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Compost Characterization and Impact of Different Manuring Practices on Growth and Yield Attributes of Rainfed Maize

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Abstract

A field experiment was conducted for two years during *kharif* 2022 and 2023 at ZARS, GKVK, Bengaluru to characterize different composts and to study the impact of different manuring practices on the growth and yield attributes of rainfed maize. The experiment was laid out in split-split plot design with eighteen treatments replicated thrice. The main plot treatments were manure application methods: surface and subsurface manuring, the sub-plot treatments include types of manure *viz.,* farm, city and blended compost, additionally, the sub-sub-plot treatments were rate of manure application (125% RDM, 100% RDM and 75% RDM). Characterization of composts revealed that city and blended compost was nutrient dense compared to farm compost. Among the treatments, combination of subsurface manuring with blended compost at 125% RDM recorded significantly higher growth and yield attributes of maize such as plant height (254 cm), number of leaves plant^{-1} (8.00), leaf area (1977 cm^2 plant^{-1}), dry matter production at harvest (267 g plant^{-1}), cob length (22.32 cm), cob girth (18.22 cm), grain yield (9.03 t ha^{-1}) and stover yield (14.87 t ha^{-1}) which was on par with subsurface manuring with blended compost at 100% RDM. The lowest growth and yield attributes were recorded in absolute control. The findings of the study revealed that applying 100 per cent blended compost at 20 cm subsurface depth could be an option to enhance maize productivity.

Keywords : Maize, Compost, Surface manuring, Subsurface manuring, Productivity

Intensive agricultural methods and cultivation of exhaustive crops have resulted in soil degradation leading to deterioration in soil quality (Karthika *et al.*, 2018). Application of organic manures along with chemical fertilizers has been suggested as a sustainable farmland management practice to improve soil fertility and crop production. The addition of organic manures to the soil increases its organic matter content, which not only improves physical properties but also speeds up nutrient cycling and boosts soil biological activity (Magray and Sharma, 2022). But the effectiveness of manure utilization by crops depends on the application method, the type of manure used and the rate at which it is applied (Zhang *et al.,* 2020). Organic manures can be applied to the soil by surface and subsurface methods. Surface method of manuring is the oldest, simple and cost-effective method of applying manure directly onto the soil surface without incorporation (Rasmussen, 2002). Subsoil manuring is a new technology developed at La Trobe University, Australia to improve the productivity of crops grown with sodic subsoils. It involves the deep placement of high rates of organic manures into the clay enriched 'B' horizon (Sale *et al.,* 2018).

The type of manure used also plays a crucial role in determining its effectiveness for crop growth, as different manures provide varying nutrient profiles, decomposition rates and benefits to soil health. The most conventional type of organic manure or compost used in agricultural soils is Farm Yard Manure (FYM) or farm compost (Dutta *et al.,* 2024). Over the years, the availability of FYM has significantly declined due to its diversion for other domestic uses (Indoria *et al.,* 2017). Considering the consequent decline in the availability, other alternatives are necessary to enhance the overall functional capacity of the soil. The increase in population, per capital income and expansion of urbanization have led to increase in variety and amount of municipal solid wastes (Mamo *et al.,* 2021) and municipal solid waste compost or city compost is becoming increasingly popular as a sustainable alternative. A significant concern with city compost is the potential for heavy metal toxicity which can pose risks to both soil health and crop safety. However, these challenges can be mitigated by blending city compost with other organic materials such as FYM, green waste or biochar.

Cereals are the staple food crops of future food systems and maize (*Zea mays* L.) stands as the most important multipurpose crop that provides human food, animal and poultry feed, livestock fodder and raw materials for industry (Khan *et al.,* 2018). In Karnataka, during 2022-2023, maize was grown in an area of 19.51 lakh ha with a production of 56.60 lakh tonnes with a productivity of 2960 kg ha^{-1}, contributing 34.51 per cent to the total country's production (Anonymous, 2023). Increasing the soil's sustainability and fertility is necessary to increase maize productivity, as maize consumes fertilizers voraciously and exhausts considerably large amount of nutrients during the growing season compared to other cereal crops (Kihara *et al*., 2024). To boost maize productivity by improving overall soil health, the use of organic manures in conjunction with inorganic fertilizers can be a more effective option. Keeping this background in view, the present study was carried out to characterize the physico-chemical properties of different composts and to compare the effect of manuring practices on growth and yield of maize.

Material And Methods

A field experiment was conducted during the *kharif* 2022 and 2023 at 'F' block, ZARS, University of Agricultural Sciences, GKVK, Bengaluru. The experimental site is situated in the Eastern Dry Zone of Karnataka at an elevation of 930 meters above mean sea level. The study area had a moist and semi-arid climate with a mean annual rainfall ranging from 680 to 890 mm. The soil of the experimental site was found to be red sandy loam in texture and was acidic in reaction (pH 6.09), low in organic carbon (4.5 mg kg^{-1}) low in electrical conductivity (0.23 dS m^{-1}), low in available nitrogen (210.75 kg ha^{-1}), high in available phosphorus (112.42 kg ha^{-1}) and low in available potassium (119.19 kg ha^{-1}).

The study aimed to characterize the composts and to evaluate the influence of different methods of application, type of manures and rate of manure application on growth, yield and quality of maize. The investigation was proceeded in three distinct phases collection and preparation of composts which included farm, city and blended composts. The city compost was procured from the Karnataka Compost Development Corporation Limited, Bengaluru, Karnataka while the farm compost was collected from the Research Institute on Organic Farming, GKVK, Bengaluru, Karnataka. The blended composts were prepared thoroughly by mixing farm and city composts in precise proportions based on the recommended rate of 10 and 7.5 t ha^{-1} respectively. In the second phase, characterization of composts, all the compost materials were analyzed for their physical, electrical, chemical and biological properties. In the third phase, field evaluation, the experiment was laid out in split-split design with 18 treatments and one absolute control replicated thrice.

Treatments consisted of two 1. methods of manuring (M_1- Surface manuring and M_2- Subsurface manuring) as main plots, 2. three types of compost (C_1-Farm compost, C_2- City compost and C_3- Blended compost) as sub plots and 3. three rates of manure application (D_1-125% RDM, D_2-100% RDM and D_3-75% RDM) as sub-sub plots. In order to impose subsurface manuring a shallow trench of 20-25 cm depth was dug manually at 60 cm apart; later specific compost was filled as per the treatments in each replication. Whereas, in surface manuring treatments, composts were uniformly spread on the soil surface. The total quantity of composts applied to the experimental plots were measured on a weight-by-weight basis. These plots were left undisturbed for 14 days. Subsequently, the application of recommended dose of fertilizers for rainfed maize 100:50: 25 kg ha^{-1} were applied uniformly to all plots except absolute control. Half dose of nitrogen and a full dose of phosphorus and potassium were applied as basal doses at the time of sowing and the remaining nitrogen was top-dressed at 30 DAS during earthing up. Sowing of maize variety JP 2007 was taken up at a spacing of 60 cm x 30 cm after the application of fertilizers. Normal post-sowing agronomic practices recommended for this region to raise a healthy maize crop were followed. All the three composts were analyzed for various physical, electrical, chemical and biological properties using standard procedures. Growth and yield attributes were recorded at 30, 60, 90 DAS and at harvest. The grain and straw yield obtained from each net plot area was converted to t ha^{-1}. The data recorded on various parameters were subjected to Fisher's method of analysis of variance and interpretation of the data was made as given by Gomez and Gomez (1984). The level of significance used in 'F' was P = 0.05. The mean values of main plot, sub-plot and highest order interaction effects were separately subjected to Duncan's Multiple Range Test (DMRT) using the corresponding error mean sum of squares and degrees of freedom values under OPSTAT program.

Results and Discussion

Characterization of Composts

All three composts *viz.,* farm, city and blended compost were analyzed and the values are presented in Table 1. Physical characterization of composts revealed that all three composts were black in colour, homogeneous, had a fine powdery texture and were free from any foul odour. This signifies that the procured compost was mature and stable, where complete decomposition of complex organic materials

Table 1

Physical, electrical, chemical and biological characterization of composts

Parameters	Farm compost	City compost	Blended compost
Physical properties			
Colour	Black	Black	Black
Odour	No foul odour	No foul odour	No foul odour
Moisture (%)	36.50	24.38	29.73
Electrical properties			
pH	7.54	6.45	7.03
Electrical conductivity (dS m^{-1})	3.68	2.20	1.34
Chemical properties			
Organic carbon (%)	21.66	27.17	26.79
Humic acid (%)	4.24	6.57	5.24
Fulvic acid (%)	2.51	3.50	3.16
Humin (%)	93.24	89.93	91.60
C:N ratio	14.55	10.69	10.63
Total Nitrogen (%)	1.49	2.54	2.52
Total Phosphorus (%)	0.56	0.69	0.6
Total Potassium (%)	0.48	0.68	0.52
Total Calcium (%)	1.07	2.08	1.50
Total Magnesium (%)	0.64	0.38	0.52
Total Sulphur (%)	0.24	0.43	0.33
Iron (mg kg^{-1})	9831	8446	7567
Zinc (mg kg^{-1})	129	392	203
Manganese (mg kg^{-1})	615	188	376
Copper (mg kg^{-1})	30.21	207.00	95.57
Nickel (mg kg^{-1})	33.86	24.31	27.53
Cadmium (mg kg^{-1})	ND	3.58	2.36
Chromium (mg kg^{-1})	26.25	33.09	29.78
Lead (mg kg^{-1})	25.65	52.91	17.63
Mercury (mg kg^{-1})	ND	ND	ND
Biological properties			
Bacteria (CFU g^{-1})	6×10^{7}	9×10^{7}	3×10^{7}
Fungi (CFU g^{-1})	12×10^{4}	38×10^{4}	10×10^{4}
Actinomycetes (CFU g^{-1})	16×10^{3}	17×10^{3}	17×10^{3}

into smaller, stable humic substances has occurred (Chen *et al.,* 2023). Moisture content and bulk density were highest in farm compost (36.50% and 0.76 Mg m^{-3}, respectively) followed by blended compost and city compost. The coarser particle size of blended and city compost might have resulted in higher volume per unit quantity of compost which might have resulted in lower bulk density compared to farm compost (Kirchhoff *et al.,* 2002). Similar results were reported by Punitha and Prakasha (2016) and Veena and Sathish (2022).

pH of farm compost was slightly alkaline in nature (7.54), blended compost was neutral in reaction (7.03) and city compost was slightly acidic in nature (6.45). This was consistent with the findings of Dnyaneshwar (2021) and Singh *et al.* (2023). Among three composts, the highest EC was noted in farm compost (3.68 dS m^{-1}) followed by city compost and lowest in blended compost. Afifi *et al.* (2012) opined that organic materials upon decomposition liberate basic ions that accumulate on the surface of composts and raise the EC of compost.

Chemical characterization of composts revealed that city compost recorded higher total organic carbon (27.17%). This was due to the presence of more stable and humified organic matter (Vasundhara *et al.,* 2019). Similarly, humic fractions such as humic acid (6.57%) and fulvic acids (3.50%), were higher in city compost but humin content was highest in farm compost (93.25%). Major nutrient analysis revealed that total nitrogen, phosphorus and potassium content was high in city compost (2.54, 0.69 and 0.68, respectively). This was due to the variations in nutrient content of composting materials used for its preparation. Among the composts, C:N ratio was higher in farm compost (14.55) followed by city compost (10.69) and lowest in blended compost (10.63). Concentration of secondary nutrients in composts showed slight variations, the total calcium and sulphur content were highest in city compost (2.08 and 0.43%, respectively) whereas total magnesium content (0.64%) was highest in farm compost. This was due to the production of calcium oxides, hydroxides and sulphates during organic matter decomposition whereas magnesium-rich crop residues added during compost preparation was the reason for higher magnesium content. Similar findings were also reported by Dnyaneshwar (2021). Micronutrients such as iron, manganese and nickel contents were highest in farm compost (9831, 615 and 33.89 mg kg^{-1}, respectively). But copper content was highest in city compost (207 mg kg^{-1}). The concentration of the micronutrients in the raw materials used for the composting could be the reason for the variation in micronutrient content in the composts. Heavy metal analysis in composts revealed that cadmium (3.58 mg kg^{-1}), chromium (33.09 mg kg^{-1}) and lead content (52.91 mg kg^{-1}) was highest in city compost. Mercury was not detected in any of the three composts. Similar ranges were also reported by Vasundhara *et al.* (2019) and Dnyaneshwar (2021).

Enumeration of bacteria, fungi and actinomycetes revealed that total bacterial (9×10^7 CFU g^{-1}), fungal (38×10^4 g^{-1}) and actinomycetes (17×10^3 CFU g^{-1}) population was more in city compost. This was the result of complex organic matter, high carbon content, lower C: N ratio and more nutrient content that acted as a substrate for the growth of microorganisms (Punitha and Prakasha, 2016).

Growth Attributes of Maize

The data pertaining to growth attributes of maize influenced by the methods, types of compost and rate of manure application during two years of experimentation (2022 and 2023) and their pooled means are presented in Tables 2 and 3.

Plant Height (cm)

Plant height is a direct indicator of the growth and overall vigour of the plant (Yang *et al.,* 2024). In *kharif* 2022, surface manuring (M_1) produced the tallest plants (228 cm). Whereas in *kharif* 2023, subsurface manuring (M_2) outperformed surface manuring (M_1) and produced the tallest plants (263 cm). In pooled means, both the treatments were on par. The increased plant height in subsurface manuring was due to the residual effect of compost applied in the initial year. The consistent nutrient availability might have

TABLE 2

Influence of different manuring practices on plant height and number of leaves

Treatments	Plant height (cm)			Number of leaves		
	2022	2023	Pooled	2022	2023	Pooled
Method of manuring (M)						
M_1-Surface manuring	228 ^{a}	230 ^{b}	229 ^{a}	6.51 ^{a}	8.08 ^{b}	7.29 ^{a}
M_2-Subsurface manuring	198 ^{b}	263 ^{a}	231 ^{a}	5.63 ^{b}	9.33 ^{a}	7.48 ^{a}
S.Em.±	2.13	2.45	1.50	0.11	0.13	0.11
Type of manure (C)						
C_1- Farm compost	202 ^{c}	234 ^{c}	218 ^{c}	5.74 ^{a}	8.16 ^{a}	6.95 ^{b}
C_2- City compost	213 ^{b}	244 ^{b}	229 ^{b}	6.09 ^{a}	8.79 ^{a}	7.44 ^{ab}
C_3-Blended compost	224 ^{a}	262 ^{a}	243 ^{a}	6.37 ^{a}	9.16 ^{a}	7.77 ^{a}
S.Em.±	2.12	1.63	1.01	0.15	0.15	0.12
Rate of manure application (D)						
D_1-125% RDM	217 ^{a}	250 ^{a}	234 ^{a}	6.11 ^{a}	8.90 ^{a}	7.50 ^{a}
D_2-100% RDM	214 ^{a}	247 ^{b}	231 ^{b}	6.09 ^{a}	8.80 ^{a}	7.45 ^{a}
D_3-75% RDM	208 ^{b}	243 ^{c}	226 ^{c}	6.00 ^{a}	8.41 ^{a}	7.21 ^{b}
S.Em.±	1.86	1.65	1.02	0.12	0.13	0.10
Interaction (M×C×D)						
$M_1C_1D_1$	222 ^{ef}	226 ^{k}	224 ^{h}	6.33 $^{a-f}$	8.00 ^{e}	7.17 ^{abc}
$M_1C_1D_2$	219 ^{f}	220 ^{l}	219 ^{i}	6.22 $^{a-f}$	7.89 ^{e}	7.06 ^{abc}
$M_1C_1D_3$	210 ^{h}	211 ^{m}	212 ^{j}	6.11 $^{a-f}$	6.51 ^{f}	6.31 ^{c}
$M_1C_2D_1$	225 ^{de}	231 ^{j}	228 ^{fg}	6.44 $^{a-e}$	8.22 ^{de}	7.33 ^{ab}
$M_1C_2D_2$	227 ^{cd}	232 ^{ij}	230 ^{ef}	6.55 $^{a-d}$	8.22 ^{de}	7.39 ^{ab}
$M_1C_2D_3$	229 ^{c}	234 ^{ij}	231 ^{de}	6.56 $^{a-d}$	8.25 ^{de}	7.40 ^{ab}
$M_1C_3D_1$	250 ^{a}	243 ^{g}	246 ^{b}	6.89 ^{a}	8.60 ^{cde}	7.74 ^{a}
$M_1C_3D_2$	243 ^{b}	238 ^{h}	241 ^{c}	6.78 ^{ab}	8.56 ^{cde}	7.67 ^{a}
$M_1C_3D_3$	230 ^{c}	235 ^{hi}	233 ^{d}	6.67 ^{abc}	8.44 ^{cde}	7.56 ^{ab}
$M_2C_1D_1$	196 ^{k}	252 ^{e}	224 ^{h}	5.44 ^{efg}	9.22 $^{a-d}$	7.33 ^{ab}
$M_2C_1D_2$	191 ^{l}	248 ^{f}	219 ^{i}	5.35 ^{fgh}	8.89 $^{b-e}$	7.12 ^{abc}
$M_2C_1D_3$	174 ^{m}	246 ^{fg}	210 ^{j}	5.00 ^{gh}	8.45 ^{cde}	6.72 ^{bc}
$M_2C_2D_1$	197 ^{k}	255 ^{de}	226 ^{gh}	5.56 $^{d-g}$	9.33 ^{abc}	7.44 ^{ab}
$M_2C_2D_2$	199 ^{jk}	256 ^{d}	228 ^{fg}	5.67 $^{c-g}$	9.34 ^{abc}	7.51 ^{ab}
$M_2C_2D_3$	202 ^{ij}	258 ^{d}	230 ^{ef}	5.78 $^{b-g}$	9.36 ^{abc}	7.57 ^{ab}
$M_2C_3D_1$	214 ^{g}	295 ^{a}	254 ^{a}	6.00 $^{a-g}$	10.00 ^{a}	8.00 ^{a}
$M_2C_3D_2$	207 ^{h}	287 ^{b}	247 ^{b}	6.00 $^{a-g}$	9.89 ^{ab}	7.95 ^{a}
$M_2C_3D_3$	203 ^{i}	275 ^{c}	239 ^{c}	5.89 $^{a-g}$	9.48 ^{abc}	7.68 ^{a}
S.Em.±	4.56	4.04	2.50	0.30	0.31	0.23
Absolute control	165	168	167	4.33	4.67	4.50

Note : Means followed by the same letter(s) within a column are not significantly different by DMRT (p=0.05)

TABLE 3

Influence of different manuring practices on leaf area and dry matter production plant^{-1} at harvest in maize

Treatments	Leaf area (cm^2 plant^{-1})			Dry matter production (g plant^{-1})		
	2022	2023	Pooled	2022	2023	Pooled
Method of manuring (M)						
M_1-Surface manuring	1505 ^{a}	1554 ^{b}	1529 ^{b}	241 ^{a}	236 ^{b}	238 ^{b}
M_2-Subsurface manuring	1211 ^{b}	1921 ^{a}	1566 ^{a}	214 ^{b}	283 ^{a}	248 ^{a}
S.Em.±	35.13	14.01	18.42	1.96	1.31	0.99
Type of manure (C)						
C_1- Farm compost	1217 ^{c}	1566 ^{c}	1391 ^{c}	216 ^{c}	249 ^{c}	233 ^{c}
C_2- City compost	1361 ^{b}	1723 ^{b}	1542 ^{b}	226 ^{b}	259 ^{b}	243 ^{b}
C_3-Blended compost	1496 ^{a}	1923 ^{a}	1709 ^{a}	240 ^{a}	270 ^{a}	255 ^{a}
S.Em.±	23.61	19.56	10.67	1.74	1.46	1.29
Rate of manure application (D)						
D_1-125% RDM	1402 ^{a}	1813 ^{a}	1607 ^{a}	231 ^{a}	264 ^{a}	247 ^{a}
D_2-100% RDM	1376 ^{b}	1741 ^{b}	1558 ^{b}	228 ^{a}	260 ^{b}	244 ^{b}
D_3-75% RDM	1295 ^{c}	1658 ^{c}	1476 ^{c}	224 ^{b}	254 ^{c}	239 ^{c}
S.Em.±	24.18	32.33	18.95	1.37	1.30	0.96
Interaction (M×C×D)						
$M_1C_1D_1$	1441 ^{d}	1482 ^{i}	1462 ^{h}	231 ^{g}	234 ^{k}	233 ^{l}
$M_1C_1D_2$	1438 ^{d}	1481 ^{i}	1460 ^{h}	227 ^{h}	231 ^{k}	229 ^{m}
$M_1C_1D_3$	1399 ^{e}	1286 ^{j}	1342 ^{k}	223 ^{i}	210 ^{l}	217 ^{n}
$M_1C_2D_1$	1444 ^{d}	1570 ^{h}	1507 ^{g}	235 ^{f}	237 ^{j}	236 ^{jk}
$M_1C_2D_2$	1444 ^{d}	1582 ^{h}	1513 ^{g}	238 ^{e}	238 ^{j}	238 ^{j}
$M_1C_2D_3$	1460 ^{c}	1608 ^{g}	1534 ^{f}	242 ^{d}	239 ^{j}	241 ^{i}
$M_1C_3D_1$	1798 ^{a}	1681 ^{f}	1740 ^{c}	263 ^{a}	248 ^{h}	256 ^{c}
$M_1C_3D_2$	1655 ^{b}	1680 ^{f}	1667 ^{d}	258 ^{b}	244 ^{i}	251 ^{d}
$M_1C_3D_3$	1465 ^{c}	1611 ^{g}	1538 ^{f}	247 ^{c}	243 ^{i}	245 ^{gh}
$M_2C_1D_1$	1124 ^{i}	1719 ^{e}	1421 ^{i}	209 ^{l}	277 ^{ef}	243 ^{hi}
$M_2C_1D_2$	1050 ^{j}	1714 ^{e}	1382 ^{j}	207 ^{l}	274 ^{f}	241 ^{i}
$M_2C_1D_3$	850 ^{k}	1713 ^{e}	1282 ^{l}	198 ^{m}	270 ^{g}	234 ^{kl}
$M_2C_2D_1$	1227 ^{h}	1850 ^{d}	1539 ^{f}	213 ^{k}	278 ^{de}	246 ^{fg}
$M_2C_2D_2$	1293 ^{g}	1858 ^{cd}	1576 ^{e}	215 ^{jk}	279 ^{de}	247 ^{fg}
$M_2C_2D_3$	1296 ^{g}	1868 ^{c}	1582 ^{e}	216 ^{jk}	281 ^{cd}	248 ^{ef}
$M_2C_3D_1$	1381 ^{f}	2572 ^{a}	1977 ^{a}	231 ^{g}	307 ^{a}	267 ^{a}
$M_2C_3D_2$	1373 ^{f}	2132 ^{b}	1752 ^{b}	224 ^{i}	296 ^{b}	260 ^{b}
$M_2C_3D_3$	1301 ^{g}	1860 ^{cd}	1580 ^{e}	217 ^{j}	283 ^{c}	250 ^{de}
S.Em.±	59.22	79.20	46.43	3.36	3.20	2.36
Absolute control	800	1185	993	180	186	183

Note : Means followed by the same letter (s) within a column are not significantly different by DMRT (p=0.05)

Plate 1 : Overview of surface and subsurface manuring in a) *kharif* 2022 and b) *kharif* 2023

enhanced the conversion of carbohydrates into protein, which then elaborated into protoplasm and cell wall material, leading to increased cell size, cell expansion and overall plant height. These results are in agreement with the findings of Hamna (2021) who reported that subsoil manuring with poultry and sheep manures increased the plant height in pigeon pea.

Plant height of maize significantly varied with the types of manures employed. Blended compost (C_3) produced substantially taller plants followed by city compost (C_2) and lowest in farm compost (C_1). This was due to balanced and higher nutrient profile, which rendered the availability of nutrients during the earlier stages of plant growth that promoted cell division, expansion and elongation resulting in taller plants. Several researchers have documented the positive effect of compost application on plant height such as Babu *et al.* (2020) in baby corn.

Similarly, higher rate of manure application had a substantial impact on plant height. Application of compost at 125% RDM (D_1) resulted in taller plants and was on par with 100% RDM (D_2) and lowest in 75% RDM (D_3). This might be due to the consistent availability of nutrients that supported cell division and elongation of intercalary meristem at the base of internodes during the growth and development of maize leading to increased plant height (Bhutto *et al.,* 2023).

The interaction effect of methods of application, type of manures and rate of manure application exhibited varying trends and significantly influenced the plant height. In *kharif* 2022, the treatment combination surface manuring with blended compost at 125% RDM (M1C3D1) recorded taller plants at harvest (250 cm). Whereas in *kharif* 2023 and pooled means, the treatment combination subsurface manuring with blended compost at 125% RDM ($M_2C_3D_1$) recorded significantly higher plant height (295 and 254 cm, respectively). The lowest plant height was recorded in absolute control treatment in 2022 (165 cm), 2023 (168 cm) and in pooled means (167 cm). Similar results were also reported by Majumder *et al.* (2016) and Hamna (2021).

Number of Leaves Plant^{-1}

The methods of manuring exerted a significant influence on number of leaves plant^{-1}. During *kharif* 2022, number of leaves plant^{-1} were significantly more in surface manuring (M_1) (6.51), whereas in *kharif* 2023, it was significantly higher in subsurface manuring (M_2) (9.33). In the pooled means, methods of manuring did not significantly influence the number of leaves plant^{-1}. Similar results were also reported by Majumder *et al.* (2016) in wheat.

Number of leaves plant^{-1} did not differ significantly with the different types of compost in 2022 and 2023. In the pooled means, significantly higher number of leaves plant^{-1} at harvest was noticed in blended compost (C_3) (7.77) which was on par with city compost (C_2) (7.44). Number of leaves plant^{-1} was less in farm compost (C_1) (6.95) which was in turn on par with city compost (C_2). These results align with Lalrinsangi *et al.* (2024).

TABLE 3

Influence of different manuring practices on leaf area and dry matter production plant^{-1} at harvest in maize

Treatments	Leaf area (cm^2 plant^{-1})			Dry matter production (g plant^{-1})		
	2022	2023	Pooled	2022	2023	Pooled
Method of manuring (M)						
M_1-Surface manuring	1505 a	1554 b	1529 b	241 a	236 b	238 b
M_2-Subsurface manuring	1211 b	1921 a	1566 a	214 b	283 a	248 a
S.Em.±	35.13	14.01	18.42	1.96	1.31	0.99
Type of manure (C)						
C_1- Farm compost	1217 c	1566 c	1391 c	216 c	249 c	233 c
C_2- City compost	1361 b	1723 b	1542 b	226 b	259 b	243 b
C_3-Blended compost	1496 a	1923 a	1709 a	240 a	270 a	255 a
S.Em.±	23.61	19.56	10.67	1.74	1.46	1.29
Rate of manure application (D)						
D_1-125% RDM	1402 a	1813 a	1607 a	231 a	264 a	247 a
D_2-100% RDM	1376 b	1741 b	1558 b	228 a	260 b	244 b
D_3-75% RDM	1295 c	1658 c	1476 c	224 b	254 c	239 c
S.Em.±	24.18	32.33	18.95	1.37	1.30	0.96
Interaction (M×C×D)						
$M_1C_1D_1$	1441 d	1482 i	1462 h	231 g	234 k	233 l
$M_1C_1D_2$	1438 d	1481 i	1460 h	227 h	231 k	229 m
$M_1C_1D_3$	1399 e	1286 j	1342 k	223 i	210 l	217 n
$M_1C_2D_1$	1444 d	1570 h	1507 g	235 f	237 j	236 jk
$M_1C_2D_2$	1444 d	1582 h	1513 g	238 e	238 j	238 j
$M_1C_2D_3$	1460 c	1608 g	1534 f	242 d	239 j	241 i
$M_1C_3D_1$	1798 a	1681 f	1740 c	263 a	248 h	256 c
$M_1C_3D_2$	1655 b	1680 f	1667 d	258 b	244 i	251 d
$M_1C_3D_3$	1465 c	1611 g	1538 f	247 c	243 i	245 gh
$M_2C_1D_1$	1124 i	1719 e	1421 i	209 l	277 ef	243 hi
$M_2C_1D_2$	1050 j	1714 e	1382 j	207 l	274 f	241 i
$M_2C_1D_3$	850 k	1713 e	1282 l	198 m	270 g	234 kl
$M_2C_2D_1$	1227 h	1850 d	1539 f	213 k	278 de	246 fg
$M_2C_2D_2$	1293 g	1858 cd	1576 e	215 jk	279 de	247 fg
$M_2C_2D_3$	1296 g	1868 c	1582 e	216 jk	281 cd	248 ef
$M_2C_3D_1$	1381 f	2572 a	1977 a	231 g	307 a	267 a
$M_2C_3D_2$	1373 f	2132 b	1752 b	224 i	296 b	260 b
$M_2C_3D_3$	1301 g	1860 cd	1580 e	217 j	283 c	250 de
S.Em.±	59.22	79.20	46.43	3.36	3.20	2.36
Absolute control	800	1185	993	180	186	183

Note : Means followed by the same letter (s) within a column are not significantly different by DMRT (p=0.05)

Number of leaves plant^{-1} was not influenced by the rate of manure application in both the years of experimentation. In the pooled means, number of leaves plant^{-1} was significantly more with manures at 125% RDM (D_1) (7.50) and was on par with 100% RDM (D_2) (7.45). Significantly lesser number of leaves plant^{-1} were recorded with 75% RDM (D_3) (7.21). These results endorse the findings of Bhutto *et al.* (2023). The interaction effects of methods of application, type of manures and rate of manure application were found non-significant in number of leaves plant^{-1} at harvest in 2022, 2023 and in pooled means.

Leaf Area Plant^{-1} (cm^2)

Leaf area plant^{-1} increased as the crop matured, peaking at 90 DAS followed by a decline towards the harvesting stage (Table 3). Significant difference in leaf area plant^{-1} was noted due to methods of manuring. In *kharif* 2022, leaf area was significantly higher in surface manuring (M_1) (1505 cm^2 plant^{-1}). In contrast, during *kharif* 2023 and pooled means, subsurface manuring (M_2) recorded significantly higher leaf area (1921 and 1566 cm^{2}plant^{-1}, respectively). It would probably be due to the carry-over effects of organic manures applied in initial year of study. Subsurface placement of compost enhanced root growth by placing nutrients directly within the active root zone which ensured efficient nutrient absorption and provided a consistent nutrient supply, supported robust root activity, promoted cell division and elongation in leaves, ultimately increasing leaf area (Gill *et al.*, 2008).

Among composts, blended compost (C_3) recorded significantly higher leaf area (1496, 1923 and 1709 cm^2 plant^{-1}) followed by city compost (C_2) whereas significantly lower leaf area was recorded in farm compost (C_1) (1217, 1566 and 1391 cm^2 plant^{-1}) in 2022, 2023 and pooled means, respectively. A similar study by Orluchukwu *et al.* (2019) demonstrated that combining two organic manures produced a synergistic effect in rice and improved the growth by enriching the soil with additional micronutrients and increasing the exchangeable bases that are essential for enzymatic activities, chlorophyll synthesis, cell division and leaf expansion.

Application of manures at 125% RDM (D_1) recorded significantly higher leaf area (1402, 1813 and 1607 cm^2 plant^{-1}) in 2022, 2023 and pooled means respectively, followed by 100% RDM (D_2) and the lowest wasin 75% RDM (D_3) (1295, 1658 and 1476 cm^2 plant^{-1}) This could be primarily due to the nutrient rich environment which stimulated the production of growth-promoting hormones like auxins and cytokinin which play key roles in cell division and expansion particularly in leaf tissues resulting in more leaf area (Bhat *et al.,* 2013). During *kharif* 2022, the treatment combination surface manuring with blended compost at 125% RDM ($M_1C_3D_1$) recorded significantly higher leaf area (1798 cm^2 plant^{-1}). Whereas, in *kharif* 2023 and pooled means, the treatment combination subsurface manuring with blended compost at 125% RDM ($M_2C_3D_1$) recorded significantly higher leaf area (2572 and 1977 cm^2 plant^{-1}, respectively). The lowest leaf area was recorded in the absolute control in 2022, 2023 and pooled means (800, 1185 and 993 cm^2 plant^{-1}, respectively).

Dry Matter Production (g plant^{-1})

Details of dry matter production plant^{-1} influenced by different manuring practices is given in Table 3. Between the methods of application, surface manuring (M_1) recorded significantly higher dry matter production in 2022 (241 g plant^{-1}). In contrast, subsurface manuring (M_2) recorded significantly higher dry matter production in 2023 (283 g plant^{-1}) and pooled means (248 g plant^{-1}). This can be attributed to the residual effect of manures that promoted the rapid formation of the source, extended the reproductive growth period and allowed for greater transfer of assimilates ultimately resulting in higher DMP (Gill *et al.,* 2008). The present results are consistent with the findings of Hamna (2021), who reported higher dry matter production under subsurface manuring in pigeon pea.

Dry matter production significantly varied with the different types of manures. Blended compost (C_3) recorded significantly higher dry matter production in 2022 (240 g plant^{-1}), 2023 (270 g plant^{-1}) and pooled means (255 g plant^{-1}) followed by city compost (C_2). The lowest dry matter production plant^{-1} was in farm compost (C_1) in 2022 (216 g plant^{-1}), 2023 (249 g plant^{-1}) and pooled means (233 g plant^{-1}). Increased dry matter accumulation in blended compost might be attributed to the continuous and steady release of nutrients which enabled the leaf area duration to extend, thus favouring the plants to increase the photosynthetic rate which in turn led to higher accumulation of dry matter (Ponmozhi *et al.,* 2019).

The application of manures at different rates significantly influenced the dry matter production plant^{-1}. Application of compost at 125% RDM (D_1) recorded significantly higher dry matter production plant^{-1} at harvest in 2022 (231 g plant^{-1}), 2023 (264 g plant^{-1}) and pooled means (247 g plant^{-1}) which was comparable with 100% RDM (D_2) in 2022, 2023 and pooled means and the lowest was recorded in 75% RDM (D_3) in 2022 (224 g plant^{-1}), 2023 (254 g plant^{-1}) and pooled means (239 g plant^{-1}). This is in agreement with earlier findings by Kokkora *et al.* (2008) who revealed that dry matter yield of forage maize enhanced with increase in compost application rate.

The interaction effect of methods of application, types of manures and rate of manure application significantly influenced dry matter production plant^{-1}. In *kharif* 2022, significantly higher dry matter production plant^{-1} was recorded in the treatment combination surface manuring with blended compost at 125% RDM ($M_1C_3D_1$) (263 g plant^{-1}). In *kharif* 2023 and pooled means, the treatment combination subsurface manuring with blended compost at 125% RDM ($M_2C_3D_1$) recorded significantly higher dry matter production plant^{-1} at harvest (307 and 267 g plant^{-1}, respectively). The lowest dry matter production plant^{-1} at harvest was recorded in absolute control at harvest in 2022, 2023 and pooled means (180, 186 and 183 g plant^{-1}, respectively). Majumder *et al.* (2016) also reported positive impact of subsurface placement of higher rates of manures on dry matter production in maize, validating the results of the present study.

Yield Attributes of Maize

Cob Length (cm)

Methods of manuring significantly influenced cob length in both the years of experimentation and pooled means (Table 4). Surface manured plots (M_1) yielded significantly longer cobs (19.08 cm) in 2022. In contrast, significantly longer cobs were noticed in subsurface manured plots (M_2) in the year 2023 (22.93 cm) and in pooled means (20.00 cm).

Similarly, cob length was significantly influenced by the types of manures and blended compost (C_3) produced significantly lengthier cobs in 2022 (19.32 cm), 2023 (22.42 cm) and in pooled means (20.87 cm). The cobs were smaller with farm compost (C_1) (17.15, 20.23 and 18.69 cm) which was on par with city compost (C_2) (15.56, 20.95 and 19.35 cm). This might be due to higher availability of nutrients from the composts and inorganic fertilizers up to cob formation (Mohsin *et al.* 2012).

The rate of manure application also had a significant influence on cob length. Among the rates of application, significantly longer cobs (18.45, 21.60 and 20.02 cm) were noticed in treatments with 125% RDM (D_1) which was on par with 100 % RDM (D_2) (18.17, 21.32 and 19.74 cm). The shortest cobs (17.60, 20.68 and 19.14 cm) were noticed in 75% RDM (D_3). Parallel to the present study, Bhat *et al.* (2013) inferred that applying composts at rates ranging from 10 to 30 t ha^{-1} resulted in a consistent increase in cob length.

In the interaction effect, during *kharif* 2022, significantly longer cobs (22.37 cm) were noticed in treatment surface manuring with blended compost at 125% RDM ($M_1C_3D_1$) which was on par with surface manuring with blended compost at 100% RDM ($M_1C_3D_2$) (21.61 cm). During *kharif* 2023 and in the

TABLE 4

Influence of manuring practices on cob length and cob girth of maize

Treatments	Cob length (cm)			Cob girth (cm)		
	2022	2023	Pooled	2022	2023	Pooled
Method of manuring (M)						
M_1-Surface manuring	19.08 ^{a}	19.47 ^{b}	19.27 ^{b}	16.81 ^{a}	17.13 ^{b}	16.97 ^{a}
M_2-Subsurface manuring	17.07 ^{b}	22.93 ^{a}	20.00 ^{a}	14.83 ^{b}	19.89 ^{a}	17.36 ^{a}
S.Em.±	0.13	0.06	0.08	0.24	0.15	0.14
Type of manure (C)						
C_1- Farm compost	17.15 ^{b}	20.23 ^{b}	18.69 ^{b}	15.16 ^{b}	17.78 ^{b}	16.47 ^{b}
C_2- City compost	17.75 ^{b}	20.95 ^{b}	19.35 ^{b}	15.56 ^{b}	18.41 ^{ab}	16.98 ^{ab}
C_3-Blended compost	19.32 ^{a}	22.42 ^{a}	20.87 ^{a}	16.75 ^{a}	19.35 ^{a}	18.05 ^{a}
S.Em.±	0.15	0.18	0.13	0.21	0.32	0.24
Rate of manure application (D)						
D_1-125% RDM	18.45 ^{a}	21.60 ^{a}	20.02 ^{a}	18.81 ^{a}	20.02 ^{a}	17.45 ^{a}
D_2-100% RDM	18.17 ^{ab}	21.32 ^{b}	19.74 ^{ab}	18.69 ^{b}	19.74 ^{ab}	17.35 ^{b}
D_3-75% RDM	17.60 ^{b}	20.68 ^{c}	19.14 ^{b}	18.04 ^{c}	19.14 ^{c}	16.71 ^{c}
S.Em.±	0.23	0.20	0.24	0.21	0.16	0.15
Interaction (M×C×D)						
$M_1C_1D_1$	18.15 ^{bcd}	19.41 ^{de}	18.78 $^{d-g}$	16.05 ^{bcd}	16.85 ^{h}	16.45 ^{d}
$M_1C_1D_2$	17.87 $^{b-e}$	19.12 ^{de}	18.50 ^{fg}	15.81 ^{bcde}	16.82 ^{h}	16.32 ^{d}
$M_1C_1D_3$	17.84 $^{b-e}$	18.34 ^{e}	18.09 ^{g}	15.2 ^{bcde}	15.36 ^{i}	15.28 ^{e}
$M_1C_2D_1$	18.25 ^{bcd}	19.44 ^{de}	18.85 $^{d-g}$	16.22 ^{bc}	16.95 ^{gh}	16.59 ^{d}
$M_1C_2D_2$	18.31 ^{bc}	19.45 ^{de}	18.88 $^{d-g}$	16.27 ^{b}	17.00 ^{gh}	16.64 ^{d}
$M_1C_2D_3$	18.52 ^{bc}	19.70 ^{de}	19.11 $^{d-g}$	16.28 ^{b}	17.08 ^{gh}	16.68 ^{d}
$M_1C_3D_1$	22.37 ^{a}	20.06 ^{cd}	21.21 ^{b}	19.61 ^{a}	18.54 ^{def}	19.08 ^{a}
$M_1C_3D_2$	21.61 ^{a}	19.92 ^{d}	20.77 ^{bc}	19.57 ^{a}	18.22 ^{efg}	18.90 ^{a}
$M_1C_3D_3$	18.82 ^{b}	19.74 ^{de}	19.28 $^{d-g}$	16.31 ^{b}	17.37 ^{fgh}	16.84 ^{cd}
$M_2C_1D_1$	16.80 ^{def}	21.79 ^{b}	19.30 $^{d-g}$	14.67 ^{e}	19.52 $^{b-e}$	17.10 ^{bcd}
$M_2C_1D_2$	16.43 ^{ef}	21.40 ^{bc}	18.92 $^{d-g}$	14.58 ^{e}	19.49 $^{b-e}$	17.04 ^{cd}
$M_2C_1D_3$	15.80 ^{f}	21.30 ^{bc}	18.55 ^{efg}	14.65 ^{e}	18.63 $^{c-f}$	16.64 ^{d}
$M_2C_2D_1$	17.08 $^{c-f}$	22.31 ^{b}	19.70 $^{c-f}$	14.79 ^{de}	19.73 ^{bcd}	17.26 ^{bcd}
$M_2C_2D_2$	17.17 $^{c-f}$	22.35 ^{b}	19.76 ^{cde}	14.89 ^{cde}	19.83 ^{bcd}	17.36 ^{bcd}
$M_2C_2D_3$	17.19 $^{c-f}$	22.43 ^{b}	19.81 ^{cd}	14.89 ^{cde}	19.87 ^{bcd}	17.38 ^{bcd}
$M_2C_3D_1$	18.06 ^{bcd}	26.57 ^{a}	22.32 ^{a}	15.13 ^{bcde}	21.30 ^{a}	18.22 ^{ab}
$M_2C_3D_2$	17.64 $^{b-e}$	25.64 ^{a}	21.64 ^{ab}	14.92 ^{cde}	20.77 ^{ab}	17.84 ^{bc}
$M_2C_3D_3$	17.43 $^{b-e}$	22.58 ^{b}	20.00 ^{cd}	14.97 ^{bcde}	19.91 ^{bc}	17.44 ^{bcd}
S.Em.±	0.57	0.59	0.40	0.49	0.51	0.36
Absolute control	13.36	15.59	14.47	13.08	13.88	13.48

Note : Means followed by the same letter (s) within a column are not significantly different by DMRT (p=0.05)

pooled analysis, significantly longer cobs (26.57 and 22.32 cm, respectively) were measured in treatment combination subsurface manuring with blended compost at 125% RDM ($M_2C_3D_1$) which was on par with subsurface manuring with blended compost at 100% RDM ($M_2C_3D_2$) (26.57 and 25.64 cm, respectively). Significantly shorter cobs were noticed in absolute control during both the years (13.36 and 15.59 cm, respectively) and in pooled means (14.47 cm). The beneficial effects of combining compost and subsurface manuring in increasing yield attributes have been documented by Majumder *et al.* (2016) in maize and Hamna (2021) in pigeon pea.

Cob Girth (cm)

Cob girth influenced by different manuring practices are shown in Table 4. Methods of manuring showed substantial variation for cob girthin both the years of experimentation and pooled means. Among the methods, surface manured plots (M_1) obtained significantly wider cob girth (16.81 cm) during 2022, whereas in 2023 and pooled means subsurface manured plots (M_2) obtained wider cob girth (19.89 and 17.36 cm, respectively). Similarly, types of manures also showed considerable effects on cob girth. Blended compost (C_3) recorded significantly wider cob girth (16.75, 19.35 and 18.05 cm) and was comparable to city compost (C_2). The smaller cob girth was recorded in farm compost (C_1) (15.16, 17.78 and 16.47 cm) in 2022, 2023 and pooled means, respectively which was on par with city compost. Increase in yield attributes due to combined effect of manures were reported by Raj *et al.* (2023) in maize.

The rate of manure application showed significant variation with cob girth, as a result, cob girth increased with increasing the rate of manure application. Significantly larger cob girth (18.81, 20.02 and 17.45 cm) was noticed in treatments with 125% RDM (D_1) followed by 100% RDM (D_2) and lowest in 75% RDM (D_3) (18.04, 19.14 and 16.71 cm) in 2022, 2023 and pooled means, respectively.

In the interaction, during *kharif* 2022, significantly larger cob girth (19.61 cm) was in treatment combination surface manuring with blended compost at 125% RDM ($M_1C_3D_1$) which was on par with surface manuring with blended compost at 100% RDM ($M_1C_3D_2$) (19.57 cm). During *kharif* 2023, significantly larger cob girth (21.30 cm) was measured in combination subsurface manuring with blended compost at 125% RDM ($M_2C_3D_1$) which was on par with subsurface manuring with blended compost at 100% RDM ($M_2C_3D_2$) (20.77 cm). Significantly lower cob girths were noticed in absolute control during both the years and pooled means (13.08, 13.88 and 13.48 cm, respectively). Similarly, Hamna (2021) reported that the residual effects of organically amended sheep and poultry manure improved nutrient availability in subsoil-manured plots and improved the yield components such as cob girth.

Grain Yield (t ha^{-1})

The influence of different manuring practices on grain yield, as shown in Table 5, revealed that grain yield was significantly differed by manuring methods in both the observation years and the combined means. Comparing the methods of application, surface manuring (M_1) produced significantly superior grain yield during 2022 (7.68 t ha^{-1}), out performing subsurface manuring by 19.62 per cent. However, in 2023, subsurface manuring (M_2) out performed surface manuring (M_1) by 26.00 per cent with a grain yield of 9.74 t ha^{-1} and also achieved the highest pooled average of 8.08 t ha^{-1} (4.93%) which was in line with the findings of Sale *et al.* (2018), they demonstrated consistent yield improvements in the second and third years following the initiation of subsoil manuring in wheat and canola between 2009 and 2012.

Similarly, grain yield was significantly influenced by the types of manures applied. Throughout the experimentation *i.e.,* 2022, 2023 and pooled means, blended compost (C_3) recorded significantly higher grain yield (7.80, 9.16 and 8.48 t ha^{-1}, respectively) followed by city compost (C_2) (7.20, 8.78 and 7.99 t ha^{-1}, respectively) and lowest in farm compost (C_1) (6.16, 8.26 and 7.21 t ha^{-1}). City and blended composts due to their low C: N ratio exert their

TABLE 5

Influence of manuring practices on grain and stover yield of maize

Treatments	Grain yield (t ha^{-1})			Stover yield (t ha^{-1})		
	2022	2023	Pooled	2022	2023	Pooled
Method of manuring (M)						
M_1-Surface manuring	7.68^{a}	7.73^{b}	7.70^{b}	12.46^{a}	12.19^{b}	13.27^{a}
M_2-Subsurface manuring	6.42^{b}	9.74^{a}	8.08^{a}	10.59^{b}	16.32^{a}	13.76^{a}
S.Em.±	0.06	0.06	0.05	0.22	0.28	0.14
Type of manure (C)						
C_1- Farm compost	6.16^{c}	8.26^{c}	7.21^{c}	10.60^{b}	13.02^{c}	12.64^{b}
C_2- City compost	7.20^{b}	8.78^{b}	7.99^{b}	11.66^{a}	14.37^{b}	13.60^{ab}
C_3-Blended compost	7.80^{a}	9.16^{a}	8.48^{a}	12.31^{a}	15.37^{a}	14.31^{a}
S.Em.±	0.13	0.08	0.07	0.15	0.17	0.23
Rate of manure application (D)						
D_1-125% RDM	7.25^{a}	8.97^{a}	8.11^{a}	11.77^{a}	14.74^{a}	13.81^{a}
D_2-100% RDM	7.15^{a}	8.73^{a}	7.94^{a}	11.56^{a}	14.31^{a}	13.60^{a}
D_3-75% RDM	6.75^{b}	8.49^{b}	7.62^{b}	11.24^{a}	13.72^{b}	13.13^{b}
S.Em.±	0.07	0.09	0.07	0.11	0.18	0.10
Interaction (M×C×D)						
$M_1C_1D_1$	6.94^{cd}	8.20^{c}	7.57^{def}	11.51^{c}	12.07^{e}	12.79^{ef}
$M_1C_1D_2$	6.73^{cde}	7.23^{d}	6.98^{f}	11.29^{c}	11.97^{e}	12.63^{f}
$M_1C_1D_3$	6.38^{def}	6.15^{e}	6.27^{g}	10.99^{cd}	9.91^{f}	10.95^{g}
$M_1C_2D_1$	7.81^{b}	7.85^{cd}	7.83^{b-e}	12.52^{b}	12.41^{e}	13.47^{c-f}
$M_1C_2D_2$	7.83^{b}	7.87^{cd}	7.85^{b-e}	12.54^{b}	12.32^{e}	13.43^{c-f}
$M_1C_2D_3$	7.88^{b}	7.93^{cd}	7.90^{bcd}	12.62^{b}	12.14^{e}	13.38^{def}
$M_1C_3D_1$	8.95^{a}	8.20^{c}	8.57^{ab}	14.13^{a}	13.15^{e}	14.64^{ab}
$M_1C_3D_2$	8.68^{a}	8.15^{c}	8.41^{abc}	13.81^{a}	12.97^{e}	14.39^{abc}
$M_1C_3D_3$	7.89^{b}	7.94^{cd}	7.92^{bcd}	12.70^{b}	12.78^{e}	13.74^{b-e}
$M_2C_1D_1$	5.95^{ef}	9.45^{b}	7.70^{c-f}	10.23^{de}	15.25^{cd}	13.40^{def}
$M_2C_1D_2$	5.92^{f}	9.33^{b}	7.62^{c-f}	10.08^{de}	14.67^{d}	13.21^{def}
$M_2C_1D_3$	5.01^{g}	9.22^{b}	7.11^{ef}	9.53^{e}	14.27^{d}	12.83^{ef}
$M_2C_2D_1$	6.43^{def}	9.54^{b}	7.99^{bcd}	10.73^{cd}	16.35^{bc}	13.71^{b-e}
$M_2C_2D_2$	6.68^{c-f}	9.63^{b}	8.15^{bcd}	10.76^{cd}	16.43^{b}	13.76^{b-e}
$M_2C_2D_3$	6.57^{def}	9.84^{ab}	8.20^{bcd}	10.78^{cd}	16.55^{b}	13.84^{bcd}
$M_2C_3D_1$	7.45^{bc}	10.61^{a}	9.03^{a}	11.49^{c}	19.19^{a}	14.87^{a}
$M_2C_3D_2$	7.05^{cd}	10.17^{ab}	8.61^{ab}	10.91^{cd}	17.46^{b}	14.19^{a-d}
$M_2C_3D_3$	6.76^{cd}	9.87^{ab}	8.32^{a-d}	10.82^{cd}	16.65^{b}	14.05^{a-d}
S.Em.±	0.18	0.23	0.17	0.27	0.45	0.26
Absolute control	4.05	4.85	4.45	8.17	8.56	8.37

Note : Means followed by the same letter(s) within a column are not significantly different by DMRT (p=0.05) maximum effect on soil more quickly, while farm compost due to a high C: N ratio might have taken a longer period to reach its full effect. As a result, the nutrient supply was more with the city and blended composts, resulted in increased uptake of nutrients, better translocation of photosynthates from source to sink and higher grain yield (Babu *et al.* 2020).

The rate of manure application showed significant variations with respect to grain yield. Among the different rates, significantly higher grain yield was noticed in treatments 125% RDM (D_1) (7.25, 8.97 and 8.11t ha^{-1} respectively) followed by 100% RDM (D_2) (7.15, 8.73 and 7.94 t ha^{-1} respectively) and lowest in 75% RDM (D_3) (6.16, 8.26 and7.21 t ha^{-1}, respectively). The higher grain yield with an increased rate of manure application might be attributed to improved growth and yield attributes of maize, including plant height, number ofleaves, leaf area, dry matter production, cob length, cob girth, number of kernels per row and grain weight. In the interaction, during *kharif* 2022, significantly higher grain yield was recorded in treatment combination surface manuring with blended compost at 125% RDM ($M_1C_3D_1$) (8.95 t ha^{-1}) which was on par with surface manuring with blended compost at 100% RDM ($M_1C_3D_2$) (8.68 t ha^{-1}). During *kharif* 2023 and pooled analysis, significantly higher grain yield was measured in treatment combination subsurface manuring with blended compost at 125% RDM ($M_2C_3D_1$) (10.61 and 9.03 t ha^{-1}) which was on par with subsurface manuring with blended compost at 100% RDM ($M_2C_3D_2$) (10.17 and 8.61 t ha^{-1}). Significantly lower grain yield was noticed in absolute control during both the years and in pooled means (4.05, 4.85 and 4.45 t ha^{-1} respectively). The results were in corroboration with the findings of Majumder *et al.* (2016) in spring maize.

Stover Yield (t ha^{-1})

Comparing the methods, surface manuring (M_1) yielded significantly superior stover yield during 2022 (12.46 t ha^{-1}), whereas sub-surface manuring (M_2) yielded significantly higher stover yield in 2023 (12.19 t ha^{-1}) and pooled means (13.76 t ha^{-1}). The present results align with the findings of Reiman *et al.* (2009), they revealed that deep injection of manures at 45 cm depth enhanced the stover yield in maize.

Similarly, stover yield was significantly influenced by the types of manures applied. Throughout the experimentation, blended compost (C_3) recorded significantly higher stover yield (12.31, 15.37 and 14.31 t ha^{-1}, respectively) followed by city compost (C_2) (11.66, 14.37 and 13.60 t ha^{-1}, respectively) and lowest in farm compost (C_1) (10.60, 13.02 and 12.64 t ha^{-1}, respectively). This could be attributed to the increased leaf and stem dry matter production per plant, resulting from consistent supply of nutrients throughout the growth period.

Among the rates of manure application, significantly higher stover yield was noticed in treatments 125% RDM (D_1) (11.77, 14.74 and 13.81 t ha^{-1}) followed by 100% RDM (D_2) (11.56, 14.31 and 13.60 t ha^{-1}) and lowest in 75% RDM (D_3) (11.24, 13.72 and 13.13 t ha^{-1}). Similar results were also reported by Singh *et al*. (2023).

In the interaction, during *kharif* 2022, significantly higher stover yield was recorded in treatment combination surface manuring with blended compost at 125% RDM ($M_1C_3D_1$) (14.13 t ha^{-1}) which was on par with surface manuring with blended compost at 100% RDM ($M_1C_3D_2$) (13.81 t ha^{-1}), followed by rest of treatment combinations. During *kharif* 2023 and pooled analysis, stover yield was significantly higher insubsurface manuring with blended compost at 125% RDM ($M_2C_3D_1$) (19.19 and 14.87 t ha^{-1}, respectively). Significantly lower stover yields were in absolute control (8.17, 8.56 and 8.37 t ha^{-1} respectively). These findings are consistent with studies reported by Majumder *et al.* (2016) and Sale *et al.* (2018) in wheat.

The outcomes of present study showed that the growth and yield were influenced by the methods, type and rate of manure application. The combination of subsurface manuring with blended compost at 125% RDM has recorded higher growth and yield attributes such as plant height, number of leaves plant^{-1}, leaf area, dry matter production, cob length, cob girth and stover yield. Similarly, combination of subsurface manuring with blended compost at 125% RDM recorded higher grain yield (9.03 t ha^{-1}) which was on par with subsurface manuring with blended compost at 100% RDM (8.61 t ha^{-1}). Hence the study revealed that subsurface manuring with blended compost at 125% RDM could be the best alternative to enhance maize productivity.

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