Response of *Helianthus annuus* L to Organic, Bio- and Mineral Fertilization: Implications for Phyto-Architecture and Environmental Variance

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ABSTRACT

Literature of ornamental, medical and aromatic plants, department of plant production, Faculty of environmental agricultural science,Arish university, Egypt. Arid conditions make sustainable agriculture demand effective fertilization strategies which are sustainable in terms of productivity as well as environment. The research was done in North Sinai, Egypt, in the summer of 2021 and 2022 to assess the phyto-architectural and phenological performance of two sunflower varieties (Sakha-53 and Giza-102) to various organic, bio, and mineral fertilization levels. The experiment was set up in the form of split-split-plot with repeated measures to determine the effects of two seasons, the main-plot factor being the two organic sources (mixed sheep/goat manure and chicken manure) and the sub-plot factor being the variety of bio- and mineral fertilizers and the split-split-plot factor being the two cultivars. It showed that Sakha-53 performed better than Giza-102 on most characteristics and there was overall improvement in the second season because of the long-term residual fertilization effects. The mixture of chicken manure and EM-1 biofertilizer was most effective, which resulted in the flowering process speeding up significantly, a decrease in time of vegetative growth, and a significant increase in structural characteristics of stem diameter (2.14 cm), head diameter (24.27 cm), root diameter (6.13 cm), and leaf length (34.47 cm). Analysis of environmental variance indicated that certain characteristics such as stem diameter remained stable and could therefore be used to select breeding and leaf characteristics were very flexible and sensitive to fertilization. These findings emphasize the value of integrated nutrient management for enhancing sunflower productivity in arid regions.

Keywords: Sunflower; *Helianthus annuus*; chicken manure; EM-1 biofertilizer; phyto-architecture; environmental variance; integrated nutrient management; sustainable agriculture.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a vital oilseed crop globally, prized for its high oil content, good fatty acid ratio and the capacity to adapt to various agro-ecological factors. In Egypt, the production of sunflower has major potential to fill the disparity between the production and consumption of edible oil. Nevertheless, its yield is still lower than the world levels, which is mainly caused by the difficult soil conditions, lack of water resources, and ineffective crop management practices. To overcome these threats, there is urgent necessity of effective fertilization mechanisms that may not only maximize nutrient provision, but also provide long-term soil protection and sustainability (Singh and Singh, 2022).

In recent years, the shift from excessive reliance on synthetic mineral fertilizers towards more sustainable, eco-friendly alternatives has gained traction. There is a significant role that organic fertilizers, including animal manure, can play as they improve the physical, chemical, and biological properties of the soil, increase the content of organic matter and enhance the process of cycling nutrients. Manure is also very important, like chicken manure which contains more nitrogen (N) and phosphorus (P) and lower carbon to nitrogen (C/N) ratio than sheep/goat manure. This low C/N ratio will allow a faster decomposition process and more rapid availability of nutrients which will provide a more immediate nutritional effect on plants, whereas sheep/goat manure will release nutrients at a slower rate and over a prolonged period which is important to establish long-term soil fertility (Misra and Sen, 2023, Manzoor et al., 2024).

Moreover, the application of biofertilizers as well as mineral fertilizers gives a comprehensive nutritional solution to crops. Biofertilizers (EM-1 and TS) are non-traditional sources of nutrients, but microbial inoculants that include useful microorganisms like lactic acid bacteria, yeasts, and photosynthetic bacteria (Soni et al., 2024; Bairwa et al., 2023). These microbes are bacterial catalysts, they help the decomposition and mineralization of organic matter and result in increased nutrient availability and uptake by the plant. They also generate plant growth-promoting hormones and enzymes, accelerate root growth and inhibit soil-borne pathogens, and result in a healthier and more robust soil ecosystem. Their use in combination with organic fertilizers enhances the activity of microorganisms and

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their efficiency in nutrient usage leading to increased productivity (Mahapatra et al., 2022).

The combined use of organic, bio, and mineral fertilizers--a strategy known as Integrated Nutrient Management (INM)--is particularly effective in harsh environments. This approach ensures a balanced, continuous nutrient supply, as the mineral fertilizers give an immediate nutrient supply, whereas organic and biofertilizers provide long-term soil fertility and enhanced efficiency in nutrient use (Padbhushan et al., 2021). The tested integrated approach has demonstrated the ability to improve the growth and production of sunflower in stressful environments, such as salinity and drought (Hammad et al., 2025; Hanhur et al., 2022).

Although the influence of different fertilization approaches on sunflower has been examined, very little has been done to provide a thorough evaluation of the application of significant phyto-architectural properties and their environmental sustainability in cultivars in Egypt (Hafez et al., 2021). Phyto-architecture, i.e. the diameter of the stems, the morphotype of the leaves, and the diameter of the seeds are major factors in determining photosynthetic abilities, lodging protection and, eventually, seed production (Sadras and Villalobos, 2021). These characteristics are also responsive to various fertilization ratios, which need to be well understood to come up with strong and productive cultivars that can survive in arid environments (Meena and Sujatha, 2022). In addition, in this research, the author comes up with another important concept known as environmental variance (VE) to assess the plasticity and stability of these traits among various seasons. These methods are useful to plant breeders in understanding which traits are more genetically stable and therefore safe as targets to selection, and which are environmentally plastic and can be manipulated by agricultural management (Falconer and Mackay, 1996; Lynch and Walsh, 1996).

Therefore, the present study aimed to evaluate the response of two Egyptian sunflower cultivars, Sakha-53 and Giza-102, to various organic, bio, and mineral fertilization strategies under the specific environmental conditions of North Sinai. The specific objectives were to: (i) assess the influence of fertilization treatments on sunflower phyto-architectural traits, (ii) estimate the extent of environmental variance and its implications for breeding and management, and (iii) identify the most promising fertilization combinations for enhancing sunflower productivity under arid conditions.

MATERIALS AND METHODS

The field experiments were carried out at the Experimental Farm of the Faculty of Environmental Agricultural Sciences, Al-Arish University, North Sinai, Egypt, during the two successive summer seasons of 2021 and 2022. The region is characterized by an arid climate with hot summers and limited annual rainfall.

Table 1. Metrological data of Al-Arish zone during 2021 and 2022 summer seasons, average monthly values

Month	Air temperature (°C)	Relative humidity (%)	Precipitation (mm)	Wind speed (m/s)
	Minimum	Maximum		
	2021	2022	2021	2022
February	9.59	10.14	18.52	18.03
March	10.82	11.50	19.66	20.85
April	13.23	13.83	23.19	23.20
May	17.59	17.12	29.60	26.99
June	21.89	19.22	31.66	29.47
Juley	23.41	22.38	33.16	31.95
August	24.00	23.32	33.51	32.86

Source: The central laboratory for agricultural climate, agricultural research center, Ministry of Agriculture and Land Reclamation, Egypt.

Table2. Soil analysis for the experimental farm of Al-Arish university, determinations at beginning of the summer growing season, in 0 – 30 cm of soil depth

Texture:	Sandy-loam	EC	(ds/m)	pH	$CaCO_3$	Cations (mg/L):	Anions (mg/L):
Coarse sand (%)	65.10	1.60	8.52	3.89	K+	0.47	Cl-
Fine sand (%)	20.90				Na+	2.61	SO4-
Silt (%)	2.60	Organic carbon	(g/kg)	Organic matter	(g/kg)	Mg++	2.18
Clay (%)	11.40	1.09	2.05	Ca++	2.60	CO3-	-

Two sunflower (*Helianthus annuus* L.) cultivars, Sakha-53 and Giza-102, were used in this study. Seeds were obtained from the Oil Crops Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt. The experimental field was divided into two main plots according to the type of organic fertilization, each applied at a rate of 20 m^3/fed. The first main plot received mixed sheep and goat manure, while the second was amended with chicken manure. Each main plot was further subdivided into three subplots corresponding to the following treatments, in addition to a control (organic fertilizer only):

- Biofertilizer EM-1, applied at concentrations of 2, 4, and 5 ml/L.
- Biofertilizer TS, applied at concentrations of 20, 25, and 30 ml/L.
- Mineral fertilizer NPK (20-20-20), applied at concentrations of 1.5, 2, and 5 g/L.

Organic fertilizers were incorporated into the soil two weeks before sowing, while bio- and mineral fertilizers were applied at the vegetative growth stage. Standard agronomic practices for sunflower production in the region were followed throughout the growing seasons. The experiment was laid out in a split-split-plot design with repeated measures within a randomized complete block design (RCBD) with three replications. This design was chosen to account for the hierarchical application of treatments: organic fertilizer sources were assigned to the main plots, bio- and mineral fertilizers were applied to the subplots, and the two cultivars were planted within the split-split-plots. The data were collected from the same experimental units during both the 2021 and 2022 growing seasons.

At 50% flowering, the following traits were measured on an average of five plants per subplot: Days to 50% flowering, Stem diameter (cm), Head diameter (cm), Root diameter (cm), Leaf length (cm), leaf width (cm), and leaf angle of upper leaves (°), Petiole length (cm).

Statistical analysis

Data were subjected to a multi-factor Analysis of Variance (ANOVA) appropriate for a split-split-plot design with repeated measures. This design accounts for the hierarchical structure of the experiment and the presence of multiple error terms, thereby avoiding the common mistake of testing all factors against a single residual error which can lead to inflated F-statistics and an increased risk of Type I errors. The analysis was performed following the procedures of Steel and Torrie (1980). The main-plot factor, organic fertilizer sources, was tested against the Rep × Organic interaction (Error a). Sub-plot factors, including bio- and mineral fertilizers, cultivars, and seasons, as well as their interactions, were tested against the appropriate error terms (Error b). Mean comparisons were carried out using the Least Significant Difference (LSD) test at the 5% level of probability with the aid of the MSTAT-C software package. Environmental variance (V_E) was estimated as the difference between phenotypic variance (V_P) and genotypic variance (V_G), according to the methods of Falconer and Mackay (1996) and Lynch and Walsh (1996).

RESULTS AND DISCUSSION

Based on the statistical analysis, the combined ANOVA Table 3 across both seasons indicated that all studied traits—days to 50% flowering, stem diameter, head diameter, root diameter, leaf length, leaf width, leaf angle, and leaf petiole length—were significantly ($p \leq 0.01$) affected by organic fertilization (Factor A), bio/mineral fertilization (Factor B), cultivar (Factor C), and season (Factor D). The significant interactions (AB, AC, BC, ABC, etc.) were particularly important, as they showed that the response of sunflower traits was not just a result of individual factors, but a complex interplay between fertilizer type and cultivar. This highlights the importance of using an integrated nutrient management approach (Padbhushan et al., 2021). The seasonal ANOVA (Table 4) further confirmed these results separately for 2021 and 2022, with Sakha-53 showing consistently higher mean squares than Giza-102, reflecting its superior genetic potential (Meena and Sujatha, 2022; Sadras and Villalobos, 2021).

Trait-Specific Responses:

Days to 50% Flowering (Table 5), The analysis of this trait, which indicates earliness, shows a clear trend of Giza-102 flowering earlier than Sakha-53 across all treatments and seasons. The most significant acceleration in flowering was observed with the application of EM-1 at a concentration of 4 ml/L in the chicken manure plots, reducing flowering to 66.71 days for Sakha-53 and 61.88 days for Giza-102. It's also noteworthy that the flowering duration in the second season was consistently shorter than in the first season. The acceleration of flowering under biofertilization treatments compared with the control suggests that biofertilizers, particularly EM-1, enhanced nutrient uptake and reduced vegetative growth duration, which is crucial for maximizing yield in regions with short growing seasons or water limitations (Bairwa et al., 2023).

Table 3. Overall Mean Squares for the Studied Traits in Sunflower

Source of variation	d.f	Days to 50% flowering	Stem diameter (cm)	Head diameter (cm)	Root diameter (cm)	Leaf length (cm)	Leaf width (cm)	Leaf angle (°)	Leaf petiole (cm)
Replications	2	0.42**	0.07**	6.12**	0.46**	0.50**	2.79**	0.56**	0.19**
Organic fertilization (A)	1	9.24**	0.20**	54.86**	21.38**	239.48**	48.63**	34.06**	2.96**
Bio and mineral fertilization (B)	9	137.21**	0.77**	107.77**	13.22**	201.69**	205.75**	12.17**	5.71**
A × B	9	1.43**	0.02**	1.01**	0.52**	5.76**	1.29**	0.74**	0.03**
Cultivars (C)	1	1187.53**	24.63**	3772.14**	261.36**	5489.93**	3995.86**	4926.19**	76.23**
A × C	1	0.19**	0.0001**	0.88**	5.79**	135.75**	22.66**	1.59**	0.06**
B × C	9	1.75**	0.06**	23.75**	0.85**	126.65**	106.20**	0.73**	0.08**
A × B × C	9	0.50**	0.02**	0.97**	0.06**	5.56**	1.07**	0.15**	0.06**
Seasons (D)	1	4.97**	0.09**	14.13**	6.44**	38.02**	38.71**	56.13**	1.10**
A × D	1	3.38**	0.01**	11.22**	0.67**	0.86**	0.06**	1.99**	0.09**
B × D	9	0.75**	0.01**	0.17**	0.01**	1.29**	0.43**	0.23**	0.04**
A × B × D	9	0.63**	0.004**	1.72**	0.04**	0.56**	0.49**	0.15**	0.01**
C × D	1	10.67**	0.002**	0.49**	0.01**	3.83**	0.52**	2.37**	0.01**
A × C × D	1	0.003**	0.001**	0.84**	0.35**	0.21**	4.19**	1.56**	0.02**
B × C × D	9	0.70**	0.002**	0.33**	0.02**	0.68**	1.01**	0.34**	0.01**
A × B × C × D	9	0.41**	0.001**	0.40**	0.04**	0.21**	0.47**	0.88**	0.02**
Error	158	0.01	0.001	0.09	0.01	0.025	0.08	0.01	0.004
Total	239								
CV (%)		0.14	2.83	1.89	2.66	0.76	1.75	0.25	0.83

** and * indicate significance at the 0.01 and 0.05 probability levels, respectively. ns = not significant.

Stem Diameter (Table 6), The Sakha-53 cultivar showed superior stem diameter compared to Giza-102. The highest value was recorded in the plots treated with chicken manure and EM-1 at a concentration of 5 ml/L, which led to a significant increase in stem diameter to 2.14 cm for Sakha-53 and 1.33 cm for Giza-102. Increased stem diameter is a key indicator of improved plant vigor and structural integrity, which is essential for withstanding environmental stresses like wind and for supporting a heavier head (Hafez et al., 2021).

Head diameter showed a significant response to fertilization, with Sakha-53 again demonstrating superiority. The combination of chicken manure and EM-1 fertilizer produced the highest head diameter, with the Sakha-53 cultivar achieving its peak at 5 ml/L of EM-1 concentration with a value of 24.27 cm, compared to 21.82 cm for Giza-102. This marked increase in head diameter is a direct and impactful finding, as head diameter is directly correlated with seed yield (Sadras and Villalobos, 2021). The significant difference underscores the superior effect of combined organic and biofertilization in boosting reproductive success and economic returns (Hammad et al., 2025).

Root Diameter (Table 8), also showed a strong positive response to fertilization. The chicken manure treatment consistently yielded better results than the mixed sheep and goat manure. The combination of chicken manure and EM-1 at a 5 ml/L concentration resulted in a significant increase in root diameter for the Sakha-53 cultivar to **6.13 cm**, which was a **26.8%** increase compared to the control. These results indicate improved root development and soil exploration capacity, which is essential under the sandy soils of Al-Arish for efficient water and nutrient absorption (Singh and Singh, 2022).

Leaf Length, Width, Angle, and Petiole (Tables 9-12), For all leaf characteristics, the chicken manure plots consistently showed better results than the mixed sheep and goat manure plots. The second season also generally surpassed the first, and Sakha-53 performed better than Giza-102 in all treatments.

Table 4. Seasonal Analysis of Variance (ANOVA) for the Studied Traits in Sunflower during the 2021 and 2022 Summer Seasons at Al-Arish

Source of variation	Season	d.f	Days to 50% flowering	Stem diameter(cm)	Head diameter(cm)	Root diameter(cm)	Leaf length(cm)	Leaf width(cm)	Leaf angle (°)	Leaf petiole(cm)
Replications	2021	2	0.18**	0.05**	1.10**	0.05**	0.10**	1.45**	0.12**	0.05**
Replications	2022	2	0.25**	0.02**	6.03**	0.06**	0.47**	1.34**	0.50**	0.10**
Organic fertilization(A)	2021	1	0.72**	0.07**	57.84**	7.24**	134.51**	22.59**	26.25**	2.05**
Organic fertilization(A)	2022	1	11.90**	0.13**	8.23**	14.81**	105.83**	27.70**	9.80**	1.00**
Bio & mineral fertilization(B)	2021	9	63.56**	0.34**	54.14**	6.74**	91.24**	108.79**	5.30**	3.08**
Bio & mineral fertilization(B)	2022	9	74.40**	0.44**	53.80**	6.58**	111.47**	97.39**	7.10**	2.66**
A × B	2021	9	1.17**	0.01**	2.02**	0.40**	4.28**	1.11**	0.61**	0.02**
A × B	2022	9	0.88**	0.01**	0.71**	0.17**	2.03**	0.68**	0.28**	0.03**
Cultivars (C)	2021	1	711.65**	12.12**	1843.26**	131.94**	2601.87**	2043.76**	2572.43**	37.20**
Cultivars (C)	2022	1	486.54**	12.51**	1929.37**	129.42**	2891.89**	1952.62**	2356.14**	39.05**
A × C	2021	1	0.12**	0.001**	0.0001ns	4.50**	73.31**	23.17**	0.0001ns	0.07**
A × C	2022	1	0.07**	0.0001ns	1.73**	1.64**	62.66**	3.68**	3.15**	0.01ns
B × C	2021	9	1.53**	0.04**	11.48**	0.54**	55.80**	60.37**	0.57**	0.05**
B × C	2022	9	0.91**	0.03**	12.61**	0.33**	71.52**	46.84**	0.51**	0.04**
A × B × C	2021	9	0.74**	0.01**	1.06**	0.08**	3.27**	0.76**	0.67**	0.06**
A × B × C	2022	9	0.17**	0.01**	0.36*	0.02*	2.50**	0.79**	0.37**	0.02**
Error	2021	78	0.01**	0.002**	0.02**	0.002**	0.006**	0.042**	0.005**	0.005**
Error	2022	78	0.009**	0.001**	0.13**	0.001**	0.042**	0.128**	0.018**	0.004**
Total	2021	119	—	—	—	—	—	—	—	—
Total	2022	119	—	—	—	—	—	—	—	—
CV%	2021	—	0.14	3.26	0.95	1.26	0.39	1.27	0.15	0.89
CV%	2022	—	0.14	2.24	2.27	2.96	0.97	2.11	0.30	0.77

** and * indicate significance at the 0.01 and 0.05 probability levels, respectively. ns = not significant.

The highest leaf length for Sakha-53 was 34.47 cm with EM-1 at 5 ml/L in chicken manure plots, compared to 31.25 cm for Giza-102. Similarly, the highest leaf width was 26.68 cm for Sakha-53 with the same treatment, compared to 24.96 cm for Giza-102. These results suggest that integrated fertilization enhances photosynthetic surface area, supporting higher biomass accumulation and ultimately, a more productive plant. Leaf petiole length showed the most effective response to the combined mineral fertilization of NPK at 5 g/L within the chicken manure treatment, with a value of 16.63 cm for Sakha-53 and 14.82 cm for Giza-102. Broader leaves and longer petioles facilitate better leaf display and improve canopy photosynthesis, allowing the plant to optimize light capture throughout the day (Hafez et al., 2021).

Environmental Variance and Its Implications:

Environmental variance (VE) is not a measure of experimental accuracy but rather a key finding in quantitative genetics that quantifies the variation in a trait's phenotype that cannot be attributed to genetic differences (Lynch and Walsh, 1996). A lower VE value indicates that a trait is more stable and less influenced by environmental fluctuations, making it a good candidate for plant breeding selection. A higher VE suggests the trait is more plastic and highly responsive to environmental factors, making it amenable to improvement through agronomic interventions.

The environmental variance estimates (Table 13) revealed that stem diameter (0.133) and petiole length (0.561) were the most environmentally stable traits. This is a critical finding because it suggests that these traits are genetically more stable across different seasons and environmental conditions, making them reliable targets for future breeding programs aimed at developing resilient sunflower varieties. In contrast, leaf length (35.72) and leaf width (28.81) were the most environmentally sensitive traits.

Table 5. Response of Sunflower Cultivars Sakha-53 and Giza-102 to Days to 50% Flowering for Fertilization under Al-Arish conditions during the two successful summer growing seasons 2021 and 2022, respectively

Treatment	Sakha-53				Giza-102				X
	1st Season	2nd Season	X	ΔD(%)	1st Season	2nd Season	X	ΔD(%)	
Mixed sheep and goat manure (20 m³/feddan)									
Control	72.29d	72.30e	72.30	+0.01	69.09j	68.91j	69.00	-0.26	70.65
EM1 (2 ml/L)	69.61k	69.88h	69.75	+0.39	66.24o	66.19o	66.22	-0.08	67.98
EM1 (4 ml/L)	67.97o	67.22o	67.59	-1.10	62.83r	62.84r	62.84	+0.02	65.21
EM1 (5 ml/L)	69.96o	67.24o	68.60	-3.89	66.05o	62.77r	64.41	-4.97	66.50
XEM1	69.18	68.11	68.65	-1.55	65.04	63.93	64.48	-1.71	66.57
TS (20 ml/L)	72.77c	73.07c	72.92	+0.41	68.23l	68.05l	68.14	-0.26	70.53
TS (25 ml/L)	70.21i	69.00kl	69.60	-1.72	64.00p	65.18p	64.59	+1.84	67.10
TS (30 ml/L)	70.08ij	69.00kl	69.54	-1.54	63.97p	65.17p	64.57	+1.82	67.05
XTS	71.02	70.36	70.69	-0.93	65.40	66.13	65.77	+1.12	68.23
XBIO.	70.10	69.23	69.67	-1.24	65.22	65.03	65.12	-0.29	67.39
NPK (1.5 g/L)	74.12a	74.15b	74.14	+0.04	69.34hi	69.32i	69.33	-0.03	71.73
NPK (2 g/L)	71.05gh	70.34g	70.70	-1.00	65.67m	66.54n	66.11	+1.32	68.40
NPK (5 g/L)	71.00h	70.00h	70.50	-1.41	65.47n	66.48n	65.97	+1.55	68.24
XNPK	72.06	71.50	71.78	-0.77	66.83	67.45	67.14	+0.93	69.46
XGoat	71.14	70.57	70.85	-0.80	66.59	66.61	66.60	+0.02	68.72
Chicken manure (20 m³/feddan)									
Control	71.85e	71.23f	71.54	-0.87	68.25k	68.00k	68.13	-0.37	69.83
EM1 (2 ml/L)	70.10ij	69.40i	69.75	-1.00	64.81n	65.71o	65.26	+1.38	67.51
EM1 (4 ml/L)	67.27q	66.15qr	66.71	-1.66	62.09s	61.66s	61.88	-0.70	64.29
EM1 (5 ml/L)	67.19q	66.10qr	66.65	-1.63	62.00s	61.65s	61.83	-0.56	64.24
XEM1	68.19	67.22	67.70	-1.42	62.97	63.01	62.99	+0.06	65.35
TS (20 ml/L)	72.99b	72.77d	72.88	-0.31	67.62m	68.07l	67.85	+0.66	70.36
TS (25 ml/L)	69.57k	68.52m	69.05	-1.51	64.00p	64.03p	64.02	+0.05	66.53
TS (30 ml/L)	69.21lm	68.37m	68.79	-1.22	63.88p	63.97p	63.93	+0.15	66.36
XTS	70.59	69.89	70.24	-1.00	65.17	65.36	65.26	+0.29	67.75
XBIO.	69.39	68.55	68.97	-1.21	64.07	64.18	64.13	+0.18	66.55
NPK (1.5 g/L)	74.00a	74.46a	74.23	+0.62	69.93h	70.32h	70.13	+0.57	72.18
NPK (2 g/L)	71.42f	69.28ij	70.35	-3.00	67.16n	66.21o	66.68	-1.41	68.52
NPK (5 g/L)	71.20g	69.14jk	70.17	-2.90	67.00no	66.00o	66.50	-1.49	68.33
XNPK	72.21	70.96	71.58	-1.73	68.03	67.51	67.77	-0.76	69.68
XChicken	70.71	69.82	70.27	-1.25	66.10	65.97	66.04	-0.20	68.15
X (overall)	70.92	70.20	70.56	-1.02	66.35	66.29	66.32	-0.09	68.44

This suggests they are highly plastic traits, whose expression is significantly influenced by environmental factors. This insight is highly practical for farmers, as it shows which traits are most amenable to improvement through agronomic interventions, such as integrated fertilization (Falconer and Mackay, 1996).

Table 6. Response of Sunflower Cultivars Sakha-53 and Giza-102 to Stem Diameter (cm) for Fertilization

Treatment	Sakha-53				Giza-102				X
	1st Season	2nd Season	X	ΔD (%)	1st Season	2nd Season	X	ΔD (%)	
Mixed sheep and goat manure (20 m³/feddan)									
Control	1.33i	1.34h	1.33	+0.75	0.83o	0.85q	0.84	+2.41	1.09
EM1 (2 ml/L)	1.67cd	1.61f	1.64	-3.59	0.91n	0.91op	0.91	0.00	1.28
EM1 (4 ml/L)	1.92b	1.94b	1.93	+1.04	1.17j-l	1.21i	1.19	+3.42	1.56
EM1 (5 ml/L)	1.64b	1.99b	1.81	+21.34	0.97j-l	1.23i	1.10	+26.80	1.46
XEM1	1.74	1.85	1.79	+6.32	1.01	1.12	1.07	+10.89	1.43
TS (20 ml/L)	1.47f-h	1.51g	1.49	+2.72	0.88no	0.87pq	0.87	-1.14	1.18
TS (25 ml/L)	1.74c	1.81d	1.78	+4.02	1.10l	1.13j	1.11	+2.73	1.45
TS (30 ml/L)	1.75c	1.83cd	1.79	+4.57	1.10l	1.13j	1.12	+2.73	1.45
XTS	1.65	1.72	1.69	+4.24	1.03	1.04	1.04	+0.97	1.36
XBIO.	1.70	1.78	1.74	+4.71	1.02	1.08	1.05	+5.88	1.40
NPK (1.5 g/L)	1.43h	1.50g	1.47	+4.90	0.87no	0.88o-q	0.88	+1.15	1.17
NPK (2 g/L)	1.54ef	1.57f	1.56	+1.95	0.99m	1.00lm	1.00	+1.01	1.28
NPK (5 g/L)	1.55ef	1.59f	1.57	+2.58	1.00m	1.01lm	1.01	+1.00	1.29
XNPK	1.51	1.55	1.53	+2.65	0.96	0.96	0.96	0.00	1.25
XGoat	1.56	1.61	1.59	+3.21	0.96	0.99	0.97	+3.13	1.28
Chicken manure (20 m³/feddan)									
Control	1.45gh	1.46g	1.45	+0.69	0.90no	0.91op	0.90	+1.11	1.18
EM1 (2 ml/L)	1.52fg	1.50g	1.51	-1.32	1.00m	0.98mn	0.99	-2.00	1.25
EM1 (4 ml/L)	2.10a	2.14a	2.12	+1.90	1.21jk	1.29h	1.25	+6.61	1.69
EM1 (5 ml/L)	2.13a	2.14a	2.14	+0.47	1.22j	1.29h	1.26	+5.74	1.70
XEM1	1.92	1.93	1.92	+0.52	1.14	1.19	1.17	+4.39	1.54
TS (20 ml/L)	1.50f-h	1.48g	1.49	-1.33	0.93mn	0.93no	0.93	0.00	1.21
TS (25 ml/L)	1.70cd	1.88c	1.79	+10.59	1.00m	1.19i	1.10	+19.00	1.44
TS (30 ml/L)	1.74c	1.88c	1.81	+8.05	1.13kl	1.22i	1.18	+7.96	1.49
XTS	1.64	1.75	1.70	+6.71	1.02	1.12	1.07	+9.80	1.38
XBIO.	1.78	1.84	1.81	+3.37	1.08	1.15	1.12	+6.48	1.46
NPK (1.5 g/L)	1.47f-h	1.48g	1.47	+0.68	0.91n	0.93no	0.92	+2.20	1.20
NPK (2 g/L)	1.62de	1.69e	1.65	+4.32	1.00m	1.05kl	1.03	+5.00	1.34
NPK (5 g/L)	1.64d	1.70e	1.67	+3.66	1.13kl	1.10jk	1.12	-2.65	1.39
XNPK	1.58	1.62	1.60	+2.53	1.01	1.03	1.02	+1.98	1.31
XChicken	1.65	1.69	1.67	+2.42	1.02	1.06	1.04	+3.92	1.35
X (overall)	1.60	1.65	1.63	+3.13	0.99	1.03	1.01	+4.04	1.32

Table 7. Response of Sunflower Cultivars Sakha-53 and Giza-102 to Head Diameter (cm) for Fertilization

Treatment	Sakha-53				Giza-102				X
	1st Season	2nd Season	X	ΔD (%)	1st Season	2nd Season	X	ΔD (%)	
Mixed sheep and goat manure (20 m³/feddan)									
Control	15.04n	15.27l	15.15	+1.53	9.83s	10.75r	10.29	+9.36	12.72
EM1 (2 ml/L)	15.60l	17.75i	16.68	+13.78	10.00s	11.67p	10.84	+16.70	13.76
EM1 (4 ml/L)	22.33d	23.24c	22.79	+4.08	12.08o	13.45m	12.77	+11.34	17.77
EM1 (5 ml/L)	17.66b	23.73bc	20.70	+34.37	10.64q	14.17l	12.41	+33.18	16.55
XEM1	18.53	21.58	20.05	+16.46	10.91	13.10	12.00	+20.07	16.03
TS (20 ml/L)	15.33lm	16.98jk	16.16	+10.76	9.90s	11.13q	10.52	+12.42	13.34
TS (25 ml/L)	21.09f	21.33e	21.21	+1.14	11.50p	11.47p	11.48	-0.26	16.35
TS (30 ml/L)	21.67e	22.20d	21.93	+2.45	11.67p	11.57p	11.62	-0.86	16.78
XTS	19.36	20.17	19.77	+4.18	11.02	11.39	11.21	+3.36	15.48
XBIO.	18.95	20.87	19.91	+10.13	10.96	12.24	11.60	+11.68	15.76
NPK (1.5 g/L)	15.13mn	16.67k	15.90	+10.18	9.87s	11.00qr	10.43	+11.45	13.17
NPK (2 g/L)	18.18i	18.67h	18.42	+2.70	10.09s	11.13qr	10.61	+10.31	14.52
NPK (5 g/L)	19.07g	19.49g	19.28	+2.24	10.63q	11.20q	10.91	+5.36	15.10
XNPK	17.46	18.28	17.87	+4.70	10.20	11.11	10.65	+8.92	14.26
XGoat	17.60	18.82	18.21	+6.93	10.49	11.59	11.04	+10.49	14.62
Chicken manure (20 m³/feddan)									
Control	16.00k	16.67k	16.33	+4.19	10.03s	11.00qr	10.52	+9.67	13.43
EM1 (2 ml/L)	18.27i	17.60ij	17.93	-3.67	12.13o	11.00qr	11.57	-9.32	14.75
EM1 (4 ml/L)	23.90a	23.93ab	23.92	+0.13	15.10k	14.95k	15.02	-0.99	19.47
EM1 (5 ml/L)	24.00a	24.53a	24.27	+2.21	15.43j	15.33j	15.38	-0.65	19.82
XEM1	22.06	22.02	22.04	-0.18	14.22	13.76	13.99	-3.23	18.02
TS (20 ml/L)	17.90j	17.13i-k	17.52	-4.30	11.60p	11.00qr	11.30	-5.17	14.41
TS (25 ml/L)	22.47cd	22.33d	22.40	-0.62	11.60p	12.02o	11.81	+3.62	17.10
TS (30 ml/L)	22.63c	23.63bc	23.13	+4.42	12.00o	12.03o	12.02	+0.25	17.57
XTS	21.00	21.03	21.02	+0.14	11.73	11.68	11.71	-0.43	16.36
XBIO.	21.53	21.53	21.53	0.00	12.98	12.72	12.85	-2.00	17.19
NPK (1.5 g/L)	17.67j	17.33ij	17.50	-1.92	11.27q	11.00qr	11.13	-2.40	14.32
NPK (2 g/L)	18.71h	19.47g	19.09	+4.06	11.07qr	11.04qr	11.05	-0.27	15.07
NPK (5 g/L)	18.80gh	20.33f	19.57	+8.14	11.70pq	11.00qr	11.35	-5.98	15.46
XNPK	18.39	19.04	18.72	+3.53	11.34	11.01	11.18	-2.91	14.95
XChicken	19.36	19.69	19.53	+1.70	11.83	11.86	11.84	+0.25	15.68
X (overall)	18.48	19.26	18.87	+4.22	11.16	12.01	11.58	+7.62	15.22

LSD (at $P \leq 0.05$)

Table 8. Response of Sunflower Cultivars Sakha-53 and Giza-102 to Root Diameter (cm) for Fertilization

Treatment	Sakha-53				Giza-102				X
	1st Season	2nd Season	X	ΔD (%)	1st Season	2nd Season	X	ΔD (%)	X
Mixed sheep and goat manure (20 m³/feddan)									
Control	2.72m	2.82no	2.77	+3.68	1.25t	1.18t	1.21	-5.60	1.99
EM1 (2 ml/L)	2.95l	3.61hi	3.28	+22.37	1.96q	2.10o	2.03	+7.14	2.65
EM1 (4 ml/L)	4.90d	5.03c	4.97	+2.65	2.92n	3.16m	3.04	+8.22	4.00
EM1 (5 ml/L)	3.53d	5.12c	4.32	+45.04	2.04p	3.17m	2.60	+55.39	3.46
XEM1	3.79	4.59	4.19	+21.11	2.31	2.81	2.56	+21.65	3.38
TS (20 ml/L)	2.90l	3.29jk	3.10	+13.45	1.82r	1.95q	1.89	+7.14	2.49
TS (25 ml/L)	4.31ef	4.56de	4.43	+5.80	2.03p	2.32o	2.17	+14.29	3.30
TS (30 ml/L)	4.35e	4.60de	4.48	+5.75	2.00p	2.40o	2.20	+20.00	3.33
XTS	3.85	4.15	4.00	+7.79	1.95	2.22	2.08	+13.85	3.04
XBIO.	3.82	4.37	4.10	+14.40	2.13	2.52	2.33	+18.31	3.21
NPK (1.5 g/L)	2.60n	3.02lm	2.81	+16.15	1.70s	1.58st	1.64	-7.06	2.23
NPK (2 g/L)	3.83ij	4.09f	3.96	+6.79	1.82r	2.00p	1.91	+9.89	2.94
NPK (5 g/L)	3.89i	4.13f	4.01	+6.17	1.85r	2.00p	1.93	+8.11	2.97
XNPK	3.44	3.75	3.60	+9.01	1.79	1.86	1.83	+3.91	2.71
XGoat	3.45	3.83	3.64	+11.01	1.82	2.02	1.92	+10.99	2.78
Chicken manure (20 m³/feddan)									
Control	3.45k	3.45ij	3.45	0.00	1.51t	1.69s	1.60	+11.92	2.53
EM1 (2 ml/L)	4.24f	4.70d	4.47	+10.85	2.00p	2.65n	2.33	+32.50	3.40
EM1 (4 ml/L)	5.96a	6.19a	6.08	+3.86	3.44j	3.73i	3.58	+8.43	4.83
EM1 (5 ml/L)	6.00a	6.25a	6.13	+4.17	3.48j	3.80h	3.64	+9.20	4.88
XEM1	5.40	5.71	5.56	+5.74	2.97	3.39	3.18	+14.14	4.37
TS (20 ml/L)	4.02h	4.47e	4.25	+11.19	1.81r	2.45o	2.13	+35.36	3.19
TS (25 ml/L)	5.21c	5.60b	5.40	+7.49	2.44o	2.81n	2.62	+15.16	4.01
TS (30 ml/L)	5.31b	5.63b	5.47	+6.03	2.48o	2.91n	2.70	+17.34	4.08
XTS	4.85	5.23	5.04	+7.84	2.24	2.72	2.48	+21.43	3.76
XBIO.	5.12	5.47	5.30	+6.84	2.61	3.06	2.83	+17.24	4.06
NPK (1.5 g/L)	3.78j	4.19f	3.99	+10.85	1.66s	2.26o	1.96	+36.14	2.98
NPK (2 g/L)	4.05h	4.55de	4.30	+12.35	1.23t	2.08p	1.66	+69.11	2.98
NPK (5 g/L)	4.15g	4.61de	4.38	+11.08	1.28t	2.16p	1.72	+68.75	3.05
XNPK	4.00	4.45	4.22	+11.25	1.39	2.17	1.78	+56.12	3.00
XChicken	4.42	4.71	4.57	+6.56	2.03	2.49	2.26	+22.66	3.41
X (overall)	3.94	4.27	4.10	+8.38	1.93	2.25	2.09	+16.58	3.09

Table 9. Effect of fertilization treatments on leaf length (cm) of Sakha-53 and Giza-102 during 2021–2022 at Al-Arish

Treatment	Sakha-53				Giza-102				X
	1st Season	2nd Season	X	ΔD (%)	1st Season	2nd Season	X	ΔD (%)	
Mixed sheep and goat manure (20 m³/feddan)									
Control	17.23o	17.28mn	17.26	+0.29	13.80u	13.87v	13.83	+0.51	15.54
EM1 (2 ml/L)	26.56f	28.33e	27.45	+6.66	16.40s	17.00r	16.70	+3.66	22.08
EM1 (4 ml/L)	30.02c	32.08c	31.05	+6.86	18.00o	19.10o	18.55	+6.11	24.80
EM1 (5 ml/L)	24.61c	32.18c	28.39	+30.72	16.70r	19.30o	18.00	+15.57	23.20
XEM1	27.06	30.87	28.96	+14.08	17.03	18.47	17.75	+8.45	23.59
TS (20 ml/L)	21.25k	24.62h	22.94	+15.86	14.80t	15.60t	15.20	+5.41	19.07
TS (25 ml/L)	23.50h	24.13i	23.82	+2.68	15.60s	16.30s	15.95	+4.49	19.89
TS (30 ml/L)	23.50h	24.07i	23.78	+2.43	15.70s	16.50s	16.10	+5.10	19.94
XTS	22.75	24.27	23.51	+6.68	15.37	16.13	15.75	+5.08	19.63
XBIO.	24.91	27.57	26.24	+10.60	16.20	17.30	16.75	+6.73	21.49
NPK (1.5 g/L)	20.80l	22.06j	21.43	+6.06	14.20t	15.00t	14.60	+5.63	18.02
NPK (2 g/L)	18.93n	19.27k	19.10	+1.79	13.90u	14.60u	14.25	+5.04	16.68
NPK (5 g/L)	19.10m	19.20k	19.15	+0.52	14.10t	14.90t	14.50	+5.67	16.83
XNPK	19.61	20.18	19.89	+2.91	14.07	14.83	14.45	+5.40	17.17
XGoat	21.66	23.15	22.41	+5.45	15.00	15.93	15.47	+6.20	18.94
Chicken manure (20 m³/feddan)									
Control	16.75st	17.27mn	17.01	+3.10	12.87v	12.80v	12.84	-0.54	14.93
EM1 (2 ml/L)	30.00c	32.00c	31.00	+6.67	19.80n	20.50n	20.15	+3.59	25.58
EM1 (4 ml/L)	33.57b	34.57b	34.07	+2.98	24.40k	25.80k	25.10	+5.74	29.58
EM1 (5 ml/L)	33.93a	35.00a	34.47	+3.15	25.10j	26.60j	25.85	+5.98	30.16
XEM1	32.50	33.86	33.18	+4.18	23.10	24.30	23.70	+5.19	28.44
TS (20 ml/L)	29.00d	30.00d	29.50	+3.45	18.80p	19.50o	19.15	+3.78	24.33
TS (25 ml/L)	26.16g	27.13g	26.65	+3.71	17.50q	18.20p	17.85	+4.86	22.25
TS (30 ml/L)	26.43f	27.67f	27.05	+4.62	17.60q	18.40p	18.00	+4.55	22.53
XTS	27.20	28.27	27.73	+3.79	17.97	18.73	18.35	+4.23	23.04
XBIO.	29.85	31.06	30.46	+4.05	20.53	21.57	21.05	+5.06	25.75
NPK (1.5 g/L)	27.27e	28.40e	27.83	+4.14	17.00r	17.90q	17.45	+5.29	22.64
NPK (2 g/L)	22.00j	22.08j	22.04	+0.36	16.00s	16.80r	16.40	+5.00	19.22
NPK (5 g/L)	22.65i	22.33j	22.49	-1.41	16.10s	16.90r	16.50	+4.97	19.50
XNPK	23.97	24.27	24.12	+1.25	16.37	17.20	16.78	+5.07	20.45
XChicken	25.10	25.92	25.51	+3.27	18.17	19.20	18.69	+5.67	22.10
X (overall)	23.38	24.53	23.96	+4.92	16.59	17.57	17.08	+5.91	20.52

Table 10. Effect of fertilization treatments on leaf width (cm) of Sakha-53 and Giza-102 during 2021–2022 at Al-Arish

Treatment	Sakha-53				Giza-102				X
	1st Season	2nd Season	X	ΔD (%)	1st Season	2nd Season	X	ΔD (%)	
Mixed sheep and goat manure (20 m³/feddan)									
Control	11.80uv	12.32m-p	12.06	+4.41	10.40st	10.53st	10.47	+1.25	11.27
EM1 (2 ml/L)	18.27h	20.23e	19.25	+10.73	12.80op	13.50op	13.15	+5.47	16.20
EM1 (4 ml/L)	27.60c	28.04b	27.82	+1.52	16.30n	17.00n	16.65	+4.29	22.24
EM1 (5 ml/L)	19.22c	28.93a	24.08	+50.57	13.00op	17.20m	15.10	+32.42	19.59
XEM1	21.70	25.73	23.72	+18.57	14.17	16.24	15.23	+14.61	19.47
TS (20 ml/L)	17.50jk	18.10gh	17.80	+3.43	12.00q	12.50pq	12.25	+4.17	15.03
TS (25 ml/L)	19.83f	20.89de	20.36	+5.35	14.10o	14.80o	14.45	+4.96	17.03
TS (30 ml/L)	20.00f	21.00d	20.50	+5.00	14.20o	15.00o	14.60	+5.48	17.40
XTS	19.11	20.00	19.55	+4.66	13.43	14.10	13.77	+5.00	16.55
XBIO.	20.40	22.87	21.63	+12.11	13.95	14.82	14.38	+6.15	16.48
NPK (1.5 g/L)	16.07l	17.50h	16.78	+8.90	13.00	13.70	13.35	+5.38	14.95
NPK (2 g/L)	17.47jk	18.14gh	17.80	+3.84	14.20	14.90	14.55	+4.93	16.70
NPK (5 g/L)	17.77ij	18.53g	18.15	+4.28	13.00	13.70	13.35	+5.38	15.75
XNPK	17.10	18.06	17.58	+5.61	13.90	14.63	14.27	+5.25	16.28
XGoat	17.43	19.03	18.23	+9.18	13.96	14.75	14.36	+5.67	16.30
Chicken manure (20 m³/feddan)									
Control	12.77o-q	13.27j-l	13.02	+3.92	11.40rs	11.77q	11.59	+3.25	12.31
EM1 (2 ml/L)	21.57e	22.30c	21.93	+3.38	14.20o	14.90o	14.55	+4.93	18.24
EM1 (4 ml/L)	30.00b	28.67ab	29.34	-4.43	19.10m	18.20m	18.65	-4.71	24.00
EM1 (5 ml/L)	30.40a	29.13a	29.77	-4.18	19.60l	18.70l	19.15	-4.59	24.46
XEM1	27.32	26.70	27.01	-2.27	17.63	17.27	17.45	-2.04	22.23
TS (20 ml/L)	19.00g	20.80de	19.90	+9.47	12.90p	13.40op	13.15	+3.88	16.53
TS (25 ml/L)	22.40d	22.76c	22.58	+1.61	14.80o	15.60o	15.20	+5.41	18.89
TS (30 ml/L)	22.63d	22.93c	22.78	+1.33	14.90o	15.80o	15.35	+5.96	19.07
XTS	21.34	22.16	21.75	+3.84	14.20	14.93	14.57	+5.14	18.16
XBIO.	24.33	24.43	24.38	+0.41	15.92	16.32	16.12	+2.51	20.25
NPK (1.5 g/L)	17.20k	19.43f	18.32	+12.97	11.90qr	12.50p	12.20	+5.04	15.26
NPK (2 g/L)	17.70ij	18.56g	18.13	+4.86	12.80op	13.50op	13.15	+5.47	15.64
NPK (5 g/L)	18.07hi	18.67g	18.37	+3.32	13.00op	13.70op	13.35	+5.38	15.86
XNPK	17.66	18.89	18.27	+7.08	12.57	13.23	12.90	+5.25	15.58
XChicken	19.77	20.25	20.01	+2.43	14.65	15.35	15.00	+4.71	17.51
X (overall)	18.60	19.64	19.12	+5.59	13.55	14.47	14.01	+6.79	16.57

Table 11. Effect of fertilization treatments on leaf angle (°) of Sakha-53 and Giza-102 during 2021–2022 at Al-Arish

Treatment	Sakha-53				Giza-102				X
	1st Season	2nd Season	X	ΔD (%)	1st Season	2nd Season	X	ΔD (%)	
Mixed sheep and goat manure (20 m³/feddan)									
Control	46.37l	47.49h	46.93	+2.42	47.78g	48.90d	48.34	+2.34	47.63
EM1 (2 ml/L)	47.61hi	47.49h	47.55	-0.25	48.10fg	48.80de	48.45	+1.46	48.00
EM1 (4 ml/L)	48.82d	50.21b	49.51	+2.85	49.30cd	50.60b	49.95	+2.64	49.73
EM1 (5 ml/L)	47.60d	50.22b	48.91	+5.50	48.60e	49.90c	49.25	+2.67	49.08
XEM1	48.01	49.31	48.66	+2.71	48.56	49.77	49.11	+2.49	48.89
TS (20 ml/L)	47.37j	47.30h	47.33	-0.15	48.70e	49.80c	49.25	+2.26	48.29
TS (25 ml/L)	48.26f	49.31c-e	48.79	+2.18	49.50c	50.80b	50.15	+2.63	49.47
TS (30 ml/L)	48.30f	49.35cd	48.83	+2.17	49.60c	50.90b	50.25	+2.62	49.54
XTS	47.98	48.65	48.32	+1.40	49.27	50.50	49.88	+2.50	49.10
XBIO.	47.99	48.98	48.49	+2.06	49.27	50.36	49.82	+2.21	49.16
NPK (1.5 g/L)	47.05r	47.30h	47.18	+0.53	48.40f	49.20d	48.80	+1.65	47.99
NPK (2 g/L)	47.55i	48.52g	48.03	+2.04	48.90de	49.60cd	49.25	+1.43	48.64
NPK (5 g/L)	47.70h	48.58fg	48.14	+1.84	49.00de	49.70cd	49.35	+1.46	48.75
XNPK	47.43	48.13	47.78	+1.48	48.77	49.50	49.14	+1.49	48.46
XGoat	47.45	48.39	47.92	+1.98	48.84	49.59	49.22	+1.54	48.57
Chicken manure (20 m³/feddan)									
Control	47.65hi	48.43g	48.04	+1.64	48.80e	49.50cd	49.15	+1.43	48.60
EM1 (2 ml/L)	48.30f	49.30c-e	48.80	+2.07	49.20d	49.90c	49.55	+1.42	49.18
EM1 (4 ml/L)	49.93a	50.75a	50.34	+1.64	50.40a	51.50a	50.95	+2.18	50.65
EM1 (5 ml/L)	49.96a	50.93a	50.45	+1.94	50.50a	51.60a	51.05	+2.18	50.75
XEM1	49.40	50.33	49.86	+1.88	50.03	51.00	50.51	+1.94	50.18
TS (20 ml/L)	48.20f	49.10e	48.65	+1.87	51.60d	52.80c	52.20	+2.33	50.03
TS (25 ml/L)	48.98c	49.40cd	49.19	+0.86	49.70b	51.00a	50.35	+2.61	48.10
TS (30 ml/L)	49.12b	49.49c	49.31	+0.75	49.90ab	50.60b	50.25	+1.40	49.78
XTS	48.77	49.33	49.05	+1.15	49.63	50.33	49.98	+1.41	49.52
XBIO.	49.08	49.83	49.46	+1.53	49.83	50.61	50.22	+1.57	49.84
NPK (1.5 g/L)	47.90g	48.82f	48.36	+1.92	49.00de	49.80c	49.40	+1.63	48.88
NPK (2 g/L)	48.58e	49.19de	48.88	+1.26	49.60c	50.30bc	49.95	+1.41	49.41
NPK (5 g/L)	48.63e	49.30c-e	48.96	+1.38	49.70c	50.40bc	50.05	+1.41	49.51
XNPK	48.37	49.10	48.73	+1.51	49.43	50.17	49.80	+1.50	49.26
XChicken	48.55	49.30	48.92	+1.55	49.50	50.29	49.90	+1.59	49.41
X (overall)	48.00	48.85	48.42	+1.77	49.17	49.94	49.56	+1.56	48.99

Table 12. Response of Sunflower Cultivars Sakha-53 and Giza-102 to Leaf Petiole for Fertilization

Treatment	Sakha-53				Giza-102				X
	1st Season	2nd Season	X	ΔD (%)	1st Season	2nd Season	X	ΔD (%)	
Mixed sheep and goat manure (20 m³/feddan)									
Control	7.44kl	7.52k	7.48	+1.08	6.40s	6.70r	6.55	+4.69	7.02
EM1 (2 ml/L)	7.64kl	7.80gh	7.72	+2.09	6.80r	7.20p	7.00	+5.88	7.36
EM1 (4 ml/L)	8.05fg	8.40c	8.22	+4.35	7.30p	7.80o	7.55	+6.85	7.89
EM1 (5 ml/L)	7.71f	8.43bc	8.07	+9.34	7.60p	8.10no	7.85	+6.58	7.96
XEM1	7.80	8.21	8.00	+5.26	7.23	7.70	7.47	+6.51	7.73
TS (20 ml/L)	7.53i-l	7.71hi	7.62	+2.39	6.90q	7.40p	7.15	+7.25	7.95
TS (25 ml/L)	8.03fg	8.23d	8.13	+2.49	7.40p	7.90no	7.65	+6.76	8.60
TS (30 ml/L)	8.09f	8.25d	8.17	+1.98	7.70o	8.20no	7.95	+6.49	8.98
XTS	7.88	8.06	7.97	+2.28	7.33	7.83	7.58	+6.82	8.51
XBIO.	7.84	8.14	7.99	+3.83	7.28	7.77	7.53	+6.66	8.46
NPK (1.5 g/L)	8.30e	8.52b	8.41	+2.65	6.70r	7.10q	6.90	+5.97	7.68
NPK (2 g/L)	8.71b-d	8.77a	8.74	+0.69	7.20p	7.70o	7.45	+6.94	8.35
NPK (5 g/L)	8.75bc	8.84a	8.79	+1.03	7.50p	8.00no	7.75	+6.67	8.70
XNPK	8.59	8.71	8.65	+1.40	7.13	7.60	7.37	+6.59	8.24
XGoat	7.93	8.13	8.03	+2.52	7.05	7.54	7.30	+6.96	8.15
Chicken manure (20 m³/feddan)									
Control	7.63i	7.80gh	7.71	+2.23	6.60s	7.00q	6.80	+6.06	7.58
EM1 (2 ml/L)	7.92gh	7.99e	7.96	+0.88	7.00q	7.50p	7.25	+7.14	8.13
EM1 (4 ml/L)	8.60d	8.74a	8.67	+1.63	7.50p	8.10no	7.80	+8.00	8.80
EM1 (5 ml/L)	8.66cd	8.76a	8.71	+1.15	7.80o	8.40no	8.10	+7.69	9.10
XEM1	8.39	8.50	8.44	+1.31	7.43	8.00	7.72	+7.61	8.68
TS (20 ml/L)	7.80h	7.85fg	7.83	+0.64	7.10q	7.70p	7.40	+8.45	8.25
TS (25 ml/L)	8.23e	8.40c	8.32	+2.07	7.60p	8.20no	7.90	+7.89	8.90
TS (30 ml/L)	8.28e	8.46bc	8.37	+2.18	7.90o	8.50no	8.20	+7.59	9.20
XTS	8.11	8.24	8.17	+1.60	7.53	8.13	7.83	+7.97	8.78
XBIO.	8.25	8.37	8.31	+1.45	7.49	8.06	7.77	+7.61	8.73
NPK (1.5 g/L)	8.70b-d	8.78a	8.74	+0.92	6.90q	7.50p	7.20	+8.70	7.97
NPK (2 g/L)	8.80ab	8.82a	8.81	+0.23	7.40p	8.00no	7.70	+8.11	8.26
NPK (5 g/L)	8.88a	8.83a	8.85	-0.56	7.70o	8.30no	8.00	+7.79	8.43
XNPK	8.79	8.81	8.80	+0.23	7.33	7.93	7.63	+8.19	8.53
XChicken	8.23	8.34	8.28	+1.34	7.32	7.87	7.59	+7.53	8.47
X (overall)	8.08	8.23	8.15	+1.86	7.18	7.71	7.44	+7.36	8.30

Table 13. Seasonal and total environmental variance of sunflower traits (Sakha-53 and Giza-102) under different fertilization strategies during 2021–2022 at Al-Arish

Character	Environmental variance (1st season)	Environmental variance (2nd season)	Pooled (Total)
Days to 50% flowering	10.71	9.68	10.03
Stem diameter (cm)	0.132	0.137	0.133
Head diameter (cm)	20.54	21.39	21.05
Root diameter (cm)	1.66	1.72	1.64
Leaf length (cm)	33.88	39.29	35.72
Leaf width (cm)	30.19	27.60	28.81
Leaf angle (°)	22.18	20.47	21.37
Leaf petiole (cm)	0.573	0.539	0.561

CONCLUSION

The present study demonstrated that integrating organic, bio- and mineral fertilizers significantly improved the phyto-architectural traits of sunflower under North Sinai conditions. The combination of chicken manure with EM-1 biofertilizer proved to be the most effective treatment, reducing days to 50% flowering to 66.7 days and increasing head diameter, root diameter, and leaf length to 24.3 cm, 6.1 cm, and 34.5 cm, respectively. Sakha-53 outperformed Giza-102 across most measured traits, confirming its superior adaptability to arid environments. These findings emphasize the importance of integrated nutrient management as a sustainable approach to improve sunflower performance under sandy soils.

RECOMMENDATIONS

For Agricultural Practice

- **Adopt Integrated Fertilization:** Farmers in arid and semi-arid regions are strongly advised to adopt an integrated nutrient management strategy by combining chicken manure at a rate of 20 m^3/feddan with EM-1 biofertilizer. For maximum effectiveness, a concentration of 5 ml/L of EM-1 is recommended, although a 4 ml/L concentration also provides economically viable and excellent results.
- **Cultivar Selection:** The Sakha-53 cultivar is recommended for its consistent genetic superiority and robust performance under this integrated fertilization system compared to the Giza-102 cultivar.
- **Soil Fertility Improvement:** The regular application of organic manures should be maintained to enhance soil organic matter content and long-term fertility, especially in sandy soils.

For Future Research

- **Economic Analysis:** A detailed, long-term economic analysis is needed to quantify the cost-benefit of this integrated system versus conventional mineral fertilization, including labor, material costs, and the value of increased crop yield.
- **Longitudinal Studies:** The experiment should be extended for more than two seasons to fully assess the cumulative residual effects of the bio-organic fertilizers on soil health and crop productivity.
- **Microbiological Analysis:** A deeper microbiological analysis of the EM-[1] product and its interaction with the soil and chicken manure could provide new insights into the specific mechanisms that drive plant growth and soil improvement.

This study underscores the importance of an integrated nutrient management approach that respects both the genetic potential of the plant and its environmental interactions. Adopting these practices can not only contribute to increased crop productivity but also represents a crucial step towards achieving sustainable and resilient agriculture in environmentally challenged regions.

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الملخص العربي

استجابة أصناف دوار الشمس (*Helianthus annuus L.*) للتسميد العضوي والحيوي والمعدني: دلالات على البنية الفيتومورفولوجية والتباين البيئي

دينا عبد العاطى سليمان أحمد و محمد سيد سليم بطاح

التجربة تمت بالمزرعة البحثية بكلية العلوم الزراعية البيئية جامعة العريش شمال سيناء مص وتتطلب الزراعة المستدامة في الظروف القاحلة استراتيجيات تسميد فعّالة تحقق التوازن بين الإنتاجية والسلامة البيئية. أُجريت هذه الدراسة في شمال سيناء، مصر، خلال الموسمين الصيفيين ٢٠٢١ و ٢٠٢٢ لتقييم الاستجابات الفينولوجية والبنيوية لنباتين من دوّار الشمس (صنفان: سخا-٥٣ والجيزة-١٠٢) تجاه معاملات تسميد عضوية، حيوية، ومعدنية مختلفة .صُممت التجربة على أساس تصميم القطع المنشقة المنشقة مع القياسات المتكررة على مدار موسمين، حيث كانت المصادر العضوية (مخلفات الأغنام/الماعز المختلطة ومخلفات الدواجن) هي العامل الرئيسي، ومجموعة من الأسمدة الحيوية والمعدنية هي العامل الثانوي، والصنفان هما العامل الثالث .أظهرت النتائج أن الصنف سخا-٥٣ تفوق على الجيزة-١٠٢ في معظم الصفات، ولوحظ تحسن شامل في الموسم الثاني بفضل التأثيرات المتبقية للتسميد على المدى الطويل. كان التسميد بمخلفات الدواجن مع السماد الحيوي EM-1 هو المعاملة الأكثر فعالية باستمرار، مما أدى إلى تسريع ملحوظ في التزهير، وتقليل مدة النمو الخضري، وزيادة واضحة في الصفات الهيكلية مثل قطر الساق (٢.١٤ سم)، قطر القرص (٢٤.٢٧ سم)، قطر الجذر (٦.١٣ سم)، وطول الورقة (٣٤.٤٧ سم) .أظهر تحليل التباين البيئي أن صفات مثل قطر الساق كانت مستقرة وراثيًا، مما يجعلها مثالية للاختيار في برامج التربية، في حين كانت صفات الأوراق مرنة جدًا وتستجيب للتسميد. تؤكد هذه النتائج على قيمة الإدارة المتكاملة للمغذيات في تعزيز إنتاجية دوّار الشمس في المناطق القاحلة.

الكلمات المفتاحية :دوار الشمس؛ *Helianthus annuus*؛ سماد الدجاج؛ السماد الحيوي EM-1 ؛ البنية الفيتومورفولوجية ؛ التباين البيئي؛ الإدارة المتكاملة للمغذيات؛ الزراعة المستدامة.