Many factors can explain the variation in grains mineral contents such as specific crop responses to nutrients, usefulness of soil extractions, or the complex physiological processes in mineral translocation from roots to grains [75].

5. Conclusions

The combination of compost and biostimulants (VIUSID® agro) significantly increased the grain yield of wheat cultivars, chemical constituents and macro and micronutrients composition of grains. The replacement of nitrogen fertilizer with compost (50% compost + 50% mineral nitrogen fertilizer along with 1.5 L ha^{-1} of biostimulants (VIUSID® agro) is recommended to reduce mineral nitrogen fertilization and to improve the yield and the grain quality of wheat. To maximize the agronomic sustainable productivity of wheat crop, more information is needed on the long-term effects of biostimulants (VIUSID® agro) in combination with organic amendments on the status of soil nutrient availability for sustainable wheat production especially under other abiotic stresses including unexpected climatic fluctuations.

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