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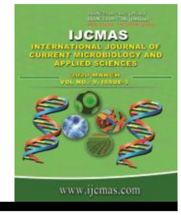

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Effect of Zero Tillage Practices and Nutritional Levels on Microbes, Enzymatic Activities in Soil and Productivity of Pigeonpea under Rainfed Situations

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A B S T R A C T

A field experiment was conducted at KVK, Kalburgi, on black soils. The zero tillage practices were followed since 3 years in five main plots and different reduced nutrient levels were imposed as subplots, by following split plot design. Every year same crop pigeonpea genotype TS-3R was grown. The prophylactic measures were undertaken against pests and diseases. Biological observations were analysed at 50 per cent flowering. Results of experiment shows that higher seed yield, stalk yield, SPAD values and sustainable yield index were observed in zero till-raised bed with residues retention along with application of 100 per cent recommended dose of inorganic fertilizer compared to other combinations. Higher nodules, nodule weight, Arbuscular mycorrhizal fungi (AMF) root colonization, enzymatic activities and population of microbial enumeration were observed in zero tillage raised bed with residues retention and lowest was found in conventional tillage practices, Significantly higher microbial properties, nodule number and weight were recorded with the treatment received no fertilizer and decreased with increase in the dose of inorganic fertilizer and lowest number was found in 100 per cent recommended inorganic fertilizers. Looking to yield levels in zero tillage practices and higher microbial properties in zero fertilizer, it can be concluded that sustainable yield were observed in reduced dose of nutrient in zero tillage practices, there, by saving of 50 per cent nutrient requirement in long term zero tillage practices.

Introduction

Conservation agriculture (CA) aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. The retained surface crop residues increase the soil porosity and organic carbon.

Residues mulch relieves water stress by reducing evaporation from the soil and keeping the surface soil moist during dry spells. The concept of nitrogen synchrony is combining fertilizer with residues may serve to match the rate of soil N supply with the rate of plant N uptake, helps to increase the N use efficiency and reduce the N losses through leaching. Root colonization with arbuscular mycorrhizal fungi (AMF) can enhance the uptake of phosphorus. Thus fertilizer use or enhance the fertilizer use efficiency by minimum or zero tillage practices. All the modern practices like intensive tillage and high fertilizer use are energy intensive, as they use large share in global energy budget and these practices lead to emission of GHGs and which has led to global warming and climate change. Hence energy use efficiency in crop production is need of the hour.

The Roots of most plant species are usually colonized with AMF, the major function of AMF symbiosis for host plant helps to improve phosphorus nutrition, by enhancing the uptake of phosphorus by plant roots by providing larger surface area for absorbing the nutrients. Solubilisation of p is achieved by rhizospheric modification through the release of organic acids phosphatase enzymes and some specialized metabolites, like siderophores (Shenoy and Kalagudi, 2005).

AMF helps to ameliorate plant mineral nutrition, to enhance water stress tolerance, better soil aggregate formation, which helps for improving soil physical properties, these are the important factors for successful low-input farming, which helps for sustainable agriculture production.

Enzymatic activities are considered to be good indicators of soil quality because they control the release of nutrients for plants and the growth of microorganisms. The activity of urease has also been widely used in the evaluation of soil quality changes due to soil management; example of nitrogen cycle process is characterized by urease activity. Significantly higher activity of urease and microbial biomass was measured using the minimum tillage system.

The highest dehydrogenase activity was measured during no tillage systems employed. (Mikanova *et al.*, 2009) Therefore, in the present study, a polygonal approach was used to evaluate the sustainability of different conservation agricultural practices and inturn in reducing the nutrient requirement using biological, microbial and nutrient.

Materials and Methods

The experiment was conducted at Krishi Vigyan Kendra Farm, Kalburgi, University of Agricultural Sciences, Raichur, which is located at 16^0 2' North latitude, 76^0 42' East longitude. The soil was black soil of the order Vertisols. Zero tillage was practiced since last 3 years. Different nutrient doses were imposed as sub-plots during 2015 and 2016. Every year same crop pigeonpea was grown.

The rainfall received during 2015 was 601.1 mm, which was 20.86 per cent low as compared to average. Certified seeds of pigeonpea genotype TS-3R (12.5 kg ha^{-1}) were sown with help of zero till machine. The prophylactic measures were undertaken against pests based on economic thresh hold level (ETL). The chlorophyll content was measured with help of SPAD chlorophyll meter. Plants from the net plot after threshing were dried and their weight was recorded from which stalk yield worked out and seeds were threshed and weighed.

All the Soil biological observations were analysed at 50 per cent flowering. Fresh and unsieved soil sample from rhizosphere zone were collected from the randomly selected seedlings in all plots at mid flowering stage and it was used for analysing the soil enzymes. The soil samples were used for determining dehydrogenase activity by the procedure described by Casida *et al.,* (1964), Phosphatase activity by Evazi and Tabatabai (1979), Urease activity by Tabatabai and Bremner (1972), nodule number and nodule dry weight were recorded in five plants uprooted at mid flowering stage in gross plot area. Nodules were counted and expressed as number per plant. Nodules dry weight was expressed as mg per plant. Mycorrhizal root colonization (AMF) was estimated as per the procedure proposed by Philips and Hayman (1970).

The isolation and enumeration was done by using N-free malic acid semisolid medium for *Azatobacter* following MPN technique (Cochran, 1950), Pikovskaya's medium for phosphate solubilizers (Pikovskaya, 1948) and Kings B medium for *Fluorescent pseudomonas*. The number of colony forming units (CFU) was recorded. The counts were expressed per gram of soil.

The data collected from the experiment were analysed statistically following the procedure described by Gomez and Gomez (1984). The mean values of main plot, sub-plot and interaction were separately subjected to Duncan's multiple range test for analysis.

Results and Discussion

The pooled data of pigeonpea indicated that, among the conservation agriculture practices zero till-raised bed with residues retention consistently produced higher seed and stalk yield (1,383 and 5,163 kg ha^{-1}, respectively) compared to conventional tillage practice followed by zero till-raised bed without residues retention (1,285 and 4,843 kg ha^{-1}, respectively). Sepat *et al.,* (2015) observed that zero tillage with raised bed had lower traffic compaction especially at deeper soil layer and deep prolific roots of pigeonpea explored the deeper layer, helps nutrient recycling and seed yields were higher in raised bed than flat bed.

Among the nutrient doses, 100 per cent recommended dose of inorganic fertilizer recorded significantly higher seed and stalk yield (1,274 and 4,736 kg ha^{-1}, respectively), but it was on par with 75 per cent (1,229 and 4,642 kg ha^{-1}, respectively) recommended doses of inorganic fertilizer. Leaf litter fall in pigeonpea provide good scope for nutrient recycling as indicated by Ahlawat *et al.,* (2005).

The interaction effect of conservation agricultural practices and nutrient doses varied significantly in pooled data and highest seed and stalk yield were recorded when 100 per cent recommended dose of inorganic fertilizer was applied in zero till-raised bed with crop residues retention (1,447 and 5,297 kg ha^{-1}, respectively) and it was on par with 75 per cent recommended doses of inorganic fertilizer in zero till raised bed with residues retention.

This was due to even reduced dose of fertilizer in pigeonpea can produce more pod by the virtue of higher branches per plant and retention of flower in ideal soil environment with good soil moisture content and translocation of accumulated photosynthates to sink by producing higher seed weight per plant.

Sharma *et al.,* (2012) also indicated the same results in pigeonpea that plant height, pods per plant and 100 seed weight were highest in 100 per cent RDF along with application of 5 tonnes FYM per hectare treatment. Pigeonpea yield recorded was more in 100 per cent RDF than 0 per cent RDF. Even under lower fertilizer dose, conservation agriculture practices help to build up of organic matter and improved recycling of inorganic inputs. Similar results were confirmed by Sainju *et al.,* (2006).

Sustainable yield index

Significantly higher sustainable yield index was recorded in zero till-raised bed with residues retention (0.73) compared to other practices, lower was observed in conventional tillage (0.51). Among the nutrient doses, significantly higher sustainable yield index was recorded in 100 per cent recommended dose of inorganic fertilizer (0.64) than other doses.

Significantly higher sustainable yield index was observed in zero till-raised bed with residues retention along with application of 100 per cent recommended dose of inorganic fertilizer (0.74) compared to other combinations, but was on par with 75 and 50 per cent doses in zero till raised bed with residues retention. The nearness of the SYI to 1 implies the closeness to an ideal condition that can sustain maximum crop yields, whereas deviation from 1 indicates losses to sustainability (Reddy *et al.,* 1999).

Chlorophyll content (SPAD values)

The pooled data indicated that effect of different conservation agricultural practices varied significantly with SPAD values at all the stages of crop. SPAD values recorded at mid flowering (42.10) was higher in zero tillage raised bed with crop residues retention than remaining treatments.

Higher SPAD values were recorded when 100 per cent recommended dose of inorganic fertilizer applied at mid flowering (41.73). Application of 100 per cent recommended levels of nutrients in zero till-raised bed with residues retention recorded higher SPAD values at mid flowering (44.00). Higher quantity of fertilizer has increased plant chlorophyll content and plant biomass growth thereby increasing SPAD values (Govaerts *et al.,* 2006). This was due to balanced nutrient helps to more chlorophyll development in crop plant, which helped in production of higher plant dry matter (Kumar *et al.,* 2014).

Nodule number, nodule weight and arbuscular mycorrhizal fungi (AMF) root colonization

Significantly higher nodules, nodule weight and Arbuscular mycorrhizal fungi (AMF) root colonization were observed in zero tillage raised bed with residues retention (19.92, 124.59 mg plant^{-1} and 21.04 %) and lowest was found in conventional tillage practices (15.58, 81.68 mg plant^{-1} and 14.87 %). Significantly higher nodule number recorded with the treatment received no fertilizer (18.73, 106.41 mg plant^{-1} and 22.17 %) and number decreased with increase in the dose of inorganic fertilizer and lowest number was found in 100 per cent recommended inorganic fertilizers (17.00, 99.82 mg plant^{-1} and 14.74 %).

Interaction effect of zero nutrient in zero tillage raised bed with residues retention (21.33, 128.92 mg plant^{-1} and 25.56 %) was higher compared to all other combinations. Higher number of nodules per plant and higher biologically fixed nitrogen in soybean grown in CA than conventional (Muchabi *et al.,* 2014). Nodulation and nodule dry weight on flat bed and conventional tillage was less due to water stagnation due to reduced root growth, nodule fresh mass, root mass density in conventional tillage and on flat beds by inhibiting aerobic respiration (Singh *et al.,* 2010).

Higher root nodule at lower dose of fertilizer was due to the fact that the mineral nitrogen reduces nodule formation and thereby affecting symbiotic N fixation, smaller starter dose stimulate nodule formation. Rhizobium population was increased at lower pH towards neutral pH (Basu *et al.,* 2008).

Enzymatic activity

Among the conservation agricultural practices zero till-raised bed with residues retention recorded higher dehydrogenase enzyme activity (18.33□ g TPF $g^{-1}day^{-1}$), phosphatase enzyme activity (32.33 □ g p-NP g^{-1} h^{-1}) and urease enzyme activity (3.39 µg NH_4-N g^{-1} h^{-1}) compared to all other conservation agricultural practices and significantly lowest enzymatic activity were observed in conventional tillage practice (8.34 □ g TPF $g^{-1}day^{-1}$, 23.0 □ g p-NP g^{-1} h^{-1} and 1.09 µg NH_4-N g^{-1} h^{-1}, respectively).

These results were due to lower C:N ratio material like legume avoids initial immobilization. It helps to build up higher soil organic carbon which increases the microbial activity. Different doses of recommended inorganic fertilizer had non-significant effect on dehydrogenase and urease activity, but phosphatase activity was significant with different nutrient doses.

Enzymatic activity was increased with reduction in recommended dose of inorganic fertilizer, the higher dehydrogenase enzyme activity (14.44 □ g TPF $g^{-1}day^{-1}$), phosphatase enzyme activity (28.62 □ g p-NP g^{-1} h^{-1}) and urease enzyme activity (2.49 µg NH_4-N g^{-1} h^{-1}) were recorded with the treatment received zero fertilizer.

Interaction effect of different conservation agricultural practices and fertilizer doses was varied significantly. Significantly the higher dehydrogenase enzyme activity (18.53□ g TPF $g^{-1}day^{-1}$), phosphatase enzyme activity (32.55 □ g p-NP g^{-1} h^{-1}) and urease enzyme activity (3.60 µg NH_4-N g^{-1} h^{-1}) were found in treatment where no fertilizer was applied in zero till- raised bed with crop residues retention. The no-tillage practices increased the availability of soil enzymes like acid phosphatase, amylase, cellulose *etc.*

Table.1 Description of experimental treatments

Main plots – zero tillage practices
M_1: Zero tillage - Flatbed – No crop residue retention on the surface **M_2: Zero tillage- Flatbed - Crop residue retention on the surface** **M_3: Zero tillage- Raised bed - No crop residue retention on the surface** **M_4: Zero tillage- Raised bed - Crop residue retention on the surface** **M_5: Conventional tillage**
Sub plots – Nutrient levels
S_1 : 100 % recommended dose of inorganic fertilizers (25:50:0.0:20 kg N, P_2O_5, K_2O, S ha^{-1}+ 15 kg $ZnSO_4$ ha^{-1}) **S_2 : 75 % recommended dose of inorganic fertilizers (18.75:37.5:0.0:15 kg N, P_2O_5, K_2O,S ha^{-1} + 11.25 kg $ZnSO_4$ ha^{-1})** **S_3 : 50 % recommended dose of inorganic fertilizers (12.5:25:0.0:10 kg N, P_2O_5, K_2O, S ha^{-1} + 7.5 kg $ZnSO_4$ ha^{-1})** **S_4 : 0 % recommended dose of inorganic fertilizers (0.0:0.0:0:0.0 kg N, P_2O_5, K_2O, S ha^{-1} + 0.0 kg $ZnSO_4$ ha^{-1})**

Table.2 Effect of zero tillage practices and nutrient levels on yield, nodulation and sustainable yield index of pigeonpea (Pooled)

Treatments	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Sustainable yield index	SPAD values at 50% flowering	Nodules per plant	Nodule dry weight (mg plant^{-1})	AMF root colonization (%)
Zero tillage practices (M)							
M_1	1,122 ^{d}	4,309 ^{c}	0.60 ^{d}	38.80 ^{cd}	16.96 ^{c}	96.96 ^{c}	18.05 ^{ab}
M_2	1,223 ^{c}	4,641 ^{b}	0.67 ^{b}	39.88 ^{bc}	18.63 ^{b}	110.25 ^{b}	19.36 ^{a}
M_3	1,285 ^{b}	4,843 ^{b}	0.65 ^{c}	40.91 ^{ab}	17.79 ^{bc}	101.46 ^{c}	18.92 ^{a}
M_4	1,383 ^{a}	5,163 ^{a}	0.73 ^{a}	42.10 ^{a}	19.92 ^{a}	124.59 ^{a}	21.04 ^{a}
M_5	1,018 ^{e}	3,983 ^{d}	0.51 ^{e}	37.23 ^{d}	15.58 ^{d}	81.68 ^{d}	14.87 ^{b}
S.Em±	18	79	0.003	0.55	0.37	1.98	1.09
Nutrient levels (S)							
S_1	1,274 ^{a}	4,736 ^{a}	0.64 ^{a}	41.73 ^{a}	17.00 ^{c}	99.82 ^{a}	14.74 ^{a}
S_2	1,229 ^{ab}	4,642 ^{ab}	0.64 ^{a}	40.50 ^{b}	17.33 ^{c}	101.43 ^{a}	17.40 ^{a}
S_3	1,188 ^{b}	4,550 ^{bc}	0.63 ^{ab}	39.38 ^{c}	18.03 ^{b}	104.28 ^{a}	19.47 ^{a}
S_4	1,133 ^{c}	4,424 ^{c}	0.62 ^{b}	37.53 ^{d}	18.73 ^{a}	106.41 ^{a}	22.17 ^{a}
S.Em±	14	41	0.003	0.38	0.17	3.41	1.49
Interaction (M × S)							
M_1S_1	1,190 $^{f-h}$	4,455 $^{e-i}$	0.61 ^{g}	40.87 $^{a-d}$	16.17 ^{jk}	94.80 ^{h}	14.88 $^{d-f}$
M_1S_2	1,141 ^{hi}	4,345 $^{f-i}$	0.60 ^{gh}	39.84 $^{b-f}$	16.50 $^{i-k}$	95.85 ^{gh}	16.52 $^{b-f}$
M_1S_3	1,107 ^{ij}	4,276 $^{f-j}$	0.59 ^{hi}	38.69 $^{b-g}$	17.17 $^{g-j}$	97.97 $^{f-h}$	19.30 $^{a-e}$
M_1S_4	1,050 ^{jk}	4,161 $^{g-j}$	0.58 ^{i}	35.79 ^{fg}	18.00 $^{e-h}$	99.22 $^{f-h}$	21.50 $^{a-c}$
M_2S_1	1,275 ^{de}	4,769 $^{a-f}$	0.68 ^{c}	41.70 $^{a-c}$	18.17 $^{d-g}$	106.19 $^{d-g}$	16.45 $^{b-f}$
M_2S_2	1,243 $^{d-g}$	4,704 $^{b-f}$	0.68 ^{c}	40.88 $^{a-d}$	18.33 $^{d-f}$	108.52 $^{d-f}$	19.05 $^{b-e}$
M_2S_3	1,209 $^{e-h}$	4,598 $^{d-g}$	0.67 ^{cd}	39.45 $^{b-f}$	18.83 $^{c-e}$	112.01 $^{c-e}$	19.23 $^{a-e}$
M_2S_4	1,165 $^{g-i}$	4,493 $^{d-h}$	0.66 ^{de}	37.50 $^{d-g}$	19.17 ^{cd}	114.27 $^{b-d}$	22.70 ^{ab}
M_3S_1	1,358 ^{bc}	5,010 $^{a-d}$	0.66 ^{de}	42.79 ^{ab}	17.00 $^{h-k}$	98.35 $^{f-h}$	13.78 ^{ef}
M_3S_2	1,308 ^{cd}	4,902 $^{a-e}$	0.66 ^{de}	41.87 $^{a-c}$	17.33 $^{f-i}$	99.83 $^{f-h}$	18.21 $^{b-e}$
M_3S_3	1,265 $^{d-f}$	4,797 $^{a-f}$	0.65 ^{ef}	40.26 $^{a-e}$	18.00 $^{e-h}$	102.44 $^{e-h}$	21.07 $^{a-d}$
M_3S_4	1,209 $^{e-h}$	4,662 $^{c-g}$	0.64 ^{f}	38.08 $^{c-g}$	18.83 $^{c-e}$	105.21 $^{d-h}$	22.62 ^{ab}
M_4S_1	1,447 ^{a}	5,297 ^{a}	0.74 ^{a}	44.00 ^{a}	18.67 $^{c-e}$	120.97 $^{a-c}$	17.26 $^{b-f}$
M_4S_2	1,407 ^{ab}	5,212 ^{ab}	0.73 ^{ab}	42.36 ^{ab}	19.50 ^{bc}	122.51 ^{ab}	19.29 $^{a-e}$
M_4S_3	1,365 ^{bc}	5,132 $^{a-c}$	0.73 ^{ab}	41.73 $^{a-c}$	20.17 ^{b}	125.97 ^{a}	22.06 $^{a-c}$
M_4S_4	1,314 ^{cd}	5,010 $^{a-d}$	0.72 ^{b}	40.97 $^{a-d}$	21.33 ^{a}	128.92 ^{a}	25.56 ^{a}
M_5S_1	1,101 ^{ij}	4,147 $^{g-j}$	0.52 ^{j}	39.27 $^{b-g}$	15.00 ^{l}	78.80 ^{i}	11.35 ^{f}
M_5S_2	1,049 ^{jk}	4,046 $^{h-j}$	0.52 ^{j}	37.77 $^{c-g}$	15.00 ^{l}	80.46 ^{i}	13.93 ^{ef}
M_5S_3	993 ^{kl}	3,945 ^{ij}	0.51 ^{j}	36.56 $^{e-g}$	16.00 ^{k}	83.05 ^{i}	15.71 $^{c-f}$
M_5S_4	929 ^{l}	3,792 ^{j}	0.49 ^{k}	35.31 ^{g}	16.33 $^{i-k}$	84.43 ^{i}	18.49 $^{b-e}$
S.Em±	27	158	0.005	1.10	0.46	3.41	1.97

Table.3 Effect of zero tillage practices and nutrient levels on soil enzymatic activities and microbial enumeration of pigeonpea at mid flowering stage (Pooled)

Treatments	Dehydrogenase (µg TPF $g^{-1}day^{-1}$)	Phosphatase (µg p-NP g^{-1} h^{-1})	Urease (µg NH_4-N g^{-1} h^{-1})	P-Solubilisers (10^4 cfu g^{-1})	Free living N_2 fixers (10^6 cfu g^{-1})	*Fluorescent pseudomonas* (10^4 cfu g^{-1})
Zero tillage practices (M)						
M_1	13.96 ^{c}	27.72 ^{d}	1.91 ^{c}	18.00 ^{c}	14.13 ^{b}	11.08 ^{bc}
M_2	15.55 ^{b}	30.03 ^{b}	2.79 ^{b}	23.00 ^{b}	19.25 ^{ab}	13.13 ^{ab}
M_3	14.90 ^{b}	28.87 ^{c}	2.56 ^{b}	19.38 ^{c}	15.46 ^{b}	11.21 ^{bc}
M_4	18.33 ^{a}	32.33 ^{a}	3.39 ^{a}	25.83 ^{a}	22.33 ^{a}	15.92 ^{a}
M_5	8.34 ^{d}	23.00 ^{e}	1.09 ^{d}	9.46 ^{d}	8.75 ^{c}	8.63 ^{c}
S.Em±	0.23	0.23	0.08	0.76	1.52	1.22
Nutrient levels (S)						
S_1	14.02 ^{a}	28.18 ^{c}	2.20 ^{a}	16.37 ^{d}	13.20 ^{d}	9.83 ^{b}
S_2	14.13 ^{a}	28.31 ^{b}	2.30 ^{a}	17.96 ^{c}	14.83 ^{c}	11.47 ^{ab}
S_3	14.29 ^{a}	28.46 ^{ab}	2.39 ^{a}	19.97 ^{b}	16.87 ^{b}	12.57 ^{ab}
S_4	14.44 ^{a}	28.62 ^{a}	2.49 ^{a}	22.30 ^{a}	19.03 ^{a}	14.10 ^{a}
S.Em±	0.17	0.06	0.08	0.46	0.15	0.79
Interaction (M × S)						
M_1S_1	13.77 ^{h}	27.51 ^{d}	1.77 ^{j}	16.00 ^{g}	11.00 ^{jk}	8.50 ^{de}
M_1S_2	13.84 ^{h}	27.65 ^{d}	1.88 ^{ij}	16.50 ^{g}	13.67 $^{g-j}$	10.50 ^{de}
M_1S_3	14.03 ^{h}	27.78 ^{d}	1.96 ^{ij}	18.67 $^{e-g}$	15.17 $^{f-h}$	11.50 $^{b-e}$
M_1S_4	14.23 ^{gh}	27.96 ^{d}	2.04 ^{i}	21.17 ^{de}	16.67 ^{ef}	13.83 $^{a-d}$
M_2S_1	15.33 $^{b-e}$	29.79 ^{b}	2.65 $^{f-h}$	20.33 $^{d-f}$	15.83 ^{fg}	10.67 $^{c-e}$
M_2S_2	15.46 $^{b-d}$	29.91 ^{b}	2.77 $^{e-g}$	21.83 $^{c-e}$	17.67 $^{d-f}$	12.67 $^{a-d}$
M_2S_3	15.65 ^{bc}	30.12 ^{b}	2.83 ^{ef}	23.17 ^{cd}	19.83 ^{cd}	13.67 $^{a-d}$
M_2S_4	15.79 ^{b}	30.33 ^{b}	2.93 ^{de}	26.67 ^{ab}	23.67 ^{a}	15.50 $^{a-c}$
M_3S_1	14.62 ^{fg}	28.68 ^{c}	2.42 ^{h}	15.67 ^{g}	13.00 ^{h}	9.33 ^{de}
M_3S_2	14.81 $^{e-g}$	28.81 ^{c}	2.51 ^{gh}	18.00 ^{fg}	13.83 $^{g-i}$	10.17 $^{c-e}$
M_3S_3	15.01 $^{d-f}$	28.94 ^{c}	2.60 $^{f-h}$	20.67 $^{d-f}$	17.17 $^{d-f}$	11.83 $^{b-e}$
M_3S_4	15.17 $^{c-f}$	29.04 ^{c}	2.72 $^{e-g}$	23.17 ^{cd}	17.83 $^{d-f}$	13.50 $^{a-d}$
M_4S_1	18.19 ^{a}	32.12 ^{a}	3.16 ^{cd}	22.00 ^{cd}	19.33 $^{c-e}$	13.83 $^{a-d}$
M_4S_2	18.23 ^{a}	32.25 ^{a}	3.31 ^{bc}	24.67 ^{bc}	21.00 ^{bc}	15.50 $^{a-c}$
M_4S_3	18.36 ^{a}	32.39 ^{a}	3.48 ^{ab}	27.17 ^{ab}	23.33 ^{ab}	16.83 ^{ab}
M_4S_4	18.53 ^{a}	32.55 ^{a}	3.60 ^{a}	29.50 ^{a}	25.67 ^{a}	17.50 ^{a}
M_5S_1	8.19 ^{i}	22.78 ^{e}	1.00 ^{k}	7.83 ^{i}	6.83 ^{l}	6.83 ^{e}
M_5S_2	8.32 ^{i}	22.92 ^{e}	1.06 ^{k}	8.83 ^{hi}	8.00 ^{l}	8.50 ^{de}
M_5S_3	8.39 ^{i}	23.07 ^{e}	1.12 ^{k}	10.17 ^{hi}	8.83 ^{kl}	9.00 ^{de}
M_5S_4	8.47 ^{i}	23.23 ^{e}	1.18 ^{k}	11.00 ^{h}	11.33 $^{i-k}$	10.17 $^{c-e}$
S.Em±	0.28	0.30	0.09	1.14	1.69	1.83

The increased microbial activity improved the nutrient availability and circulation of minerals (Sharma *et al.,* 2011). Mina *et al.,* (2008) found that increased enzyme activity was due to higher level of intercellular and or extracellular enzymes, immobilized by recalcitrant humic moieties.

Population of P – solubilisers, free living N_2 fixers and *fluorescent pseudomonas*

The data on population of microbial enumeration in rhizosphere soil collected at mid flowering stage were varied significantly with different zero tillage practice. Significantly the higher P- solubilizers (25.83 $\times 10^4$ cfu g^{-1}), free living N_2 fixers (22.33 $\times 10^6$ cfu g^{-1}) and *Fluorescent pseudomonas* (15.92 10^4 cfu g^{-1}) were recorded with zero - till raised bed with residues retention compared to other practices. Significantly the lower population of microbes observed in conventional tillage (9.46 $\times 10^4$ cfu g^{-1}, 8.75 $\times 10^6$ cfu g^{-1} and 8.63 $\times 10^4$ cfu g^{-1}, respectively).

Application of 100 per cent recommended levels of inorganic fertilizer dose recorded lower P- solubilizers (16.37 $\times 10^4$ cfu g^{-1}), free living N_2 fixers (13.20 $\times 10^6$ cfu g^{-1}) and *Fluorescent pseudomonas* (9.83 $\times 10^4$ cfu g^{-1}) count. The population of microbial enumeration count was increased with reduction of nutrient doses. The highest population have enumerated with no fertilizer (22.30 $\times 10^4$ cfu g^{-1}, 19.03 $\times 10^6$ cfu g^{-1} and 14.10 $\times 10^4$ cfu g^{-1}, respectively)

The populations of microbial enumeration count were influenced significantly by interactive effect of zero tillage practice and nutrient levels. The higher P- solubilizers (29.50 $\times 10^4$ cfu g^{-1}), free living N_2 fixers (25.67 $\times 10^6$ cfu g^{-1}) and *Fluorescent pseudomonas* (17.50 $\times 10^4$ cfu g^{-1}) count were recorded in zero till-raised bed with residues retention along with zero fertilizer treatment compared to all other combinations. These results were due to the favourable effect of zero tillage with residues retention on soil microbial population was mainly due to increased soil aeration, cooler and wetter conditions along with higher soil organic carbon content. Plant residues on surface contribute to suppression of soil–borne pathogens in minimum tillage systems due to microbial antagonists.

The yield, yield parameters and all microbial parameters were higher in zero till raised bed with residue retention. The effect of nutrient doses shown increase in nutrient application increases the yield and yield parameters, but all the microbial parameters like Nodule number, nodule weight and Arbuscular mycorrhizal fungi (AMF) root colonization**,** dehydrogenase, phosphatase and urease enzyme activity were higher in treatment where no fertilizer applied. Finally, it can be concluded that reduced dose of nutrient helps in sustaining the crop yield in conservation agriculture practices. In conservation agriculture practice of zero till raised bed with residue retention, there was saving of 50 per cent inorganic fertilizer.

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