

# Effect of Spent Mushroom Substrate-Based Compost Enriched with Micronutrients on the Productivity of Maize (*Zea mays* L.) and Soil Health

Pratyush Ranjan Sahu<sup>1</sup>, Nishith Das<sup>2</sup>

M.Sc. Scholar, Department of Agronomy, School of Agriculture, GIET University, Gunupur, Odisha, India  
Assistant Professor, Department of Agronomy, School of Agriculture, GIET University, Gunupur, Odisha, India.

**Abstract-** The incorporation of agro-industrial residues like spent mushroom substrate (SMS) into nutrient management strategies provides a sustainable pathway for intensive agriculture. A field experiment was carried out during the Kharif of 2025 at GIET University, Odisha, to assess the impact of SMS-based compost supplemented with zinc (Zn), boron (B), and neem cake on the physiological, yield, and economic indices of maize (*Zea mays* L., var. VNR 4226). Utilizing a Randomized Block Design (RBD) with eight treatments and three replications, the study revealed that integrating SMS with micronutrients and the Recommended Dose of Fertilizers (RDF) significantly augmented crop performance. Treatment 8 (T8) (SMS@7t/ha + dried plant debris@2t/ha + cow dung@1t/ha + 5% Zn + B + RDF) delivered the highest plant stature (217.47 cm), maximum dry matter accumulation (237.63 g/plant), and superior yield attributes. This resulted in an exceptional kernel yield of 8.17 t/ha, a 175% increase over the FYM control. Soil chemical properties, notably available phosphorus, improved considerably under SMS regimes. Economically, T8 yielded the highest net monetary returns (₹1,18,642/ha), whereas T6 (RDF + 5% neem cake) optimized the Benefit-Cost ratio (2.38). These findings advocate for the integrated use of fortified SMS compost to enhance maize productivity and soil health.

**Keywords-** Maize, spent mushroom substrate, zinc, boron, integrated nutrient management, yield attributes, soil fertility.

## I. INTRODUCTION

Maize (*Zea mays* L.) is an essential cereal crop of global significance, vital for food security, livestock feed, and industrial processing. Despite its high genetic yield potential, actual farm productivity is frequently constrained by the depletion of soil organic matter and micronutrient deficiencies, exacerbated by a historical over-reliance on synthetic fertilizers. To foster sustainable agricultural intensification, Integrated Nutrient Management (INM) systems are increasingly advocated to restore edaphic health and sustain crop yields.

Spent Mushroom Substrate (SMS), a lignocellulosic by-product of commercial fungal cultivation, presents a lucrative organic resource. Rich in residual fungal biomass, extracellular enzymes, and essential nutrients, composted SMS improves soil aggregation, moisture retention, and microbial activity. Furthermore, soils in eastern India often

suffer from widespread deficiencies in crucial trace elements, specifically zinc (Zn) and boron (B). Zinc plays an obligatory role in auxin biosynthesis and enzymatic regulation, while boron is imperative for cellular integrity, pollen tube elongation, and grain setting. Consequently, this study was undertaken to exhaustively evaluate the interactive effects of SMS-based composts, fortified with micronutrients and botanicals like neem cake, on the holistic growth, yield, soil properties, and economic feasibility of maize production.

### Materials and Methods

The experiment was conducted during the Kharif 2025 season at the Instructional Research Farm, School of Agriculture, GIET University, Gunupur, Odisha, located in the North Eastern Ghats agro-climatic zone. The soil was a sandy loam with a slightly acidic pH (6.13), low electrical conductivity (0.22 dS/m), and moderate organic carbon (0.53%). The

baseline available N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O were 180.08, 4.04, and 295.58 kg/ha, respectively.

The trial utilized a Randomized Block Design (RBD) with three replications and eight treatments: T1: FYM alone (Control); T2: RDF (120:60:60 N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg/ha); T3: SMS @9t/ha + fresh cow dung slurry @1t/ha + RDF; T4: SMS @7t/ha + dried plant debris @2t/ha + cow dung @1t/ha + RDF; T5: T1 + 5% Neem cake + RDF; T6: T2 + 5% Neem cake + RDF; T7: T3 + 5% (Zn + B) + RDF; T8: T4 + 5% (Zn + B) + RDF. Maize seeds

(VNR 4226) were sown at a 60 x 30 cm spacing. Standard agronomic procedures were followed, and comprehensive data on growth parameters, yield attributes, soil properties, and economics were documented and subjected to statistical analysis (ANOVA).

## II. RESULTS AND DISCUSSION

### Plant Height

Table 1 delineates the temporal progression of plant height. While initial height at 30 DAS showed no significant variance, treatments exerted a profound impact at 60 DAS, 90 DAS, and harvest. T8 recorded the highest terminal plant stature (217.47 cm), demonstrating statistical parity with T7 (215.10 cm).

Treatment	30 DAS (cm)	60 DAS (cm)	90 DAS (cm)	At Harvest (cm)
T1	40.33	157.07	162.93	161.51
T2	47.33	170.00	169.93	176.73

T3	47.67	176.87	193.80	191.86
T4	49.00	179.13	197.33	186.05
T5	45.67	171.40	175.07	173.32
T6	49.67	173.93	187.93	193.39
T7	48.33	181.40	209.37	215.10
T8	50.00	182.13	213.67	217.47
S.Em (±)	1.93	4.69	6.99	9.04
C.D. (p=0.05)	NS	14.22	21.19	27.41

### Leaf Area Index (LAI)

Canopy development expanded significantly under nutrient-enriched regimes (Table 2). By 60 and 90 DAS, T8 achieved the maximal LAI of 11.03 and 10.53, respectively.

Treatment	30 DAS	60 DAS	90 DAS
T1	0.23	2.69	2.57
T2	0.27	4.31	4.11
T3	0.34	9.48	9.06
T4	0.34	5.79	5.53
T5	0.30	4.58	4.37
T6	0.34	5.63	5.38
T7	0.36	9.97	9.52
T8	0.41	11.03	10.53
S.Em (±)	0.03	0.37	0.31
C.D. (p=0.05)	NS	1.12	0.94

### Dry Matter Production

Table 3 illustrates biomass accumulation. T8 yielded the highest terminal dry matter (237.63 g/plant), vastly outperforming the control (62.71 g/plant).

Treatment	30 DAS (g)	60 DAS (g)	90 DAS (g)	At Harvest (g)
T1	10.44	32.64	57.13	62.71
T2	11.88	52.23	91.41	98.52
T3	13.68	70.22	122.89	128.31
T4	13.86	115.09	201.41	204.39
T5	12.60	55.51	97.14	102.04
T6	12.96	68.27	119.47	124.72
T7	13.86	120.86	211.51	217.39
T8	14.40	133.72	230.66	237.63
S.Em (±)	0.91	4.16	7.10	4.98
C.D. (p=0.05)	NS	12.60	21.53	15.12

**Growth Rates**

Tables 4, 5, and 6 document the Crop Growth Rate (CGR), Relative Growth Rate (RGR), and phenological transitions. T8 displayed the most robust CGR at 23.9 g/m<sup>2</sup>/day between

30 and 60 DAS. High-nutrient treatments exhibited a marginal delay in anthesis (54-55 days to tasseling) compared to the control (49.67 days), extending the vegetative phase.

Table 4: Crop Growth Rate (g/m<sup>2</sup>/day)

Treatment	0-30 DAS	30-60 DAS	60-90 DAS	90-Harvest
T1	2.08	4.4	4.8	1.1
T2	2.3	8.1	7.8	1.3
T3	2.7	11.3	10.5	1.08
T4	2.7	20.2	17.2	0.5
T5	2.5	8.6	8.3	0.9
T6	2.5	11.1	10.24	1.05
T7	2.7	21.4	18.13	1.1
T8	2.8	23.9	19.3	1.4
S.Em (±)	0.18	0.89	0.94	1.17
C.D. (p=0.05)	NS	2.7	2.85	NS

Table 5: Relative Growth Rate (mg/g/day)

Treatment	0-30 DAS	30-60 DAS	60-90 DAS	90-Harvest
T1	118.3	38.0	17.5	1.2
T2	122.6	49.4	18.7	3.0
T3	127.3	54.5	19.7	1.7
T4	127.8	70.6	18.0	0.6
T5	124.6	49.4	18.7	2.0
T6	125.5	55.4	18.7	1.7
T7	127.8	72.2	19.4	1.1
T8	129.0	74.3	18.9	3.7
S.Em (±)	4.92	13.12	1.67	2.7
C.D. (p=0.05)	NS	NS	NS	NS

Table 6: Days to 50% tasseling and 50% silking

Treatment	Days to 50% Tasseling	Days to 50% Silking
T1	49.67	55.00
T2	54.33	57.67
T3	52.67	56.33
T4	52.33	55.67
T5	50.00	55.33
T6	53.33	58.67
T7	55.67	59.33
T8	54.33	57.33
S.Em (±)	1.40	1.11
C.D. (p=0.05)	NS	NS

The significant increases in plant height, LAI, dry matter, and CGR under T8 and T7 are attributed to the sustained nutrient release from SMS combined with the critical roles of Zn and B in enzymatic activation and cellular expansion. This aligns with the findings of Tuhy et al. (2015) and Kaflea et al. (2022), who reported enhanced vegetative vigor in maize treated with micronutrient-enriched organic amendments. Furthermore, Khalil et al. (2024) and Hussain et al. (2022) highlighted how such integrations improve photosynthetic efficiency, corroborating the superior dry matter accumulation and CGR observed in this study, which was similarly reported by Kumar et al. (2019) and Dwivedi et al. (2022). The slight delay in phenological stages under nutrient-dense conditions corroborates findings by Dinthaingam et al. (2024), where extended vegetative periods contributed to larger photosynthetic machinery prior to reproductive transitions.

**Yield and Yield Attributes**

Tables 7a, 7b, and 8 highlight the profound enhancement in reproductive metrics and final yield. T8 optimized every yield parameter, yielding maximum cobs/plant, heavy cob weight (278.9 g), and 48.00 kernels/row. Consequently, T8 secured the absolute maximum kernel yield of 8.17 t/ha, a remarkable 175% improvement against the FYM control (2.97 t/ha).

Table 7a: Yield Attributes

Treatment	Cobs/plant	Cob Length (cm)	Cob Girth (cm)
T1	1.00	18.73	12.12
T2	1.03	21.17	12.63
T3	1.11	22.50	14.89
T4	1.16	22.50	15.25
T5	1.06	21.50	14.02
T6	1.07	21.53	14.55
T7	1.20	22.67	16.10
T8	1.49	22.67	16.33
S.Em (±)	0.06	0.76	0.80
C.D. (p=0.05)	0.17	2.31	2.42

Table 7b: Yield Attributes (Continued)

Treatment	Cob Wt. (g)	Rows/Cob	Kernels/Row
T1	178.6	10.00	26.67
T2	212.1	12.67	43.00
T3	252.2	14.67	45.00
T4	269.6	14.67	45.33
T5	243.4	14.00	43.00
T6	244.8	14.00	44.00
T7	275.0	15.33	45.67
T8	278.9	15.33	48.00
S.Em (±)	13.25	0.61	1.83
C.D. (p=0.05)	40.18	1.84	5.54

Table 8: Crop Yield

Treatment	Kernel Yield (t/ha)	Stalk Yield (t/ha)	Harvest Index (%)
T1	1.78	4.83	26.92
T2	5.87	6.46	39.33
T3	7.76	8.32	46.87
T4	7.86	8.53	48.00
T5	7.01	7.60	40.13
T6	7.41	7.95	46.00
T7	7.95	8.60	50.67
T8	8.17	8.74	51.00
S.Em (±)	0.41	0.39	2.26
C.D. (p=0.05)	1.25	1.18	6.87

The superiority of T8 in driving reproductive metrics is fundamentally linked to the synergistic interaction of organic matter from SMS and the application of micronutrients Zn and B, which drastically enhance pollen viability and grain filling (Bayar et al., 2023). Our results demonstrating a 175% increase in kernel yield are in strict conformity with Prusty et al. (2020) and Mas-ud et al. (2022), who documented significant yield amplifications upon integrating NPK with organics and micronutrients. Additionally, Dwivedi et al. (2022) corroborated that pairing organic manures with specific trace elements forms the most productive and biologically efficient approach for sustaining maize yields.

#### Post-Harvest Soil Properties

Tables 9 and 10 present the post-harvest edaphic physical and chemical states. Bulk density showed a numerical decline in SMS-integrated plots, bottoming at 1.35 g/cm<sup>3</sup> in T8. Chemically, available soil phosphorus elevated significantly to 8.00 kg/ha in T4, and organic carbon marginally appreciated to 0.61% under T8.

Table 9: Soil Physical Properties

Treatment	pH	EC (dS/m)	Bulk (g/cm <sup>3</sup> )
T1	6.13	0.22	1.42
T2	6.09	0.23	1.41
T3	6.16	0.24	1.38
T4	6.18	0.23	1.39
T5	6.15	0.24	1.41
T6	6.16	0.23	1.40
T7	6.23	0.24	1.36
T8	6.22	0.24	1.35
S.Em (±)	0.08	0.01	0.01
C.D. (p=0.05)	NS	NS	NS

Table 10: Soil Chemical Properties

Treatment	OC (%)	N (kg/ha)	P2O5 (kg/ha)	K2O (kg/ha)
T1	0.51	172.67	3.00	299.33
T2	0.54	178.33	3.33	290.67
T3	0.56	179.67	7.33	308.67
T4	0.56	186.33	8.00	295.67
T5	0.54	189.33	4.00	297.00
T6	0.54	191.00	5.33	309.00
T7	0.57	196.00	7.67	306.00
T8	0.61	198.67	5.33	303.33
S.Em (±)	0.03	12.84	0.48	7.34
C.D. (p=0.05)	NS	NS	1.45	NS

The enhancement of stable carbon fractions and reduction in soil bulk density, alongside the solubilization of fixed soil phosphorus by microbial and organic acid action within the decomposing SMS, is well-supported by Yang et al. (2024) and Nugroho et al. (2023). Moreover, the successful conservation of available nitrogen observed in treatments utilizing neem cake aligns seamlessly with its well-established nitrification-inhibiting properties, effectively mitigating leaching losses as reported by Mas-ud et al. (2022).

**Economic Evaluation**

Table 11 establishes the financial viability of the tested paradigms. T8 rewarded capital inputs with maximum gross (₹2,09,190/ha) and net returns (₹1,18,642/ha). T6 (RDF + 5% neem cake), however, presented the greatest capital efficiency, yielding the premier Benefit-Cost ratio of 2.38.

Treatment	Cost (₹/ha)	Gross (₹/ha)	Net (₹/ha)	B:C Ratio
T1	75687	80687	5000	1.07
T2	73931	150570	76639	2.04
T3	88984	198720	109736	2.23
T4	85220	201435	116215	2.36
T5	89134	179640	90506	2.02
T6	79726	189765	110039	2.38
T7	94311	203700	109389	2.16
T8	90548	209190	118642	2.31

The economic superiority of integrated nutrient management, evidenced by the high net returns under T8 and the optimal B:C ratio under T6, echoes the conclusions drawn by Dwivedi et al. (2022) and Prusty et al. (2020). Their research similarly emphasized the cost-effectiveness, improved nutrient recovery, and vastly higher net monetary returns associated with combined organic-inorganic fertilization programs targeting maize.

### III. CONCLUSION

The empirical synthesis strongly endorses Integrated Nutrient Management systems over singular applications for robust maize cultivation. By employing spent mushroom substrate combined with plant debris, cow dung, zinc, and boron along with standardized NPK fertilizers (T8), the physiological vitality and terminal yield of the crop were maximized. This integrated matrix achieved an outstanding kernel yield of 8.17 t/ha, rehabilitated soil physical conditions, and significantly augmented phosphorus bioavailability. From an economic standpoint, the integration of SMS and micronutrients guarantees high net returns, proving to be an ecologically sound and commercially astute strategy for sustaining intensive maize agriculture in tropical and sub-tropical agro-ecosystems.

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