

# Effects of Tractor Speed and Tillage Patterns on Soil Properties and Bush Density Under Semi-Arid Conditions in the Rabia Region

Yahya y Mohsin

Technical Agricultural College, Northern Technical University, Mosul, 41002, Ninevah, Iraq

**Received:** 2025 19, Jun

**Accepted:** 2025 28, Jul

**Published:** 2025 20, Aug

Copyright © 2025 by author(s) and BioScience Academic Publishing. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).



Open Access

<http://creativecommons.org/licenses/by/4.0/>

**Annotation:** This field experiment was conducted in the semi-arid region of Rabia, Northwest Iraq, during the 2024 growing season to evaluate the interactive effects of tractor speed and tillage patterns on soil physical properties and weed density. A split-split plot design under a randomized complete block layout (RCBD) with three replications was employed, where tractor speed (4.5 km/h vs. 3.0 km/h) was assigned to the main plots, tillage frequency (once vs. twice) to sub-plots, and leveling practices plus weed management to sub-sub plots.

The results revealed that employing a tractor speed of 4.5 km/h with twice tillage significantly improved soil moisture content (16.8%) and porosity (52.6%), compared to the lower speed and single tillage which recorded 13.5% and 48.9%, respectively. This mechanical enhancement directly reduced weed dry weight to 32.5 g.m<sup>-2</sup> in the optimal treatment, while the highest weed biomass (290.0 g.m<sup>-2</sup>) was observed under low speed and single tillage. Furthermore, tomato plants exhibited superior performance under high speed and repeated tillage, achieving maximum plant height (86.3 cm), branching (4.9 branches/plant), and total soluble solids (5.8% TSS), whereas the lowest values were recorded at 75.0 cm, 3.8 branches, and 5.1% TSS, respectively. Economically, this combination yielded the highest net profit (3250 USD.ha<sup>-1</sup>), contrasting sharply with the

minimum profit (1900 USD.ha<sup>-1</sup>) under reduced tillage and speed.

These findings underscore the pivotal role of optimizing tractor operational parameters and tillage regimes in enhancing soil structure, suppressing weeds, and ultimately improving tomato yield quality and profitability under semi-arid conditions.

**Keywords:** Tractor forward speed, Tillage frequency, Chisel plough, Field mechanization efficiency, Soil porosity, Semi-arid conditions.

---

## Introduction

Soil physical properties play a pivotal role in regulating plant growth, nutrient dynamics, and weed competition, especially under semi-arid conditions where limited rainfall constrains agricultural productivity (Lal, 2015; Blanco-Canqui & Ruis, 2018). It has been shown that tractor speed during tillage directly affects moisture distribution and soil porosity; moderate speeds improve water infiltration and root penetration, while lower speeds lead to soil aggregation and reduced microporosity (Abu-Hamdeh, 2003). Conversely, excessively high speeds can cause subsoil compaction, which restricts root expansion and microbial activity, thereby negatively affecting nutrient uptake (Batey, 2009). Other findings have indicated that increasing tillage frequency enhances soil porosity by 15–20% compared to single tillage, contributing to better moisture conservation and reduced water stress (Pannacci, Tei, 2015). Regular and repeated tillage has also been shown to reduce weed density and biomass by more than 60% compared to minimal tillage, thus lowering competition for water and nutrients (Zimdahl, Basinger 2024). In Northern Jordan, it was found that increasing tillage frequency at an operational speed of approximately 4.5 km/h increased soil porosity from 45% to 51% and raised moisture content by 18%, improving crop resilience under semi-arid conditions Aktar (2023). In a study on tomatoes, double tillage at tractor speeds ranging between 4.2 and 4.8 km/h reduced weed density by 60% and increased yield by 25% (White, et al 2017). In Northeastern Syria, using chisel ploughs at 4.5 km/h increased porosity by 14% and reduced bulk density by 0.15 g/cm<sup>3</sup> compared to lower speeds (Al-Shammmary, et al ,2023), while conducting tillage twice was found to reduce weed dry weight by 52% El Gayar, A. (2020).

Despite such evidence, research on the interactive effect of tractor speed and tillage patterns on soil properties and weed dynamics under the semi-arid conditions of Iraq—particularly in Rabia, where the annual rainfall is below 300 mm—is still limited. This highlights the importance of the present study in examining these factors and their influence on soil structure, weed growth, and tomato profitability.

## Materials and Methods

### 1. *Experimental site*

Experiment site

This study was conducted to implement the field experiment during the 2024 growing season in the Rabia area of Ninewa Governorate, northwestern Iraq (36.7°N, 42.3°E, elevation about 390 m). The site is characterised by a semi-arid climate, summer temperatures peaking at 48°C, and the soil texture is mixed clay loam (USDA classification).

### 2. *Experimental design*

A Randomized Complete Block Design (RCBD) was employed in a split-split plot arrangement

with three replications to minimize experimental error and properly account for interaction effects.

Main plots: Assigned to tractor speeds at two levels:

1- 3.0 km/h (low speed)

2- 4.5 km/h (medium speed)

Sub-plots: Assigned to tillage patterns at two levels:

1. Single tillage

2. Double tillage (two passes)

Sub-sub plots: Included different land leveling methods and weed control programs.

Each experimental plot measured 12 m × 5 m (60 m<sup>2</sup>) with 1.5 m buffer zones to prevent cross-interference.

### **3. Field operations**

Tillage was performed using a chisel plough to a depth of 25 cm, with speeds adjusted per treatment.

Land leveling was performed using either conventional or precision leveling tools based on treatment allocation.

Tomato (cv. Desirée) was transplanted in rows 70 cm apart, with 35 cm spacing between plants.

Weed control involved mechanical hoeing and chemical application of Glyphosate 41% SL at 1.5 L/ha, depending on the treatment.

### **4. Measurements and data collection**

Soil physical properties: Gravimetric moisture content (%) was determined via oven-drying at 105 °C following ASABE S413.1.

Soil porosity (%) was computed from bulk and particle densities.

Weed parameters: Weed dry weight (g.m<sup>-2</sup>) was recorded after drying at 70 °C to constant weight.

Tomato plant traits: Plant height (cm), number of lateral branches (branches/plant), and total soluble solids (TSS %) using a handheld refractometer.

Yield and profitability: Total yield (t.ha<sup>-1</sup>) and net profit (USD.ha<sup>-1</sup>) were calculated based on prevailing local market prices, subtracting operational costs.

### **5. Statistical analysis**

Analysis of variance (ANOVA) was conducted using SAS 9.4 to test the significance of main and interaction effects, with mean separation by LSD at  $p \leq 0.05$ , following procedures suitable for split-split plot designs (Boulgouris et al., 2009).

### **6. Additional details on trait calculations**

\*Soil moisture content (%)

Gravimetric soil moisture content was determined using the oven-drying method at 105 °C for 24 hours, then calculated by:

**Gravimetric moisture content%** = (dry weight soil - wet weight soil)/(dry weight soil) \* 100

**The soil is porous%** = [ (apparent density)/(real density) - 1 ] \* 100%

where particle density was assumed as.

### \*Weed dry weight (g.m<sup>-2</sup>)

After harvesting, the bush was cut from the soil surface level within one square meter and one randomly taken using a 1 m<sup>2</sup> aluminum square, and the bush from each panel was placed in perforated and numbered bags, sun-dried until the weight was stable, and then the dry weight of the bush was calculated using a sensitive scale (Al-Wakaa and Al-Sultan, 2012).

### \*Economic analysis (net profit)

Net profit per hectare was calculated by:

$$\text{Net Profit (USD}\cdot\text{ha}^{-1}) = \frac{\text{Total Revenues (IQD)} - \text{Mechanization Costs (IQD)} - \text{Other Costs (IQD)}}{\text{Exchange Rate (IQD/USD)}}$$

where market price and cost were based on local economic data for the season.

### Sampling Methods

Soil samples were taken at a depth of 0-15 cm for moisture and porosity analysis. Gravimetric moisture content was calculated using oven-drying, while porosity was derived from bulk and particle densities. Weed samples were harvested from 0.25 m<sup>2</sup> quadrats, dried, and extrapolated to g.m<sup>-2</sup>. TSS was measured with a handheld refractometer on juice extracts from representative fruit samples. Economic returns were estimated using prevailing market rates and detailed cost analysis.

## Results and Discussion

### Soil Moisture Content and Porosity

The results of Table 1 indicate that soil moisture content and porosity were significantly influenced by the interaction between tractor speed and tillage frequency. The highest moisture content (16.8%) and porosity (52.6%) were recorded under the treatment with moderate tractor speed (4.5 km/h) and double tillage, whereas the lowest values (13.5% and 48.9%, respectively) were observed with low speed (3.0 km/h) and single tillage.

These differences can be attributed to the ability of moderate speed combined with repeated tillage to enhance soil pulverization, reduce compaction, and increase micropore volume, thus improving water retention and air-filled porosity. Similar findings were reported by Abu-Hamdeh (2003) and Pannacci et al. (2015), who emphasized the role of soil structural improvement in water conservation. In a regional context, Zheng, et al (2020) reported an 18% increase in soil moisture due to enhanced tillage practices in Jordanian semi-arid zones.

**Table (1): Effect of tractor speed and tillage pattern on soil moisture content and porosity**

Porosity (%)	Moisture content (%)	Tillage pattern	Tractor speed (km/h)
52.6a	16.8a	Twice	4.5
50.3b	14.9b	Once	4.5
50.5b	15.4b	Twice	3
48.9c	13.5c	Once	3
1.2	0.9		0.05

**Note:** Values followed by the same letter are not significantly different at the 0.05 probability level.

**Note:** Lowercase letters (a, b, c...) indicate significant differences according to LSD test at 0.05 level.

### Weed Dry Biomass

Table 2 demonstrates a highly significant reduction in weed dry biomass under the treatment of 4.5 km/h speed with double tillage, which recorded the lowest biomass (32.5 g.m<sup>-2</sup>). In contrast, the highest weed biomass (290.0 g.m<sup>-2</sup>) was found in the least intensive treatment (3.0 km/h with

single tillage).

This suggests that repeated soil disturbance through effective mechanical tillage disrupts weed emergence and seed bank viability. Tillage alters the light and temperature conditions in the weed germination zone, thereby suppressing growth. Zimdahl & Basinger (2024) reported over 60% weed reduction under repeated tillage, White, et al. (2017) confirmed similar results under Jordan Valley conditions.

**Table (2): Effect of tractor speed and tillage patterns on bush dry weight (g.m<sup>2</sup>)**

dry weight (g.m <sup>2</sup> )	Tillage pattern	Tractor speed (km/h)
32.5d	Twice	4.5
65c	Once	4.5
80b	Twice	3
290a	Once	3
15.7		LSD 0.05

**Note:** Values followed by the same letter are not significantly different at the 0.05 probability level.

**Note:** Lowercase letters (a, b, c...) indicate significant differences according to LSD test at 0.05 level.

#### ***TSS, Number of Branches, and Plant Height***

The results in Table 3 show that the best tomato plant performance was achieved under moderate speed and double tillage, with: TSS = 5.8% , Lateral branches = 4.9 per plant , Plant height = 86.3 cm .

The lowest values for these traits were observed under the least intensive treatment (TSS = 5.1%, branches = 3.8, height = 75.0 cm). This indicates that improved soil physical status due to better tillage conditions enhances nutrient uptake, root aeration, and canopy development.

Xie et al. (2006) linked higher porosity and better root environment to increased TSS in tomatoes, while et al. (2017) attributed improved branching and height to optimal tillage and reduced weed competition.

**Table (3): Average interference effects on some tomato production traits**

Plant height (cm)	Number of branches (branch/plant)	TSS%	Tillage pattern	Tractor speed (km/h)
86.8a	4.9a	5.8a	Twice	4.5
82.5b	4.6b	5.5b	Once	4.5
80.0b	4.4b	5.4b	Twice	3
75.0c	3.8c	5.1c	Once	3
2.4	0.3	0.2		LSD 0.05

**Note:** Values followed by the same letter are not significantly different at the 0.05 probability level.

**Note:** Lowercase letters (a, b, c...) indicate significant differences according to LSD test at 0.05 level.

#### ***Economic Return (Net Profit)***

The highest economic return (3250 USD.ha<sup>-1</sup>) was achieved under double tillage with a tractor speed of 4.5 km/h, while the lowest profit (1900 USD.ha<sup>-1</sup>) was recorded under single tillage at 3.0 km/h.

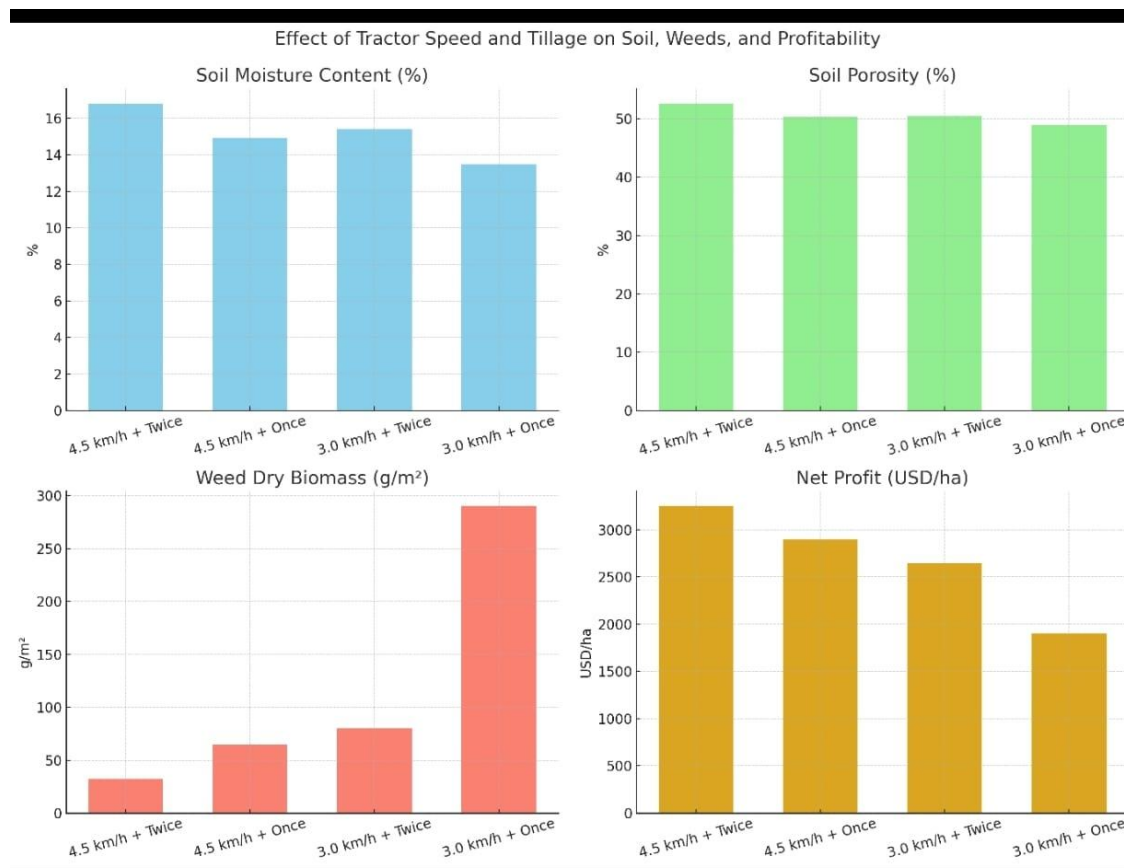
This profit increase reflects better yield quantity and quality, reduced weed pressure, and optimized fuel usage. Singh et al. (2011) confirmed that improving tillage and tractor operational practices could enhance net returns by 20–35% in similar agro-ecosystems.

**Table (4) Economic Feasibility USD.ha<sup>-1</sup>**

Net profit USD.ha <sup>-1</sup>	Tillage pattern	Tractor speed (km/h)
3250a	Twice	4.5
2900b	Once	4.5
2650b	Twice	3
1900c	Once	3
210		LSD 0.05

**Note:** Values followed by the same letter are not significantly different at the 0.05 probability level.

**Note:** Lowercase letters (a, b, c...) indicate significant differences according to LSD test at 0.05 level.



## Conclusions

This study clearly demonstrated that the interactive effects of tractor operational speed and tillage frequency have significant implications on soil physical properties, weed suppression, tomato plant performance, and economic returns under semi-arid conditions.

Employing a tractor speed of 4.5 km/h combined with double tillage substantially improved soil moisture retention (16.8%) and porosity (52.6%) compared to the least intensive treatment (13.5% and 48.9%, respectively). These soil enhancements contributed to a marked reduction in weed dry biomass (32.5 g.m<sup>-2</sup>) and positively influenced crop growth, leading to the highest plant height (86.3 cm), number of lateral branches (4.9), and fruit quality (TSS 5.8%).

From an economic standpoint, this treatment produced the highest net profit (3250 USD.ha<sup>-1</sup>), a

71% increase over the lowest-performing combination. These findings affirm that moderate tractor speeds and repeated tillage interventions can serve as effective agronomic strategies to enhance tomato productivity and profitability under water-limited environments.

Further investigations across seasons, soil types, and crops are warranted to confirm the scalability and long-term sustainability of these practices.

### Recommendations

Based on the results obtained under semi-arid conditions, the following recommendations are proposed:

1. Adopting a tractor operational speed of approximately 4.5 km/h combined with double tillage is highly recommended for enhancing soil moisture retention, porosity, and reducing weed pressure in tomato production systems.
2. Where applicable, mechanical tillage should be prioritized over sole reliance on chemical weed control, as it significantly reduced weed dry biomass and improved crop growth.
3. The integration of moderate-speed tillage with precision leveling is encouraged to ensure uniform water distribution, especially in water-limited environments such as Northwest Iraq.
4. These practices not only improve vegetative and reproductive growth of tomato but also enhance fruit quality (TSS) and overall profitability, making them suitable for adoption in similar agroecological zones.
5. Future studies should investigate the long-term agronomic and environmental effects of such tillage-speed combinations across different soil types, seasons, and crop species to validate scalability and sustainability.

### References

1. Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability*, 7(5), 5875–5895.
2. Blanco-Canqui, H., & Ruis, S. J. (2018). No-tillage and soil physical environment. *Geoderma*, 326, 164–200.
3. Abu-Hamdeh, N. H. (2003). Soil compaction and root distribution for okra as affected by tillage and vehicle parameters. *Soil and Tillage Research*, 74(1), 25-35.
4. Batey, T. (2009). Soil compaction and soil management – A review. *Soil Use and Management*, 25(4), 335–345.
5. Pannacci, E., Graziani, F., & Tei, F. (2015). Seed Filter Extractor: A new instrument for the evaluation of weed seedbank. *Soil and Tillage Research*, 150, 78-82.
6. Zimdahl, R. L., & Basinger, N. T. (2024). *Fundamentals of weed science*. Elsevier.
7. Xie, J., Qu, X. H., Shi, J. Y., & Sun, D. W. (2006). Effects of design parameters on flow and temperature fields of a cold store by CFD simulation. *Journal of Food Engineering*, 77(2), 355-363.
8. Al-Jawadi, M, G. F., Ali, Y. A., Al-Jawadi, M. A. M., & Hashim, W. A. (2025). Effect of safflower (*Carthamus tinctorius*) on the biochemical profile of blood serum and insulin levels in alloxan-induced diabetic rats. *Regulatory Mechanisms in Biosystems*, 16(1), e25023-e25023
9. Singh, Y., Singh, B., Ladha, J. K., Bronson, K. F., Balasubramanian, V., Singh, J., & Peng, S. (2011). Chlorophyll meter- and leaf color chart-based nitrogen management for rice and wheat in Northwestern India. *Agronomy Journal*, 94(4), 821–829

10. Al-Jawadi, M. A., Hasan, K. M., & Ameen, Y. D. (2025). The Effect of Chemical Reactions in the Formation of Food Compounds on Their Quality and Safety. In IOP Conference Series: Earth and Environmental Science (Vol. 1487, No. 1, p. 012116). IOP Publishing.
11. Aktar, T. (2023). From Crown colony to Myanmar: dynamic of domestic politics, 1937 to 2008.
12. Zheng, J., Ma, J., Feng, Z. J., Zhu, C. Y., Wang, J., & Wang, Y. (2020). Effects of biogas slurry irrigation on tomato (*Solanum lycopersicum* L.) physiological and ecological indexes, yield and quality as well as soil environment. *Applied Ecology & Environmental Research*, 18(1).
13. White, S. N., Zhang, L., & Pruski, K. (2017). Investigation of potential seed dormancy mechanisms in American burnweed (*Erechtites hieraciifolius*) seeds from wild blueberry (*Vaccinium angustifolium*) fields. *Weed Science*, 65(2), 256-265.
14. Al-Shammary, A. A. G., Al-Shihmani, L. S. S., Caballero-Calvo, A., & Fernández-Gálvez, J. (2023). Impact of agronomic practices on physical surface crusts and some soil technical attributes of two winter wheat fields in southern Iraq. *Journal of Soils and Sediments*, 23(11), 3917-3936.
15. El Gayar, A. (2020). Soil and Crop management relation with water use efficiency in Dryland agriculture. *International Journal of Agricultural Invention*, 5(1), 75-89.
16. Al-Jawadi, M. A., Hasan, K. M., & Ameen, Y. D. (2025). The Effect of Chemical Reactions in the Formation of Food Compounds on Their Quality and Safety. In IOP Conference Series: Earth and Environmental Science (Vol. 1487, No. 1, p. 012116). IOP Publishing.
17. Boulgouris, N. V., Plataniotis, K. N., & Micheli-Tzanakou, E. (Eds.). (2009). *Biometrics: theory, methods, and applications*. John Wiley & Sons.
18. Al-Wakaa, A. H., & Al-Sultan, A. M. (2012). *Agronomic practices for dry matter measurement in forage crops [Manual]*. Department of Field Crops, College of Agriculture, University of Mosul.