# EFFECT OF TILLAGE, CROP RESIDUE MANAGEMENT AND NUTRIENT LEVELS ON ENERGETICS, MICROBIAL GROWTH, DEHYDROGENASE ACTIVITY, WEED PARAMETERS, QUALITY PARAMETERS AND SOIL PHYSICO-CHEMICAL PROPERTIES OF MAIZE (*Zea mays* L.)


## ABSTRACT

The field experiment on "Effect of tillage, crop residue management and nutrient levels on energetics, microbial growth, dehydrogenase activity, weed parameters, quality parameters and soil physico-chemical properties of maize (*Zea mays* L.)" was conducted during *rabi* season of 2022-23 at Maize Research Centre, Professor Jayashankar Telangana State Agriculture University, Agricultural Research Institute, Rajendranagar, Hyderabad, Telangana. The experiment comprised of 12 treatment combinations laid out in a split–plot design with three replications. The main–plot treatments included four different tillage practices:$M_1$-Conventional tillage (Plough + Cultivator + Rotovator), $M_2$-Residue incorporation (After 10 days of spreading the haulms, only rotovator was run), $M_3$- Residue incorporation (After spreading the haulms, microbial consortium was sprayed and after 10 days only rotovator was run) and $M_4$- Zero-tillage (Only microbial consortium was sprayed on the haulms). Sub–plot treatments included three nutrient levels: $N_1$- 100% RDF (240-80-80 N-$P_2O_5$-$K_2O$ kg $ha^{-1}$), $N_2$: 100% RDN & P and 50% RDK (240-80-40 N-$P_2O_5$-$K_2O$ kg $ha^{-1}$), and $N_3$: 87.5% of RDN, 75% RDP and 75% RDK (210-60-60 N-$P_2O_5$-$K_2O$ kg $ha^{-1}$). Results revealed that, among the tillage practices, residue incorporation ($M_3$) had recorded significantly higher total microbial population, dehydrogenase activity and post-harvest soil available NPK of maize and lowest weed density and weed dry matter and it was on par with zero-tillage ($M_4$) whereas all the parameters were significantly lower in conventional tillage ($M_1$). However, Energy indices *viz*., energy use efficiency, specific energy, net energy, energy productivity, energy intensiveness was found to be the best in $M_1$ -conventional tillage. Among the different nutrient levels, $N_1$ (100% RDF) had shown significantly higher total microbial population, dehydrogenase activity and post-harvest soil available NPK of maize. Energy indices *viz*., energy use efficiency, specific energy, net energy and energy productivity was found to be the best in $N_1$- 100% RDF. Whereas energy intensiveness was found to be best with $N_3$- 87.5% of RDN, 75% RDP and 75% RDK. However, energy indices like energy use efficiency, energy productivity and energy intensiveness indicated non-significant effect of different nutrient levels. Tillage as well as nutrient levels did not exert any significant effect on moisture content and bulk density at sowing, tasselling & silking and at harvest stages. Similar results were followed with quality parameters. The interaction effect due to tillage and nutrient levels on soil microbial studies, enzymatic activity, weed parameters, quality parameters, soil physico-chemical parameters, and energy indices was found non-significant.

Key words: - Maize; microbial consortium; nutrient levels; residue incorporation; tillage.

## 1. INTRODUCTION

In India, maize (*Zea mays* L.) holds the position of being the third most significant cereal crop, following rice and wheat. It is cultivated across a wide spectrum of environments and holds tremendous promise in terms of bolstering food and feed supplies, nutritional security, and the potential to increase farmers income twofold. Maize distinguishes itself as a crop that requires less water, and when compared to paddy cultivation, it can result in substantial savings of up to 90% in water usage and 70% in power consumption (Maize outlook report–April,2023).

The area under maize in India accounts to 10.04 M ha with a production and productivity of 33.62 MMT & 3349 kg $ha^{-1}$ respectively and contributed to 9% in national food basket (Directorate of Economics and Statistics, GOI 2022).

The conventional methods of crop production have led to a significant rise in production costs and energy consumption due to excessive tillage and the indiscriminate use of nitrogen fertilizers. In the context of agriculture, the availability of energy remains and will continue to be a crucial cornerstone to ensure sustainable and dependable food production. Moreover, effective management of both nitrogen and energy is of paramount importance for researchers, as they must carefully address these concerns to reduce the cost of these resources without negatively impacting agricultural productivity. It's worth noting that by employing the right amount of energy inputs, the yield of various crops can potentially increase up to 30% by using optimal level of energy inputs (Chaudhary *et al*., 2006).

Sustainable management of agricultural wastes is a significant concern worldwide, particularly in emerging countries like India with a growing population, production rate, and economy (Agoramoorthy *et al*., 2008). India, in particular, generates over 500 million tons of crop residues annually (Gupta *et al*., 2012).

Burning of crop residues causes the air pollution and lead to loss of soil biota, huge biomass, organic carbon and plant nutrients. An estimated 80-90% of nitrogen (N), 25% of phosphorus (P), 20% of potassium (K), and 50% of sulfur (S) contained in crop residues are released as various gaseous and particulate matter forms, leading to atmospheric pollution and contributing to global warming (Kaur *et al*., 2019).

Crop residue management under the ZT system significantly influences soil physicochemical and biological properties (Rakesh *et al*., 2021b).

According to Rashidi and Keshavarzpour (2007), CT results in a looser and finer soil structure compared to zero-tillage and produces less water flow into the soil profile, which reduces nitrate leaching.

In addition to raising TOC and its various pools, organic additions also speed up soil microbial activity, which raises the levels of microbial biomass carbon (MBC), microbial biomass nitrogen (MBN), soil enzymatic activity, and ultimately soil quality (Melero *et al*., 2008; Sharma *et al*., 2020).

In a long-term experiment with different nutrient management practices in a maize–onion cropping system, enzymatic activities (dehydrogenase, acid phosphatase, and alkaline phosphatase) in soil were increased with organic nutrient management compared to the chemical fertilizer application (Sridevi *et al*., 2011).

A potential strategy for restoring soil fertility, enhancing physico-chemical characteristics, and maintaining crop yields is recycling agricultural leftovers in the soil (Choudhary *et al*., 2019). However, additional resources like water, nutrients, and bio-inoculum are needed to promote agricultural waste decomposition when it occurs in situ (Thakur *et al*., 2019). Legumes are among the agricultural leftovers that contribute to sustainability because they improve soil fertility, boost system productivity, and generate financial rewards (Dhakal *et al*., 2016).

Maize being an exhaustive crop has very high nutrient demand and its productivity primarily rely upon nutrient management systems. A better physical, chemical, and microbiological environment may boost crop production per unit of applied nutrients. This is crucial given the current energy crisis, high fertilizer costs, and limited purchasing power of the agricultural community (Singh *et al*., 2019).

The incorporation of leguminous crop residues like soybean, cowpea, and chickpea has been demonstrated to enhance soil physical attributes such as water-holding capacity and soil permeability. Furthermore, the inclusion of leguminous crop residues has been found to boost crop growth and productivity by increasing the nutrient availability in the root zone for subsequent cereals like maize and sorghum (Sarkar *et al.,* 2020).

In the current study, our goal was to evaluate whether the tillage, crop residue management and nutrient levels could improve the energetics, microbial growth, dehydrogenase activity, weed parameters, quality parameters and soil physico-chemical properties of maize.

## 2. MATERIAL AND METHODS

This experiment was conducted at Agricultural Research Institute (ARI), Maize Research Centre, Professor Jayashankar Telangana State Agriculture University, Rajendranagar, Hyderabad, Telangana during *rabi*, 2022-23. The experimental site was geographically located at 17° 3’ N latitude,78° 39’ E longitude and an altitude of 494 m above mean sea level (MSL) and 1 km away from IIMR (Indian Institute of Millets Research). According to Troll’s climatic classification, it falls under Semi- Arid Tropical region (SAT). The experimental site was in Southern Telangana Argo-Climatic Zone. The experiment comprised of 12 treatment combinations laid out in a split–plot design with three replications. The main-plot treatments included four different tillage and residue management practices (residue used was soybean haulm): $M_1$-Conventional tillage (Plough + Cultivator + Rotovator), $M_2$- Residue incorporation (After 10 days of spreading the haulms, only rotovator was run), $M_3$- Residue incorporation (After spreading the haulms, microbial consortium was sprayed and after 10 days, only rotovator was run) and $M_4$- Zero-tillage (Only microbial consortium was sprayed on the haulms). Microbial consortium developed by PJTSAU was used which comprises of *Trichoderma viridae*, *Phenerochaeta chrysosprium* and *Aspergillus niger* @ 2% spray to the weight of added residue. Sub-plot treatments included three nutrient levels: $N_1$- 100% RDF (240-80-80 N-$P_2O_5$-$K_2O$ kg $ha^{-1}$), $N_2$: 100% RDN & P and 50% RDK (240-80-40 N-$P_2O_5$-$K_2O$ kg $ha^{-1}$), and $N_3$: 87.5% of RDN, 75% RDP and 75% RDK (210-60-60 N-$P_2O_5$-$K_2O$ kg $ha^{-1}$). Recommended nitrogen was applied to the maize crop in three (3) splits at the time of sowing (basal), knee high and flowering stages in the form of urea as per treatments. Recommended phosphorus (80 kg $P_2O_5$ $ha^{-1}$) was applied in single dose at the time of sowing in the form of SSP as per the treatments and recommended potassium (80 kg $K_2O$ $ha^{-1}$) was applied to maize crop in two (2) splits at the time of sowing(basal) and flowering stages in the form of muriate of potash as per treatments. Soil type of the experimental site was vertisol. The soil of the experimental site was medium clay loam, slightly alkaline, low in organic carbon and nitrogen, high in available phosphorus and potassium. The maize hybrid DHM-121 was sown on 15$^{th}$ November 2022 with a seed rate of 20 kg ha$^{-1}$ Spacing used was 60×20 cm. The climate of the experimental region is semi-arid (dry). The weekly mean maximum temperature ranged from 27.4°C to 33.9°C, with an average of 30.8°C, throughout the crop growth period, while the weekly mean minimum temperature ranged from 11.2°C to 18.9°C, with an average of 15.1°C. In terms of relative humidity, the weekly mean RH-I (morning) ranged from 74.6% to 97.1%, with an average of 84%, while the RH-II (afternoon) ranged from 17.4% to 63.9%, with an average of 36.6%. Using the USWB Class - A open pan evaporimeter, the weekly mean bright sunshine hours per day ranged from 3.6 to 10.1 hours, with an average of 7.6 hours. Weekly mean evaporation ranged from 2.3 to 5.3 mm per day, with an average of 3.7 mm per day. The wind speed stretched from 2.0 to 4.1 km hr$^{-1}$. No rainfall was observed during the crop growth period. The effect of tillage, crop residue management and nutrient levels on energetics, microbial growth, dehydrogenase activity and soil physico-chemical properties of maize (*Zea mays* L.) has been recorded.

## RESULTS AND DISCUSSION

The important findings and the influence made from the investigation are as follows:

### Energy indices

Among the various tillage treatments, $M_1$ -conventional tillage exhibited significantly higher energy use efficiency (11.09 %) (Table 1). Conversely, $M_3$ -residue incorporation along with microbial consortium spray exhibited markedly lower energy use efficiency (2.72 %). Higher energy use efficiency with conventional tillage was due to the higher energy output in terms of kernel and stover yield with low proportion of increase in energy input. Similar results were reported by Parihar *et al*. (2011). Among the various treatment combinations evaluated, $M_1$ -conventional tillage exhibited significantly elevated net energy (219956 MJ ha$^{-1}$). However, significantly lowest net energy was with $M_2$ -Residue incorporation, only rotovator was run (157369 MJ ha$^{-1}$). due to higher energy equivalent for conventional tillage and the lower energy equivalent in residue incorporation. Similar results were reported by Parihar *et al*. (2011). $M_3$ -residue incorporation along with microbial consortium spray achieved significantly higher energy productivity (4.98 MJ kg$^{-1}$) and it exhibited comparable results with $M_4$ -zero tillage (4.96 MJ kg$^{-1}$). Conversely, $M_1$ -

conventional tillage exhibited markedly lower energy productivity (1.22 MJ $kg^{-1}$). Energy productivity is related to yield and input, in residue incorporation along with microbial consortium spray higher yields along with lower total input energy led to higher energy productivity. Similar results were reported by others (Banerjee *et al.*, 2006; Meena and Biswas, 2014). $M_3$ -residue incorporation along with microbial consortium spray achieved significantly higher energy intensiveness (1.41 MJ $Rs^{-1}$) and it exhibited comparable results with $M_4$ -zero tillage (1.41 MJ $Rs^{-1}$). Conversely, $M_1$ -conventional tillage exhibited markedly lower energy intensiveness (0.30 MJ $Rs^{-1}$). This was due to higher energy output in terms of seed and stover as compared to corresponding conventional tillage. Similar results were reported by Parihar *et al*. (2011).

With respect to energy indices, application of 87.5% of RDN, 75% RDP and 75% RDK ($N_3$) recorded significantly highest specific energy (8.96 MJ $kg^{-1}$) whereas significantly lowest specific energy was with $N_1$- 100% RDF (8.31 MJ $kg^{-1}$). This infers that 100% RDF application of chemical fertilizers increased the energy use for producing per unit seed yield. Similar results were reported by Deva and Kolhe, 2018b. Application of 100% RDF ($N_1$) resulted significantly highest net energy (186674 MJ $ha^{-1}$), whereas significantly lowest net energy was recorded with $N_3$- 87.5% of RDN, 75% RDP and 75% RDK (163509 MJ $ha^{-1}$). owing to higher energy equivalent for 100% RDF and lower energy equivalent under lower nutrient levels. Similar results were reported by Deva and Kolhe, 2018b.

Energy indices like energy use efficiency, energy productivity and energy intensiveness were non-significant due to different nutrient levels. Similar results were reported by (Meena *et al*. 2015; Karunakaran and Behera, 2013).

The interaction effect due to tillage and nutrient levels on energy indices was found non- significant.

## Microbial population and Dehydrogenase activity

Total microbial population of bacteria, fungi and actinomycetes (74.9, 67.4 and 64.3 CFU x $10^6$ $g^{-1}$ respectively) (Table 2) after harvesting and dehydrogenase activity (64.0 and 42.1 µg TPF $g^{-1}$ $day^{-1}$ respectively) at tasselling & silking and at harvest stages (Table 3) were significantly higher with $M_3$-residue incorporation along with microbial consortium spray and it was statistically on par with $M_4$ -zero tillage microbial population of bacteria, fungi and actinomycetes (71.1, 62.4 and 60.1 CFU x $10^6$ $g^{-1}$ respectively) and dehydrogenase activity (57.7 and 36.3 µg TPF $g^{-1}$ $day^{-1}$ respectively). Conversely, treatment $M_1$ -

conventional tillage exhibited markedly lower microbial population of bacteria, fungi and actinomycetes (53.6, 41.7 and 40.9 CFU x $10^6$ $g^{-1}$ respectively) and dehydrogenase activity (52.9 and 29.5 µg TPF $g^{-1}$ $day^{-1}$ respectively). Higher microbial population in plots consisting of incorporation of soybean residue along with microbial consortium spray was due to the establishment and secretion of polysaccharides by inoculated microbial species that enhanced the multiplication of indigenous soil microbial population and lower microbial activity in comparison to plots without addition of residue and microbial consortia. Kukreja *et al*. (1991) also reported significant increase in microbial population with residue incorporation and microbial consortia. Higher microbiological activity as a consequence of increased microbial population with addition of biomass carbon in the form of crop residues lead to higher dehydrogenase activity in soil under residue addition. Similar results were reported by Diekow *et al*. (2005).

Application of 87.5% of RDN, 75% RDP and 75% RDK i.e., ($N_3$) achieved significantly higher microbial population of bacteria, fungi and actinomycetes (67.4, 58.3 and 55.9 CFU x $10^6$ $g^{-1}$ respectively) and dehydrogenase activity (54.8 and 38.2 µg TPF $g^{-1}$ $day^{-1}$ respectively) and it was comparable with $N_2$-100% RDN & P and 50% RDK microbial population of bacteria, fungi and actinomycetes (65.8, 56.4 and 53.2 CFU x $10^6$ $g^{-1}$ respectively) and dehydrogenase activity (52.3 and 36.7 µg TPF $g^{-1}$ $day^{-1}$ respectively). Conversely, treatment $N_1$- 100% RDF exhibited markedly lower microbial population of bacteria, fungi and actinomycetes (64.3, 54.5 and 51.7 CFU x $10^6$ $g^{-1}$ respectively) and dehydrogenase activity (51.3 and 35.1 µg TPF $g^{-1}$ $day^{-1}$ respectively). Higher microbial count at lower nutrient levels was due to the fact that the microbial communities become more active in search of limited nutrients like nitrogen and phosphorus. In nutrient-poor environments, microbes may multiply to access and compete for available nutrients, contributing to higher microbial population. These findings were similar with those reported by Kukreja *et al*. (1991)

**Weed parameters**

Weed parameters (weed density and weed dry matter) at 30 and 60 DAS and at harvest were significantly higher (6.5, 7.2 and 5.6 No. $m^{-2}$ and 6.3, 6.8 and 5.5 g $m^{-2}$ respectively) with M1 - conventional tillage (Table 4). However, significantly lowest weed density and weed dry matter (5.6, 6.4 and 4.7 No. $m^{-2}$ and, 5.7, 6.2 and 4.8 g $m^{-2}$ respectively) were with M3- residue incorporation along with microbial consortium spray and it was on par with M4 -zero tillage.

Application of 100% RDF (N1) recorded significantly highest weed density (6.2, 7.0 and 5.3 No. $m^{-2}$ respectively) and weed dry matter (6.4, 7.1 and 5.6 g $m^{-2}$ respectively) and it was on par with N2- 100% RDN & P and 50% RDK (6.0, 6.8 and 5.1 No. $m^{-2}$ respectively) and weed dry matter (6.1, 6.7 and 5.3 g $m^{-2}$ respectively). However, significantly lowest weed density was with N3- 87.5% of RDN, 75% RDP and 75% RDK (5.8, 6.6 and 4.9 No. $m^{-2}$ respectively) and weed dry matter (6.0, 6.6 and 5.1 g $m^{-2}$ respectively). Similar results on lower weed density with residue incorporation were reported by Pratibha *et al.* (2021).

**Quality parameters**

Data pertaining to crude protein content (%) and protein yield (kg $ha^{-1}$) as influenced by tillage and nutrient levels is presented in Table 5. Tillage as well as nutrient levels did not exert any significant effect on crude protein content and protein yield in maize kernel and stover. The interaction between tillage and nutrient levels was also found non-significant on crude protein content and protein yield in maize kernel and stover which can be attributed to balanced nutrient levels, resilient maize root systems and complex interactions in soil ecosystems. It's worth noting that these results may be influenced by specific soil conditions, nutrient ratios, and the developmental stages of the crops. Similar results were reported by (Kumar *et al*. 2015; Wafula *et al*. 2021).

## SOIL PHYSICO-CHEMICAL PROPERTIES

**Moisture content (%)**

Data pertaining to moisture content (%) as influenced by tillage and nutrient levels is presented in Table 6. Tillage as well as nutrient levels did not exert any significant effect on moisture content at sowing, tasselling & silking and at harvest stages. The interaction between tillage and nutrient levels was also found non-significant on moisture content. Variability in soil moisture content across locations, soil types and climatic conditions can mask the effects of tillage and nutrient levels. Similar results were also reported by Tesfahunegn, (2019).

**Bulk density (g $cc^{-1}$)**

Data pertaining to bulk density (g $cc^{-1}$) as influenced by tillage and nutrient levels is presented in Table 6. Soil bulk density at sowing, tasselling & silking and at harvest stages, did not differ significantly in response to tillage and nutrient levels. Interaction of tillage and nutrient levels also did not show any significant influence on soil bulk density. Bulk density is an indicator of soil compactness which varies with the management practices. However, this variation is to a very small extent and does not change drastically with any management practices.Similar results were also reported by Pant and Ram, (2018).

**Post harvest soil pH, EC and OC (%)**

Data pertaining to post harvest soil pH, EC ($dSm^{-1}$) and OC (%) as influenced by tillage and nutrient levels is presented in Table 7. Indicates that post-harvest soil pH, EC ($dSm^{-1}$) and OC (%) were not significantly influenced by tillage and nutrient levels as well as due to their interaction. This was due to the fact that soil buffering capacity resisted the changes in short term management system. Similar results of non-significant effect on post-harvest soil properties were reported by Kumar *et al*. (2015) and Bhakthi *et al*. (2021).

**Post-harvest soil available N, $P_2O_5$ and $K_2O$ (kg $ha^{-1}$)**

Among the tillage practices, $M_3$ -residue incorporation along with microbial consortium spray recorded significantly higher post-harvest soil available N, $P_2O_5$ and $K_2O$ (231, 83 and 325 kg $ha^{-1}$ respectively) (Table 8) and it was on par with $M_4$ -zero tillage (228, 81 and 323 kg $ha^{-1}$ respectively) and $M_2$ -Residue incorporation, only rotovator was run (227, 80 and 321 kg $ha^{-1}$ respectively). However, significantly lowest post-harvest soil available N, $P_2O_5$ and $K_2O$ was with $M_1$ -conventional tillage (220, 77 and 316 kg $ha^{-1}$ respectively). Similar results on higher nutrient availability with higher dose of fertilizer along with microbial inoculants compared to lower dose were reported by Yadav, (2020) and Singh *et al*. (2019).

Application of 100% RDF ($N_1$) recorded significantly higher post-harvest soil available N, $P_2O_5$ and $K_2O$ (239, 91 and 352 kg $ha^{-1}$ respectively) and it was on par with $N_2$-100% RDN & P and 50% RDK (234, 88 and 293 kg $ha^{-1}$ respectively), whereas, significantly lowest post-harvest soil available N, $P_2O_5$ and $K_2O$ was recorded with $N_3$- 87.5% of RDN, 75% RDP and 75% RDK (206, 78 and 323 kg $ha^{-1}$ respectively). These results are in line with Kumar *et al*. (2019) and Singh *et al*. (2010).

**conclusion**

1. Residue incorporation (M3) and zero-tillage (M4) showed significantly higher total microbial population, dehydrogenase activity, and post-harvest soil available NPK levels in maize when compared to conventional tillage (M1). However, conventional

tillage (M1) demonstrated superior energy indices, such as energy use efficiency, specific energy, net energy, and energy productivity.

2. Nutrient level N1 (100% RDF) resulted in significantly higher total microbial population, dehydrogenase activity, and post-harvest soil available NPK levels of maize. Similarly, N1 exhibited superior energy indices, except for energy intensiveness, where N3 (87.5% of RDN, 75% RDP, and 75% RDK) was the best.
3. Moisture Content and Bulk Density: Neither tillage practices nor nutrient levels had a significant impact on moisture content and bulk density at various growth stages (sowing, tasselling & silking, and harvest).
4. Interaction Effect: The interaction between tillage practices and nutrient levels did not yield significant effects on soil microbial studies, enzymatic activity, weed parameters, quality parameters, soil physico-chemical parameters, and energy indices.

**Table 1 Energy indices as influenced by tillage and nutrient levels**

| **Treatments** | **Energy use efficiency (%)** | **Specific energy (MJ kg$^{-1}$)** | **Net energy (MJ ha$^{-1}$)** | **Energy productivity (MJ kg$^{-1}$)** | **Energy intensiveness (MJ Rs$^{-1}$)** |
|---|---|---|---|---|---|
| Main plots: **Tillage** | | | | | |
| **M$_1$**: Conventional tillage (Plough + Cultivator + Rotovator) | 11.09 | 2.61 | 219956 | 1.22 | 0.30 |
| **M$_2$**: Residue incorporation (Only rotovator was run) | 2.75 | 10.54 | 157369 | 4.92 | 1.32 |
| **M$_3$**: Residue incorporation (Only rotovator was run + Microbial consortium spray) | 2.72 | 10.60 | 168395 | 4.98 | 1.41 |

| | | | | | |
|---|---|---|---|---|---|
| **$M_4$**: Zero-tillage (Only microbial consortium was sprayed on the haulms) | 2.73 | 10.59 | 162830 | 4.96 | 1.41 |
| S.Em± | 0.05 | 0.11 | 2028 | 0.05 | 0.01 |
| CD (p=0.05) | 0.32 | 0.64 | 12340 | 0.30 | 0.05 |
| Sub plots: **Nutrient levels** | | | | | |
| **$N_1$:** 100% RDF | 4.88 | 8.31 | 186674 | 3.90 | 1.11 |
| **$N_2$:** 100% RDN & P and 50% RDK | 4.81 | 8.48 | 181230 | 3.98 | 1.13 |
| **$N_3$:** 87.5% of RDN, 75% RDP and 75% RDK | 4.78 | 8.96 | 163509 | 4.18 | 1.10 |
| S.Em± | 0.04 | 0.08 | 1013 | 0.09 | 0.02 |
| CD (p=0.05) | NS | 0.25 | 2989 | NS | NS |
| **Interaction** | | | | | |
| **Sub treatment at same level of main treatment** | | | | | |
| S.Em± | 0.07 | 0.18 | 2483 | 0.07 | 0.18 |
| CD (p=0.05) | NS | NS | NS | NS | NS |
| **Main treatment at same level of sub treatment** | | | | | |
| S.Em± | 0.06 | 0.17 | 2027 | 0.06 | 0.17 |
| CD (p=0.05) | NS | NS | NS | NS | NS |

****RDF: - Recommended dose of fertilizer, RDN: - Recommended dose of nitrogen, RDP: - Recommended dose of phosphorus, RDK: - Recommended dose of potassium, NS: - Non significant.**

**Table 2 Total microbial population as influenced by tillage and nutrient levels**

| **Treatments** | **Bacteria (cfu $g^{-1}$ x $10^6$)** | **Fungi (cfu $g^{-1}$ x $10^4$)** | **Actinomycetes (cfu $g^{-1}$ x $10^3$)** |
|---|---|---|---|
| Main plots: **Tillage** | | | |
| **$M_1$**: Conventional tillage (Plough + Cultivator + Rotovator) | 53.6 | 41.7 | 40.9 |
| **$M_2$**: Residue incorporation (Only rotovator was run) | 63.6 | 54.1 | 49.1 |
| **$M_3$**: Residue incorporation (Only rotovator was run + Microbial consortium spray) | 74.9 | 67.4 | 64.3 |

| | | | |
|---|---|---|---|
| **$M_4$**: Zero-tillage (Only microbial consortium was sprayed on the haulms) | 71.1 | 62.4 | 60.1 |
| S.Em± | 2.60 | 2.08 | 1.96 |
| CD (p=0.05) | 7.1 | 6.2 | 5.6 |
| Sub plots: **Nutrient levels** | | | |
| **$N_1$:** 100% RDF | 67.4 | 58.3 | 55.9 |
| **$N_2$:** 100% RDN & P and 50% RDK | 65.8 | 56.4 | 53.2 |
| **$N_3$:** 87.5% of RDN, 75% RDP and 75% RDK | 64.3 | 54.5 | 51.7 |
| S.Em± | 0.57 | 0.74 | 0.96 |
| CD (p=0.05) | 1.5 | 2.0 | 2.8 |
| **Interaction** | | | |
| **Sub treatment at same level of main treatment** | | | |
| S.Em± | 6.82 | 8.22 | 7.86 |
| CD (p=0.05) | NS | NS | NS |
| **Main treatment at same level of sub treatment** | | | |
| S.Em± | 3.18 | 3.93 | 4.35 |
| CD (p=0.05) | NS | NS | NS |

****RDF: - Recommended dose of fertilizer, RDN: - Recommended dose of nitrogen, RDP: - Recommended dose of phosphorus, RDK: - Recommended dose of potassium, NS: - Non significant.**

**Table 3 Dehydrogenase activity of maize at tasselling & silking and at harvest as influenced by tillage and nutrient levels**

| **Treatments** | **Dehydrogenase activity (µg TPF $g^{-1}$ $day^{-1}$)** | |
|---|---|---|
| | **Tasselling & silking** | **At harvest** |
| Main plots: **Tillage** | | |
| **$M_1$**: Conventional tillage (Plough + Cultivator + Rotovator) | 52.9 | 29.5 |
| **$M_2$**: Residue incorporation (Only rotovator was run) | 56.7 | 33.7 |
| **$M_3$**: Residue incorporation (Only rotovator was run + Microbial consortium spray) | 64.0 | 42.1 |

| | | |
|---|---|---|
| **$M_4$**: Zero-tillage (Only microbial consortium was sprayed on the haulms) | 57.7 | 36.3 |
| S.Em± | 2.27 | 2.19 |
| CD (p=0.05) | 6.5 | 6.1 |
| Sub plots: **Nutrient levels** | | |
| **$N_1$:** 100% RDF | 54.8 | 38.2 |
| **$N_2$:** 100% RDN & P and 50% RDK | 52.3 | 36.7 |
| **$N_3$:** 87.5% of RDN, 75% RDP and 75% RDK | 51.3 | 35.1 |
| S.Em± | 1.03 | 0.75 |
| CD (p=0.05) | 2.8 | 2.2 |
| **Interaction** | | |
| **Sub treatment at same level of main treatment** | | |
| S.Em± | 7.83 | 6.74 |
| CD (p=0.05) | NS | NS |
| **Main treatment at same level of sub treatment** | | |
| S.Em± | 3.72 | 3.10 |
| CD (p=0.05) | NS | NS |

****RDF: - Recommended dose of fertilizer, RDN: - Recommended dose of nitrogen, RDP: - Recommended dose of phosphorus, RDK: - Recommended dose of potassium, NS: - Non significant.**

**Table 4 Weed density (No. $m^{-2}$) and weed dry matter (g $m^{-2}$) in maize at different intervals as influenced by tillage and nutrient levels**

| **Treatments** | **Weed density (No. $m^{-2}$)** | | | **Weed dry matter (g $m^{-2}$)** | | |
|---|---|---|---|---|---|---|
| | **30 DAS** | **60 DAS** | **At harvest** | **30 DAS** | **60 DAS** | **At harvest** |
| Main plots: **Tillage** | | | | | | |
| **$M_1$**: Conventional tillage (Plough + Cultivator + Rotovator) | 30.4 (6.5) | 38.5 (7.2) | 21.5 (5.6) | 28.8 (6.3) | 34.7 (6.8) | 20.5 (5.5) |
| **$M_2$**: Residue incorporation (Only rotovator was run) | 24.8 (5.9) | 32.5 (6.7) | 16.2 (5.0) | 25.5 (6.0) | 30.6 (6.4) | 17.4 (5.1) |
| **$M_3$**: Residue incorporation (Only rotovator was run + Microbial consortium spray) | 21.3 (5.6) | 29.3 (6.4) | 13.7 (4.7) | 22.4 (5.7) | 27.5 (6.2) | 14.6 (4.8) |
| **$M_4$**: Zero-tillage (Only microbial consortium was sprayed on the haulms) | 22.1 (5.7) | 30.5 (6.5) | 14.8 (4.8) | 24.3 (5.9) | 28.6 (6.3) | 15.2 (4.8) |
| S.Em± | 0.12 | 0.11 | 0.10 | 0.06 | 0.08 | 0.07 |
| CD (p=0.05) | 0.42 | 0.38 | 0.36 | 0.19 | 0.28 | 0.26 |
| Sub plots: **Nutrient levels** | | | | | | |
| **$N_1$:** 100% RDF | 27.1 (6.2) | 36.8 (7.0) | 18.9 (5.3) | 29.2 (6.4) | 37.3 (7.1) | 21.4 (5.6) |
| **$N_2$:** 100% RDN & P and 50% RDK | 25.0 (6.0) | 34.3 (6.8) | 17.5 (5.1) | 26.5 (6.1) | 32.6 (6.7) | 18.6 (5.3) |
| **$N_3$:** 87.5% of RDN, 75% RDP and 75% RDK | 23.8 (5.8) | 31.8 (6.6) | 15.4 (4.9) | 25.7 (6.0) | 32.0 (6.6) | 17.3 (5.1) |
| S.Em± | 0.07 | 0.08 | 0.06 | 0.08 | 0.14 | 0.10 |
| CD (p=0.05) | 0.23 | 0.28 | 0.21 | 0.28 | 0.40 | 0.36 |
| **Interaction** | | | | | | |
| **Sub treatment at same level of main treatment** | | | | | | |
| S.Em± | 0.31 | 0.28 | 0.27 | 0.26 | 0.28 | 0.26 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS |
| **Main treatment at same level of sub treatment** | | | | | | |
| S.Em± | 0.30 | 0.27 | 0.26 | 0.28 | 0.27 | 0.28 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS |

Note: Figures in parenthesis are transformed values, square root transformation $\sqrt{x} + 1$ was used for statistical analysis.

****RDF: - Recommended dose of fertilizer, RDN: - Recommended dose of nitrogen, RDP: - Recommended dose of phosphorus, RDK: - Recommended dose of potassium, NS: - Non significant.**

**Table 5 Crude protein content and protein yield of maize as influenced by tillage and nutrient levels**

| Treatments | Protein content (%) | | Protein yield (kg $ha^{-1}$) | |
|---|---|---|---|---|
| | Kernel | Stover | Kernel | Stover |
| Main plots: **Tillage** | | | | |
| **$M_1$**: Conventional tillage (Plough + Cultivator + Rotovator) | 8.92 | 2.30 | 743 | 218 |
| **$M_2$**: Residue incorporation (Only rotovator was run) | 8.95 | 2.37 | 790 | 231 |
| **$M_3$**: Residue incorporation (Only rotovator was run + Microbial consortium spray) | 9.33 | 2.46 | 861 | 256 |
| **$M_4$**: Zero-tillage (Only microbial consortium was sprayed on the haulms) | 9.22 | 2.40 | 796 | 242 |
| S.Em± | 0.31 | 0.07 | 42.29 | 14.57 |
| CD (p=0.05) | NS | NS | NS | NS |
| Sub plots: **Nutrient levels** | | | | |
| **$N_1$:** 100% RDF | 9.29 | 2.45 | 848 | 252 |
| **$N_2$:** 100% RDN & P and 50% RDK | 9.25 | 2.43 | 825 | 247 |
| **$N_3$:** 87.5% of RDN, 75% RDP and 75% RDK | 8.77 | 2.32 | 719 | 216 |
| S.Em± | 0.22 | 0.05 | 18.52 | 12.64 |
| CD (p=0.05) | NS | NS | NS | NS |
| **Interaction** | | | | |
| **Sub treatment at same level of main treatment** | | | | |
| S.Em± | 0.48 | 0.09 | 47.61 | 21.86 |
| CD (p=0.05) | NS | NS | NS | NS |
| **Main treatment at same level of sub treatment** | | | | |
| S.Em± | 0.43 | 0.08 | 37.05 | 32.76 |
| CD (p=0.05) | NS | NS | NS | NS |

****RDF: - Recommended dose of fertilizer, RDN: - Recommended dose of nitrogen, RDP: - Recommended dose of phosphorus, RDK: - Recommended dose of potassium, NS: - Non significant.**

**Table 6 Bulk density (g $cc^{-1}$) and Moisture content (%) at different intervals as influenced by tillage and nutrient levels**

| | **Bulk density (g $cc^{-1}$)** | | | **Moisture content (%)** | | |
|---|---|---|---|---|---|---|
| **Treatments** | **At sowing** | **Tasselling & silking** | **At harvest** | **At sowing** | **Tasselling & silking** | **At harvest** |
| Main plots: **Tillage** | | | | | | |
| **$M_1$**: Conventional tillage (Plough + Cultivator + Rotovator) | 1.66 | 1.65 | 1.65 | 23.20 | 25.91 | 22.10 |
| **$M_2$**: Residue incorporation (Only rotovator was run) | 1.66 | 1.65 | 1.65 | 24.44 | 26.65 | 22.24 |
| **$M_3$**: Residue incorporation (Only rotovator was run + Microbial consortium spray) | 1.66 | 1.65 | 1.65 | 24.60 | 26.98 | 22.58 |
| **$M_4$**: Zero-tillage (Only microbial consortium was sprayed on the haulms) | 1.65 | 1.65 | 1.65 | 24.84 | 27.43 | 22.73 |
| S.Em± | 0.01 | 0.01 | 0.01 | 0.16 | 0.67 | 0.29 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS |
| Sub plots: **Nutrient levels** | | | | | | |
| **$N_1$:** 100% RDF | 1.66 | 1.65 | 1.65 | 24.51 | 27.08 | 22.68 |
| **$N_2$:** 100% RDN & P and 50% RDK | 1.66 | 1.65 | 1.65 | 24.33 | 26.78 | 22.40 |
| **$N_3$:** 87.5% of RDN, 75% RDP and 75% RDK | 1.66 | 1.65 | 1.65 | 23.97 | 26.06 | 22.15 |
| S.Em± | 0.01 | 0.01 | 0.01 | 0.30 | 0.37 | 0.38 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS |
| **Interaction** | | | | | | |
| **Sub treatment at same level of main treatment** | | | | | | |
| S.Em± | 0.01 | 0.01 | 0.01 | 0.18 | 1.12 | 1.02 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS |
| **Main treatment at same level of sub treatment** | | | | | | |
| S.Em± | 0.02 | 0.02 | 0.02 | 0.78 | 1.16 | 1.10 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS |
| Initial value | **1.66** | | | **23.85%** | | |

****RDF: - Recommended dose of fertilizer, RDN: - Recommended dose of nitrogen, RDP: - Recommended dose of phosphorus, RDK: - Recommended dose of potassium, NS: - Non**

significant.

**Table 7 Initial and final soil pH, EC and OC as influenced by tillage and nutrient levels**

| **Treatments** | **pH** | **EC ($dSm^{-1}$)** | **OC (%)** |
|---|---|---|---|
| Main plots: **Tillage** | | | |
| **$M_1$**: Conventional tillage (Plough + Cultivator + Rotovator) | 8.4 | 0.44 | 0.44 |
| **$M_2$**: Residue incorporation (Only rotovator was run) | 8.4 | 0.44 | 0.45 |
| **$M_3$**: Residue incorporation (Only rotovator was run + Microbial consortium spray) | 8.3 | 0.43 | 0.48 |
| **$M_4$**: Zero-tillage (Only microbial consortium was sprayed on the haulms) | 8.3 | 0.43 | 0.47 |
| S.Em± | 0.05 | 0.01 | 0.01 |
| CD (p=0.05) | NS | NS | NS |
| Sub plots: **Nutrient levels** | | | |
| **$N_1$:** 100% RDF | 8.4 | 0.44 | 0.48 |
| **$N_2$:** 100% RDN & P and 50% RDK | 8.4 | 0.44 | 0.47 |
| **$N_3$:** 87.5% of RDN, 75% RDP and 75% RDK | 8.3 | 0.43 | 0.45 |
| S.Em± | 0.08 | 0.01 | 0.01 |
| CD (p=0.05) | NS | NS | NS |
| **Interaction** | | | |
| **Sub treatment at same level of main treatment** | | | |
| S.Em± | 0.16 | 0.03 | 0.03 |
| CD (p=0.05) | NS | NS | NS |
| **Main treatment at same level of sub treatment** | | | |
| S.Em± | 0.08 | 0.02 | 0.03 |
| CD (p=0.05) | NS | NS | NS |
| Initial value | **8.2** | **0.42** | **0.45** |

****RDF: - Recommended dose of fertilizer, RDN: - Recommended dose of nitrogen, RDP: - Recommended dose of phosphorus, RDK: - Recommended dose of potassium,**

**NS: - Non significant.**

**Table 8 Post harvest soil available NPK in maize as influenced tillage and nutrient levels**

| **Treatments** | **Soil N at harvest (kg ha$^{-1}$)** | **Soil P at harvest (kg ha$^{-1}$)** | **Soil K at harvest (kg ha$^{-1}$)** |
|---|---|---|---|
| Main plots: **Tillage** | | | |
| **$M_1$**: Conventional tillage (Plough + Cultivator + Rotovator) | 220 | 77 | 316 |
| **$M_2$**: Residue incorporation (Only rotovator was run) | 227 | 80 | 321 |
| **$M_3$**: Residue incorporation (Only rotovator was run + Microbial consortium spray) | 231 | 83 | 325 |
| **$M_4$**: Zero-tillage (Only microbial consortium was sprayed on the haulms) | 228 | 81 | 323 |
| S.Em± | 2.7 | 1.03 | 2.4 |
| CD (p=0.05) | 8.2 | 4.1 | 7.4 |
| Sub plots: **Nutrient levels** | | | |
| **$N_1$:** 100% RDF | 239 | 91 | 352 |
| **$N_2$:** 100% RDN & P and 50% RDK | 234 | 88 | 293 |
| **$N_3$:** 87.5% of RDN, 75% RDP and 75% RDK | 206 | 78 | 323 |
| S.Em± | 2.09 | 0.92 | 3.09 |
| CD (p=0.05) | 6.3 | 3.5 | 9.1 |
| Interaction | | | |
| Sub treatment at same level of main treatment | | | |
| S.Em± | 4.66 | 3.79 | 10.42 |
| CD (p=0.05) | NS | NS | NS |
| Main treatment at same level of sub treatment | | | |
| S.Em± | 3.45 | 3.23 | 918 |
| CD (p=0.05) | NS | NS | NS |
| Initial value | **234** | **86** | **343** |

****RDF: - Recommended dose of fertilizer, RDN: - Recommended dose of nitrogen,**

**RDP: - Recommended dose of phosphorus, RDK: - Recommended dose of potassium, NS: - Non significant.**

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