

## Tillage and Green Manuring Effects on Nutrient Composition, Uptake and Yield Components of Maize (*Zea mays* L.)

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Received 14 June 2025, Accepted 5 August 2025, Published on 5 September 2025

### ABSTRACT

Soil and water conservation is vital for sustainable development of farming systems especially in India, where a large proportion of the population depends directly on agriculture for their livelihood. Ensuring the future of farming requires placing the highest importance on conservation. Formulating and implementing effective conservation strategies is fundamental to securing the future of farming through the adoption of

resilient and resource-efficient agricultural practices. In line with this goal, a two-year study was undertaken during the *kharif* seasons of 2022 and 2023 on the topic, tillage and green manuring effects on nutrient composition, uptake and yield components of maize (*Zea mays* L.). The findings from the two-year investigation presented that minimum tillage ( $M_T$ ) significantly enhanced nutrient accumulation (N, P and K). In relation to conventional tillage ( $C_T$ ),  $M_T$  increased N, P and K content in seed by 1.37%, 4.34% and 4.65%, respectively and N and P content in stover by 1.61% and 5.55%. Seed and stover yield also improved slightly under  $M_T$  by 0.16% and 0.29%, respectively. Furthermore,  $M_T$  elevated N and P uptake in seed by 1.55% and 1.77%. The interactive effect of  $T_M G_6$  i.e. Minimum tillage with green manuring through Dhaincha 2 tonnes + Cowpea 2 tonnes @ 4 tonnes  $ha^{-1}$ , demonstrated the highest effectiveness among all treatment combination, significantly boosting nutrient concentration, uptake, and yield.  $T_M G_6$  increased N and P content in seed by 24% and 28.57%, and in stover by 18.58% and 60%, respectively, compared to  $T_C G_0$ . Similarly, N and P uptake in seed rose by 31.91% and 33.95%, and in stover by 25.26% and 69.70% respectively. Another promising treatment,  $T_M G_2$  ( $M_T$  + Dhaincha @ 4 t  $ha^{-1}$ ), led to marked improvements in K content and uptake.

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**Keywords** Nutrient, NPK, Dhaincha, Cowpea, Manuring.

## INTRODUCTION

Conservation of soil and water is crucial in India due to increasing land degradation, declining soil fertility, and growing water scarcity, especially in agriculture-dependent regions. Unsustainable land use, erosion, and overuse of groundwater threaten food security and rural livelihoods. Effective conservation is essential to ensure long-term productivity and environmental stability. Adopting appropriate tillage practices and incorporating green manure can offer practical solutions in the long run for conservation of natural resources. Conservation and minimum tillage reduces soil disturbance, preserves organic matter, and minimizes erosion, while improving water retention. Green manure, such as leguminous cover crops, enhances soil structure, boosts organic carbon, and increases nutrient availability, especially nitrogen and potassium. Together, these practices improve soil health, promote efficient water use, and enhance crop yields sustainably. They also reduce reliance on chemical fertilizers, making farming eco-friendlier and cost-effective. Promoting these methods can play a significant role in restoring soil productivity and achieving sustainable agriculture in India.

Maize (*Zea mays* L.) is a major cereal crop widely grown in India and across the world for food, feed, and industrial purposes. It is highly valued for its adaptability, high yield potential, and diverse uses. Maize seeds are rich in carbohydrates, providing a quick source of energy. They also contain moderate amounts of protein, dietary fiber, and essential vitamins such as B-complex (especially thiamine and niacin). Additionally, maize is a good source of minerals like magnesium, phosphorus and iron. Its nutritional value makes it important in human diets, animal feed, and processed food products. Maize seed is a highly nutritious cereal grain that serves as a staple food in many regions. It is rich in carbohydrates, providing about 72–74 g per 100 grams, making it an excellent source of energy. Maize also contains 8–11 g of protein, which contributes to muscle growth and repair, though it lacks some essential amino acids. Its fat content ranges from 3.5 to 5 g, mainly comprising healthy unsaturated fats. In addition, maize offers dietary fiber, B-complex vitamins, and essential minerals like phosphorus and magnesium, making it

valuable for both human diets and animal feed.

Nagaland, located in the hilly Northeastern region of India, faces significant challenges related to soil degradation, making soil conservation a critical need. The state's terrain is dominated by steep slopes, and traditional farming practices like shifting cultivation (*jhum*) often lead to soil erosion, nutrient loss, and declining productivity. Heavy rainfall during the monsoon further accelerates erosion, washing away the fertile topsoil and reducing land suitability for cultivation. As agriculture is the main livelihood for a large portion of the population, conserving soil is essential for food security, sustainable land use and rural development. Soil conservation methods such as terracing, agroforestry, green manuring, appropriate tillage and permanent farming systems can help stabilize slopes, retain moisture, and restore soil fertility. Promoting awareness, adopting sustainable farming techniques, and integrating indigenous knowledge with modern practices are crucial for long-term ecological balance and agricultural sustainability in Nagaland. The present study aims to address the issues caused by improper tillage practices and promote the greater adoption of organic nutrient sources by incorporating green manures into farming systems.

## MATERIALS AND METHODS

The experiment was conducted during the *kharif* seasons of the year 2022 and 2023 at the experimental farm of Department of Soil and Water Conservation, School of Agricultural Sciences, Nagaland University. The experimental field is located at 310 meters above mean sea level. Its coordinates are 25°45'01" N latitude and 93°51'20" E longitude. The experimental site receives an average rainfall of 2000–2500 mm. The experiment was conducted in split plot design. The experiment consists of two factors- tillage as the main plot and green manuring as the sub plot. For the main plot two different types of tillage operation namely minimum tillage ( $T_M$ ) and conventional tillage ( $T_C$ ) was implemented whereas for the sub plots seven sub plots namely control ( $G_0$ ), Green manuring through Dhaincha @ 2 tonnes  $ha^{-1}$  ( $G_1$ ), Green manuring through Dhaincha @ 4 tonnes  $ha^{-1}$  ( $G_2$ ), Green manuring through Cowpea @ 2 tonnes  $ha^{-1}$  ( $G_3$ ), Green manuring through Cowpea @ 4 tonnes

**Table 1.** Initial soil properties and methods followed for determination.

Soil parameters	Value	Methods employed	Reference
pH	5.51	Glass electrode pH meter (1:2.5 soil and water ratio)	Jackson (1973)
Organic carbon (%)	2.04	Walkley and Black, rapid titration	Jackson (1973)
Cation exchange capacity (cmol (p <sup>+</sup> ) kg <sup>-1</sup> )	10.31	Centrifuge method	Baruah and Barthakur (1997)
Available N (kg ha <sup>-1</sup> )	376.32	Alkaline potassium permanganate method	Subbiah and Asija (1956)
Available P (kg ha <sup>-1</sup> )	12.05	Bray's No. 1 method	Bray and Kurtz (1945)
Available K (kg ha <sup>-1</sup> )	154.24	Neutral ammonium acetate method	Hanway and Heidel (1952)

ha<sup>-1</sup> (G<sub>4</sub>), Green manuring through Dhaincha (1 t ha<sup>-1</sup>) and Cowpea (1 t ha<sup>-1</sup>) @ 2 tonnes ha<sup>-1</sup> (G<sub>5</sub>), Green manuring through Dhaincha (2 t ha<sup>-1</sup>) and Cowpea (2 t ha<sup>-1</sup>) @ 4 tonnes ha<sup>-1</sup> (G<sub>6</sub>) was incorporated. The experiment was replicated thrice and the total number of treatment combinations was fourteen. The treatment combinations were T<sub>M</sub>G<sub>0</sub>, T<sub>M</sub>G<sub>1</sub>, T<sub>M</sub>G<sub>2</sub>, T<sub>M</sub>G<sub>3</sub>, T<sub>M</sub>G<sub>4</sub>, T<sub>M</sub>G<sub>5</sub>, T<sub>M</sub>G<sub>6</sub>, T<sub>C</sub>G<sub>0</sub>, T<sub>C</sub>G<sub>1</sub>, T<sub>C</sub>G<sub>2</sub>, T<sub>C</sub>G<sub>3</sub>, T<sub>C</sub>G<sub>4</sub>, T<sub>C</sub>G<sub>5</sub>, T<sub>C</sub>G<sub>6</sub>. The total number of plots for the experiment was 42. Recommended dose of fertilizer for the crop was applied before sowing of crop. Nitrogen content in seed and stover were analyzed by Modified Kjeldhal method as described by (Black 1965). Phosphorus content in seed and stover was determined by vanadomolybdo-phosphorus yellow color method as outlined by Jackson (1973) by using spectrophotometer at 470 nm. Potassium content in seed and stover was determined by flame photometer as described by Chapman and Pratt (1961). Nutrient uptake was calculated by multiplying the yield with nutrient content. Prior to sowing of seeds, soil samples were collected from various locations of the experimental field at 15 cm depth to evaluate various initial soil properties (Table 1). The various soil properties were evaluated following standard procedures. Gomez and Gomez (2004) technique was followed in the data analysis. T<sub>o</sub> compare mean differences, critical difference (CD) and standard error of the mean (SEM ±) values were provided.

## RESULTS AND DISCUSSION

### Nutrient content, seed and stover yield

A rational analysis of seed and stover nutrient content

is presented in Table 2. In the main plot (Tillage), the use of minimum tillage (T<sub>M</sub>) led to an enhancement in seed and stover N, P, and K concentrations over conventional tillage (C<sub>T</sub>). With reference to nitrogen content in seed and stover, T<sub>M</sub> with the nitrogen content of 1.47% in seed and 1.26% in stover was recorded to be higher than that of C<sub>T</sub> which was detailed at 1.45% and 1.24% respectively. This amounted to an increase of approximately 1.37% in seed and 1.61% in stover in relation to N content. This outcome may be due to ability of minimum tillage to increase nitrogen in maize seed and stover by enhancing microbial activity and preserving organic matter, improving nitrogen availability. Conventional tillage disrupts this balance and leads to greater nitrogen loss. Sime and Aune (2016) reported that minimum tillage, when combined with practices like residue retention or organic amendments, enhances soil structure and moisture retention, leading to better maize establishment. This improved growth environment indirectly supports higher nitrogen uptake by promoting stronger root development and increased nutrient availability. Comparable results were also outlined by Li *et al.* (2023) and Batyrbek *et al.* (2022). In the sub plot (Green manuring) the incorporation of (G<sub>6</sub>) i.e. Green manuring through Dhaincha 2 tonnes + Cowpea 2 tonnes @ 4 tonnes ha<sup>-1</sup> was found to be superior over all the treatments. The highest N content in seed and stover was observed with the incorporation of G<sub>6</sub> (1.55% and 1.33% respectively) whereas the lowest was in G<sub>0</sub> (1.28% and 1.16%) when compared it showed an increase of 21.09% and 14.65% respectively. The interaction table outlined that the combination of T<sub>M</sub>G<sub>6</sub> i.e. Minimum tillage with Green manuring through Dhaincha 2 tonnes +

**Table 2.** Effect of tillage and green manuring on nutrient composition, seed and stover yield and its interaction (pooled). T<sub>M</sub>- Minimum tillage, T<sub>C</sub>- Conventional tillage, G- Green manuring, NS- Non significant, SEM ± – Standard error of the mean, CD- Critical difference.

Treatments	N content (%)		P content (%)		K content (%)		Seed yield (kg ha <sup>-1</sup> )	Stover yield (kg ha <sup>-1</sup> )
	Seed	Stover	Seed	Stover	Seed	Stover		
Tillage								
T <sub>M</sub>	1.47	1.26	0.24	0.19	0.45	1.32	5584.98	7386.84
T <sub>C</sub>	1.45	1.24	0.23	0.18	0.43	1.31	5575.58	7365.26
SEm ±	<b>0.0019</b>	<b>0.0015</b>	<b>0.0017</b>	<b>0.0008</b>	<b>0.0022</b>	<b>0.0037</b>	<b>0.0365</b>	<b>0.2226</b>
CD @ 5%	<b>0.0074</b>	<b>0.0059</b>	<b>0.0068</b>	<b>0.0030</b>	<b>0.0085</b>	NS	<b>0.1431</b>	<b>0.8742</b>
Green manuring								
G <sub>0</sub>	1.28	1.16	0.22	0.15	0.39	1.22	5366.82	7219.25
G <sub>1</sub>	1.48	1.23	0.24	0.17	0.42	1.27	5586.45	7311.24
G <sub>2</sub>	1.49	1.27	0.24	0.20	0.52	1.34	5646.52	7418.10
G <sub>3</sub>	1.47	1.23	0.23	0.19	0.41	1.33	5556.91	7309.26
G <sub>4</sub>	1.51	1.28	0.24	0.19	0.44	1.32	5618.71	7517.19
G <sub>5</sub>	1.48	1.25	0.23	0.18	0.43	1.31	5594.05	7319.42
G <sub>6</sub>	1.55	1.33	0.25	0.22	0.48	1.39	5692.48	7537.90
SEm ±	<b>0.0041</b>	<b>0.0036</b>	<b>0.0019</b>	<b>0.0028</b>	<b>0.0029</b>	<b>0.0046</b>	<b>0.1739</b>	<b>0.6379</b>
CD @ 5%	<b>0.0118</b>	<b>0.0101</b>	<b>0.0053</b>	<b>0.0079</b>	<b>0.0083</b>	<b>0.0130</b>	<b>0.4946</b>	<b>1.8138</b>
Interaction								
T <sub>M</sub> G <sub>0</sub>	1.31	1.19	0.22	0.16	0.40	1.23	5374.21	7259.40
T <sub>M</sub> G <sub>1</sub>	1.49	1.23	0.25	0.17	0.42	1.26	5590.75	7313.59
T <sub>M</sub> G <sub>2</sub>	1.51	1.27	0.25	0.21	0.53	1.35	5650.14	7423.03
T <sub>M</sub> G <sub>3</sub>	1.48	1.23	0.24	0.18	0.42	1.33	5561.04	7313.10
T <sub>M</sub> G <sub>4</sub>	1.51	1.29	0.24	0.20	0.46	1.32	5625.01	7521.79
T <sub>M</sub> G <sub>5</sub>	1.48	1.25	0.24	0.19	0.43	1.32	5597.54	7326.39
T <sub>M</sub> G <sub>6</sub>	1.55	1.34	0.27	0.24	0.50	1.41	5696.16	7550.58
T <sub>C</sub> G <sub>0</sub>	1.25	1.13	0.21	0.15	0.39	1.22	5359.43	7179.10
T <sub>C</sub> G <sub>1</sub>	1.47	1.23	0.24	0.17	0.42	1.28	5582.16	7308.90
T <sub>C</sub> G <sub>2</sub>	1.48	1.26	0.23	0.19	0.51	1.34	5642.90	7413.16
T <sub>C</sub> G <sub>3</sub>	1.47	1.23	0.22	0.20	0.40	1.33	5552.78	7305.42
T <sub>C</sub> G <sub>4</sub>	1.51	1.27	0.23	0.19	0.43	1.32	5612.42	7512.60
T <sub>C</sub> G <sub>5</sub>	1.47	1.24	0.22	0.18	0.43	1.31	5590.56	7312.44
T <sub>C</sub> G <sub>6</sub>	1.54	1.32	0.24	0.21	0.47	1.38	5688.80	7525.23
SEm ±	<b>0.0059</b>	<b>0.0050</b>	<b>0.0026</b>	<b>0.0039</b>	<b>0.0041</b>	<b>0.0065</b>	<b>0.2460</b>	<b>0.9021</b>
CD @ 5%	<b>0.0166</b>	<b>0.0143</b>	<b>0.0075</b>	<b>0.0112</b>	<b>0.0118</b>	NS	<b>0.6994</b>	<b>2.5650</b>

Cowpea 2 tonnes @ 4 tonnes ha<sup>-1</sup> was found to be superior over all the other treatment combination. In the interaction table the highest N content in seed was recorded in the combination of T<sub>M</sub>G<sub>6</sub> with 1.55% for seed and 1.34% for stover and the lowest in T<sub>C</sub>G<sub>0</sub> with 1.25% and 1.13%, illustrating an increase of 24% and 18.58% respectively over T<sub>C</sub>G<sub>0</sub> i.e. Conventional tillage + Control.

The evidence associated to phosphorus content in seed and stover is presented in Table 2. In the main plot (Tillage), P content in seed and stover was

significantly improved with the implementation of M<sub>T</sub> as compared to C<sub>T</sub>. M<sub>T</sub> increased the P content in seed by 4.34% and stover by 5.55% as compared to C<sub>T</sub>. This outcome may be attributed to the ability of minimum tillage to enhance phosphorus content in maize seed and stover by preserving soil structure, promoting microbial activity, and maintaining organic matter, factors that collectively improve phosphorus availability. In contrast, conventional tillage disrupts soil integrity and accelerates nutrient loss, thereby limiting phosphorus uptake. In the sub plot (Green manuring), the incorporation of (G<sub>6</sub>) i.e. Green ma-

nuring through Dhaincha 2 tonnes + Cowpea 2 tonnes @ 4 tonnes ha<sup>-1</sup> was found to be superior over all the treatments in P content in seed and stover. The highest P content in both seed and stover was observed in G<sub>6</sub>. Pertaining to the seed, the highest P content was observed in G<sub>6</sub> which was 0.25% and the lowest was in G<sub>0</sub> which was recorded at 0.22%, presenting an increase of 13.63% when computed. As for P content in stover, G<sub>6</sub> which was 0.22% and the lowest was in G<sub>0</sub> which was recorded at 0.15%, presenting an increase of 46.66%. Medeiros *et al.* (2019) disclosed that the use of *Arachis pintoias* green manure in combination with natural phosphate led to a more than 300% increase in phosphorus content and uptake by maize. This synergy enhances phosphorus availability, resulting in improved maize growth and higher phosphorus levels in the seeds. This observation is supported by the work of Lee *et al.* (2020). The interaction table revealed that the combination of T<sub>M</sub>G<sub>6</sub> i.e. Minimum tillage with Green manuring through Dhaincha 2 tonnes + Cowpea 2 tonnes @ 4 tonnes ha<sup>-1</sup> was found to be superior over all the other treatment combination. In the interaction table the highest P content in seed was recorded in the combination of T<sub>M</sub>G<sub>6</sub> with 0.27% and the lowest in T<sub>C</sub>G<sub>0</sub> with 0.21%, illustrating an increase of 28.57% when equated. The P content in stover unveiled that an increase of 60% in P content in stover was observed when the highest (T<sub>M</sub>G<sub>6</sub>) was differentiated with the lowest (T<sub>C</sub>G<sub>0</sub>). The rise in P content may be because, green manures increases phosphorus in maize by improving organic matter and microbial activity, which enhance phosphorus release and availability during decomposition.

Potassium content in seed and stover is briefed in Table 2. In the main plot (Tillage), K content in seed and stover was significantly improved with the implementation of M<sub>T</sub> as compared to C<sub>T</sub>. M<sub>T</sub> increased the P content in seed by 4.65% and stover by 0.76% as compared to C<sub>T</sub>. In the sub plot, the incorporation of G<sub>2</sub> i.e. Green manuring through Dhaincha @ 4 tonnes ha<sup>-1</sup> increased the K content in seed by 33.33% as compared to G<sub>0</sub> i.e. control which exhibited the least value. Whereas, the incorporation of G<sub>6</sub> increased the K content in stover by 13.93% as compared to G<sub>0</sub> i.e. control, which showed the least effectiveness among all the treatment in the sub plot. In relation to the interaction between tillage and green manuring, T<sub>M</sub>G<sub>2</sub> i.e.

Minimum tillage + Green manuring through Dhaincha @ 4 tonnes ha<sup>-1</sup> with 0.53% K content in seed presented an increase of about 35.89%, as compared to T<sub>C</sub>G<sub>0</sub> i.e. Conventional tillage + Control with 0.39% K content in seed. Zhou *et al.* (2020) conveyed that potassium is an essential macronutrient for maize, playing a key role in its growth, yield and overall nutrient uptake and content. Research indicates that appropriate potassium supplementation either via inorganic fertilizers or green manuring boosts maize performance by increasing the efficiency of nutrient absorption. Collaborating evidences comes from the study done by Singh *et al.* (2023). As for the K content in stover, the combination of T<sub>M</sub>G<sub>6</sub> was found to be superior over all the other treatment combination. In the interaction table the highest K content in stover was recorded in the combination of T<sub>M</sub>G<sub>6</sub> with 1.41% and the lowest in T<sub>C</sub>G<sub>0</sub> with 1.22%, demonstrating an increase of 15.57% when compared. The outcome may be because green manure improves potassium content in seeds and stover by enhancing soil organic matter and microbial activity, which increases potassium availability and uptake. It also improves root growth, allowing better access to soil nutrients.

The measured seed and stover yield are outlined in Table 2. The main plot (Tillage) recorded an increase in seed and stover yield of maize with the implementation of Minimum tillage (M<sub>T</sub>) in contrast to Conventional tillage (C<sub>T</sub>) 0.16% and 0.29% increase in seed and stover yield was observed with the implementation of (M<sub>T</sub>) in comparison to (C<sub>T</sub>). The exploitation of green manures especially with Green manuring through Dhaincha 2 tonnes + Cowpea 2 tonnes @ 4 tonnes ha<sup>-1</sup> i.e. G<sub>6</sub> led to 6.06% and 4.41% increase in seed and stover yield as compared to (G<sub>0</sub>) i.e. Control. Su *et al.* (2022) in their study in North China Plain, concluded that the use of green manure treatments led to a notable improvement in spring maize grain yields, showing an increase ranging from 5.38% to 11.68% when compared to traditional winter fallow practices. Under conditions of optimized nitrogen application, maize yields peaked at 14,312.2 kg ha<sup>-1</sup>. These findings highlight the dual benefits of green manure enhancing crop productivity while simultaneously reducing the dependency on synthetic nitrogen fertilizers. This outcome aligns with those of Wang *et al.* (2023) and Duvvada *et al.* (2024). In the

**Table 3.** Effect of tillage and green manuring on nutrient uptake and its interaction (pooled). T<sub>M</sub>- Minimum tillage, T<sub>C</sub>- Conventional tillage, G- Green manuring, NS- Non significant, SEm ±- Standard error of the mean, CD- Critical difference.

Treatments	N uptake (kg ha <sup>-1</sup> )		P uptake (kg ha <sup>-1</sup> )		K uptake (kg ha <sup>-1</sup> )	
	Seed	Stover	Seed	Stover	Seed	Stover
Tillage						
T <sub>M</sub>	82.41	92.99	13.63	14.22	25.15	97.23
T <sub>C</sub>	81.15	91.37	12.74	13.49	24.21	96.58
SEm ±	<b>0.1047</b>	<b>0.1114</b>	<b>0.0958</b>	<b>0.0556</b>	<b>0.1205</b>	<b>0.2749</b>
CD @ 5%	<b>0.4110</b>	<b>0.4372</b>	<b>0.3762</b>	<b>0.2182</b>	<b>0.4732</b>	NS
Green manuring						
G <sub>0</sub>	68.74	83.64	11.67	10.95	21.15	88.38
G <sub>1</sub>	82.45	89.87	13.64	12.37	23.46	92.61
G <sub>2</sub>	84.13	93.96	13.60	15.08	29.22	99.65
G <sub>3</sub>	81.87	90.09	12.83	14.07	22.74	97.40
G <sub>4</sub>	84.75	96.10	13.34	14.53	24.82	99.23
G <sub>5</sub>	82.50	91.37	12.82	13.24	23.87	96.13
G <sub>6</sub>	88.04	100.26	14.37	16.71	27.51	104.97
SEm ±	<b>0.2305</b>	<b>0.2667</b>	<b>0.1043</b>	<b>0.2064</b>	<b>0.1633</b>	<b>0.3363</b>
CD @ 5%	<b>0.6554</b>	<b>0.7584</b>	<b>0.2966</b>	<b>0.5870</b>	<b>0.4644</b>	<b>0.9563</b>
Interaction						
T <sub>M</sub> G <sub>0</sub>	70.49	86.51	12.00	11.37	21.32	89.17
T <sub>M</sub> G <sub>1</sub>	83.02	90.20	13.79	12.43	23.48	92.03
T <sub>M</sub> G <sub>2</sub>	85.03	94.40	14.13	15.84	29.66	100.33
T <sub>M</sub> G <sub>3</sub>	82.12	90.20	13.35	13.41	23.45	97.39
T <sub>M</sub> G <sub>4</sub>	84.93	96.66	13.69	14.92	25.69	99.04
T <sub>M</sub> G <sub>5</sub>	82.91	91.82	13.25	13.68	23.88	96.46
T <sub>M</sub> G <sub>6</sub>	88.37	101.18	15.19	17.87	28.58	106.21
T <sub>C</sub> G <sub>0</sub>	66.99	80.77	11.34	10.53	20.99	87.58
T <sub>C</sub> G <sub>1</sub>	81.87	89.53	13.49	12.30	23.45	93.19
T <sub>C</sub> G <sub>2</sub>	83.23	93.53	13.07	14.33	28.78	98.97
T <sub>C</sub> G <sub>3</sub>	81.62	89.98	12.31	14.73	22.03	97.41
T <sub>C</sub> G <sub>4</sub>	84.56	95.54	13.00	14.15	23.95	99.42
T <sub>C</sub> G <sub>5</sub>	82.09	90.92	12.39	12.80	23.85	95.79
T <sub>C</sub> G <sub>6</sub>	87.70	99.33	13.56	15.55	26.45	103.72
SEm ±	<b>0.3259</b>	<b>0.3772</b>	<b>0.1475</b>	<b>0.2920</b>	<b>0.2310</b>	<b>0.4756</b>
CD @ 5%	<b>0.9268</b>	<b>1.0726</b>	<b>0.4195</b>	<b>0.8302</b>	<b>0.6568</b>	<b>1.3524</b>

interaction segment, T<sub>M</sub>G<sub>6</sub> was found to be grander over all the other treatment combination showcasing an increase in seed and stover yield by 6.28% and 5.17% respectively in contrast to T<sub>C</sub>G<sub>0</sub>.

### Nutrient uptake

The data concerning N, P and K uptake in seed and stover is specified in Table 3. In the main plot (Tillage) the N uptake in seed and stover was significantly higher in M<sub>T</sub> compared to C<sub>T</sub>. Nitrogen uptake in seed was 82.41% for M<sub>T</sub> and 81.15% for C<sub>T</sub>. A com-

parison between the two revealed a 1.55% increase in M<sub>T</sub> over C<sub>T</sub> whereas, nitrogen uptake in stover was 92.99% under minimum tillage (M<sub>T</sub>) and 91.37% under conventional tillage (C<sub>T</sub>), showing a 1.77% higher uptake with M<sub>T</sub>. This outcome may be because of minimum tillage which improves nitrogen uptake by enhancing soil structure, moisture retention and microbial activity, which together increase nitrogen availability and reduce losses. In contrast to conventional tillage, it also preserves organic matter and promotes better root development, leading to more efficient nutrient absorption. In the sub plot (Green

manuring) relating to N uptake in seed and stover, the use of ( $G_6$ ) was found to be superior over all the treatments with the lowest in  $G_0$ . An increase of 28.07% and 19.87% was observed in N uptake in seed and stover, respectively with the incorporation of  $G_6$  over  $G_0$ . The interaction table also portrayed that  $T_M G_6$  was found to be superior over all the other treatment combination and the worst was in  $T_C G_0$ . Nitrogen uptake in seed and stover increased by 31.91% and 25.26% respectively, computing  $T_M G_6$  and  $T_C G_0$ .

The data pertaining to P uptake in seed and stover in the main plot illustrates that Minimum tillage ( $T_M$ ) in comparison to Conventional tillage ( $T_C$ ) increased the value of P uptake in seed by 6.98% and stover by 5.41%. These results may be due to the ability of minimum tillage to increase P uptake in maize by preserving mycorrhiza fungi, enhancing soil structure, and improving moisture retention, which help roots access immobile phosphorus more effectively. It also boosts organic matter and microbial activity, reducing phosphorus losses and promoting gradual nutrient release from surface residues. The data compiled for the sub plot revealed that addition of in relation to P uptake in seed and stover, green manures with  $G_6$  was found to be superior over all the treatments with the lowest observed in  $G_0$ . An increase of 23.13% and 52.60% P uptake in seed and stover respectively was found when  $G_6$  and  $G_0$  was computed and compared. Rani *et al.* (2021) quantified that the incorporation of *Arachis pintoi* as green manure, along with natural phosphate sources, resulted in more than a 300% increase in phosphorus uptake and marked enhancements in maize development and soil microbial activity. In a similar way, leguminous green manures such as sun hemp and dhaincha have proven effective in enhancing nutrient availability, with sun hemp leading to the highest phosphorus uptake in maize. These outcomes were supported by Medeiros *et al.* (2019). The interaction section revealed that combination between  $T_M G_6$  performed significantly better in P uptake in seed and stover indicating an increase of 33.95% and 69.70% respectively as compared to  $T_C G_0$ .

The data on potassium uptake in seed and stover under main plot treatments reveal that minimum

tillage ( $M_T$ ) enhanced P uptake by 3.88% in seed and 0.67% in stover compared to conventional tillage ( $C_T$ ). This outcome appears to favor minimum tillage, as it improves soil structure, higher moisture retention, and enhanced nutrient availability, which support better root growth and absorption in comparison to conventional tillage. The findings in sub plot disclose that the  $G_2$  i.e. Green manuring through Dhaincha @ 4 tonnes  $ha^{-1}$  increased the K uptake in seed by 39.20% and with the incorporation of  $G_6$  i.e. Green manuring through Dhaincha 2 tonnes + Cowpea 2 tonnes @ 4 tonnes  $ha^{-1}$  increased the K uptake in stover by 18.77% as compared to  $G_0$  i.e. Control. These findings may be attributed to the ability of green manures to enhance potassium uptake in seed and stover through the gradual release of nutrients during decomposition, which increases potassium availability in the soil. Moreover, green manures improve soil structure and stimulate microbial activity, thereby supporting better root development and nutrient absorption. Solangi *et al.* (2019) specified that various green manure crops, including hairy vetch and common vetch, have shown a greater ability to absorb potassium (K) from the soil when compared to more conventional cover crops like ryegrass. These leguminous green manures are particularly effective at mobilizing and accumulating K, likely due to their deeper root systems and enhanced nutrient cycling capabilities. As a result, they offer a more efficient strategy for improving K availability in the soil, which can benefit subsequent crops in rotation. Parallel outcomes were documented by Kumar *et al.* (2020) and Maruthi *et al.* (2023). In the interaction between tillage and green manuring,  $T_M G_2$  increased the K uptake in seed by 41.30% and  $T_C G_6$  increased the K uptake in stover by 21.27% as compared to  $T_C G_0$  i.e. Conventional tillage + Control.

## CONCLUSION

After conducting the research for two years, the following conclusions can be drawn.  $M_T$  significantly improved the N, P and K content in seed and N and P content in stover. With the implementation of  $M_T$ , N content in seed increased by 1.37%, P by 4.34% and K by 4.65% as compared to  $C_T$ . The N and P content in stover also improved by 1.61% and 5.55% respectively.  $M_T$  also increased to seed yield by 0.16%

and stover by 0.29% in contrast to  $C_T$ . The N and P uptake was increased 1.55% and 1.77% respectively, with the use of  $M_T$ . Addition of organic manures revealed that  $G_6$  increased the N and P content and uptake in seed and stover and K content in stover was significantly improved. K content and uptake in seed was significantly improved. The interaction between tillage and green manuring revealed that the blend of  $T_M G_6$  i.e. Minimum tillage + Green manuring through Dhaincha 2 tonnes + Cowpea 2 tonnes @ 4 tonnes  $ha^{-1}$  performed was the preeminent among all the other treatment combination. It significantly increased the N and P content and uptake in seed and stover including seed and stover yield. An increase of 24% and 28.57% in N and P content in seed and 18.58% and 60% in N and P content in stover was observed computing  $T_M G_6$  and  $T_C G_0$ . The increase in N and P uptake in seed was at 31.91% and 33.95% and for stover it was at 25.26% and 69.70% respectively, computing  $T_M G_6$  and  $T_C G_0$ .  $T_M G_2$  augmented the K content and uptake in seed by 35.89% and 41.30% respectively, whereas  $T_M G_2$  enhanced the K content and uptake in stover by 15.57% and 21.27% respectively. In light of these findings,  $T_M G_6$  and  $T_M G_2$  appear to be promising options for improving nutrient content, uptake efficiency, and maize seed and stover yield.

#### ACKNOWLEDGMENT

The authors acknowledge the help and technical support from the Department of Soil and Water Conservation, Nagaland University, School of Agricultural Sciences, Medziphema Campus for successful completion of this two years' research.

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