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IMPACT OF INTEGRATED ORGANOMINERAL FERTILIZER APPLICATION ON GROWTH, YIELD, QUALITY, AND HEALTH-RELATED COMPOUNDS OF SWEET CORN

Ozlem ALAN[1*], *Bulent BUDAK*[1], *Fatih SEN*[2], *Muttalip GUNDOGDU*[3]

[1]*Ege University, Odemis Vocational Training School, Izmir, Türkiye*
[2]*Ege University, Faculty of Agriculture, Department of Horticulture, Izmir, Türkiye*
[3]*Bolu Abant Izzet Baysal University, Faculty of Agriculture, Department of Horticulture, Bolu, Türkiye*
**Corresponding Author: ozlem.alan@ege.edu.tr*

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ABSTRACT

In this study, the effectiveness of two organomineral formulations (OMF I and OMF II) on the growth, yield, kernel quality and health-related compounds of sweet corn were evaluated. Organomineral fertilizers were compared with chemically fertilized and unfertilized control to evaluate their effects as a basic fertilizer source. Field experiments were conducted using a randomized complete block design, with three replications over 2 years. Two cultivars (cv. 'Sentinel' and cv. 'Khan') were used as plant material. The results indicated that (1) compared to control, the application of organomineral and chemical fertilizers resulted in improvements in most growth, yield and quality traits of sweet corn in both cultivars; (2) use of organomineral fertilizers led to similar or significantly higher than chemical fertilizer in plant height, leaf number per plant, ear size, ear weight, ear yield (husked and de-husked) and total soluble solids. However, these effects showed responses that varied with type of organomineral fertilizer or cultivar; (3) use of OMF I treatment with cv. 'Khan' significantly improved ear size, ear weight, ear yield (husked and de-husked), colour traits, total phenolic content and antioxidant activity compared to other treatments.

Keywords: antioxidant activity; ear yield; plant height; total phenolic content; total soluble solid*; Zea mays* L. var. *saccharata*

INTRODUCTION

Despite recent innovations and modern approaches, most of the world's agriculture still relies on conventional practices and faces ongoing sustainability and soil fertility challenges. Chemical fertilizers (CFs) are among the most widely used, but their long-term and excessive use has numerous adverse effects, including soil fertility degradation, reduction in soil microbial populations and increased soil erosion and acidification (Shen et al., 2021). Additionally, the overuse of CFs can reduce food quality by leading to higher nitrate accumulation in crops and reduced synthesis of ascorbic acid and phenols (Ye et al., 2020). Using organic fertilizers (OFs) in agricultural production represents an alternative to using CF. OFs have been employed to enhance soil structure by increasing its organic matter content, which improves water retention, aeration, and root development (Toor et al., 2020). They also support the activity of beneficial microorganisms and facilitate the recycling of waste materials, thereby contributing to a more sustainable agricultural system (Rehman et al., 2020). However, OFs have limitations, such as lower nutrient concentrations, often requiring larger quantities to achieve the same fertility levels as CFs (Verma et al., 2020).

Integrated nutrient management has been widely recognised as a method for maximising agronomic efficiency and crop productivity while maintaining sustainable soil health and fertility (Selim, 2020). In this context, the development of organomineral fertilizers (OMFs), which combine organic materials with mineral nutrients, has gained attention as a sustainable approach to preserving soil fertility in agricultural production (Syed et al., 2021). Smith et al. (2020) highlighted that OMFs provide a balanced approach to plant nutrition by harnessing the complementary benefits of organic matter and synthetic nutrients. Research has shown that OMFs are a superior alternative to CFs, offering a high potential for nutrient provision to plants and contributing to the long-term maintenance of the physical, chemical and microbiological properties of the soil (Ayeni and Ezeh, 2017). Additionally, OMFs can reduce nutrient losses, such as potassium leaching, phosphorus fixation and nitrogen volatilisation, compared to OF combined with CF (Tejada et al., 2005). Abdulraheem et al. (2023) noted that OMFs also offer environmental benefits by reducing the amount of organic waste that could otherwise pollute water, soil and air. Despite these advantages, the effectiveness of OMFs can vary significantly due to differences in their composition, which affects crop growth, yield and quality. Bouhia et al. (2022) attributed this variability to the diverse raw materials and mineral sources used in OMF formulations. Furthermore, Srinivasarao et al. (2024) emphasised that the successful use of OMFs depends on proper application practices and timing to ensure that plants receive a balanced and timely supply of nutrients for optimal growth. In line with the Sustainable Development goals, countries such as India and Türkiye have implemented government policies that include financial support schemes to promote the use of OMFs among farmers (Adanacioglu and Yag, 2023; Srinivasarao et al., 2024).

Sweet corn (*Zea mays* L. var. *saccharata*) is becoming increasingly popular in cuisines worldwide, valued for its dietary fibre, vitamins and antioxidants, which contribute to a healthy diet (Alan et al., 2013). With rising demand, greater emphasis is now placed on the cultivation of sweet corn, which is produced for three distinct markets: fresh, frozen and canned (Szymanek et al., 2015). To meet stringent market requirements, sweet corn crops must exhibit high quality and appearance standards. While characteristics such as marketable yield, plant height (PH) and ear height are important to growers, the processing sector prioritizes the appearance, dimensions of the ears and quality properties of the kernels. These traits can be influenced by genotype, environment and fertilization practices (Szymanek and Tanas, 2019).

Currently, limited data are available on the use of OMFs for sweet corn cultivation (Etukudo et al., 2015; Ajibola et al., 2020; Intansari and Subiksa, 2022). Although existing studies provide a foundation for OMF use in sweet corn, further research is needed to assess the effectiveness of OMFs under various application practices and environmental conditions. Considering these points, the aims of this study were as follows: (i) to compare the effects of two OMF compositions with CFs on growth, yield, kernel quality traits and health-related compounds in sweet corn in an open-field setting; (ii) to evaluate the fertilizer value of the two OMFs across two sweet corn cultivars; and (iii) to assess new fertilization regimes where OMFs can be used as a primary fertilizer source to for sustainable produce yields and quality characteristics comparable to those of CFs.

MATERIALS AND METHODS

Plant Material and Field Management

Field experiments were conducted over 2 years in the experimental fields of the Odemis Vocational School at Ege University, Izmir, Turkey (latitude 38°12’N, longitude 27°52′E and altitude 111 m a.s.l.). Two sweet corn cultivars were used as plant material: ‘Sentinel F_1’ and ‘Khan F_1’). These cultivars, which carry the sh2 mutant gene (shrunken or super sweet), are widely grown for industry of sweet corn production in Türkiye.

The physical and chemical properties of the soil are provided in Table 1. The air temperature and mean total rainfall recorded during the cropping cycles (April–July) were 38.8°C–4.5°C and 17.0 mm in 2018 and 40.3°C–0.8°C and 30.1 mm in 2019, respectively (Figure 1).

Table 1. Physical and chemical properties of the soil

Properties	Values	Properties	Values
pH[a] (1:2.5)	7.74	Available P[g] (mg kg^{-1})	7.04
Total salt[b] (%)	0.067	Available K[h] (mg kg^{-1})	452
$CaCO_3$[c] (%)	1.11	Available Ca[h] (mg kg^{-1})	540
Sand (%)	76.92	Available Mg[h] (mg kg^{-1})	145
Clay (%)	6.78	Available Fe[ı] (mg kg^{-1})	4.72
Silt (%)	16.30	Available Zn[ı] (mg kg^{-1})	1.18
Texture[d]	Sandy loam	Available Mn[ı] (mg kg^{-1})	10.21
Organic matter[e] (%)	1.28	Available Cu[ı] (mg kg^{-1})	0.42
Total N[f] (%)	0.072		

a: 1:2.5 water extract, b: 1:2.5 Soil: conductimetric in water extract, c: calcimetric, d: Hydrometric, e: Walkley-Black method, f: Kjeldahl method, g: available olsen, h: available 1 N NH4OAc extract, ı: available DTPA extract

The experiment utilized two types of OMFs. OMF I, with an 8:8:8 N–P–K formula, contained 30% organic matter and 9% humic + fulvic extract. OMF II, with a 12:15:5 N–P–K formula, contained 10% SO_3, 20% organic matter and 7% humic + fulvic extract. For each treatment (CF, OMF I and OMF II), the fertilizers were evenly spread manually on the soil surface homogeneously. Then, all experiment plots were tilled at a depth of 0–15 cm with a rototiller. This was done 1 week before sowing the sweet corn seeds in early April of both experimental years. Seeds were sown into the field within the third week of April in both years, with 70 cm × 25 cm spacing. The experiment was conducted using a randomized complete block design with three replications. Each experimental plot covered an area of 21 m^2 (2.8 m × 7.5 m). Drip irrigation was applied as required, and weeds were controlled manually. No fungicides or insecticides were used during cultivation.

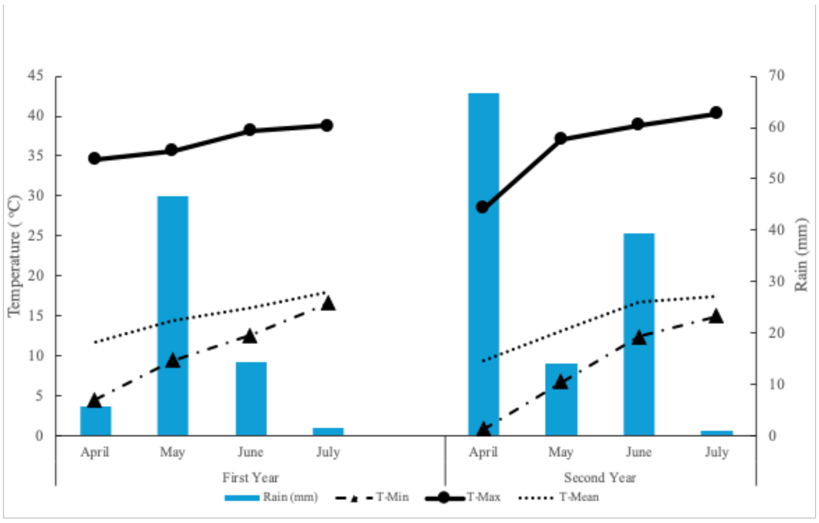

Figure 1. The air temperature and total rainfall recorded during the cropping cycles (April to July) in the 2-year experiment. (T-Min: minimum temperature, T-Max: maximum temperature, T-Mean: monthly mean temperature)

For one sweet corn crop cycle, 280 kg ha^{-1} of N, 110 kg ha^{-1} of P_2O_5 and 110 kg ha^{-1} of K_2O (Turgut, 2000) were applied based on the nutrient requirements of sweet corn plants. Field experiments were conducted under four treatment regimens: (1) control: unfertilized; (2) CF: (3) OMF I and (4) OMF II (Table 2).

Table 2. Fertilization and fertilizer dosage

Fertilization	**Fertilizer dosage (kg/ha^{-1})**					
	Composite fertilizer (15:15:15-NPK + Zn)	Urea (46% N)	Monoammonium phosphate (12-61-0)	Potassium sulphate (0-0-50)	OMF I (8:8:8 NPK)	OMF II (12:15:5 NPK)
Control	0	0	0	0	0	0
CF	700 (BF)	380 (SD)	0	0	0	0
OMF I	0	480 (SD)	93 (SD)	0	500 (BF)	0
OMF II	0	450 (SD)	50 (SD)	160 (SD)	0	500 (BF)

BF: before sowing, SD: side dressing

Growth and Yield Assessment

Days to tasseling (DT, i.e. the period from sowing to tassel appearance), days to silking (DS, i.e. the period from sowing to silk appearance), plant height (PH), leaf number per plant (LNP) and ear number per plant (ENP) were recorded on a whole plot basis. PH and LNP were measured after tasseling. Harvesting occurred when the sweet corn reached maturity, indicated by the juice consistency of the kernels, typically within the first 10 d of July each year. Twenty ears from the centre of each replication were randomly harvested by hand in the morning. The harvested plants were then taken to the processing lab, where the ears were divided into two categories for analysis: 10 ears for morphological measurements and 10 ears for quality measurements. ENP, ear diameter (ED), ear length (EL), number of rows per ear (NRE), number of kernels per row (NKR), husked ear weight (HEW) and de-husked ear weight (DEW) were recorded for morphological traits. Husked ear yield (HEY) was calculated from HEW, while de-husked ear yield (DEY) was calculated from DEW according to Alan et al. (2013).

Kernel Quality Assessment

For fresh kernel quality traits, kernels were cut from the ear 1 h after harvest, and the following measurements were recorded: kernel colour, dry matter (DM) content, total soluble solids (TSS) content, total phenolic content (TPC) and antioxidant activity (AA). Kernel colour was measured with a colorimeter at the CIE (Commission Internationale De L'eclairage) L* a* b*. Kernels were measured for each replicate, and the colour was characterised by lightness (L*), hue angle ($h°$ = $\tan^{-1}$(b*/a*)) and chroma (C* = $\sqrt{a^{*2}+b^{*2}}$). Regarding DM, kernels were dried in an oven at 65°C and the weight loss between measurements was < 0.05 g. The percentage difference between the fresh and dry weights was used to calculate the dry matter content of the kernel. For TSS, kernels were cut from the centre section of ten ears from each plot, after a 2-inch section was removed from each end of each ear. Fifteen grams from each ear were placed on a double layer square of cheesecloth. Extract was collected and placed on the a digital refractometer (PR-1, Atago, Tokyo, Japan) for analysis (Alan et al., 2014).

TPC (mg GAE/100 g FW) and AA (μmol TE/g FW)

Five grams of fresh kernels were mixed with 25 mL of methanol and homogenised using an Ika Ultra-Turrax homogeniser. The homogenates were kept at 4°C in the dark for 14–16 h before being filtered through Whatman No. 4 filter paper. The supernatants were collected and stored at −20°C until analysis (Thaipong et al., 2006). The TPC of the phenolic extract from the fresh kernels was determined using a modified Folin–Ciocaltaeu method (Swain and Hillis, 1959), with an incubation period of 120 min for colour development. Absorbance was measured at 725 nm using a spectrophotometer (Carry 100 Bio; Varian, Australia), and the results were expressed in milligrams of gallic acid equivalent (GAE) per 100 g^{-1} based on a standard curve of gallic acid (0–0.1 mg mL^{-1}). The spectrophotometric method with the ferric reducing antioxidant power was applied to measure AA in fresh kernels (Benzie and Strain, 1996). The absorbance of the supernatant was recorded using a spectrophotometer at 593 nm. The final results were calculated in μmol Trolox equivalents (TEs) per gram using a Trolox standard curve (25–500 μmol).

Statistical Analysis

Statistical analysis of variance was conducted using SPSS 19.0 for Windows (SPSS Inc., Chicago, IL, USA). Data from the cultivars were analyzed separately. The trait data generated from the fertilization treatments over 2 years were analyzed using a 2 × 4 factorial design (2 years × four fertilization treatments) arranged in a randomized complete block design with three replications. For quality attributes and health-related assays, 10 ears were analyzed for both varieties, with all assays performed in triplicate. Significant differences among groups were determined using Duncan's multiple range test at $p \leq 0.05$. Pearson's pairwise correlations were computed using the 'corrplot' package (Wei et al., 2017) in RStudio version 2022.12.0 (RStudio Team, 2020). Principal Component Analysis (PCA) was conducted with the JMP16 (SAS, USA) to explore interactions between fertilization treatments, cultivars and various traits. Additionally, data visualization included heatmap analysis using the 'Bioconductor' package in R (Gentleman et al., 2004).

RESULTS AND DISCUSSION

Effect of fertilization treatment on growth parameters

The DT, DS, PH and LNP of the treatments are presented in Table 3. The DT was not significantly influenced by the fertilization regimes for either cultivar, with mean values ranging from 53.8 d (OMF I) to 55.3 d (control) for cv. 'Sentinel' and from 52.2 d (OMF I and OMF II) to 53.0 d (CF) for cv. 'Khan'. Regarding DS, fertilizer treatments showed no significant differences for cv. 'Khan'; however, significant differences were observed for cv. 'Sentinel' ($p \leq 0.05$). Over the 2-year experiment, the control treatment increased DS compared with CF, OMF I, and OMF II (Table 3). Notably, DT and DS were significantly higher ($p \leq 0.01$) in the second year of the experiment for both cultivars. Similar findings were reported by Lahay *et al.* (2019), who compared inorganic and organo-bio fertilizers for sweet corn and found no differences in DT. They also noted that DS was influenced by fertilization treatments. They emphasised that soil fertility is among the factors affecting plant flowering. Phosphorous is crucial for assimilation and respiration processes and is necessary for the reproductive development of plants, which accelerates flowering. Moreover, Alan et al. (2011) noted that DT and DS can vary based on genotype or genotype–environment interactions.

Statistical analysis revealed significant differences in PH among fertilizer treatments for both cultivars ($p \leq 0.01$) (Table 3). Mean values indicated that the CF (cv. 'Sentinel' = 171.0 cm; cv. 'Khan' = 164.5 cm), OMF I (cv. 'Sentinel' = 171.7 cm; cv. 'Khan' = 169.3 cm) and OMF II (cv. 'Sentinel' = 171.2 m; cv. 'Khan' = 164.7 cm) fertilizer treatments exhibited similar and higher PH values compared to the control treatment for both cultivars. LNP was not significantly influenced by fertilizer treatments for cv. 'Khan' (Table 3). However, for cv. 'Sentinel', the fertilizer treatments showed a significant effect on LNP ($p \leq 0.05$). Among the treatments, OMF II (n = 10.98) and OMF I (n = 10.95) produced the highest values, followed by CF (n = 10.37). These findings align with Ajibola et al. (2020), who compared fertilizer types (urea, NPK, OMF and OF) for sweet corn. They demonstrated that OMFs improved PH and leaf area in sweet corn compared to other nutrient amendments. In the present study, both cultivars showed increases in PH and LNP (significant for cv. 'Khan' only) in the first year of the experiment. The observed differences between experimental years may be attributed to climatic conditions, especially during the first 2 months (Figure 1). In the second year, the minimum and maximum temperatures from April and May were 0.8°C and 37.1°C, respectively. Conversely, the first year had more favourable temperatures (4.5°C minimum and 35.7°C maximum) during the same period.

Effect of fertilization treatment on yield and yield-related parameters

The ENP was not significantly influenced by fertilizer treatments for either cultivar (Table 4). On average, ear number values ranged from 1.20 (control) to 1.45 (OMF I) for cv. 'Sentinel' and from 1.25 (control) to 1.42 (OMF I) for cv. 'Khan'. ENP was significantly higher in the second year of the experiment for cv. 'Sentinel', whereas cv. 'Khan' exhibited higher values during the first year (both $p \leq 0.01$).

Statistical analysis indicated that fertilization significantly affected ED for both cultivars (both $p \leq 0.01$). Additionally, the ED was significantly higher ($p \leq 0.01$) in the second year of the experiment for cv. 'Khan' only (Table 4). On average, the highest ED value was recorded in the OMF I treatment (49.8 mm for cv. 'Sentinel' and 45.2 mm for cv. 'Khan'), followed closely by the OMF II treatment (49.7 mm for cv. 'Sentinel' and 44.4 mm for cv. 'Khan'). The results for EL showed significant variations among fertilization treatments for both cultivars ($p \leq 0.01$ for cv. 'Sentinel' and $p \leq 0.05$ for cv. 'Khan'). The mean values indicated that the CF, OMF I and OMF II treatments had similar and higher EL values compared to the control treatment for both cultivars (Table 4).

Notably, EL was significantly higher (both $p \leq 0.01$) in the second year of the experiment for both cultivars.

Table 3. Changes in the plant growth parameters of cv. 'Sentinel' and cv. 'Khan' based on the different fertilizer treatments

cv. Sentinel				
Fertilization	DT	DS	PH (cm)	LNP
First year				
Control	51.0	59.3	172.0	10.37
CF	51.7	56.7	179.7	10.67
OMF I	50.0	57.3	183.3	11.10
OMF II	51.0	57.7	182.0	10.90
Second year				
Control	59.7	65.0	156.3	9.87
CF	58.3	64.3	162.3	10.07
OMF I	57.7	64.0	160.0	10.80
OMF II	59.3	64.0	160.3	11.07
First year	50.9 b	57.8 b	179.3 a	10.76
Second year	58.8 a	64.3 a	159.8 b	10.45
Mean of the years				
Control	55.3	62.2 a	164.2 b	10.12 b
CF	55.0	60.5 b	171.0 a	10.37 ab
OMF I	53.8	60.7 b	171.7 a	10.95 a
OMF II	55.2	60.8 b	171.2 a	10.98 a
(LSD 0.05)				
Year	1.128**	0.844**	2.735**	ns
Fertilizer	ns	1.193*	3.868**	0.674*
Year × fertilization	ns	ns	ns	ns
cv. Khan				
Fertilization	DT	DS	PH (cm)	LNP
First year				
Control	48.7	55.3	164.3	10.30
CF	50.0	54.3	171.3	10.40
OMF I	48.3	54.0	182.0	10.40
OMF II	49.0	55.0	168.0	10.10
Second year				
Control	56.3	63.3	153.3	9.80
CF	56.0	62.7	157.7	9.93
OMF I	56.0	62.3	156.7	10.27
OMF II	55.3	63.0	161.3	10.13
First year	49.2 b	54.7 b	171.4 a	10.29 a
Second year	55.9 a	62.8 a	157.3 b	10.03 b
Mean of the years				
Control	52.5	59.3	158.8 b	10.05
CF	53.0	58.5	164.5 a	10.17
OMF I	52.2	58.2	169.3 a	10.33
OMF II	52.2	59.0	164.7 a	10.10
(LSD 0.05)				
Year	1.315**	0.779**	3.471**	0.227*
Fertilizer	ns	ns	4.908**	ns
Year × fertilization	ns	ns	6.941**	ns

CF: chemical fertilizer, OMF: organomineral fertilizer, DT: days to tasseling, DS: days to silking, PH: plant height, LNP: leaf number per plant, *: $p \leq 0.05$, **: $p \leq 0.01$, ns: non-significant

Fertilizer treatments had no significant effect on NRE for either cultivar. Although the difference was not statistically significant, the control treatment for both cultivars showed the lowest NRE (Table 4). The effect of year on this trait was significant ($p \leq 0.05$) for cv. 'Sentinel' only, with higher NRE observed in the first year of the experiment. Fertilizer treatments had no significant effect on NKR for cv. 'Khan'. Although the difference was not statistically significant, the control treatment exhibited the lowest NKR. Conversely, significant differences in NKR were observed for cv. 'Sentinel' ($p \leq 0.01$). According to the mean results, the CF, OMF I and OMF II treatments exhibited similar values, increasing NKR by 5.2%, 8.6% and 5.7%, respectively, compared to the control treatment (Table 4).

Table 4. Changes in the plant yield and yield-related parameters of cv. 'Sentinel' and 'Khan' based on the different fertilizer treatments

cv. Sentinel									
Fertilization	ENP	ED (mm)	EL (cm)	NRE	NKR	HEW (g)	DEW (g)	HEY (ton ha−^{1})	DEY (ton ha^{-1})
First year									
Control	1.13	45.3	19.6	18.1	39.0	402.3	324.7	23.0	18.6
CF	1.20	48.7	20.9	18.2	40.7	444.3	350.0	25.4	20.0
OMF I	1.20	49.5	20.8	18.2	42.3	437.7	349.0	25.0	20.0
OMF II	1.30	49.7	21.3	18.4	40.0	452.0	357.0	25.8	20.4
Second year									
Control	1.27	46.0	21.2	16.8	38.0	382.0	275.3	21.8	15.7
CF	1.63	47.4	21.8	17.9	40.3	432.0	326.7	24.7	18.7
OMF I	1.70	50.0	21.9	18.0	41.3	438.7	330.0	25.1	18.9
OMF II	1.50	49.7	21.7	17.9	41.3	450.7	310.3	25.8	17.7
First year	1.21 b	48.3	20.7 b	18.2 a	40.5	434.1	345.2 a	24.8 a	19.7 a
Second year	1.53 a	48.3	21.7 a	17.6 b	40.3	425.8	310.6 b	24.3 b	17.8 b
Mean of the years									
Control	1.20	45.7 c	20.4 b	17.5	38.5 b	392.2 c	300.0 b	22.4 c	17.1 b
CF	1.42	48.1 b	21.4 a	18.1	40.5 a	438.2 b	338.3 a	25.0 b	19.3 a
OMF I	1.45	49.8 a	21.4 a	18.1	41.8 a	438.2 b	339.5 a	25.0 b	19.4 a
OMF II	1.40	49.7 a	21.5 a	18.1	40.7 a	451.3 a	333.7 a	25.8 a	19.1 a
(LSD 0.05)									
Year	0.160**	ns	0.267**	0.488*	ns	ns	19.151**	0.379*	0.433**
Fertilizer	ns	1.197**	0.378**	ns	1.520**	12.353**	27.084*	0.536**	0.613**
Year × fertilization	ns	ns	0.535*	ns	ns	ns	ns	ns	0.867*
cv. Khan									
Fertilization	ENP	ED (mm)	EL (cm)	NRE	NKR	HEW (g)	DEW (g)	HEY (ton ha^{-1})	DEY (ton ha^{-1})
First year									
Control	1.40	39.6	19.7	16.4	44.0	399.3	324.0	22.8	18.5
CF	1.43	40.6	20.4	16.2	45.7	417.3	331.3	23.9	18.9
OMF I	1.50	41.5	20.2	16.4	46.3	426.7	339.3	24.4	19.4
OMF II	1.43	41.7	20.8	16.3	47.3	422.7	329.0	24.2	18.8
Second year									
Control	1.10	44.6	22.2	15.2	46.7	425.7	297.3	24.3	17.0
CF	1.37	46.8	23.5	15.7	46.7	447.3	315.3	25.6	18.0
OMF I	1.33	48.8	23.8	16.4	47.0	474.7	341.3	27.1	19.5
OMF II	1.20	47.1	23.5	16.2	46.3	432.0	310.0	24.7	17.7
First year	1.44 a	40.9 b	20.3 b	16.3	45.8	416.5 b	330.9 a	23.8 b	18.9 a
Second year	1.25 b	46.8 a	23.2 a	15.9	46.7	444.9 a	316.0 b	25.4 a	18.1 b
Mean of the years									
Control	1.25	42.1 c	20.9 b	15.8	45.3	412.5 c	310.7 b	23.6 c	17.8 c
CF	1.40	43.7 b	21.9 a	16.0	46.2	432.3 b	323.3 b	24.7 b	18.5 b
OMF I	1.42	45.2 a	22.0 a	16.2	46.7	450.7 a	340.3 a	25.8 a	19.4 a
OMF II	1.32	44.4 ab	22.1 a	16.2	46.8	427.3 b	319.5 b	24.4 b	18.3 bc
(LSD 0.05)									
Year	0.137**	0.897**	0.552**	ns	ns	9.240**	10.499**	0.326**	0.389**
Fertilizer	ns	1.269**	0.780*	ns	ns	13.067**	14.847**	0.461**	0.550**
Year × fertilization	ns	ns	ns	ns	ns	18.479*	ns	0.652**	0.777*

CF: chemical fertilizer, OMF: organomineral fertilizer, ENP: ear number per plant, ED: ear diameter, EL: ear length, NRE: number of rows per ear, NKR: number of kernels per row, HEW: husked ear weight, DEW: de-husked ear weight, HEY: husked ear yield, DEY: de-husked ear yield, *: $p \leq 0.05$, **: $p \leq 0.01$, ns: non-significant

For HEW, fertilization treatments significantly affected both cultivars ($p \leq 0.01$) (Table 4). The highest HEW was obtained from the OMF II treatment (451.3 g) for cv. 'Sentinel', while cv. 'Khan' recorded its highest HEW value from the OMF I treatment (450.7 g). Additionally, HEW was significantly influenced by year only for cv.

‘Khan’ ($p \leq 0.01$), with higher values recorded in the second year of the experiment.

Statistical analysis showed that fertilization significantly affected DEW for both cultivars ($p \leq 0.05$ for cv. ‘Sentinel’ and $p \leq 0.01$ for cv. ‘Khan’). The CF (338.3 g), OMF I (339.5 g) and OMF II (333.7 g) treatments had similar values, with the highest DEW for cv. ‘Sentinel’ (Table 4). For cv. ‘Khan’, the OMF I treatment produced the highest DEW value (340.3 g), which significantly differed from both unfertilized and fertilized treatments, resulting in increases of 9.5%, 5.3% and 6.5% compared to the control, CF and OMF II treatments, respectively. Furthermore, DEW was significantly affected by year for both cultivars ($p \leq 0.01$), with higher values observed in the first year of the experiment.

Fertilizer treatments significantly affected HEY for both cultivars ($p \leq 0.01$) (Table 4). The mean results showed that HEY was highest with the OMF II treatment (25.8 ton ha^{-1}) for cv. ‘Sentinel’, whereas the highest HEY for cv. ‘Khan’ was observed with the OMF I treatment (25.8 ton ha^{-1}). Additionally, HEY was significantly higher ($p \leq 0.05$ for cv. ‘Sentinel’ and $p \leq 0.01$ for cv. ‘Khan’) in the first year of the experiment for cv. ‘Sentinel’, while it was higher in the second year for cv. ‘Khan’.

For DEY, fertilization treatments also had a significant effect on both cultivars ($p \leq 0.01$) (Table 4). The mean results indicated that the CF (19.3 ton ha^{-1}), OMF I (19.4 ton ha^{-1}) and OMF II (19.1 ton ha^{-1}) treatments yielded similar values, increasing DEY for cv. ‘Sentinel’ by 12.9%, 13.5% and 11.7%, respectively, compared to the control treatment. For cv. ‘Khan’, the OMF I treatment (19.4 ton ha^{-1}) produced the highest DEY, significantly differing from both unfertilized and other fertilized treatments. OMF I treatment increased DEY by 9.0%, 4.9% and 6.0% compared to the control, CF and OMF II treatments, respectively. Furthermore, DEY was significantly influenced by year ($p \leq 0.01$), with higher values observed in the first year of the experiment for both cultivars.

The influence of fertilizer types on the yield and yield-related parameters of sweet corn shows that both OMF I and OMF II treatments, maintained or improved the ED, EL, HEW, DEW, HEY and DEY parameters compared to the CF treatment for both cultivars. This finding aligns with the results reported by Lahay et al. (2019), Etukudo et al. (2015) and Intansari and Subiksa (2022), who also observed an increase in yield and yield-related parameters of sweet corn when OMFs were combined with CFs. However, Ajibola et al. (2020) reported that NPK treatment led to higher yield and yield parameters in sweet corn. Comparing studies on sweet corn treated with various OMFs is challenging due to differences in cultivars, environmental conditions and agronomic practices employed in each study. Variations in yield results can be attributed to differences in OMF formulations, as well as the timing and method of application, which significantly influence nutrient availability. Some fertilization systems can also reduce nutrient loss (Bouhia et al., 2022; Srinivasarao et al., 2024). Furthermore, this study found that the effect of year on most yield parameters varied according to the cultivars. Similar results found by Ilker (2011) and Kara (2011) support our findings. However, HEY and DEY were found to be higher in the first year of the experiment when climatic conditions were more favourable (Figure 1).

Effect of fertilization treatment on quality traits and health-related compounds

The colour traits of the treatments are presented in Table 5. The kernel L* value was not significantly affected by the fertilizer treatments for either cultivar, with mean values ranging from 68.8 (CF) to 70.0 (OMF II) for cv. ‘Sentinel’ and from 74.9 (control and OMF II) to 75.2 (OMF I) for cv. ‘Khan’. Notably, the L* value was significantly higher ($p \leq 0.01$) in the second year of the experiment for both cultivars. For C*, the statistical analysis indicated a significant effect of fertilization for cv. ‘Khan’, while cv. ‘Sentinel’ showed no significant influence from the fertilizer treatments. The highest mean C* value (n = 57.3) was observed in the CF treatment, followed by OMF I (n = 56.7). C* was also significantly affected by year for both cultivars ($p \leq 0.01$ for cv. ‘Sentinel’ and $p \leq 0.05$ for cv. ‘Khan’). For cv. ‘Sentinel’, the C* value was higher in the first year, whereas it increased in the second year for cv. ‘Khan’. Regarding the h° value of the kernels, no significant differences were found for cv. ‘Sentinel’; however, fertilizer treatments resulted in significant differences for cv. ‘Khan’ ($p \leq 0.01$). Both the control and OMF I treatments exhibited the highest h° value (n = 88.9) for cv. ‘Khan’. Additionally, h° was significantly higher ($p \leq 0.01$) in the second year for both cultivars. Similar findings regarding kernel colour traits were reported by Alan et al. (2014), who noted that kernel colour parameters are influenced by genotype, genotype-environment interactions and in-field management. To the best of our knowledge, this is the first comparative report on the colour traits of fresh sweet corn kernels in relation to OMFs and CFs.

For DM content, statistical analysis revealed significant differences between fertilizer treatments for cv. ‘Sentinel’ only ($p \leq 0.01$). The CF (22.2%), OMF I (22.2%) and OMF II (22.6%) treatments reduced DM content compared to the control treatment (23.5%). Conversely, for cv. ‘Khan’, DM content did not differ among the fertilization treatments and was significantly affected by year ($p \leq 0.01$), with higher DM content observed in the first year of the experiment (Table 5). TSS content was significantly influenced by fertilizer treatment for cv. ‘Khan’ ($p \leq 0.05$), while no significant differences were found in TSS content for cv. ‘Sentinel’. According to the mean values, OMF II (16.7%) had the highest TSS for cv. ‘Khan’, followed by CF (16.3%). The year also had a significant effect on TSS for cv. ‘Sentinel’ ($p \leq 0.01$), with the highest TSS recorded in the second year of the experiment (Table 5). These results align with previous studies indicating that the effects of fertilization treatments on kernel quality largely depend on the tested genotypes (Warman and Havard, 1998; Lazcano et al., 2011). Moreover, Kleinhenz (2003) noted that the refractometer, used to measure TSS, has been an effective pre-harvest method for determining sweet corn sugar content. Previous findings indicate that combining organic and inorganic fertilizers increases TSS and total sugar content compared to inorganic fertilization alone (Akinrinde and Lawal, 2006; Bharatti et al., 2020). To our knowledge, this is the first comparative report on the kernel DM and TSS content of sweet corn regarding OMF and CF.

Table 5. Changes in kernel quality and health-related compounds of cv. 'Sentinel' and 'Khan' based on the different fertilizer treatments

cv. Sentinel							
Fertilization	L*	C*	h°	DM (%)	TSS (%)	TPC (mg GAE 100 g^{-1})	AA (μmol TE g^{-1})
First year							
Control	69.0	51.9	88.3	23.9	14.7	71.2	3.30
CF	67.5	51.7	88.4	22.3	14.2	70.0	2.83
OMF I	68.7	52.8	88.6	22.2	14.4	72.3	3.12
OMF II	68.8	52.1	88.0	22.7	14.6	69.9	3.12
Second year							
Control	70.3	48.7	89.6	23.0	16.3	82.2	3.92
CF	70.0	49.4	89.3	22.0	15.5	85.9	4.12
OMF I	70.3	50.3	88.8	22.3	15.1	79.0	4.37
OMF II	71.2	50.7	89.2	22.4	15.6	85.0	4.34
First year	68.5 b	52.1 a	88.3 b	22.8	14.5 b	70.9 b	3.09 b
Second year	70.5 a	49.8 b	89.2 a	22.4	15.6 a	83.0 a	4.19 a
Mean of the years							
Control	69.6	50.3	88.9	23.5 a	15.5	76.7	3.61
CF	68.8	50.5	88.8	22.2 b	14.9	78.0	3.48
OMF I	69.5	51.6	88.7	22.2 b	14.8	75.6	3.75
OMF II	70.0	51.4	88.6	22.6 b	15.1	77.4	3.73
(LSD 0.05)							
Year	0.698**	0.767**	0.306**	ns	0.436**	1.469**	0.250**
Fertilizer	ns	ns	ns	0.745**	ns	ns	ns
Year × fertilization	ns	ns	ns	ns	ns	2.938**	ns
cv. Khan							
Fertilization	L*	C*	h°	DM (%)	TSS (%)	TPC (mg GAE 100 g^{-1})	AA (μmol TE g^{-1})
First year							
Control	73.9	55.5	88.2	25.7	15.5	82.5	3.83
CF	74.4	56.0	87.9	25.8	16.5	83.3	3.98
OMF I	74.6	56.4	88.4	25.5	16.1	83.3	3.73
OMF II	74.3	56.3	87.9	25.3	16.8	82.4	3.87
Second year							
Control	75.8	55.6	89.5	23.5	16.5	76.2	2.91
CF	75.8	58.6	89.3	23.6	16.0	78.0	3.39
OMF I	75.8	57.1	89.4	23.0	15.5	79.3	3.64
OMF II	75.5	56.3	89.0	23.5	16.5	79.6	3.38
First year	74.3 b	56.0 b	88.1 b	25.6 a	16.2	82.8 a	3.85 a
Second year	75.7 a	56.9 a	89.3 a	23.4 b	16.1	78.3 b	3.33 b
Mean of the years							
Control	74.9	55.6 c	88.9 a	24.6	16.0 b	79.3	3.37
CF	75.1	57.3 a	88.6 b	24.7	16.3 ab	80.6	3.68
OMF I	75.2	56.7 ab	88.9 a	24.2	15.8 b	81.3	3.69
OMF II	74.9	56.3 bc	88.5 b	24.4	16.7 a	81.0	3.63
(LSD 0.05)							
Year	0.416**	0.661*	0.183**	0.682**	ns	1.530*	0.224**
Fertilizer	ns	0.935**	0.259**	ns	0.612*	ns	ns
Year × fertilization	ns	1.322*	ns	ns	ns	ns	ns

CF: chemical fertilizer, OMF: organomineral fertilizer, DM: dry matter, TSS: total soluble solid, TPC: total phenolic content, AA: antioxidant activity, *: $p \leq 0.05$, **: $p \leq 0.01$, ns: non-significant

Concerning health-related compounds, TPC was not significantly affected by the fertilization treatments for either cultivar. Mean values ranged from 75.6 mg GAE 100 g^{-1} (OMF I) to 78.0 mg GAE 100 g^{-1} (CF) for cv. 'Sentinel' and from 79.3 mg GAE 100 g⁻¹ (control) to 81.3 mg GAE 100 g⁻¹ (OMF I) for cv. 'Khan'. TPC was significantly higher in the second year of the experiment for cv. 'Sentinel' ($p \leq 0.01$), whereas it was higher in the first year for cv. 'Khan' ($p \leq 0.05$, Table 5). Fertilizer treatments did not significantly affect AA in either cultivar (Table 5). Mean AA values ranged from 3.48 µmol TE g^{-1} (CF) to 3.75 µmol TE g^{-1} (OMF I) for cv. 'Sentinel' and from 3.37 µmol TE g^{-1} (control) to 3.69 µmol TE g^{-1} (OMF I) for cv. 'Khan'. Although the differences were not statistically significant, the CF, OMF I and OMF II treatments showed higher AA than the control treatment for cv. 'Khan'. The effect of year was significant for this trait in both cultivars ($p \leq 0.01$), with the highest AA content observed in the second year for cv. 'Sentinel' and in the first year for cv. 'Khan'. Contrary to our findings, previous studies on fertilizer treatments indicated that combining organic and inorganic fertilizers increases phenolic content in sweet corn (Bharatti et al., 2020). This variation in TPC and AA can be explained by the fact that TPC and AA are influenced by genotype and the eco-physiological factors such as temperature and global radiation (Ziets et al., 2010). To our knowledge, this is the first comparative report on the TPC and AA of sweet corn using OMFs and CFs.

Effect of fertilizer treatment on growth, yield and quality traits using principal component and correlation analyses

In this study, Principal Component Analysis (PCA) was applied to assess the scientific validity of the results and to identify variations across different fertilizer treatments. The PCA showed a variance ratio of 86.20% (PC1 + PC2), highlighting the impact of OMFs on growth, yield, and quality traits in sweet corn varieties. In the PCA plot, the 'Khan' variety was positioned in the first region and stood out particularly in terms of L, C, TSS, and NKR traits. In contrast, the Sentinel F1 variety was prominent in terms of NRE (Figure 2). Both OMFs and CFs were plotted in the same plane and exhibited significant differences compared to the control group. The results indicated that OMFs and CFs were more effective in enhancing the agromorphological characteristics of sweet corn than the control group.

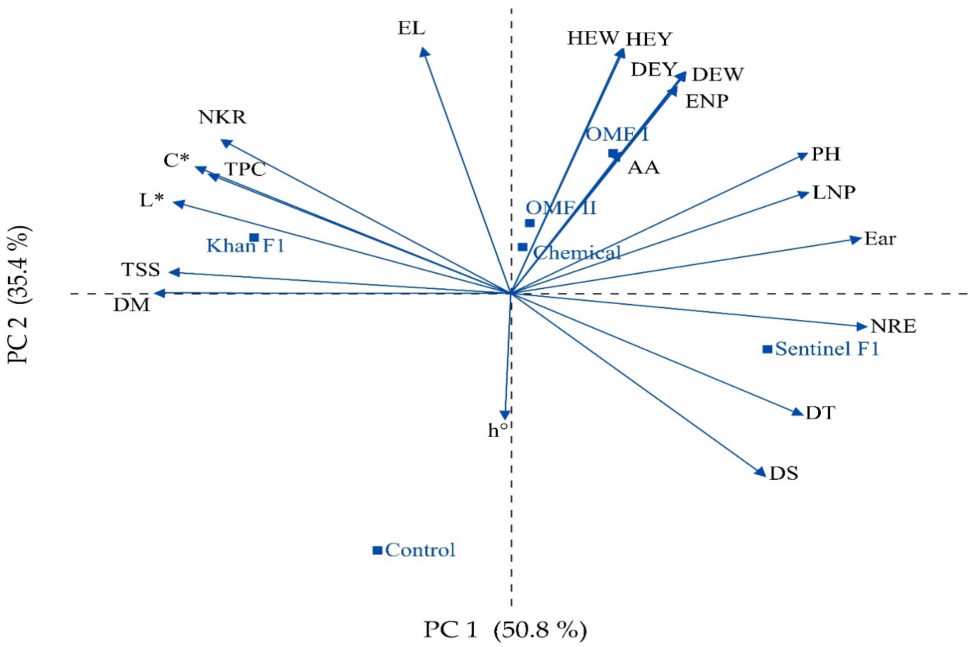

Figure 2. Correlation between sweet corn cultivars and fertilizer applications using PCA

According to the correlation analysis, a statistically positive correlation was found between DT and DS ($r = 0.88$, $p \leq 0.01$) and a negative correlation was observed between DT and NKR ($r = -0.96$, $p \leq 0.001$). The positive correlation rate between TSS and DM content of sweet corn was determined to be r=0.93 ($p \leq 0.001$). When comparing TPC with agromorphological characteristics, a positive correlation was identified between TPC and NKR ($r = 0.88$, $p \leq 0.01$), while a negative correlation ($r = -0.89$, $p \leq 0.01$) was observed with DS. In this study, positive correlations were determined between L* and C* color values and NKR, TPC, TSS, and DM (Figure 3).

The clustering analysis revealed the formation of two distinct groups among the treatments. The control treatment for cv. 'Sentinel' formed a separate group, while other treatments clustered together (Figure 4). Upon examining the grouping of agromorphological and biochemical characteristics based on the treatments, it was found that L*, C*, TPC, DM, TSS and h° values were grouped together, while other characteristics formed a different group. The heatmap analysis showed significant differences between cv. 'Khan' and cv. 'Sentinel' based on the treatments, resulting in their placement in different groups. Overall, in the OMF I treatment for cv. 'Khan', the values of HEW, HEY, DEW, DEY, EL, NKR, L*, C*, h°, TPC and AA were higher compared to the other treatments.

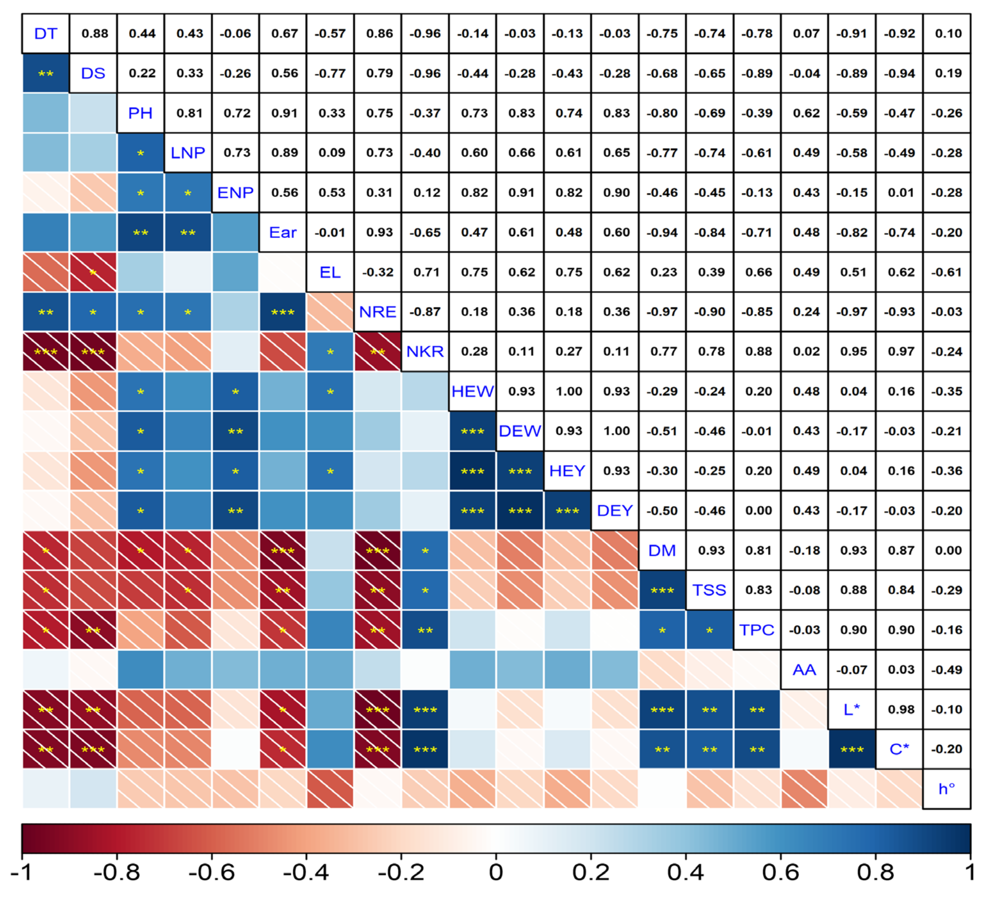

Figure 3. Correlation among physicochemical properties of. The color gradient ranging from red to blue represents correlation values between -1 and +1. *, **, and *** denote significance levels at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$, respectively. DT: Days to tasseling, DS: Days to silking, PH: Plant height, LNP: Leaf number per plant, ENP: Ear number per plant, Ear: Ear diameter, EL: Ear length, NRE: Number of rows per ear, NKR: Number of kernels per row, HEW: Husked ear weight, DEW: Dehusked ear weight, HEY: Husked ear yield, DEY: Dehusked ear yield, DM: dry matter, TSS: total soluble solid, TPC: total phenolic content, AA: antioxidant activity.

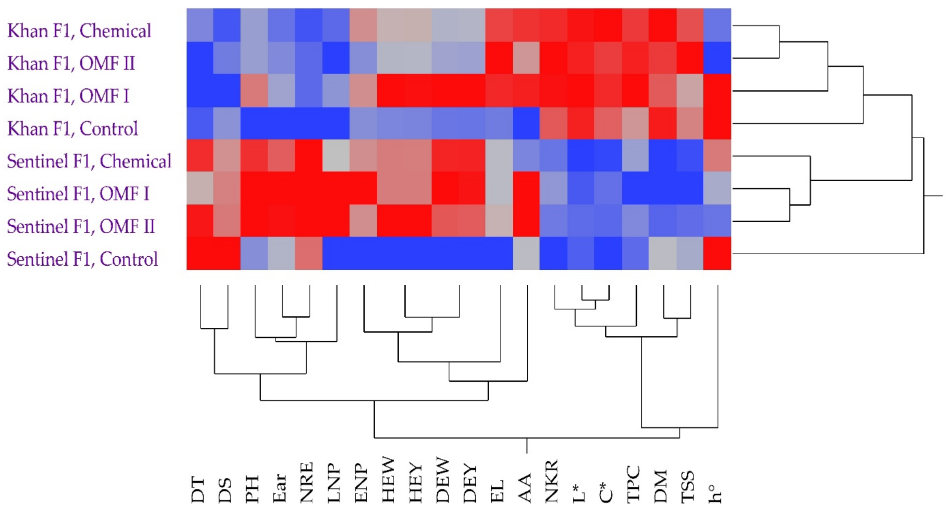

Figure 4. Clustering of cultivars based on physicochemical properties. The colour scale ranges from blue (indicating lower values) to red (indicating higher values). DT: Days to tasselling, DS: Days to silking, PH: Plant height, LNP: Leaf number per plant, ENP: Ear number per plant, Ear: Ear diameter, EL: Ear length, NRE: Number of rows per ear, NKR: Number of kernels per row, HEW: Husked ear weight, DEW: De-husked ear weight, HEY: Husked ear yield, DEY: De-husked ear yield, DM: dry matter, TSS: total soluble solids, TPC: total phenolic content, AA: antioxidant activity

CONCLUSIONS

This study demonstrated that sweet corn plants exhibited enhanced growth, yield and quality potential following the application of OMFs and CFs compared to the control group. Specifically, compared to CF, OMF I and OMF II either maintained or improved PH, LNP, ED, EL, NKR, HEW, DEW, HEY, DEY, C*, DM and TSS. However, the two OMF formulations elicited varying responses depending on the cultivar used. The application of OMF I with cv. 'Khan' resulted in increased ear size, ear weight (both husked and de-husked), ear yield (both husked and de-husked), colour traits, TPC and AA compared to the other treatments. These results suggest that OMFs are effective as a primary fertilizer source for speciality crops, such as sweet corn, in accordance with industry standards. Further research is needed to explore various OMF formulations and to assess different application timings and doses to achieve high yields without compromising the overall quality of the final product.

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