STUDIES ON MANAGEMENT PRACTICES ON GROWTH, DEVELOPMENT, TILLAGE AND NPK CONTENT OF SOYBEAN (Glycine max L.) IN THE NORTH WESTERN HIMALAYAS

ABSTRACT

A field experiment was conducted for 2 years (2022 & 2023) at Research Farm of the Department of Agronomy, CSK HPKV, Palampur on silty clay loam soils to study the performance of soybean to varied tillage and nutrient management practices. In terms of tillage practices, significantly better plant height, dry matter accumulation, number of nodules and nodule fresh and dry weight per plant, were observed in conventional tillage and zero tillage with residue retention, while zero tillage without residue resulted in the least growth parameters. The number of days to 50 % flowering and physiological maturity were not significantly influenced by both tillage and nutrient managements. The content and uptake of nitrogen, phosphorous and potassium in soybean were also found to be significantly higher in conventional tillage (CT) during the first year and in zero tillage with residue retention (ZTR) during the second, although, during both the years, CT and ZTR was at par with each other. Zero tillage without residue retention (ZT) practices marked the least content and uptake of nutrients irrespective of the years. The nutrient management practices performed alike during both the years, where significantly higher growth parameters and nutrient content and uptake were obtained in organic farming practice, which was followed by recommended dose of fertilizes and integrated nutrient management, nano-urea and Subhash Palekar natural farming. Thus, it can be concluded that though both CT and ZTR performs similarly in plant growth and development, however, in the long term sustainability, ZTR is superior to CT. Organic farming practices is a environment friendly approach and soybean being leguminous in nature greatly responds to it, thereby, adoption of ZTR and organic farming in leguminous crops can be a recommended practices for the long term quality and productivity of agriculture.

Key words: Conventional tillage, Dry matter accumulation, Nodule count, Zero tillage with residue, organic farming

Introduction

Soybean (*Glycine max* L.) is one of the most important leguminous crops grown worldwide, serving as a significant source of protein and oil (Thrane *et al*., 2017). In regions such as the Northwestern Himalayas, where the agro-climatic conditions are unique, optimizing soybean cultivation practices is crucial for achieving high yields and sustaining soil health. Among the various agronomic practices, tillage and nutrient management are critical in determining the growth and development soybean plants.

Tillage practices involves the mechanical manipulation of the soil, plays a pivotal role in influencing soil structure, moisture retention, aeration and nutrient availability (Bushari *et alet al*., 2015). Different tillage systems, ranging from conventional tillage to reduced or no-till methods, have varying effects on soil health and plant performance. The choice of tillage system can impact the microbial activity, organic matter content and soil compaction, all of which influence nutrient uptake by crops (Hu *et al*., 2021).

Nutrient management, on the other hand, involves the efficient application of fertilizers and organic amendments to meet the nutritional demands of crops while minimizing environmental impact. The application of macro and micronutrients is essential for the optimum growth and development of soybean, particularly in regions with soil nutrient deficiencies (Bagale, 2021). Maximizinng fertilizer use efficiency (FUE) and integrated nutrient management (INM) practices can help maintain soil fertility, enhance nutrient availability, and reduce dependence on chemical fertilizers (Panta and Parajulee, 2021).

In India, intensive cereal based cropping systems are the most dominant systems which are exhaustive in nature. Therefore, legume based cropping systems, as such offers a promising and sustainable alternative (Yan *et al*., 2024). Soybean, grown during the *kharif* season, is well suited to rainfed conditions and can essentially improve soil fertility through biological nitrogen fixation.

In the Northwestern Himalayas, where soil fertility is often low and erratic rainfall patterns pose additional challenges, understanding the interaction between tillage practices and nutrient management is vital. This region's complex agro-ecological characteristics require tailored agricultural practices that balance soil conservation with high productivity. The present study aims to investigate the effect of different tillage practices and nutrient management strategies on the growth, development and nutrient content of soybean with a focus on optimizing these practices for sustainable soybean cultivation in the Northwestern Himalayas. By exploring the influence of tillage and nutrient management on soybean production, this research seeks to contribute valuable insights into best practices for improving both crop yields and soil health in this region.

Material and method

The field experiment was conducted at Research Farm of the Department of Agronomy, COA, CSKHPKV, Palampur for 2 years during *kharif* 2022 and 2023. The experimental site lied in Palam valley of district Kangra, with an elevation of 1290.8 meter above mean sea level, $32^o6'$ N latitude, $76^o3'$ E longitude. A critical perusal of weekly meteorological data showed that comparatively more rainfall was received during *kharif* 2023 than *kharif* 2022, with total rainfall during the respective crop seasons being1864.6 mm and 2350.2 mm, respectively. The mean relative humidity during *kharif* 2022 and *kharif* 2023 ranged between 53 to 91 % and 53 to 92 %, respectively. A critical resume of the meteorological data showed that during *kharif* 2022, maximum and minimum temperatures were comparatively higher than *kharif* 2023. The mean maximum temperature ranged from 23.7 ^oC to 33.4 ^oC during *kharif* 2022 and the same during *kharif* 2023 was 24.3 ^oC to 29.8 ^oC. The mean minimum temperature ranged from 10.4 to 20.4 ^oC and 9.9 to 20 ^oC during *kharif* 2022 and *kharif* 2023, respectively. The soil of the experimental site was silty clay loam in texture and acidic in reaction. The soil was medium in organic carbon, medium in available nitrogen and available phosphorus and high in available potassium. The experiment was laid out in split plot design with three replications, with fifteen treatments comprising of three tillage practices in the main plot and five nutrient management practices in sub plots. The treatments in main plot included conventional tillage (CT), zero tillage with residue retention (ZTR) and zero tillage without residue retention (ZT). The sub plot treatments comprised of Recommended dose of fertilizers (RDF), 50% RDN + 100% PK (basal) + foliar spray of nano-urea @ 2ml l^{-1} (25 DAS), Integrated Nutrient Management (INM): 50% RDF + 2.5 t ha^{-1} vermicompost + *Rhizobium* + PSB, Organic farming practice (OFP): 5.0 t ha^{-1} vermicompost + *Rhizobium* + PSB + 2 sprays of vermiwash @ 10% at 25 and 45 DAS and Subhash Palekar Natural Farming practice (SPNF). The experimental field was prepared as per treatments related to tillage practices. The plots under zero tillage were cleaned by removing the stones, stubbles and weeds. The plots for conventional tillage were prepared with the help of a power tiller and levelled. Clean and bold seeds were selected and treated with *Rhizobium* and PSB in INM and OFP and with beejamrit @ 1 litre per 10 kg of seeds in case of SPNF before sowing. The Hara soya variety of soybean was used for sowing. The recommended dose of nitrogen, phosphorous and potassium were 20:60:40 kg ha^{-1}. At 15 DAS, in each plot, one meter row length was marked at two places in the net plot area and the mean number of plants was expressed as number of plants per meter row length to record the emergence count. Five plants in second row from the border row from each plot were sampled. The samples were dried in shade and then oven dried till a constant weight was obtained and was used for growth attribute estimation. The developmental studies in soybean included number of days taken to 50 per cent flowering and days taken to physiological maturity. The date on which 50 per cent plants showed flowering in the net plot was recorded and number of days to attain this was calculated from the date of sowing. The date when 95 per cent of pods on a plant turned brown in colour and leaves turned yellow and started shedding, it was considered as physiological maturity stage and the date was noted for number of days taken for maturity. To estimate nitrogen, phosphorous and potassium content and uptake of soybean standard methods given by Jackson 1973 were followed.

List 1: List of method employed for the study

Nutrient	Method employed
Nitrogen	Modified Kjeldahl's method (Jackson 1973)
Phosphorus	Vanado-molybdate phosphoric method (Jackson 1973)
Potassium	Flame photometer technique (Jackson 1973)

The nutrient uptake by crops was computed with the help of following relationship:

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (\%) x Yield (kg ha}^{-1})}{}$$

$$\overline{}$$
$$100$$

Total uptake of particular nutrient was calculated as follows:

Total uptake = uptake by seed + uptake by straw

The data on growth, development and nutrient contents and uptakes were recorded and subjected to statistical analysis. Statistical significance was tested by applying F-test at 0.05 level of probability.

Results and Discussion

Effect of tillage and nutrient management practices on growth parameters of soybean

A close perusal of data in Table 1 revealed that emergence counts were not significantly impacted by various tillage and nutrient management systems during both years of study. However, administration of various tillage practices significantly influenced the plant height, dry matter accumulation, nodule count per plant, fresh and dry weight of nodule of soybean during both *kharif* 2022 and 2023. During the first *kharif*, higher growth attributes were obtained with conventional tillage, which was followed by zero tillage with residue retention and the lowest with zero tillage without residues. In the following year, the ZTR resulted in higher growth parameters followed by CT, while the shortest were recorded with ZT. However, during both the years, CT and ZTR were at par with each other. Better plant growth with CT during the initial year could be attributed to improved soil aeration, nutrient availability and root growth (Bushari *et al*., 2015). CT practices break up the soil, enhancing aeration, improving root penetration and allowing easy access to nutrients and water initially (Rodríguez *et al*., 2022). However, over time, excessive tilling led to degraded soil structure, reduced organic matter, compaction and lower moisture retention (Toth *et al*., 2024). This might have failed CT in producing the highest growth in the later year. By the second year, ZTR practice resulted in superior plant growth probably due to better nutrient cycling and enhanced soil structure over time. Residue retention acted as mulch, covering the soil and reducing evaporation, thereby conserving soil moisture. The residue decomposed and contributed to higher soil organic matter, enhancing water holding capacity and providing a more stable environment for root growth (Li *et al*., 2018). ZT consistently resulted in the least growth in both years due to poor moisture retention and soil compaction. Absence of residue cover possibly exposed the soil to direct sunlight, increasing evaporation and reduced soil moisture (Sarker *et al*., 2022). ZT practices led to soil compaction over time, which restricted root growth, limiting the plant's ability to access water and nutrients deep in the soil, thereby, contributing to lesser growth attributes.

In terms of nutrient management practices, a similar trend was observed during both *kharif* 2022 and 2023, where, organic farming practices (OFP) resulted in significantly higher growth attributes, which was followed by INM, RDF, with both being at par with each other. Next in line was combined application of inorganic fertilisers and nano-urea and the least was observed in natural farming practices. Organic farming practices relied on organic inputs such as vermicompost and vermiwash which are rich in essential nutrients. These nutrients were released slowly and steadily as the organic matter decomposed, providing a continuous supply of nutrients throughout the crop growth stages (Mohite at al., 2024). This also improved soil structure by increasing the organic matter content and encouraging diverse soil microbial activity, which further breaks down organic matter, releasing nutrients in a form that the plants can absorb easily (Lim *et al*., 2015). INM combines both organic and inorganic nutrient sources, ensuring a balance between immediate nutrient availability from inorganic fertilizers and the slower, sustained release of nutrients from organic sources (Graham *et al*., 2017). This balanced approach ensured that plants have access to nutrients throughout the growing season, promoting strong and sustained growth (Kumar *et al*., 2024). RDF and combined application of inorganic fertilizers with nano-urea provided a rapid supply of essential nutrients like nitrogen, phosphorus and potassium, which are crucial for early plant development. However, these nutrients are often more readily available in the early stages, resulting in rapid initial growth. Nano-urea provides highly efficient nitrogen delivery, improving plant growth in the short term, but due to lack of contribution to soil organic matter it fails in the long term improvement of soil structure and fertility (Swify *et al*., 2024). Natural farming practices relied on natural inputs like jeevamrit, beejamrit, ghanjeevamrit, etc., while these inputs provided some nutrients, their availability is often lower and less consistent than organic or inorganic systems, leading to limited nutrient availability at critical growth stages, resulting in shorter plants throughout the growing season (Biswas and Pakhira, 2023).

In general, the growth of soybean was found to be greater in *kharif* 2023 than *kharif* 2022, which might be attributed to higher rainfall and humidity in the year 2023 that ensured adequate water supply, nutrient uptake and efficient photosynthesis, besides reducing water stress. The interaction between the various tillage and nutrient management practices was found to be non-significant.

Effect of tillage and nutrient management practices on developmental phases of soybean

A close perusal of the data enshrined in Table 2 revealed that the applied treatments had no significant effect on the number of days taken to attain 50 % flowering and days to physiological maturity. However, during the first year, among the tillage practices, numbers of days to attain 50 % flowering and physiological maturity were found to be lesser in CT and longer duration was observed in ZT. During *kharif* 2023, numbers of days to 50 % flowering and days to physiological maturity were found to be lesser with ZTR and longer with ZT.

Table 1: Effect of tillage and nutrient managements on growth parameters of soybean

Treatments	Emergence count at 15 DAS		Plant height (cm)		Dry matter accumulation (g m^{-2})		Number of nodules per plant		Fresh weight of nodules per plant (g)		Dry weight of nodules per plant (g)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
Tillage practices												
C_1	23.36	23.35	89.3	89.3	308.6	316.4	56.9	55.8	0.91	0.88	0.42	0.42
C_2	22.94	23.25	87.1	91.8	292.6	332.0	54.6	57.3	0.87	0.94	0.40	0.44
C_3	22.23	22.33	83.7	84.2	269.1	293.6	50.6	51.9	0.81	0.82	0.37	0.39
SEm±	0.46	0.48	0.8	0.8	5.1	3.5	0.6	0.6	0.01	0.01	0.004	0.005
CD (P =0.05)	NS	NS	3.3	3.3	20.1	13.7	2.4	2.3	0.04	0.04	0.02	0.03
Nutrient management practices												
M_1	22.78	23.01	87.2	89.5	294.7	316.7	53.3	54.2	0.85	0.87	0.40	0.41
M_2	22.54	22.73	83.9	85.8	272.2	295.8	52.4	53.5	0.84	0.86	0.39	0.40
M_3	23.03	23.42	89.2	90.5	305.9	330.8	55.4	56.8	0.89	0.91	0.41	0.43
M_4	23.53	23.85	92.8	94.1	328.3	351.8	57.7	58.5	0.92	0.94	0.43	0.44
M_5	22.32	22.60	80.3	82.3	249.6	275.0	51.5	52.2	0.82	0.84	0.38	0.39
SEm±	0.42	0.34	0.9	0.9	6.6	6.2	0.7	0.6	0.01	0.01	0.005	0.004
CD (P =0.05)	NS	NS	2.7	2.8	19.2	18.1	2.1	1.6	0.03	0.03	0.02	0.02

C_1: Conventional tillage, **C_2**: Zero tillage with Residue, **C_3**: Zero tillage without residue, **M_1**: RDF, **M_2**: 50% RDN + 100% PK + nano-urea @ 2 ml l^{-1} (25 DAS), **M_3**: INM-50% RDF + 2.5 t ha^{-1} VC + *Rhizobium*+ PSB, **M_4**: OF-5 t ha^{-1} VC + *Rhizobium* + PSB + vermi wash @ 10% (25, 40 and 55 DAS), **M_5**: Subhash Palekar's natural farming

In terms of nutrient management practices, organic farming practices recorded the least number of days while natural farming practices recorded the maximum number of days to achieve the phenophases under observation. The number of days required by a crop to achieve a particular phenophase is a varietal character and depends on weather conditions, mainly temperature varying slightly due to the cultivation practices. The interaction between the various tillage methods and nutrient management practices was found to be non-significant.

Treatments	**Days to 50 per cent flowering**		**Days to physiological maturity**	
	2022	**2023**	**2022**	**2023**
Tillage practices				
C_1	57.20	60.33	117.81	119.90
C_2	59.47	59.33	118.50	119.26
C_3	60.13	61.53	120.47	120.80
SEm±	1.12	1.49	0.76	0.63
CD (P =0.05)	NS	NS	NS	NS
Nutrient management practices				
M_1	58.56	60.00	118.97	119.99
M_2	59.44	61.67	119.44	120.16
M_3	58.33	59.44	118.49	119.53
M_4	57.56	58.33	117.98	119.36
M_5	60.78	62.56	119.75	120.78
SEm±	1.63	1.49	0.98	0.63
CD (P =0.05)	NS	NS	NS	NS

Table 2: Effect of tillage and nutrient managements on developmental stages of soybean

C_1: Conventional tillage, **C_2**: Zero tillage with Residue, **C_3**: Zero tillage without residue, **M_1**: RDF, **M_2**: 50% RDN + 100% PK + nano-urea @ 2 ml l^{-1} (25 DAS), **M_3**: INM-50% RDF + 2.5 t ha^{-1} VC + *Rhizobium*+ PSB, **M_4**: OF-5 t ha^{-1} VC + *Rhizobium* + PSB + vermi wash @ 10% (25, 40 and 55 DAS), **M_5**: Subhash Palekar's natural farming

Effect of tillage and nutrient management practices on N, P and K content in grain and straw of soybean

The data pertaining to the effect of various tillage and nutrient management practices on the nitrogen, phosphorous and potassium content in grain and straw of soybean have been embodied in Table 3. The result revealed the significant influence of the treatments on the nutrient content of grain and straw during both the years of study (2022 and 2023). A close perusal of data revealed that CT and ZTR resulted in significantly higher NPK content over ZT. In the first year, CT practices exhibited higher NPK content in soybean while in the following year, maximum content was obtained with ZTR treatments. However, during both the years, both CT and ZTR were at par with each other. Conversely, ZT exhibited lowest NPK content irrespective of the year. The variation in nutrient content between CT and ZTR could be due to differences in soil nutrient availability and microbial activity over time. In the first year, CT likely provided better mineralization due to soil disturbance, enhancing nutrient release (Vilakazi *et al*., 2022). However, in the succeeding year, ZTR treatments may have improved soil health, organic matter retention and microbial activity, leading to better nutrient availability (Chandra *et al*., 2023).

With respect to nutrient management studies, during both the years, significantly higher nutrient content in grain was noticed with OFP. It was closely followed by INM and RDF, where both were at par with each other and superior over conjoint application of inorganic fertilizers and nano-urea. The treatment comprising natural farming practices showed the lowest content of NPK in grain. Similar trends were observed in the NPK content of straw. The higher nutrient content in grain and straw with OFP could be attributed to the gradual release of nutrients from organic sources, improved soil structure and enhanced microbial activity, promoting root growth and better nutrient uptake (Paramesh *et al*., 2023). INM and RDF also provided sufficient nutrient, though slightly lower than organic systems, due to a combination of organic and inorganic inputs which might be due to reduced organic matter and nutrient cycling imbalances (Kumari *et al*., 2023). In contrast, natural farming practices, relying primarily on minimal external inputs, resulted in the lowest content, as the nutrient availability may not have been sufficient to meet the crop's full nutrition demand (Awasthi *et al*., 2020).

The interactions between different treatments had no significant effect on the NPK content of grain and straw of soybean.

Effect of tillage and nutrient management practices on N, P and K uptake in grain and straw of soybean

The mean values of NPK uptake by grain and straw along with total uptake in soybean have been presented in Table 4. A close analysis of data revealed that CT practices resulted in higher nutrient uptake in both grain and straw, which was however statistically equivalent to ZTR. The lowest uptake of NPK was recorded with ZT. However, in the succeeding year, higher NPK uptake in both grain and straw was noticed when zero tillage was practiced along with residue retention, and it was statistically at par with CT. ZT resulted in the lowest uptake of nutrients. In terms of nutrient management systems, during both the years, NPK uptake in grain and straw was recorded to be significantly higher with organic farming practices, which was followed by INM, RDF, integrated application of inorganic fertilisers and nano-urea and natural farming practices. However, INM was at par with RDF. The total uptake of nutrients in soybean followed the same trend as that in grain and straw for both tillage and nutrient management practices.

The nutrient uptake is a function of both nutrient content and yield, therefore, higher NPK content in grain and straw along with significantly larger grain and straw yields in the aforementioned treatments resulted in significantly higher uptake of NPK by both grain and straw (Dubey *et al*., 2022). The total nutrient uptake by a crop is the sum of the nutrient uptake by grain as well as straw, the higher uptake by grain and straw was reflected in superior uptake of total NPK in the aforesaid treatments.

Interaction effect of tillage practices and nutrient management practices was found to be non-significant during both the years.

Conclusion

The result of the experiment revealed that both CT and ZTR practices resulted in better growth and development of soybean. However, considering the long term benefits and sustainability of future agriculture, ZTR is more preferable that CT. Among the nutrient managements, organic farming outperformed other practices, providing steady nutrient release, enhanced soil structure and microbial activity. Therefore, ZTR and OFP emerged as the most sustainable practices for long-term soybean cultivation in the region.

Table 3: Effect of tillage and nutrient managements on N, P and K content in per cent (%) of soybean

Treatments	**N content in grain**		**N content in straw**		**P content in grain**		**P content in straw**		**K content in grain**		**K content in straw**	
	2022	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
Tillage practices												
C_1	6.22	6.28	1.56	1.60	0.472	0.494	0.182	0.192	1.51	1.53	2.29	2.32
C_2	6.20	6.36	1.54	1.66	0.464	0.507	0.177	0.198	1.50	1.55	2.26	2.37
C_3	6.07	6.20	1.45	1.51	0.453	0.476	0.160	0.175	1.46	1.49	2.19	2.24
SEm±	0.02	0.02	0.01	0.01	0.002	0.003	0.001	0.002	0.01	0.004	0.02	0.02
CD (P =0.05)	0.08	0.08	0.04	0.03	0.010	0.014	0.006	0.007	0.03	0.02	0.08	0.07
Nutrient management practices												
M_1	6.19	6.30	1.52	1.60	0.466	0.496	0.175	0.188	1.50	1.53	2.28	2.34
M_2	6.09	6.21	1.49	1.56	0.446	0.478	0.164	0.182	1.46	1.50	2.20	2.26
M_3	6.23	6.33	1.54	1.62	0.478	0.507	0.181	0.194	1.51	1.55	2.30	2.36
M_4	6.32	6.44	1.57	1.66	0.499	0.525	0.153	0.206	1.55	1.58	2.34	2.41
M_5	5.98	6.12	1.46	1.52	0.426	0.455	0.189	0.172	1.42	1.47	2.11	2.17
SEm±	0.03	0.03	0.01	0.01	0.006	0.006	0.003	0.003	0.01	0.008	0.02	0.01
CD (P =0.05)	0.08	0.07	0.02	0.03	0.017	0.017	0.009	0.009	0.02	0.02	0.07	0.04

C_1: Conventional tillage, **C_2**: Zero tillage with Residue, **C_3**: Zero tillage without residue, **M_1**: RDF, **M_2**: 50% RDN + 100% PK + nano-urea @ 2 ml l^{-1} (25 DAS), **M_3**: INM-50% RDF + 2.5 t ha^{-1} VC + *Rhizobium*+ PSB, **M_4**: OF-5 t ha^{-1} VC + *Rhizobium* + PSB + vermi wash @ 10% (25, 40 and 55 DAS), **M_5**: Subhash Palekar's natural farming

Table 4: Effect of tillage and nutrient managements on NPK uptake (kg ha^{-1}) of soybean

Treatments	N uptake						P uptake						K uptake					
	Grain		Straw		Total		Grain		Straw		Total		Grain		Straw		Total	
	2022	2023	2022	2023	2023	2022	2022	2023	2022	2023	2023	2022	2022	2023	2022	2023	2023	2022
Tillage practices																		
C_1	86.0	88.4	33.2	34.5	119.2	122.9	6.6	7.0	3.9	4.1	10.5	11.1	21.0	21.6	48.9	56.2	69.9	71.7
C_2	80.5	94.2	31.4	37.6	111.9	131.7	6.0	7.5	3.6	4.5	9.7	12.0	19.5	23.0	46.0	59.5	65.5	76.6
C_3	71.9	79.7	27.3	30.5	99.2	110.2	5.4	6.1	3.0	3.6	8.4	9.7	17.3	19.2	41.1	50.1	58.4	64.4
SEm±	1.4	1.3	0.0	0.5	2.0	1.6	0.1	0.2	0.1	0.03	0.2	0.1	0.4	0.4	1.2	0.9	1.5	1.2
CD (P =0.05)	5.6	5.1	2.4	2.0	7.9	6.2	0.4	0.4	0.4	0.1	0.7	0.4	1.6	1.6	4.7	3.5	5.9	4.6
Nutrient management practices																		
M_1	80.6	88.5	31.1	34.5	111.7	123.0	6.1	7.0	3.6	4.1	9.7	11.1	19.6	21.5	46.7	50.5	66.3	72.1
M_2	72.9	80.8	28.4	31.7	101.2	112.5	5.3	6.2	3.1	3.7	8.5	9.9	17.5	19.5	41.7	45.9	59.2	65.4
M_3	85.3	93.2	32.5	36.4	117.8	129.5	6.6	7.5	3.8	4.4	10.4	11.8	20.7	22.8	48.6	53.1	69.3	75.9
M_4	93.5	101.7	35.5	39.4	129.0	141.1	7.4	8.3	4.4	4.9	11.7	13.2	23.0	24.9	52.9	57.5	75.8	82.4
M_5	65.0	73.1	25.7	28.9	90.7	101.9	4.6	5.4	2.7	3.3	7.3	8.7	15.5	17.5	36.9	41.2	52.4	58.7
SEm±	2.3	2.3	0.8	0.7	2.8	2.8	0.2	0.1	0.1	0.1	0.3	0.3	0.6	0.6	1.2	1.2	1.6	1.6
CD (P =0.05)	6.9	6.8	2.3	2.1	8.2	8.2	0.6	0.6	0.3	0.3	0.8	0.9	1.7	1.7	3.5	3.4	4.8	4.5

C_1: Conventional tillage, **C_2**: Zero tillage with Residue, **C_3**: Zero tillage without residue, **M_1**: RDF, **M_2**: 50% RDN + 100% PK + nano-urea @ 2 ml l^{-1} (25 DAS), **M_3**: INM-50% RDF + 2.5 t ha^{-1} VC + *Rhizobium*+ PSB, **M_4**: OF-5 t ha^{-1} VC + *Rhizobium* + PSB + vermi wash @ 10% (25, 40 and 55 DAS), **M_5**: Subhash Palekar's natural farming

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