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Effect of tilth index and spot tillage with Robotic spot tiller cum planter on maize crop growth parameters

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Abstract

This study assesses the impact of robotic spot tillage on maize crop growth parameters, aiming to address issues related to excessive tillage practices. Conducted at the ICAR-IARI testing field in New Delhi, a robotic spot tiller cum planter was developed. Robotic spot tillage treatments with varying diameter, depth, and speed of operation were examined. The experimental design employed a randomized complete block design for robotic sowing with spot tillage combinations. Critical soil parameters (bulk density, cone index, aggregate uniformity coefficient, soil organic matter, and plasticity index) and crop parameters (plant height, leaf area index, root length, and cumulative root volume) were analysed to determine the optimal tilth index for maize growth. Results indicated that robotic tilling and sowing (T_1) consistently displayed the lowest tilth index (0.38), while T_3 consistently showed the highest (0.69). The $10^*15^*T_3$ and $15^*15^*T_3$ treatment combinations demonstrated higher crop parameter values, highlighting the effectiveness of robotic spot tillage for maize.

Keywords: Robotic Spot tilling, planting, root zone, soil properties, tilth index, maize, etc.

1. Introduction

Maize (*Zea mays*) is one of the most crucial cereal crops globally, serving as a staple food for millions of people. After rice and wheat, maize is the third-most significant food crop in the Indian scenario (Murdia *et al.*, 2016) [2]. One of the most resilient developing crops, maize (*Zea mays* L.) has a larger range of adaptation under a variety of agroclimatic situations. Due to its highest genetic production potential among all cereals, maize is referred to as the "queen of cereals" worldwide. It accounts for 39% of the world's grain production and is grown over approximately 190 million hectares across 165 nations with a greater diversity of soil, climate, biodiversity, and management techniques (APEDA, 2020).

Excessive soil compaction is considered as the prime reason for the physical degradation of agricultural soils (Nawaz *et al.*, 2013) [3]. The soil compaction was induced wheel load of agricultural machinery, tire dimensions, tire-soil contact characteristics and number of wheel passes (Obour and Ugarte 2021 and Gao *et al.*, 2007) [4, 5]. Severe soil compaction hindered substantial nutrition and moisture absorption, reducing root development and distribution (Bengough *et al.*, 2011 and Schjønning *et al.*, 2016) [6, 7]. The yield penalties caused by compaction in maize fields have been documented to reach 43% (Voorhees, 2000) [8]. The way that various crops react to compacted soil varies greatly. The emergence of maize, barley, and soybean seedlings is more impacted by soil compaction. According to a recent study, the compaction of agricultural tractor tyre systems decreased corn height in the first two years, while for soybeans, this effect became considerable in the third year (Shaheb, 2020) [25]. According to studies, soil compaction increases the soil's mechanical strength and decreases its porosity, which have the greatest effects on the root penetration capability (Kirby & Bengough 2002; Kristoffersen and Riley 2005) [26, 27].

Tillage is the mechanical manipulation of soil to create a favorable environment for seed germination. Tillage is one of the most important methods to reduce the soil compaction (Daniells, 2012) [14]. Soil physical properties were greatly influenced by tillage practices (Mosaddeghi *et al.*, 2009) [17]. Crop yield, root distribution, plant population density, and

seedling emergence were all impacted by changes in the physical properties of the soil (Khurshid *et al.*, 2006) ^[24]. Different tillage practices create different soil conditions which may affect the growth and yield of maize. Deep tillage and continuous tillage over a period of time leads to soil erosion, soil degradation, soil structure gets diminished, reducing soil productivity and soil organic carbon and also it consumes lot of fossil fuels adding up to greenhouse gas emissions. Traditional maize planting methods in developing countries rely on broadcast sowing, which is cost-effective but results in higher seed costs, increased intercultural operational expenses, and lower grain yields. (Swain *et al.*, 2020) ^[20]. Although zero or no tillage had given good results in conserving soil moisture and other resources in field but long-term effects may lead to increase in bulk density which is not conducive to maize growth ultimately ending up in reduced yields.

In recent years, the use of robots in agriculture has gained popularity due to its potential to increase efficiency and reduce labour costs (Matin *et al.*, 2008; Krishna, 2017; Harmanda *et al.*, 2019) ^[16, 23, 9]. Robotic planting technology holds immense promise for the agricultural industry, offering a range of substantial benefits.

To address the problems of deep tillage and zero tillage, a minimum tillage concept called robotic spot tillage was introduced in the present study. Robotic spot tillage is one type of tillage practice where a specific and minimum area which influences the effective root zone of maize plant is disturbed to a particular depth and width for seed placement. This tillage practice ensures resource conservation, avoids soil erosion and also reduces draining of nutrients from soil. There were only few research papers which have mentioned this topic, so a study is needed on robotic spot tillage. The present study is aimed to understand the effect of robotic spot tillage on maize growth parameters.

2. Material and methods

2.1 Site description

A study was conducted at the testing field of Division of Agricultural Engineering, ICAR-IARI, New Delhi. The maize variety chosen for the study was Pusa HQPM-1. The soil of the experimental field was sandy loam. In the current study, a designated experimental field measuring 108 m², with dimensions of 6m x 18m (width-length), was selected. Plant spacing 60*20 cm. The Robotic spot tiller cum planter (fig.1) was developed in Division of Agricultural Engineering, ICAR-IARI, New Delhi with overall weight of kgs, dimensions of 1.4 X1.4 m. Key components such as stepper motors, drivers, CNC controllers, and electronic components were carefully selected to ensure precision and reliability. The integration of a robust power source, consisting of six 12V batteries, was determined based on current requirements and desired runtime. The communication interface, featuring the FS-TH9X 2.4GHz 9CH transmitter and FS-IA10B receiver, played a crucial role in providing real-time control over the robotic platform's movements.

Stepper motors, including Nema 23 and Nema 17, paired with DMA 860H and TB6600 drivers, facilitated precise control over spatial movements and seed metering. The DDCS V3.1 CNC controller served as the central nervous system, orchestrating the coordination of various components for spot tilling and planting tasks. The Sabertooth dual 25A motor driver ensured efficient control over high-powered motors, contributing to the versatility of the robotic system. The E-bike MY1016ZL 24V 250W DC Motor and BLDC motor with controller provided reliable propulsion and precise control for the rotary tillage tool. The experimental design selected for the robotic sowing with suitable tillage combinations was randomised complete block design with SAS software. The experimental design outline for manually sowing maize in the field was given in Table 1.

Table 1: Experimental design outline for manually sowing maize in the field.

Sl. No.	Independent parameters	Levels	Dependent parameters
1.	Diameter (D), cm	3 (5, 10 and 15cm)	1. Tilth index (TI) 2. Plant height (30, 60, and 90days) 3. Leaf area (30, 60, and 90days) 4. Root length (30, 60, and 90days) 5. Root volume (30, 60, and 90days)
2.	Depth (d), cm	3 (5, 10 and 15cm)	
3.	Speed of operation (T)	3 T ₁ :150 rpm; T ₂ : 200 rpm; T ₃ : 300 rpm;	
4.	Replications	3	
Total =3×3×3×3 = 81			

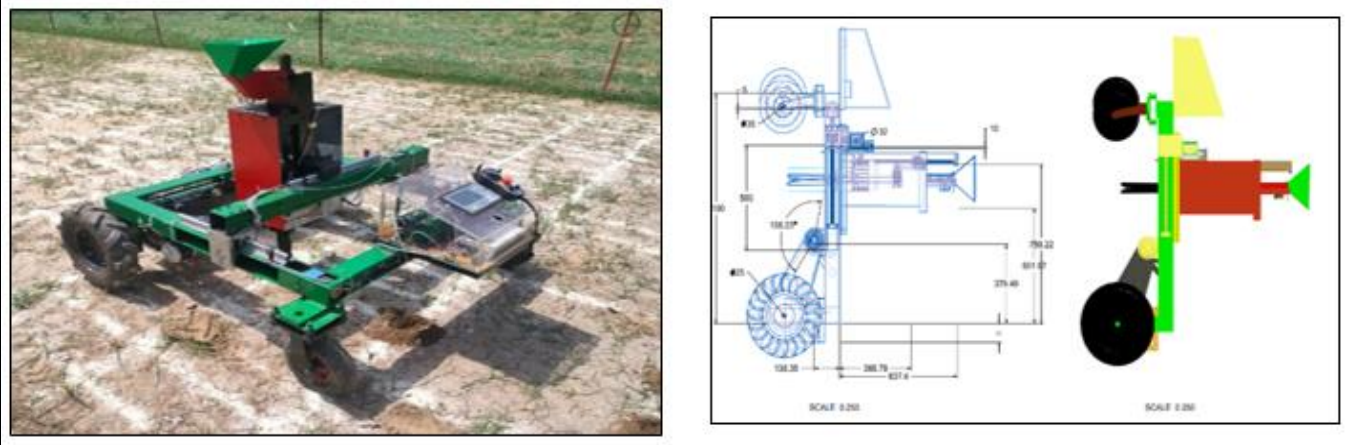


Fig 1: Developed robotic spot tiller cum planter with dimensions.

These treatments combinations included variations in seed placing zones, seed placement depth, and consecutive tillage activities for robotic sowing, as detailed in Table 2. The three levels of diameter selected were 5, 10 and 15 cm, depth selected

were 5, 10 and 15 cm and tillage types with speed of operation selected were 150 rpm, 200 rpm and 250 rpm were involved in the experiment respectively. Agronomical practices like nutrient application, irrigation, weed removal were precisely carried out to ensure proper growth of maize plants.

Table 2: Combination of experimental treatments for the manual sowing of maize.

Sl. No.	Diameter (D), cm	Depth (d), cm	Tillage (T)
1.	5	5	150 rpm (T ₁)
2.	10	10	200 rpm (T ₂)
3.	15	15	250 rpm (T ₃)

The critical soil parameters for the measurement of tilth index of the spot tillage zone in manual sowing methodology were bulk density (BD), cone index (CI), aggregate uniformity coefficient (AUC), soil organic matter (SOM), and plasticity index (PI).

Sample collection

Bulk density

The bulk density was measured by core sampler method as delineated by Arshad *et al.* (1997). The specific volume of core was inserted into the soil, removed slowly without the loss of any soil contents and then it was weighed. This soil sample subsequently dried in oven for 1050C and its weight was measured. It was calculated by equation 1:

$$BD(g/cm^3) = \frac{(\text{Weight of oven-dry soil in grams})}{(\text{Volume of soil in core sampler in cm}^3)}$$

Cone Index (CI)

The cone index was measured by cone penetrometer. The process involved placing the cone (3 mm base diameter and an apex angle of 60 degrees) on the soil surface with the shaft held vertically, and the cone's base securely positioned on the soil (Perumpral, 1987). The determination of soil cone index utilized the expression (Equation 2) recommended by Macmillan (2002), assessing the resistance encountered by the cone during penetration.

$$CI, kPa = \frac{\text{Force on the cone}}{\text{Base area of the cone}}$$

Aggregate uniformity coefficient (AUC)

Sieve analysis is fundamental technique used for determining aggregate uniformity coefficient (AUC). It involves standard set of sieves (No. 4 sieve (4.75 mm) to the No. 200 sieve (0.075 mm) were shaken thoroughly with progressively smaller square openings. For interpretation convenience, parameters like D₁₀, D₃₀, and D₆₀, corresponding to grain diameter (in mm) at 10%, 30%, and 60%, respectively, were utilized. Additionally, the coefficient of uniformity (Cu), acting as a shape parameter, was computed according to the method outlined by Kaliakin (2017) using Equation 3.

$$Cu = \frac{D_{60}}{D_{10}} \dots (3)$$

Plasticity Index (PI): For the present study Liquid limit and Plastic Limit were calculated to obtain the Plasticity index (PI). The plastic limit (PL) was determined by rolling out a thread of the fine soil portion on a flat, non-porous surface, following

ASTM Standard D 4318. The liquid limit was found out by Casagrande's apparatus. The test follows ASTM standard, allowing interpolation for the moisture content requiring 25 blows or using a correction factor for liquid limit determination from a single moisture content test. Plasticity index was calculated by Equation 5 (Kaliakin, 2017)

$$PI = LL - PL \dots$$

The soil descriptions based on PI categorize the non-plastic soils with a PI of 0, slightly plastic soils with PI less than 7, medium plastic soils with PI between 7-17, and highly plastic soils with a PI exceeding 17. The soils with a high PI predominantly consist of clay, while those with a lower PI tend to be silt-dominated. Soils with a PI nearing zero typically lack significant clay or silt content, indicating minimal fines.

Soil organic matter: In our present study, soil organic carbon (OC) was determined using the Walkley-Black (WB) method established by Walkley and Black in 1934. This method involved oxidizing carbon with acidic dichromate (Cr₂O₇²⁻) followed by titration with ferrous sulphate to determine the amount of unreacted dichromate (Plate 3.11). The OC was then calculated from the difference between the total dichromate added and the unreacted amount. This methodology (Mylavarapu *et al.*, 2014) provides an estimate of soil organic matter (OM) based on OC determination. The calculation of OC, followed the Equation 6.

$$OC, \% = \frac{(m_{LB} - m_{LS}) 0.195}{g_{soil}}$$

Where, m_{LB} is the Blank value and m_{LS} is for soil sample

Tilth index (TI) Calculations: In this study, a scientific approach was employed to develop a "tilth index" by integrating five key soil physical properties: bulk density, cone index, aggregate uniformity coefficient, organic matter content, and plasticity index. The resulting index, ranging from zero (indicating conditions unusable for plants) to one (representing a nonlimiting environment for plant growth), offers a comprehensive assessment of soil tilth. (Karlen *et al.*, 1990).

Hence, the tilth index is a vital indicator of soil quality and structure and it was calculated systematically using the all gathered soil parameters mentioned above. The derived tilth index values provided valuable insights into soil tilth and health as provided in the Equation 7.

$$CF_x = A_0 + A_1 \times X + A_2 \times X_2 \dots$$

Where, CF_x is the tilth coefficient for the soil property (X), and A₀, A₁, A₂ are constants. The tilth index (TI), was estimated as the multiplicative combination of the tilth coefficients (Equation 8), and tilth coefficients were normalized to range between 0 and 1. This normalization technique was considered based on the productivity index developed by Singh (1992). Table 3 provides the insights into the limiting, non-limiting and critical values of tilth coefficient (Singh, 1992).

$$TI = CF(BD) \times CF(CI) \times CF(AUC) \times CF(SOM) \times CF(PI) \dots (8)$$

Where, TI is the tilth index, CF_x is tilth coefficient for soil property (X).

Table 3: Key Soil Parameters Influencing Tilth Coefficient Calculation and Their Values (Singh, 1992)

Sl. No.	Soil properties	Non limiting values of CF	Critical values of CF	limiting values of CF
1.	Bulk density (BD), g /cm ³	CF(BD) = 1 for BD ≤ 1.3	CF(BD) = -1.5 + 3.87×BD - 1.5×BD ² for 1.3 ≤ BD ≤ 2.1 g /cm ³	CF(BD) = 0 for BD ≥ 2.1 g /cm ³
2.	Cone index (CI), MPa	CF(CI) = 1 for CI ≤ 1.0	CF(CI) = 1.012 - 0.002× CI - 0.01×CI ² for 1.0 ≤ CI ≤ 10 MPa	CF(CI) = 0 for CI ≥ 10 MPa
3.	Aggregate uniformity coefficient (AUC)	CF(AUC) = 1 for AUC ≥ 5	CF(AUC) = 0.348 + 0.245×AUC - 0.023× AUC ² for 2 ≤ AUC ≤ 5	CF(AUC) = 0.75, for AUC ≤ 2
4.	Soil organic matter (SOM),%	CF(SOM) = 1 for SOM ≥ 5%	CF(SOM) = 0.59 + 0.122 × SOM - 0.008 × SOM ² for 1% ≤ SOM ≤ 5%	CF(SOM) = 0.70 for SOM ≤ 1%
5.	Plasticity index (PI),%	CF(PI) = 1 for PI ≤ 15%	CF(PI) = 1.012 + 0.0009 ×PI - 0.00016×PI ² for 15% ≤ PI ≤ 40%	CF(PI) = 0.80 for PI ≥ 15%

Measurement of crop growth parameters: Plant height, Leaf area, and Root characteristics

The critical crop parameter which helps in determining optimum tilth index were plant height, leaf area index, root length and cumulative root volume. In the present study, crop parameters were systematically assessed at three distinct intervals 30, 60, and 90 days after sowing.

Plant height

The measurement of PH, a crucial indicator of growth, was conducted using a precise measuring tape or metric ruler to accurately determine the vertical distance from the plant base to the apex of the tallest shoot.

Leaf area index: The leaf area was precisely quantified using a LI-3100C area meter. This equipment accurately measured the leaf area in square centimeters (cm²).

Root parameters: The root samples were systematically collected from crop rows at 30, 60, and 90-day intervals during their growth period using a root auger. Root parameters such as root length and root volume were measured. This involved scanning the washed roots using a LA2400 scanner (Fig 2a), a tool recommended by the Division of Plant Physiology, ICAR-IARI, New Delhi, and employing winRIZHO software (Fig 2b) for analysis (Costa *et al.*, 2000). This scientifically sound methodology ensured accurate assessment and quantification of root characteristics in our research, aligning with established practices in the field.

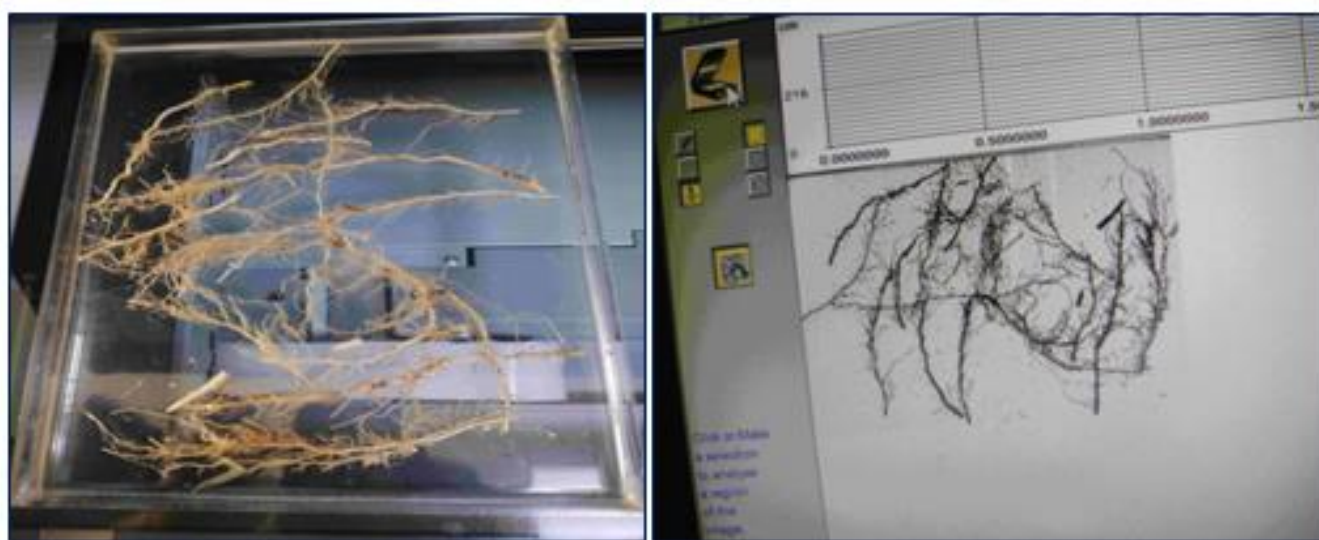


Fig 2: Root analysis with the (a) LA2400 scanner and (b) WinRIZHO root analyzer

All these above findings were analysed later by the application of statistical tools in the context of tilth index calculation and plant growth analysis under the experimental conditions.

Results and discussion

Effects of soil parameters on the tilth index in Robotic tilling and sowing experiment.

The statistical analysis of robotic tilling and sowing experiments reveals substantial variations in soil properties among different treatments. Calculated coefficients and tilth index values signify significant differences, providing valuable insights for informed agricultural soil management decisions.

Continuing the analysis, the calculated bulk density ranged from 1.31 to 1.67 g/cm³, illustrating variations in soil compaction across different treatments. Cone index values, indicative of soil resistance, displayed a range of 1.19 to 2.85 MPa, within all

treatment combinations. The aggregate uniformity coefficient, reflecting particle size distribution, varied from 2.18 and 4.66, indicating diverse responses in soil structure among treatments. Soil organic matter content ranged from 0.007% to 0.047%, with different treatment combinations. Plasticity index values ranged from 0.21 to 0.37, these results underscore the impact of different treatments on various soil properties, contributing to a comprehensive understanding of the experimental outcomes.

The statistical analysis also revealed a wide range in the coefficients of bulk density (BD) from 0.78 to 1.00, signifying diverse compaction levels influenced by various treatment combinations. Likewise, the coefficients of cone index (CI) displayed a range of 0.93 to 1.00, indicating notable variations in soil resistance. The coefficient of aggregate uniformity coefficient (AUC) ranged from 0.77 to 0.99, reflecting distinctions in particle size distribution across different

treatments. Additionally, the coefficients of soil organic matter (SOM) ranged from 0.59 to 0.70, highlighting minor variations in organic content among treatments. The coefficient of plasticity index (PI) consistently measured at 1.00 across all treatments, indicating uniformity in soil consistency responses. Importantly, the tilth index, a key parameter reflecting overall soil quality, demonstrated variations among treatments. Specifically, Treatment T₁ consistently displayed the lowest tilth index of 0.38, while T₃ consistently showed the highest tilth index of 0.69.

The coefficients of soil parameters influenced by various treatments are given in Table 4. Importantly, the tilth index, a key parameter reflecting overall soil quality, demonstrated variations among treatments. Specifically, Treatment T₁ consistently displayed the lowest tilth index of 0.38, while T₃ consistently showed the highest tilth index of 0.69.

Table 4: The coefficients of soil parameters influenced by various treatments

Tillage parameters	Treatments		
	T ₁	T ₂	T ₃
Bulk density (gm/cm ³)	0.89	0.96	1.00
Cone index (MPa)	0.93	0.96	1.00
Aggregate uniformity coefficient (AUC)	0.78	0.94	0.99
Plasticity index	1	1	1
Soil organic content (%)	0.59	0.59	0.70
Tilth index	0.38	0.54	0.69

Effect on robotic tilling and sowing on the plant height

Statistical distribution of plant height (PH) with depth of seed placement and diameter of tilled zone at the 30, 60 and 90-days growth period were shown in Fig.3. From the figure 4, it is inferred that the treatment combinations 10*15*T₃ and 15*15*T₃ at 30 days, 10*15*T₃ and 15*15*T₃ at 60 days and 10*15*T₃ and 15*15*T₃ at 90 days have showed the highest mean value while comparing the remaining treatments.

During the 30, 60, and 90-day plant growth period, a thorough investigation was conducted to assess the individual and interaction effects of key parameters, namely planting depth and tilled zone diameter. The results indicated significant differences in these effects, highlighting the distinct impact of each factor on plant growth. The high R-square value of 0.946, 0.976, and 0.975887 at 30, 60, and 90 days respectively underscores the reliability of the model in explaining the variation in plant height based on the specified parameters

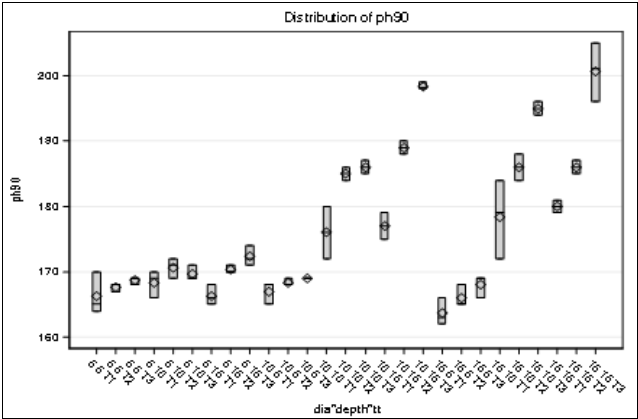
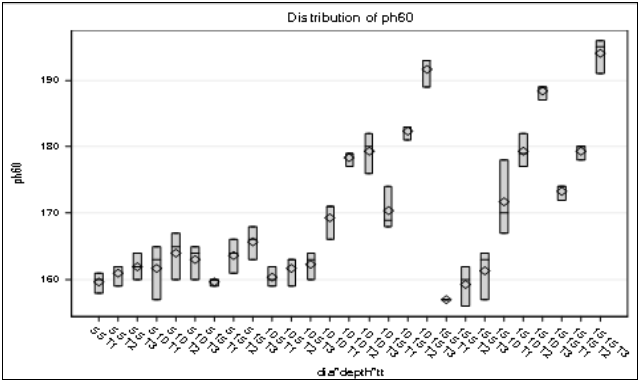
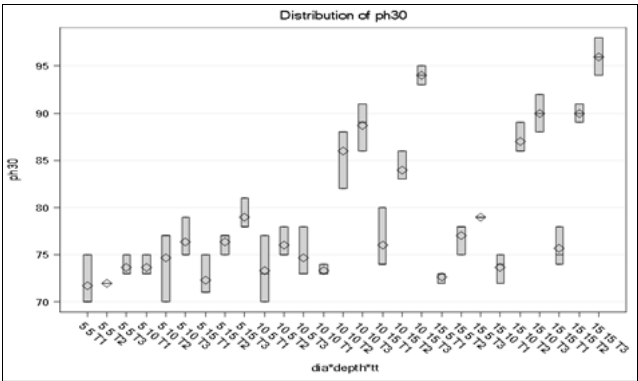
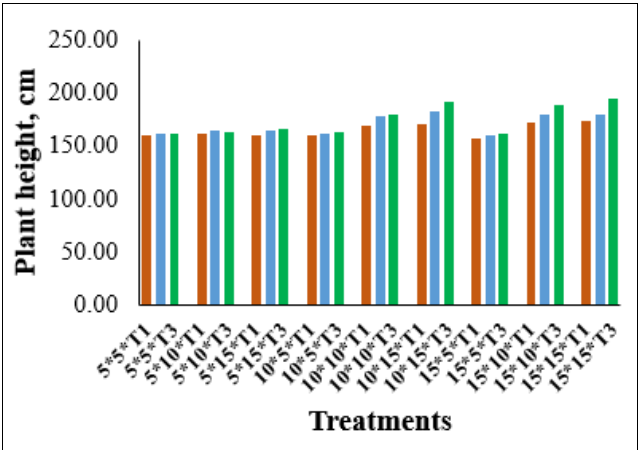
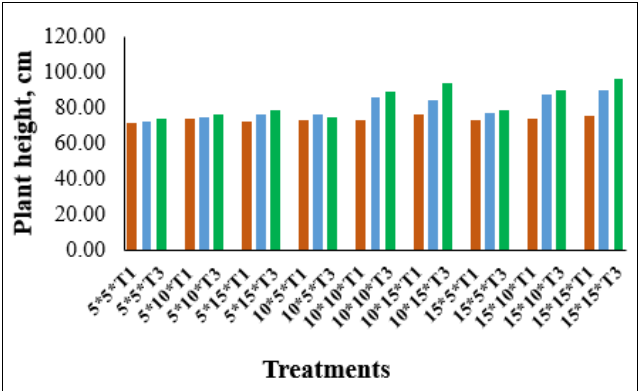


Fig 3: Statistical distribution of Plant height (PH) with Depth of seed placement and diameter of tilled zone at the (a)30, (b)60 and (c)90 days growth period



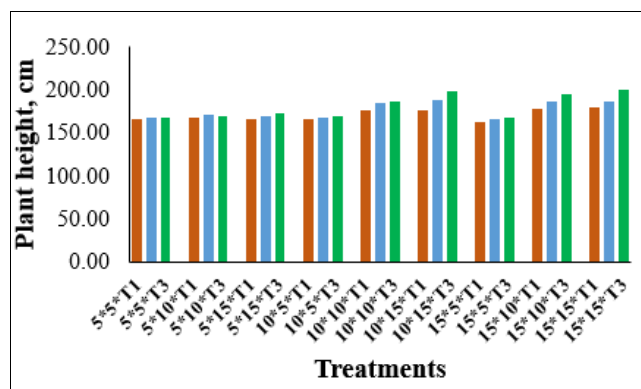
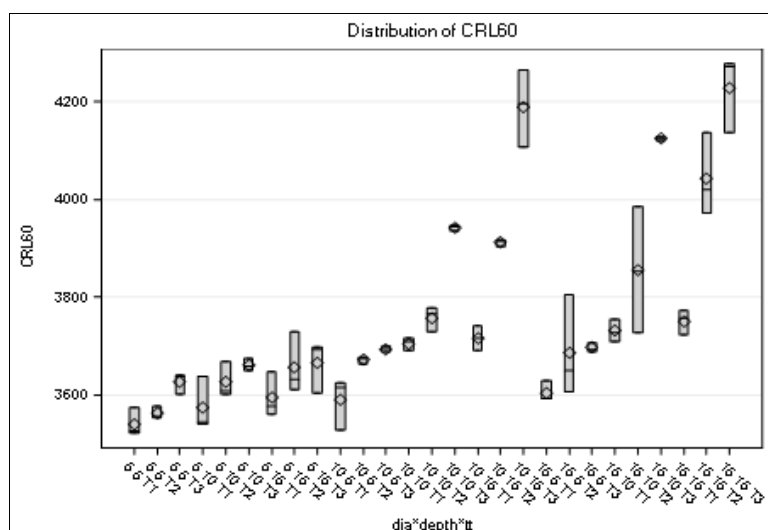
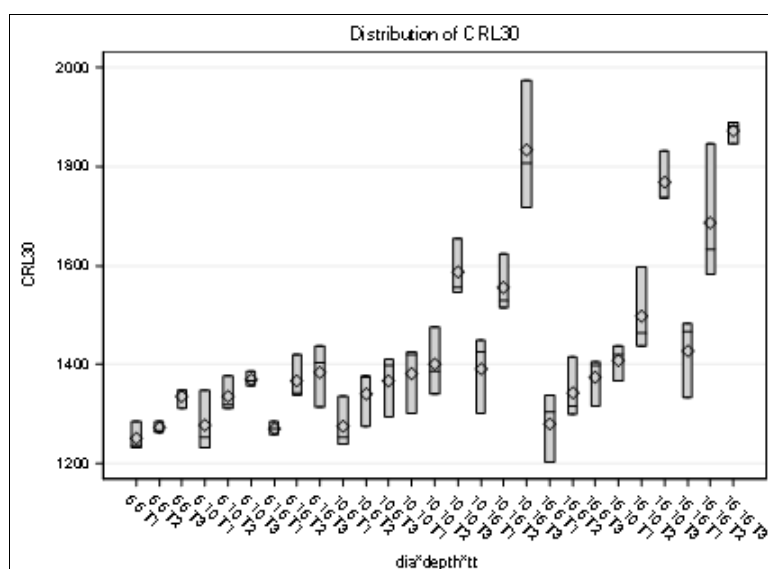


Fig 4: Distribution of Plant height (PH) with Depth of seed placement and diameter of tiled zone at the a)30, (b)60 and (c)90 days growth period

Additionally, a low Coefficient of Variation of 2.71%, 1.226 and 1.179824 suggests minimal variability in the collected data, enhancing the credibility of the findings. After the 30, 60 and 90 days the mean plant height reached 79.135 cm, 169.6173 and 176.2840 cm serving as a representative measure of overall growth performance. The bar graph (Fig.4) shows the variation in the measured values of 30-, 60- and 90-days plant height with all the selected treatment combinations and the obtained results resembles the statical observations made with the Fig.3.

Effects of robotic tillage and sowing activities on cumulative root length (CRT)

Statistical distribution of cumulative root length (CRT) with depth of seed placement and diameter of tilled zone at the 30, 60 and 90 days growth period were shown in Fig.5. In the figure, it is represented that the treatment combinations 10*15*T₃ and 15*15*T₃ at 30 days, 10*15*T₃ and 15*15*T₃ at 60 days and 10*15*T₃ and 15*15*T₃ at 90 days have showed the highest mean value while comparing the remaining treatments. Analysis at the 30, 60 and 90-days growth period revealed significant differences in individual and interaction effects of planting depth and tilled zone diameter, supported by a high R-square value of 0.922350, 0.957326 and 0.985517 respectively which emphasizes models reliability. Additionally, a low Coefficient of Variation of 4.345740, 1.336710 and 0.906729% suggests minimal variability in the collected data, enhancing the credibility of the findings. At 30, 60 and 90 days, mean cumulative root length was 1431.837 mm, 3755.734 mm, and 3243.258 mm, serving as a comprehensive metric for evaluating experimental work. The bar graph (Fig.6) shows the variation in the measured values of 30, 60 and 90 days Cumulative root length with all the selected treatment combinations and the obtained results resembles the statical observations made with the Fig.5.



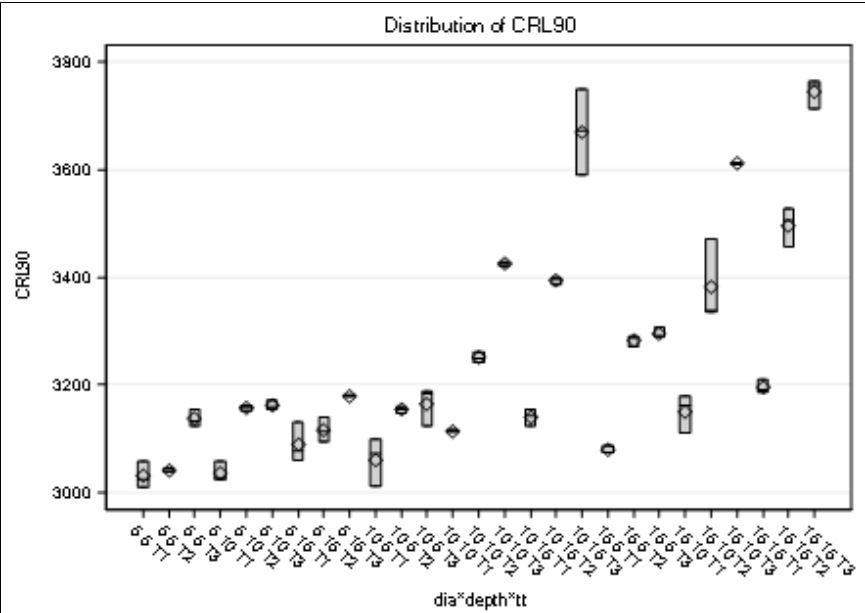
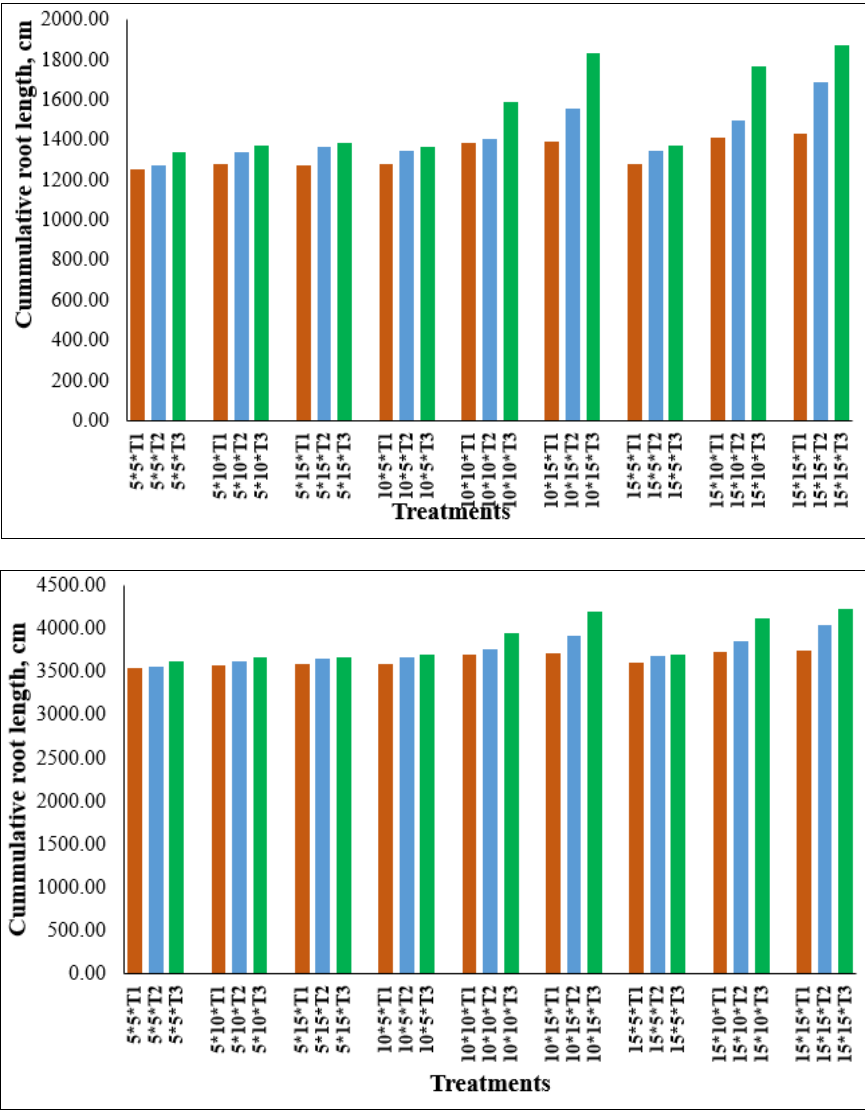


Fig 5: Statistical distribution of Cumulative root length (CRL) with Depth of seed placement and diameter of tiled zone at the (a)30, (b) 60 and (c) 90 days growth period



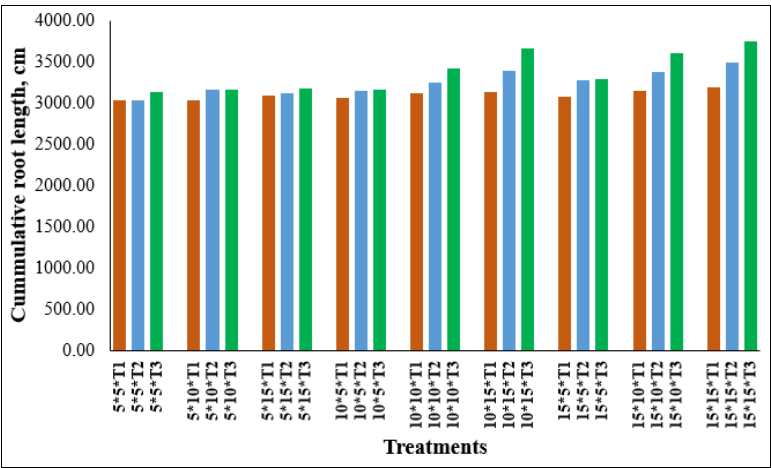
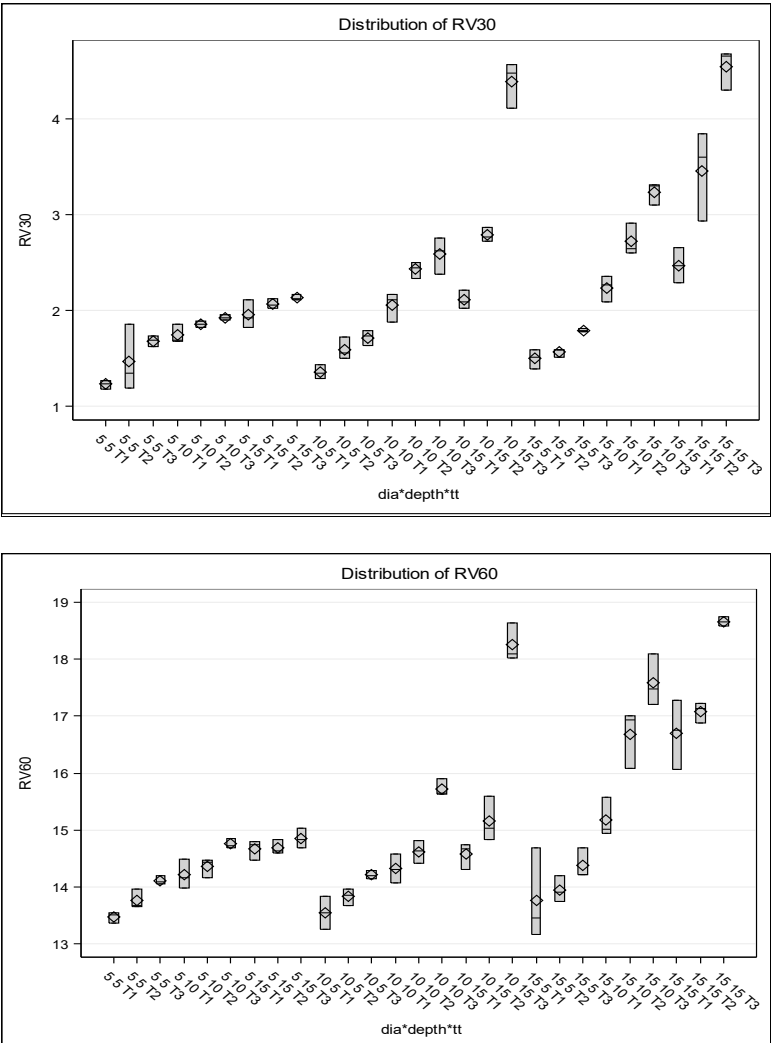


Fig 6: Distribution of Cumulative root length (CRL) with Depth of seed placement and diameter of tiled zone at the (a)30, (b)60 and (c) 90 days growth period

Effects of robotic tillage and sowing activities on root volume (RV): Statistical distribution of root volume (RV) with depth of seed placement and diameter of tiled zone at the 30, 60 and 90 days growth period were shown in Fig.7. In the figure, it is revealed that the treatment combinations 10*15*T₃ and 15*15*T₃ at 30 days, 10*15*T₃ and 15*15*T₃ at 60 days and 10*15*T₃ and 15*15*T₃ at 90 days have showed the highest mean value while comparing the remaining treatments. Analysis at 30, 60 and 90 days growth period revealed significant differences in individual and interaction effects of planting depth and tiled zone diameter, supported by a high R-square value of

0.990138, 0.981733 and 0.987984 respectively. The low Coefficient of Variation of 4.097262, 2.955180 and 2.514786 was observed at 30, 60 and 90 days respectively which reflect data consistency. At 30, 60 and 90 days, mean root volume was 4.108556 mm³, 19.84712 mm³, and 17.40332 mm³ serving as a comprehensive metric for evaluating experimental work. The bar graph (Fig.8) shows the variation in the measured values of 30, 60 and 90 days Root volume with all the selected treatment combinations and the obtained results resembles the statical observations made with the Fig.7.



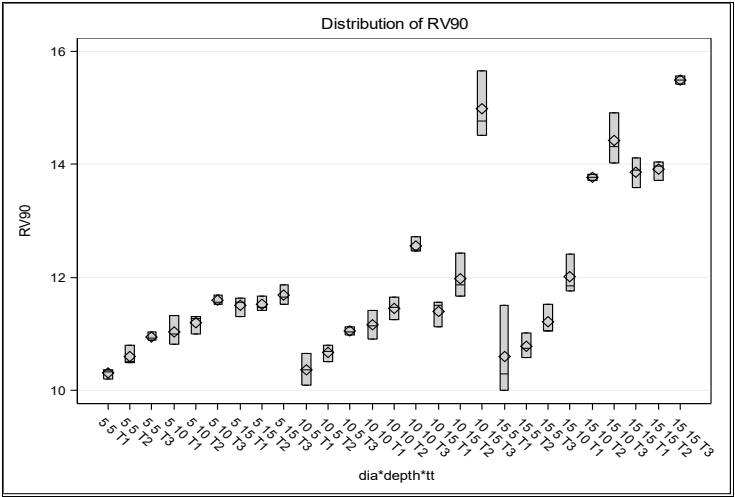


Fig 7: Statistical distribution of Root volume (RV) with Depth of seed placement and diameter of tiled zone at the (a)30, (b)60 and (c)90 days growth period

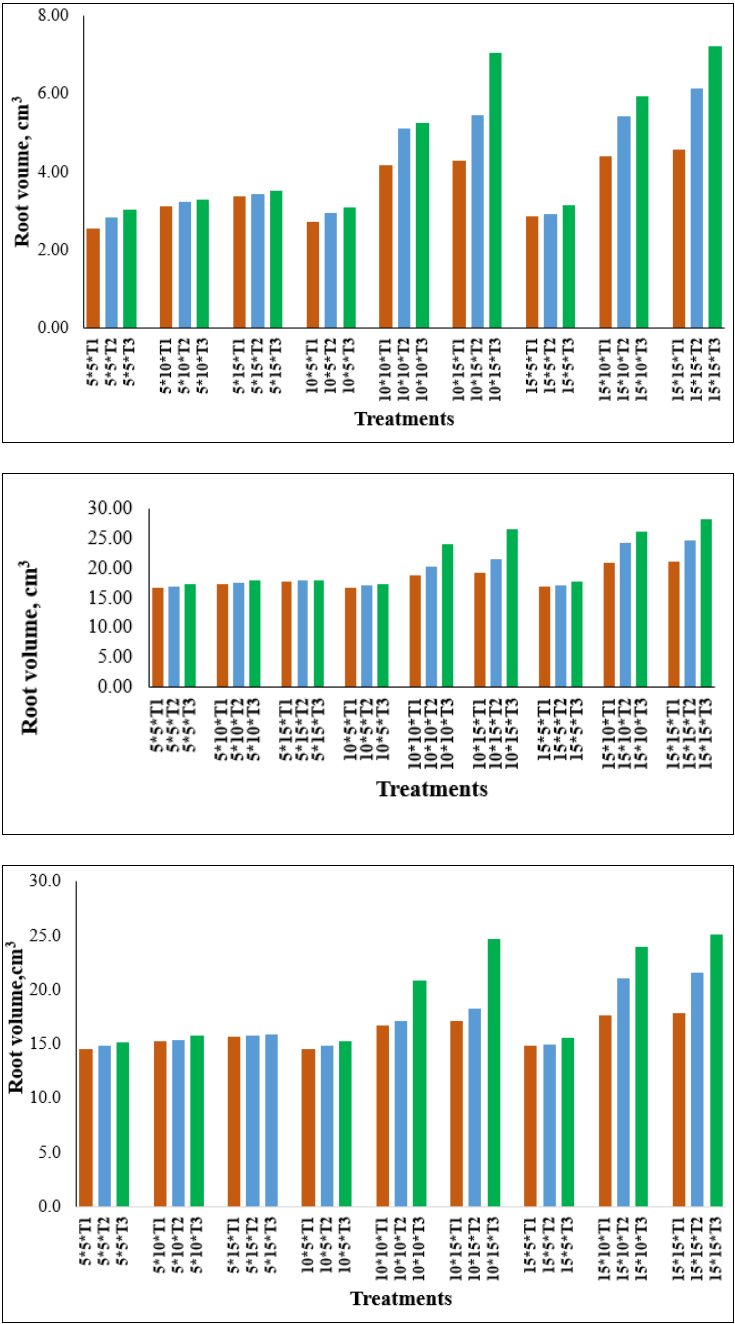


Fig 8: Distribution of root volume (RV) with depth of seed placement and diameter of tiled zone at the (a)30, (b)60 and (c)90 days growth period

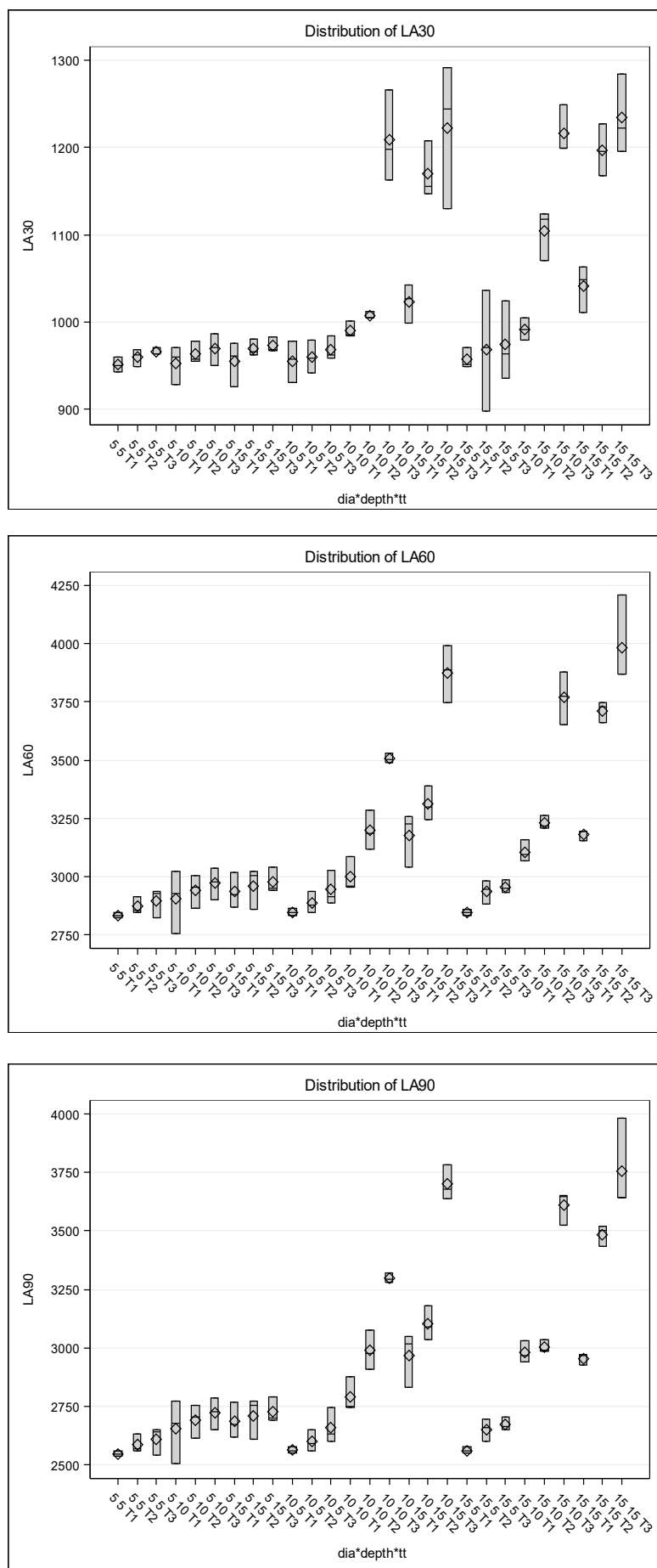


Fig 9: Statistical distribution of Leaf area with Depth of seed placement and diameter of tiled zone at the(a)30, (b)60 and (c)90 days growth period



Fig 10: Distribution of Leaf area with depth of seed placement and diameter of tiled zone at the (a)30, (b)60 and (c)90 days growth period

Effects of robotic tillage and sowing activities on Leaf area Index (LAI): Statistical distribution of leaf area index (LAI) with depth of seed placement and diameter of tilled zone at the 30, 60 and 90 days growth period were shown in figure 2. In the figure, it is revealed that the treatment combinations 10*15*T₃ and 15*15*T₃ at 30 days, 10*15*T₃ and 15*15*T₃ at 60 days and 10*15*T₃ and 15*15*T₃ at 90 days have showed the highest mean value while comparing the remaining treatments. Analysis at 30, 60 and 90 days growth period revealed significant differences in individual and interaction effects of planting depth and tilled zone diameter, supported by a high R-square value of 0.937250, 0.986051 and 0.975163. Respectively. The low

Coefficient of Variation of 3.348857, 2.081496 and 2.322274 was observed at 30, 60 and 90 days respectively which reflect data consistency. At 30, 60 and 90 days, mean leaf area were 1069.759 cm², 3505.222 cm² and 3130.273 cm² serving as a comprehensive metric for evaluating experimental work. The bar graph (Fig 10) shows the variation in the measured values of 30, 60 and 90 days Leaf area with all the selected treatment combinations and the obtained results resembles the statistical observations made with the Fig 9.

Conclusion: This study was conducted to find the effects of robotic spot tillage on maize crop growth parameters. Based on

the results obtained, robotic tilling and sowing yielded the calculated soil parameters: bulk density ranged from 1.31 to 1.67 g/cm³, cone index range of 1.19 to 2.85 MPa, aggregate uniformity coefficient varied from 2.18 and 4.66 soil organic matter content ranged 0.59% to 0.70% and plasticity index values ranged from 0.21 to 0.37. Robotic tilling and sowing the treatment T₁ consistently displayed the lowest tilth index of 0.38, while T₃ consistently showed the highest tilth index of 0.69. Across the 10*15*T₃ and 15*15*T₃ treatment combinations, all crop parameters demonstrated higher values, indicating the overall effectiveness of the robotic spot tilling instead of tilling the whole field for normal growth of maize crop. Thus, robotic spot tillage is an effective and efficient alternated method of site-specific tillage in which highest tilth index is obtained along with normal growth of maize crop. The integration of scientific research findings with the implementation of the robotic spot tiller cum planter represents a cutting-edge approach to modern agriculture, resonating with the global imperative for sustainable and technology-driven farming practices.

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