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Effect of nitrogen management on growth and physiological parameters of sweet corn (*Zea mays saccharata*) under organic farming conditions

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Abstract
The increasing demand for sustainably grown produce has amplified the relevance of organic farming, particularly for high-value crops like sweet corn (*Zea mays saccharata*). This study evaluated the impact of different organic nitrogen management strategies on growth and physiological parameters of sweet corn under organic farming conditions in the sub-humid southern plains of Rajasthan. A field experiment was conducted during the Kharif season of 2022 at MPUAT, Udaipur, using a randomized block design with eight treatments combining solid (FYM, vermicompost, neem cake) and liquid (jeevamrit, ghanjeevamrit, vermiwash) organic inputs. Key parameters observed included plant height, dry matter accumulation, leaf area index (LAI), chlorophyll content, crop growth rate (CGR), relative growth rate (RGR), and phenological events (tasseling and silking). Results revealed that the treatment combining 50% recommended dose of nitrogen (RDN) through FYM with 25% RDN applied through vermicompost at 30 and 45 days after sowing (T_6) consistently recorded superior growth attributes. T6 exhibited the highest plant height (195.60 cm), dry matter (191.89 g plant^{-1}), CGR (12.79 g m^{-2} day^{-1}), LAI (2.08), and chlorophyll content (2.25 mg g^{-1}), outperforming other treatments. No significant differences were observed in tasseling and silking dates, indicating that phenological traits remained stable across nitrogen treatments. The study concludes that phased application of integrated organic nitrogen sources, especially combining FYM and vermicompost, can effectively enhance sweet corn productivity and support sustainable organic agriculture in the region.

Keywords: Nitrogen management, sweet corn, organic farming, vermicompost, green manuring, vermiwash

1. Introduction
Maize (*Zea mays* L.), one of the world's important cereal crops, next to rice and wheat in India, because of its multi-purposeful applications in food, feed, fodder and industry, is a significant crop to food security and income generation in many agro-climatic regions (Tanumihardjo *et al.*, 2020) [12]. Among the maize types, sweet corn (*Zea mays var. saccharata*) has emerged as a specialty crop because of its soft, sweet kernels at the milky stage. It is gaining popularity in urban food consumption as a vegetable and in fresh, roasted, canned and processed forms (Revilla *et al.*, 2021) [10]. The crop is not only appreciated for its taste and quick cooking but also as a source of valuable nutrients like dietary fiber and vitamins A and C (Murdia *et al.*, 2016) [8]. The residual biomass after cob removal is also used as quality green fodder and hence sweet corn is an economically profitable and resource-saving crop. With consumer choice turning in favour of safe and sustainably produced produce, organic farming has become the preferred mode of production. Organic farming does away with synthetic inputs and depends on natural cycling of nutrients, biodiversity and soil health recovery (Siddique *et al.*, 2014) [11]. Under such a condition, nutrient management especially nitrogen, the most limiting and most important nutrient for cereal crops becomes the major issue. Unlike conventional systems, organic farming uses inputs such as farmyard manure (FYM), vermicompost, neem cake, green manures and liquid bio-stimulants such as jeevamrit, vermiwash and ghanjeevamrit. Yet, asynchronous release of nitrogen from these materials usually leads to suboptimal yield performance, especially at critical growth stages.

Optimization of nitrogen supply by strategically utilizing organic matter is an essential factor to drive vegetative growth, chlorophyll and canopy development, as well as coordinating phenological occurrences like tasseling and silking in sweet corn. Research on single organic sources has been conducted to a certain degree, but for an integrated nutrient supply system like solid and liquid organic manures under certified organic cropping systems, studies are meagre. In addition, substitutability and augmentation of conventional bulky manures using farm-derived and low-cost liquid organics pose a reasonable remedy, particularly for areas where good quality compost is a limitation. The current research bridges this research gap by assessing different organic nitrogen management practices for delivering 100% or 50% of the recommended dose of nitrogen using different combinations of solid organics (FYM, vermicompost, neem cake, green manures, legume intercrops) and liquid products (jeevamrit, ghanjeevamrit, vermiwash). The research attempts to compare their effects on key growth and physiological traits of sweet corn like plant height, dry matter production, leaf area index, chlorophyll content and tasseling and silking dates to determine effective, locally suitable and sustainable nitrogen management practices for sweet corn production in organic farming systems, thus contributing to improved crop productivity and soil health.

2. Methodology

2.1 Experimental Site and Climate

The field experiment was conducted during the *Kharif* season of 2022 at the Organic Farming Unit, Agronomy Farm, Rajasthan College of Agriculture, MPUAT, Udaipur (24°35' N, 74°42' E, altitude 582.13 m above sea level). The site falls under agro-climatic zone IV-a (Sub-humid Southern Plains and Aravalli Hills) of Rajasthan. The soil was clay loam, slightly alkaline (pH 7.9), with an electrical conductivity of 0.84 dS m^{-1}. Nutrient content included 252.8 kg ha^{-1} nitrogen (medium), 25.82 kg ha^{-1} phosphorus (medium) and 305.8 kg ha^{-1} potassium (high). The organic carbon content was 0.67%, indicating moderate organic matter levels.

2.2 Experimental Design and Treatments

The experiment was arranged in a Randomized Block Design (RBD) with three replications. Eight nitrogen management treatments were tested, comprising different combinations of organic sources such as farmyard manure (FYM), vermicompost, poultry manure, neem cake and Azotobacter biofertilizer, applied either individually or in combination (Table 1). The recommended dose of nitrogen (RDN) was 120 kg N ha^{-1}, based on the nutrient content of the organic amendments.

Table 1: Treatment details

Annotations	Treatments
T_1	Control
T_2	100% RDN through FYM
T_3	50% RDN through FYM + Intercropping of blackgram
T_4	50% RDN through FYM + Green manuring of Dhaincha (incorporation at 30 DAS)
T_5	50% RDN through FYM + Crop residue mulch @ 1 t ha^{-1} + Application of neem cake @ 500 kg ha^{-1}
T_6	50% RDN through FYM + 25% RDN through vermicompost at 30 DAS + 25% RDN through vermicompost at 45 DAS
T_7	T_1 + Intercropping of blackgram
T_8	50% RDN through FYM + Jeevamrit @ 500 liter ha^{-1} at sowing and 30 DAS and 45 DAS + Ghanjeevamrit 250 kg ha^{-1} + Spray of vermiwash at 5% at 45 DAS and 60 DAS

2.3 Crop and Cultural Practices

Sweet corn variety *Sugar-75* was sown on July 25, 2022, using a seed rate of 8 kg ha^{-1}. The row spacing was maintained at 60 cm *and* plant-to-plant spacing at 25 cm. Intercrops (blackgram) were sown in a paired row system (2:2) with a spacing of 30 cm × 10 cm. Organic practices were followed throughout, including manual weeding, neem-based pest control and regulated irrigation.

2.4 Observations recorded

2.4.1 Plant height and dry matter

At 45 DAS, 60 DAS and harvest, plant height was measured from five randomly selected plants per plot using a 100 cm scale (cm). Additionally, five plants per plot were oven-dried at 65 °C to constant weight, with dry matter recorded in grams per plant (g $plant^{-1}$).

2.4.2 Leaf Area Index (LAI)

At 45 and 60 DAS, leaf area was calculated from five plants per plot, adjusting for leaf size (small, medium, large) using the formula:

$$LAI = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Ground area (cm}^2\text{)}} \quad \text{(i)}$$

2.4.3 Chlorophyll Content

Chlorophyll content at 45 DAS was determined by extracting 100 mg of fresh leaves in 80-85% acetone and measuring absorbance at 645 nm and 663 nm. Chlorophyll concentration was calculated using the formula:

$$\text{Total chlorophyll content (mg g}^{-1}\text{ fresh weight)} = \frac{20.2\,(A645) + 8.02\,(A663)}{ax100xW} \text{ x V} \quad \text{(ii)}$$

Where a= length of the light path in the cell (usually 1 cm), V= volume of extract (ml), W= Weight of leaf sample (g)

2.4.4 Phenological Parameters

Days to 50% Tasselling and Days to 50% Silking were recorded as the number of days from sowing to the appearance of tassels in 50% of plants and the emergence of visible silk in 50% of plants, respectively.

2.5 Growth Efficiency Parameters

Crop Growth Rate (CGR) and Relative Growth Rate (RGR) were calculated for 45-60 DAS and 60 DAS-harvest using:

$$\text{CGR (g m}^{-2}\text{ day}^{-1}) = \frac{1}{A} \times \frac{W_2 - W_1}{t_2 - t_1} \quad \text{(iii)}$$

$$\text{RGR (g g}^{-1}\text{ day}^{-1}) = \frac{(\log_e W_2 - \log_e W_1)}{t_2 - t_1} \quad \text{(iv)}$$

Where log $_e$ is a natural log, W_1 and W_2= Dry weight of the plants (g m-^{2}) at time t_1 and t_2, respectively, t_1-t_2 = Time interval in days, A= Unit land area in (m^2)

2.5 Statistical analysis
Data were analyzed using analysis of variance (ANOVA) appropriate for RBD as per the method suggested by Panse and Sukhatme (1989) [9]. Treatment means were compared using the critical difference (CD) at 5% level of significance.

3. Results and Discussion
3.1 Growth Attributes
3.1.1 Plant Height
Nitrogen management under organic farming significantly influenced the plant height of sweet corn at various growth stages (Table 1). At 45 DAS, the maximum plant height (87.20 cm) was recorded under T_8 (50% RDN through FYM + 25% RDN through vermicompost at 30 DAS and 45 DAS) followed by T_6, T_5 and T_2. At 60 DAS, T_6 and T_8 (127.17 cm) exhibited superior growth, outperforming treatments T_3, T_4, T7 and the control by 10.53-24.89%. This trend persisted at harvest, where the tallest plants (195.60 cm) were recorded in T_6 and T_8, exhibiting a 10.94-17.69% increase over the control and other treatments. The integrated application of FYM and vermicompost facilitated consistent growth enhancement across all growth stages. These results suggest that integrated and phased organic nitrogen application enhances plant height more effectively than single-input or monoculture approaches. The consistent growth advantage under T_6 and T_8 can be attributed to enhanced nitrogen availability, better soil microbial activity and improved nutrient synchronization due to the staged application of organic sources (Atiyeh *et al.*, 2002; Kmetova *et al.*, 2013; Meena *et al.*, 2018; Arancon *et al.*, 2006; Jack *et al.*, 2011) [3, 6, 7, 1, 5]

3.1.2 Dry Matter Accumulation
Significant differences in dry matter accumulation were observed (Table 1). At 45 DAS, T_6 recorded the highest biomass (14.12 g plant^{-1}), 24.08-33.93% higher than T_3, T_4, T_7 and control. At 60 DAS, T_6 continued to lead with 71.67 g plant^{-1} 15.35-32.57% higher than intercropping or green manuring treatments. By harvest, T6 achieved the maximum dry matter (191.89 g plant^{-1}), surpassing T_3, T_4, T_7 and control by 14.67-19.05%. These results highlight the effectiveness of combined organic sources for enhanced biomass accumulation throughout growth stages. The result aligns with earlier findings that FYM combined with vermicompost enhances nutrient availability, soil physical conditions *and* ultimately biomass (Arancon *et al.*, 2006) [1].

3.1.3 Crop Growth Rate (CGR) and Relative Growth Rate (RGR)
Between 45-60 DAS, CGR was significantly higher under T_6 (12.79 g m^{-2} day^{-1}), outperforming T_3, T_4, T_7 and control by 22.29%, 14.55%, 24.16% and 32.21%, respectively. T_6 was comparable to T_8, T_5 and T_2, indicating the efficacy of organic amendments in promoting vegetative growth. No significant differences were observed between 60 DAS and harvest, suggesting a diminishing response to nitrogen inputs as the crop approached maturity. Relative Growth Rate (RGR) showed no significant variation between treatments during both 45-60 DAS and 60 DAS-harvest periods, indicating a consistent growth rate per unit biomass across all treatments, likely influenced by the crop's genetic growth potential during these stages.

3.1.4 Leaf Area Index (LAI)
LAI was significantly influenced by nitrogen management strategies (Table 2). At 45 DAS, T6 recorded the highest LAI (2.02), outperforming T_3, T_4, T_7 and control by 7.43-30.69%, with T_2, T_5 and T_8 showing similar values. At 60 DAS, T_6 again achieved the highest LAI (2.08), surpassing T_3, T_4, T_7 and control by 7.22-31.25%. These results highlight the positive effect of integrated and phased nutrient applications on canopy development and photosynthetic surface area.

3.1.5 Chlorophyll Content
Chlorophyll content at 45 DAS (Table 2) was significantly higher under T_6 (2.25 mg g^{-1}), reflecting superior nitrogen nutrition and photosynthetic potential. T_6 showed 5.78-11.12% higher chlorophyll content than T_3, T_4, T_7 and control. Statistically similar values were observed in T_8, T_5 and T2, suggesting that biologically active organic inputs and FYM can maintain chlorophyll stability during peak vegetative stages. The improved chlorophyll content indicates enhanced metabolic activity and nitrogen assimilation under T_6, leading to better light interception and energy capture during growth (Atarzadeh *et al.*, 2013; Channabasanagowda *et al.*, 2008) [2, 4].

3.2 Phenological Attributes
3.2.1 Days to 50% Tasseling
Data from Table 2 showed no significant difference among treatments in the days taken to reach 50% tasseling, suggesting that reproductive initiation was not markedly influenced by organic nitrogen management. This indicates that despite variability in vegetative vigor, tasseling in sweet corn is primarily governed by intrinsic genetic factors rather than external nutrient inputs.

3.2.2 Days to 50% Silking
Similarly, no significant variation was observed in days to 50% silking across treatments (Table 2), indicating that the transition from vegetative to reproductive phase remained stable under varying organic nitrogen inputs. This consistency may be due to uniform photoperiod and environmental conditions with organic inputs exerting more influence on growth dynamics than phenological development.

Table 1: Effect of nitrogen management on plant height of sweet corn under organic farming

Treatments	Plant height (cm)			Plant dry matter (g plant^{-1})			CGR (g m^{-2} day^{-1})		RGR (g g^{-1} day^{-1})	
	45 DAS	60 DAS	At harvest	45 DAS	60 DAS	At harvest	45-60 DAS	60 DAS-at harvest	45-60 DAS	60 DAS-at harvest
T_1	70.00	95.51	161.00	9.33	48.33	155.34	8.67	23.78	0.0548	0.0390
T_2	83.27	119.33	184.67	12.42	64.00	178.26	11.46	25.39	0.0546	0.0342
T_3	71.95	112.09	173.81	10.73	55.47	163.00	9.94	23.89	0.0546	0.0361
T_4	72.67	113.78	174.20	11.50	60.67	163.74	10.93	22.90	0.0554	0.0331
T_5	85.00	125.83	193.67	13.33	65.75	182.33	11.65	25.91	0.0529	0.0343
T_6	87.20	127.17	195.60	14.12	71.67	191.89	12.79	26.72	0.0543	0.0328
T_7	71.33	105.60	173.60	10.23	53.87	160.67	9.70	23.73	0.0554	0.0364
T_8	83.67	121.00	186.72	12.09	64.00	180.70	11.53	25.93	0.0559	0.0345
SEm±	2.42	3.79	6.75	0.68	3.43	5.00	0.79	1.42	0.00	0.00
C.D.(P = 0.05)	7.35	11.49	20.48	2.05	10.41	15.18	2.39	NS	NS	NS

Table 2: Effect of nitrogen management on CGR and RGR content in leaves of sweet corn under organic farming

Treatments	LAI		Chlorophyll content (mg g^{-1}) at 45 DAS	Days to 50% tasseling	Days to 50% silking
	45 DAS	60 DAS			
T_1	1.40	1.43	2.00	51.00	53.94
T_2	1.97	2.02	2.21	49.67	53.47
T_3	1.87	1.92	2.12	49.59	53.68
T_4	1.88	1.93	2.14	49.96	54.09
T_5	1.99	2.04	2.22	48.29	52.53
T_6	2.02	2.08	2.25	47.89	52.44
T_7	1.85	1.92	2.11	48.43	52.22
T_8	1.99	2.04	2.21	48.50	51.11
SEm±	0.04	0.05	0.03	1.17	0.69
C.D. (P = 0.05)	0.12	0.14	0.10	NS	NS

4. Conclusion

Based on the results from the one-year experimentation, it can be concluded that for optimal productivity and improved quality of sweet corn in the agro-climatic conditions of zone IVa (Sub-Humid Southern Plain and Aravali Hills) of Rajasthan, a nitrogen management strategy involving 50% RDN through FYM combined with 25% RDN through vermicompost at 30 DAS and 25% RDN through vermicompost at 45 DAS as soil application is most effective. This integrated nutrient management approach supports enhanced plant growth, dry matter accumulation and overall crop performance, thereby offering a sustainable solution for sweet corn cultivation in this region.

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