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Longterm zero tillage and residue management practices on soil nutrient availability and productivity of pigeonpea under dryland conditions

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Abstract

Conservation agriculture has potential for conserving the resources and enhancing productivity to achieve the goals of sustainable agriculture. Long term conservation agriculture experiment was started with main plot treatments include zero tillage raised and flat bed, with or without residue retention on surface, after six years reduced dose of nutrients as subplots at Agricultural Research Station, Bheemarayanagudi is situated in North Eastern Dry Zone (Zone-2) of Karnataka. The soil was red sandy loam. Every year same crop Pigeonpea was cultivated. The rainfall received during 2015 was 437.6 mm, which was 17.1 percent low compared to average. Rainfall received during 2016 was 398.2 mm, which was 24.56 percent low compared to average. Pooled results of the experiment revealed that zero tillage raised bed with residue retention produced higher seed and stalk yield, sustainable yield index, organic carbon and nutrient availability and uptake than other treatments. Among the nutrient doses 100 percent given higher yield and nutrient content and uptake, but economics net returns and B:C ratio were higher where zero nutrient doses. Finally, interaction of zero tillage raised bed with residue retention along with 100 percent application of nutrient dose produced higher yields but were on far with 75 and 50 percent of nutrient doses. Thus, in long term conservation agriculture practices, nutrient dose requirement can be reduced to 50 percent in pigeonpea grown under dryland conditions.

Keywords: Zero tillage, pigeonpea, residue, nutrient uptake, nutrient availability, economics

1. Introduction

Crop production in the next decade will have to produce more food from less land by making more efficient use of natural resources and with minimal impact on environment. Conservation agriculture has potential for conserving the resources and enhancing productivity to achieve the goals of sustainable agriculture. It can also be referred to as resource efficient and resource effective agriculture. Conservation agriculture practices *viz.*, minimum tillage, crop residue management and cover crop and crop rotation play an important role in bringing about favourable changes in soil physical, chemical and biological properties, which in turn improve the crop yield (Ramesh and Hegde, 2010) [12]. An approach of "Grain is to man and residue is to soil" and one more objective is to minimize the inputs originating from non-renewable energy resources like fertilizer and diesel. The retained surface crop residues increase the soil porosity and organic carbon. 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. Pigeonpea is a crop of rainfed and marginal environments, hence nutrient requirement and response are highly variable. Though the crop meets its own N requirement from biological nitrogen fixation (BNF), a starter dose at the time of sowing is recommended. Litter fall in pigeonpea and the leaves retained at harvest in North India due to cold temperature at the time of harvest and pod husks provide good scope for nutrient cycling especially N and balanced fertilization

must be ensured (P, Zn, S, *etc.*) (Ahlawat *et al.*, 2005) ^[1]. Increased use of fertilizers played an important role in the immense success in crop productivity during the period of green revolution. However, reports have shown that continuous use of fertilizers is causing environmental problems. Low efficiency in the uptake of fertilizer is a major factor that aggravates the negative environmental effects. Hence the experiment was conducted to study the effect of crop residues management practices on nutrient requirement, growth and yield of pigeonpea to assess the effect of conservation agriculture (CA) practices on chemical properties.

2. Material and Methods

The long term field experiment was started during the year 2009 at Agricultural Research Station, Bheemaranagudi, University of Agricultural Sciences, Raichur, Karnataka, India in sandy loam soils Experiment was laid in strip plot design with twenty treatment combinations of main five treatment namely M₁: Zero tillage - Flatbed – No crop residue retention on the surface, M₂: Zero tillage - Flatbed – Crop residue retention on the surface, M₃: Zero tillage- Raised bed –No crop residue retention on the surface, M₄: Zero tillage- Raised bed –Crop residue retention on the surface, M₅: Conventional tillage. Four subplots of fertilizer levels were laid out in these main plots *viz.* S₁: 100 percent RD inorganic fertilizers (25:50:00:20 kg N, P₂O₅, K₂O, S ha⁻¹+ 15 kg ZnSO₄ ha⁻¹), S₂: 75 percent RD inorganic fertilizers, S₃: 50 percent RD inorganic fertilizers and S₄: 0 percent RD inorganic fertilizers. One treatment as outside control which includes all operations were same as conventional tillage practice except for the addition of 6 tonnes of FYM per hectare which was incorporated before final harrowing. Pigeonpea genotype TS-3R (12.5 kg ha⁻¹) were used for sowing. The prophylactic measures were undertaken against pigeonpea pests and diseases. All growth, yield parameters and yields were recorded at maturity. The sample from each plot was collected from a depth of 0 to 30 cm at harvest was used for analysis of all chemical parameters. Seed and stalk harvested at maturity were separately dried in shade and ground to fine powder. The powdered samples were used for nutrient analysis. The data collected from the experiment were analysed statistically. The level of significance used in 'F' and 't' tests was P=0.05. The mean value of main plot, sub-plot and interaction were separately subjected to Duncan's multiple range test (DMRT) using the corresponding error mean sum of squares and degree of freedom values.

3. Results and Discussions

3.1 Organic carbon

Significantly higher organic carbon content was observed in zero till raised bed with residues retention (4.92 g kg⁻¹) than remaining practices with lowest in conventional tillage practice (4.31 g kg⁻¹). Parihar *et al.* (2016) ^[11] observed increased root growth and biomass, better aggregation in zero till raised bed than conventional tillage. Increased aggregation physically protects soil organic matter. The increase in the yield in zero till- raised bed with residues retention than other practices due to the improvement in soil physical environment and soil organic carbon content, which helped for better root growth. Singh *et al.*, (2016) ^[11] opined that zero tillage DSR-ZT maize recorded higher soil organic carbon content than conventional DSR-conventional maize, which inturn greatly influenced the physical, chemical and biological properties of soil. The effect of different doses of recommended inorganic

fertilizer on soil organic carbon content was non-significant. However, soil organic carbon content was higher in 100 percent recommended dose of inorganic fertilizers (4.62 g kg⁻¹). Soil organic carbon content decreased with reduction in fertilizer dose, recording lower organic carbon content (4.53 g kg⁻¹) in treatment with zero fertilizer application. The soil organic carbon content was increased significantly in zero till-raised bed with residues retention practices along with 100 percent recommended dose of inorganic fertilizer (5.03 g kg⁻¹), but was on par with 75 percent and 50 percent nutrient levels. Organic carbon content was increased when FYM was applied along with inorganic fertilizer in conventional tillage (4.41 g kg⁻¹). Higher carbon, nitrogen and potassium concentration was observed with residues retention than residues removal treatments (Jat *et al.*, 2012) ^[4]. Even under lower fertilizer dose in zero till-raised bed with residues retention help to build up of organic matter and improved recycling of inorganic inputs (Sainju *et al.*, 2006) ^[13].

3.2 Available nutrients in soil

Zero till-raised bed with residues retention was retained higher soil available nitrogen (224 kg ha⁻¹), phosphorus (30.4 kg ha⁻¹) and potassium (584.6 kg ha⁻¹), Sulphur (9.12 kg ha⁻¹) and Zinc (0.81 mg kg⁻¹) compared to all other practices. Significantly lower soil available nitrogen, phosphorus, potassium, sulphur and zinc were left in conventional tillage (198 kg ha⁻¹, 27.5 kg ha⁻¹, 563.6 kg ha⁻¹, 8.92 kg ha⁻¹ and 0.59 mg kg⁻¹, respectively). Higher available nitrogen in zero till-raised bed with residues may be attributed to less loss through immobilization, volatilization, denitrification as reported by Mina *et al.* (2008) ^[10]. Significantly higher soil available nitrogen, phosphorus, potassium, sulphur and zinc were retained in treatment with 100 percent recommended dose of inorganic fertilizers (219 kg ha⁻¹, 30.1 kg ha⁻¹, 573.7 kg ha⁻¹, 9.12 kg ha⁻¹ and 0.82 mg kg⁻¹, respectively). This might be because of most of P₂O₅ in soil exist in organic form, immobile nature of P₂O₅ and release of organic acids (Piscidic acid) during microbial decomposition which helped in releases of native phosphorus from soil (Ahlawat *et al.*, 2005) ^[1]. Significantly higher available nitrogen, phosphorus, potassium, sulphur and zinc were retained in zero till raised bed with residues retention along with 100 percent recommended dose of inorganic nutrient level (232 kg ha⁻¹, 32.0 kg ha⁻¹, 585.3 kg ha⁻¹, 9.26 kg ha⁻¹ and 0.93 mg kg⁻¹, respectively). The 100 percent recommended dose of inorganic fertilizer along with FYM retained significantly higher soil available nitrogen, phosphorus, potassium, and zinc (211 kg ha⁻¹, 29.3 kg ha⁻¹, 567 kg ha⁻¹ and 0.76 g kg⁻¹, respectively) than 50 percent recommended dose of inorganic fertilizer and no fertilizer application in conventional tillage practice. This was due to addition FYM lead to higher organic matter and development of microbial activity which helps to retain the higher available phosphorus in soil. Zero till had higher leaf litter addition and root biomass lead to higher soil organic carbon, this in turn helped to increased soil microbial biomass carbon, available nitrogen, potassium, phosphorus and sulphur (Kumar *et al.*, 2014) ^[8].

3.3 Uptake of nutrients

Significantly higher total nitrogen uptake (120.8 kg ha⁻¹), phosphorus uptake (10.81 kg ha⁻¹) and potassium uptake (41.51 kg ha⁻¹) was found in zero till-raised bed with residues retention treatment compared to all other conservation agricultural practices. Higher nitrogen uptake (108.6 kg ha⁻¹), phosphorus uptake (9.48 kg ha⁻¹) and potassium uptake (35.62

kg ha⁻¹) was observed in 100 percent recommended dose of inorganic fertilizer, but was on par with 75 percent (106.1 kg ha⁻¹, 9.21 kg ha⁻¹ and 34.76 kg ha⁻¹, nitrogen, phosphorus and potassium uptake, respectively) recommended dose of inorganic fertilizer. Higher nitrogen uptake (126.4 kg ha⁻¹), phosphorus uptake (11.48 kg ha⁻¹) and potassium uptake (43.38 kg ha⁻¹) was noticed in treatment of 100 percent recommended dose of inorganic fertilizer applied in zero till-raised bed with crop residues retention, but was on par with 75 and 50 percent recommended dose of inorganic fertilizer. The results of Gentile *et al.* (2009) [3] indicated that 100 percent fertilizer application treatment with higher nutrient uptake than zero fertilizer application. This might be due to residues with low C:N ratio supply the majority of nitrogen requirement for decomposing microorganisms, so early released nitrogen on surface soil rapidly leached to the lower depth and become unavailable to crop uptake in the initial period. Application of FYM along with recommended dose of 100 percent inorganic fertilizer recorded higher nitrogen uptake (95.7 kg ha⁻¹), phosphorus uptake (8.19 kg ha⁻¹) and potassium uptake (30.58 kg ha⁻¹) compared to all the nutrient doses in conventional tillage practices, 50 percent and no fertilizer application in zero till- flat bed without residues retention. This was due to higher soil moisture availability at all the growth stages, helped in favourable edaphic conditions increased availability nutrient to the crop with more seed and stalk yield. Chopra and Angiras (2008) [2] reported that on silty loam soils zero till treatment recorded higher uptake of nitrogen, phosphorus and potassium than conventional.

3.4 Seed and stalk yield

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). These results are in line with the findings of Kumar *et al.* (2014) [8] on deep black soils and reported that moisture content was 3.5 percent more in minimum tillage than conventional tillage at all stage of pigeonpea crop. Kantwa *et al.* (2006) [5] opined the same results in BBF system of pigeonpea which produced 10 percent higher pigeonpea seed yield and biomass yield over flatbed sowing. Kashif *et al.* (2006) [6] indicated that the mean maximum plant height, maximum number of seeds, 1000 seed weight and seed yields were recorded higher in mulch applied treatment over no mulch applied treatment. The results of Singh *et al.* (2010) [16] indicated that the higher wheat yields were recorded in optimum nitrogen and phosphorus application in permanent raised bed than flatbed compare to higher fertilizer N and P application.

Hundred percent 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 percent (1,229 and 4,642 kg ha⁻¹, respectively) recommended doses of inorganic fertilizer. Sharma *et al.* (2012) [15] also indicated the same results in pigeonpea that plant height, pods per plant and 100 seed weight were highest in 100 percent RDF along with application of 5 tonnes FYM per hectare treatment. Pigeonpea yield recorded was more in 100 percent RDF than 0 percent RDF. Higher seed and stalk yield was recorded when 100 percent 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 percent (1,407 and 5,212 kg ha⁻¹, respectively) recommended doses of inorganic fertilizer in zero till raised bed with residues retention. The pooled data indicated that the seed and stalk yield (1,202 and 4,548 kg ha⁻¹, respectively) in 100 percent RDF (recommended dose of inorganic fertilizer + FYM) was significantly higher than all the nutrient doses in conventional tillage practice. Added inorganic fertilizers enhanced the availability of these nutrients to plants. This might have resulted in profuse root and shoot growth, and thereby it activates the greater absorption of these nutrients lead to improved growth and yield attributes and finally resulted in higher seed and stalk yield (Kumawat *et al.*, 2013) [9].

3.5 Sustainable yield index

Significantly higher sustainable yield index was recorded in zero till-raised bed with residues retention (0.73) compared to other practices, lowest was observed in conventional tillage (0.51). Among the nutrient doses, significantly higher sustainable yield index was recorded in 100 percent recommended dose of inorganic fertilizer (0.64) than other doses, but was on par with 75 percent (0.64) and 50 percent (0.63) doses. Significantly higher sustainable yield index was observed in zero till-raised bed with residues retention along with application of 100 percent recommended dose of inorganic fertilizer (0.74) compared to other combinations, but was on par with 75 and 50 percent doses in zero till raised bed with residues retention.

3.6 Economics

Zero tillage raised bed with residues retention recorded significantly highest net returns (₹ 55,162 ha⁻¹) and B: C ratio (2.64) compared to other conservation agricultural practices. Lowest net returns (₹ 31,110 ha⁻¹) and B:C ratio (1.26) were recorded in conventional tillage practice. Khambalkar *et al.* (2010) [7] observed that in BBF method lower cost of operation (\$ 16.39 ha⁻¹) than in traditional method (\$ 26.50 ha⁻¹). Sepat *et al.* (2015) [14] opined that pigeonpea residues addition given highest net return over no residue's addition. 100 percent recommended dose of inorganic fertilizer recorded higher net returns (₹ 47,178 ha⁻¹) and lower B: C ratio (2.09) compared to other doses. The 100 percent recommended dose of inorganic fertilizer when applied in zero tillage raised bed with crop residues retention (₹ 57,205 ha⁻¹) recorded higher net returns compared to all other combinations, but was on par with remaining doses in zero till-raised bed with residues retention. Further it was observed that application of 100 percent RDF (recommended dose of inorganic + FYM) in conventional tillage produced higher net returns (₹ 29,206 ha⁻¹) than zero doses of recommended inorganic fertilizers in conventional tillage. B: C ratio was significantly highest when no fertilizer was applied in zero till-raised bed with residues retention practice (2.26). The 100 percent recommended dose of inorganic fertilizer along with FYM application (0.90) recorded lowest B: C ratio compared to all other combinations. Kumawat *et al.* (2013) [9] also reported that pigeonpea grown with 100 percent RDF + 5 kg Zn per hectare recorded higher cost of cultivation, gross return and net returns than control without fertilizer.

Table 1: Soil available nutrients and sustainable yield index as influenced by zero tillage practices and nutrient doses of rainfed pigeonpea (Pooled)

Treatments	Organic carbon (g kg ⁻¹)	Available Nitrogen (kg ha ⁻¹)	Available Phosphorus (kg ha ⁻¹)	Available Potassium (kg ha ⁻¹)	Available Sulphur (kg ha ⁻¹)	Available Zinc (mg kg ⁻¹)	Sustainable yield index
Tillage (M)							
M ₁	4.48 ^c	205 ^c	27.8 ^b	567.8 ^d	8.93 ^a	0.69 ^{ab}	0.60 ^d
M ₂	4.68 ^b	219 ^{ab}	30.2 ^a	581.0 ^b	9.04 ^a	0.77 ^a	0.67 ^b
M ₃	4.52 ^c	207 ^{bc}	28.0 ^b	568.4 ^c	8.99 ^a	0.70 ^{ab}	0.65 ^c
M ₄	4.92 ^a	224 ^a	30.4 ^a	584.6 ^a	9.12 ^a	0.81 ^a	0.73 ^a
M ₅	4.31 ^d	198 ^c	27.5 ^b	563.6 ^e	8.92 ^a	0.59 ^b	0.51 ^e
SEm±	0.04	3.85	0.16	0.17	0.04	0.05	0.003
Nutrient doses (S)							
S ₁	4.62 ^a	219 ^a	30.1 ^a	573.7 ^a	9.12 ^a	0.82 ^a	0.64 ^a
S ₂	4.59 ^a	214 ^b	29.3 ^b	573.3 ^a	9.04 ^a	0.76 ^a	0.64 ^a
S ₃	4.57 ^a	208 ^c	28.6 ^c	572.9 ^a	8.97 ^a	0.68 ^b	0.63 ^{ab}
S ₄	4.53 ^a	201 ^d	27.1 ^d	572.3 ^b	8.86 ^a	0.59 ^c	0.62 ^b
SEm±	0.02	136	0.05	0.03	0.05	0.02	0.003
Interaction (M × S)							
M ₁ S ₁	4.51 ^{f-i}	215 ^{b-e}	29.1 ^e	567.7 ^m	9.05 ^{a-c}	0.79 ^{b-d}	0.61 ^g
M ₁ S ₂	4.50 ^{g-j}	208 ^{d-f}	28.2 ^f	567.2 ⁿ	8.95 ^{a-c}	0.73 ^{c-f}	0.60 ^{gh}
M ₁ S ₃	4.47 ^{g-k}	205 ^{ef}	27.6 ^g	566.8 ^o	8.91 ^{bc}	0.66 ^{f-h}	0.59 ^{hi}
M ₁ S ₄	4.45 ^{h-k}	193 ^{gh}	26.4 ⁱ	566.1 ^p	8.79 ^{bc}	0.56 ^{hi}	0.58 ⁱ
M ₂ S ₁	4.71 ^{cd}	227 ^{ab}	31.7 ^a	581.6 ^e	9.13 ^{ab}	0.86 ^{ab}	0.68 ^c
M ₂ S ₂	4.70 ^{c-e}	223 ^{a-c}	30.9 ^b	581.3 ^f	9.12 ^{a-c}	0.81 ^{bc}	0.68 ^c
M ₂ S ₃	4.68 ^{c-f}	218 ^{b-d}	29.9 ^d	580.9 ^g	9.02 ^{a-c}	0.72 ^{c-f}	0.67 ^{cd}
M ₂ S ₄	4.64 ^{d-g}	209 ^{d-f}	28.2 ^f	580.2 ^h	8.90 ^{bc}	0.67 ^{e-g}	0.66 ^{de}
M ₃ S ₁	4.55 ^{d-h}	214 ^{c-f}	29.0 ^e	570.0 ⁱ	9.05 ^{a-c}	0.84 ^{ab}	0.66 ^{de}
M ₃ S ₂	4.54 ^{d-h}	208 ^{d-f}	28.3 ^f	569.7 ^j	9.05 ^{a-c}	0.77 ^{b-e}	0.66 ^{de}
M ₃ S ₃	4.53 ^{e-h}	205 ^{ef}	28.1 ^f	569.1 ^k	9.03 ^{a-c}	0.65 ^{f-h}	0.65 ^{ef}
M ₃ S ₄	4.46 ^{g-k}	202 ^{fg}	26.7 ^{hi}	568.5 ^l	8.82 ^{bc}	0.56 ^{hi}	0.64 ^f
M ₄ S ₁	5.03 ^a	232 ^a	32.0 ^a	585.3 ^a	9.26 ^a	0.93 ^a	0.74 ^a
M ₄ S ₂	4.93 ^{ab}	227 ^{ab}	30.9 ^b	584.9 ^b	9.12 ^{a-c}	0.84 ^{ab}	0.73 ^{ab}
M ₄ S ₃	4.89 ^{ab}	222 ^{a-c}	30.4 ^c	584.5 ^c	9.07 ^{a-c}	0.77 ^{b-e}	0.73 ^{ab}
M ₄ S ₄	4.84 ^{bc}	216 ^{b-e}	28.4 ^f	584.0 ^d	9.02 ^{a-c}	0.69 ^{d-f}	0.72 ^b
M ₅ S ₁	4.34 ^{i-l}	209 ^{d-f}	28.9 ^e	564.1 ^q	9.09 ^{a-c}	0.66 ^{f-h}	0.52 ^j
M ₅ S ₂	4.33 ^{j-l}	202 ^{fg}	28.2 ^f	563.9 ^q	8.97 ^{a-c}	0.63 ^{f-h}	0.52 ^j
M ₅ S ₃	4.30 ^{kl}	193 ^{gh}	27.1 ^h	563.6 ^r	8.82 ^{bc}	0.58 ^{g-i}	0.51 ^j
M ₅ S ₄	4.27 ^l	187 ^h	25.7 ^j	562.8 ^s	8.78 ^c	0.49 ⁱ	0.49 ^k
SEm±	0.06	4.99	0.20	0.19	0.10	0.05	0.005
Control	4.41	211	29.3	567.0	9.15	0.76	0.53
SEm±	0.06	5.52	0.18	0.20	0.09	0.05	0.005
CD(P=0.05)	0.17	15.8	0.53	0.57	NS	0.14	0.015

Table 2: Nutrient uptake and productivity of rainfed pigeonpea as influenced by zero tillage practices and nutrient doses (Pooled)

Treatments	Total nutrient uptake			Seed yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)	Net return	B: C ratio
	Nitrogen	Phosphorus	Potassium				
Tillage (M)							
M ₁	94.9 ^c	8.02 ^c	29.68 ^c	1,122 ^d	4,309 ^c	41,471 ^d	2.05 ^d
M ₂	108.9 ^b	9.52 ^b	35.97 ^b	1,223 ^c	4,641 ^b	46,536 ^c	2.25 ^c
M ₃	110.8 ^b	9.44 ^b	35.76 ^b	1,285 ^b	4,843 ^b	50,244 ^b	2.46 ^b
M ₄	120.8 ^a	10.81 ^a	41.51 ^a	1,383 ^a	5,163 ^a	55,162 ^a	2.64 ^a
M ₅	82.4 ^d	7.11 ^d	26.40 ^d	1,018 ^e	3,983 ^d	31,110 ^e	1.26 ^e
SEm±	1.69 ^c	0.15	0.71	18	79	978	0.04
Nutrient doses (S)							
S ₁	108.6 ^a	9.48 ^a	35.62 ^a	1,274 ^a	4,736 ^a	47,178 ^a	2.09 ^b
S ₂	106.1 ^{ab}	9.21 ^{ab}	34.76 ^{ab}	1,229 ^{ab}	4,642 ^{ab}	45,505 ^{ab}	2.09 ^b
S ₃	103.4 ^b	8.86 ^{bc}	33.62 ^b	1,188 ^b	4,550 ^{bc}	43,993 ^{bc}	2.10 ^b
S ₄	96.2 ^c	8.37 ^c	31.45 ^c	1,133 ^c	4,424 ^c	42,942 ^c	2.26 ^a
SEm±	1.39	0.15	0.50	14	41	697	0.04
Interaction (M × S)							
M ₁ S ₁	99.0 ^g	8.33 ^{g-i}	31.11 ^{gh}	1,190 ^{f-h}	4,455 ^{e-i}	43,742 ^{g-i}	2.01 ^{fg}
M ₁ S ₂	97.3 ^g	8.20 ^{hi}	30.46 ^{hi}	1,141 ^{hi}	4,345 ^{f-i}	41,850 ^{hi}	2.00 ^g
M ₁ S ₃	95.3 ^g	8.02 ^{ij}	29.51 ^{h-j}	1,107 ^{ij}	4,276 ^{f-j}	40,724 ⁱ	2.02 ^{fg}
M ₁ S ₄	88.1 ^h	7.55 ^{jk}	27.63 ^{jk}	1,050 ^{jk}	4,161 ^{g-j}	39,570 ⁱ	2.17 ^{e-g}
M ₂ S ₁	114.0 ^{c-e}	10.07 ^{cd}	37.65 ^{cd}	1,275 ^{de}	4,769 ^{a-f}	47,937 ^{e-g}	2.16 ^{e-g}
M ₂ S ₂	111.9 ^{de}	9.77 ^{de}	36.93 ^{cd}	1,243 ^{d-g}	4,704 ^{b-f}	46,945 ^{e-g}	2.19 ^{ef}
M ₂ S ₃	108.3 ^{ef}	9.34 ^{ef}	35.61 ^{de}	1,209 ^{e-h}	4,598 ^{d-g}	45,886 ^{f-h}	2.22 ^e

M ₂ S ₄	101.3 ^{fg}	8.90 ^{fg}	33.69 ^{ef}	1,165 ^{g-i}	4,493 ^{d-h}	45,377 ^{f-h}	2.42 ^{cd}
M ₃ S ₁	116.5 ^{b-d}	10.01 ^{cd}	37.43 ^{cd}	1,358 ^{bc}	5,010 ^{a-d}	52,794 ^{b-d}	2.41 ^d
M ₃ S ₂	114.1 ^{c-e}	9.73 ^{de}	36.76 ^d	1,308 ^{cd}	4,902 ^{a-e}	50,814 ^{c-e}	2.40 ^d
M ₃ S ₃	111.0 ^{de}	9.30 ^{ef}	35.81 ^{de}	1,265 ^{d-f}	4,797 ^{a-f}	49,258 ^{d-f}	2.42 ^{cd}
M ₃ S ₄	101.8 ^{fg}	8.73 ^{f-h}	33.01 ^{fg}	1,209 ^{e-h}	4,662 ^{c-g}	48,109 ^{e-g}	2.61 ^b
M ₄ S ₁	126.4 ^a	11.48 ^a	43.38 ^a	1,447 ^a	5,297 ^a	57,205 ^a	2.55 ^{b-d}
M ₄ S ₂	122.5 ^{ab}	11.07 ^{ab}	41.99 ^a	1,407 ^{ab}	5,212 ^{ab}	55,786 ^{ab}	2.58 ^{b-d}
M ₄ S ₃	120.6 ^{a-c}	10.61 ^{bc}	41.32 ^{ab}	1,365 ^{bc}	5,132 ^{a-c}	54,253 ^{a-c}	2.60 ^{bc}
M ₄ S ₄	113.9 ^{c-e}	10.07 ^{cd}	39.38 ^{bc}	1,314 ^{cd}	5,010 ^{a-d}	53,403 ^{a-d}	2.82 ^a
M ₅ S ₁	87.3 ^h	7.52 ^{jk}	28.55 ^{ij}	1,101 ^{ij}	4,147 ^{g-j}	34,214 ^j	1.31 ^h
M ₅ S ₂	84.8 ^h	7.28 ^k	27.66 ^{jk}	1,049 ^{jk}	4,046 ^{h-j}	32,129 ^{jk}	1.27 ^h
M ₅ S ₃	81.9 ^{hi}	7.05 ^{kl}	25.88 ^k	993 ^{kl}	3,945 ^{ij}	29,844 ^k	1.22 ^h
M ₅ S ₄	75.7 ⁱ	6.60 ^l	23.53 ^l	929 ^l	3,792 ^j	28,253 ^k	1.26 ^h
SEm±	2.64	0.23	0.98	27	158	1,529	0.07
Control	95.7	8.19	30.58	1,202	4,548	29,206	0.90
SEm±	2.67	0.24	0.98	27	159	1,603	0.07
CD(P=0.05)	7.65	0.70	2.82	82	454	4,582	0.20

4. Conclusion

Based on the above study, it is concluded that growing of pigeonpea on permanent site of zero till raised bed with residue retention on surface reduces the nutrient requirement upto 50 percent of recommended dose of inorganic nutrients.

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