Azzaytuna University
Agriculture faculty

مجلة النماء للعلوم والتكنولوجيا

Science & Technology's Development Journal

(STDJ)

مجلة علمية محكمة سنوية تصدر عن
كلية الزراعة جامعة الزيتونة

العدد السادس مارس 2025

STDJ ISSN: 2789-9535

Impact of Soil Mulching with Plastic on Soil Moisture Conservation and Pomegranate Growth in Libya

Ghieth Ali Omar Alsakloul[1], Omran Ali Ahmed Amshaher[2]
[1,2] Sirte university, Libya
Ghieth.alsakloul@su.edu.ly

تأثير تغطية التربة بالبلاستيك على الاحتفاظ برطوبة التربة ونمو الرمان في ليبيا

غيث على عمر الصكلول[1]، عمران علي حمد امشهر[2]
[1,2]جامعة سرت، ليبيا

الملخص:

ندرة المياه تُعَدُّ واحدةً من أكثر التحديات إلحاحاً في ليبيا، وهي دولةٌ تتميّز بمناخها الجاف، ومواردها المحدودة من المياه العذبة، وارتفاع معدلات التبخّر. هذه الظروف تستدعي ابتكار أساليب عملية وفعّالة للحفاظ على المياه وضمان استدامة الإنتاج الزراعي. تهدف هذه الدراسة إلى تقييم تأثير تغطية التربة باستخدام أغطية بلاستيكية مختلفة في الحفاظ على رطوبة التربة، وتقليل معدلات التبخر، وتعزيز نمو وإنتاجية أشجار الرمان في ليبيا. أُجريَت التجربة على أشجار رمان خضراء عمرها 7 سنوات تحت ظروف بيئية قاسية ومحدودة الموارد المائية. تمَّ استخدام تصميم القطاعات العشوائية الكاملة بثلاث مكررات، وشملت التجربة أربع معاملات[T_1 : كنترول (بدون تغطية)، T_2:غطاء بلاستيكي واحد غير مغطى بالتربة، T_3: غطاء بلاستيكي واحد مغطى بالتربة، و T_4: غطاءان بلاستيكيان أحدهما مغطى بالتربة والآخر على السطح مع وجود طبقة هوائية بينهما]. أظهرت النتائج أن تغطية التربة حسّنت بشكل ملحوظ النمو الخضري، وخصائص البراعم، وإنتاجية وجودة الثمار مقارنةً بالمعاملة غير المغطاة (الكنترول). وقد سجلت المعاملة ذات الغطاءين البلاستيكيين (T_4) أعلى إنتاجية (42–48 كجم/شجرة) ووزن للثمار (246–243 جم). تؤكد هذه النتائج على أهمية تغطية التربة في تحسين الحفاظ على المياه (رطوبة التربة) وزيادة إنتاجية المحاصيل في المناطق الجافة. ينبغي أن تركز الأبحاث المستقبلية على دمج تقنيات التغطية مع استراتيجيات أخرى لتوفير المياه وممارسات زراعية مستدامة لتعزيز مرونة الزراعة في ظل الظروف البيئية القاسية.

الكلمات المفتاحية: *ندرة المياه، تغطية التربة بالغطاء البلاستيكي، الرمان، المناطق القاحلة، ليبيا، الزراعة المستدامة.*

Abstract:

Water scarcity is one of the most pressing challenges in Libya, a country characterized by its arid climate, limited freshwater resources and high rates of evaporation. These conditions necessitate innovative and practical approaches to conserve water and sustain agricultural productivity. This study investigates the impact of soil mulching using different plastic covers on conserving soil moisture, reducing evaporation and enhancing the growth and yield of pomegranate trees in Libya. The experiment was conducted on 7-year-old green pomegranate trees under arid conditions with limited water resources. A completely randomized block design with three replicates was used, including four treatments: **T_1:** control (un-mulched), **T_2:** one plastic mulch uncovered, **T_3:** one plastic mulch covered with soil and **T_4:** two plastic mulches layered with soil and airspace between them. Results indicated that soil mulching significantly improved vegetative growth, bud characteristics, fruit yield and quality compared to the un-mulched control.

The double-layered plastic mulch treatment (T_4) produced the highest yield (42/48 kg/tree) and fruit weight (246/243 g). These findings emphasize the importance of soil mulching in improving water conservation and crop productivity in arid regions. Future research should explore integrating mulching with other water-saving strategies and sustainable practices to further enhance agricultural resilience under extreme environmental conditions.

Keywords: *Water scarcity, soil mulching, plastic mulch, pomegranate, arid regions, Libya, sustainable agriculture.*

Introduction:

Water scarcity is one of the most pressing challenges globally, driven by climate change, population growth, and increasing demands for water resources. This issue is particularly severe in arid and semi-arid regions (Liu et al., 2017).

Libya is a prime example of a country grappling with limited water resources, high evaporation rates, and dependence on non-renewable groundwater. Additionally, harsh environmental conditions, including poor soil quality and shallow rocky layers, create significant barriers to sustainable agriculture (Hamad et al., 2017). These challenges underscore the urgent need for innovative and effective solutions to conserve water and sustain agricultural productivity (Noureddine et al., 2021).

Water plays a critical role in supporting plant growth and productivity, with soil moisture directly influencing the uptake and transport of nutrients within plants. Thus, maintaining adequate soil moisture is a priority, particularly in regions with scarce water resources (Ghosh et al,. 2021).

Among the techniques available, soil mulching stands out as an effective approach to reducing water loss through evaporation, improving soil conditions, moderating surface temperatures, suppressing weed growth, and minimizing pest infestations (El-Taweel & Farag, 2015; Bombino et al., 2021; El-Beltagi et al., 2022; Beelagi et al., 2023).

Pomegranate trees are economically and nutritionally valuable crops, known for their high nutritional value and diverse applications (Beelagi et al., 2023). Additionally, they are relatively well-suited to dry conditions, making them an essential component of sustainable agriculture in arid regions (Volschenk, 2020) like Libya. However, ensuring optimal water management is crucial to enhancing tree productivity and fruit quality.

This study aims to evaluate the impact of different soil mulching techniques using plastic covers on conserving soil moisture, reducing evaporation, and enhancing the growth and yield of pomegranate trees under Libya's challenging environmental conditions. The specific objectives of the study are:

1. Assessing the effectiveness of various mulching methods in conserving moisture and reducing evaporation.
2. Investigating the impact of mulching on vegetative growth, fruit yield, and quality of pomegranate trees.
3. Providing practical recommendations to improve water use efficiency and boost crop productivity in arid regions.

Materials and methods:

1. Plant material and climate of study area

The study was conducted in Libya using 7-year-old green pomegranate trees, imported from Tunisia, which had an average height of 1.7 meters. Furthermore, the average crown width was 1.7 m × 1.5 m. These trees were cultivated under arid conditions with limited water availability, compounded by the presence of a rocky soil layer near the surface, which restricts root penetration and extension. The field experiment took place in the Algratbea region, located approximately 25 km south of the center of Sirt city, Libya (latitude 30° 30' 1.4" N, longitude 30° 19' 10.9" E, and an elevation of 46 meters above mean sea level) (Fig 1). The region experiences a Mediterranean climate, characterized by cool winters and hot, dry summers. Climate data, including average temperature, relative humidity, and wind speed, were obtained from the local weather station in Sirt city, as shown in Table1.

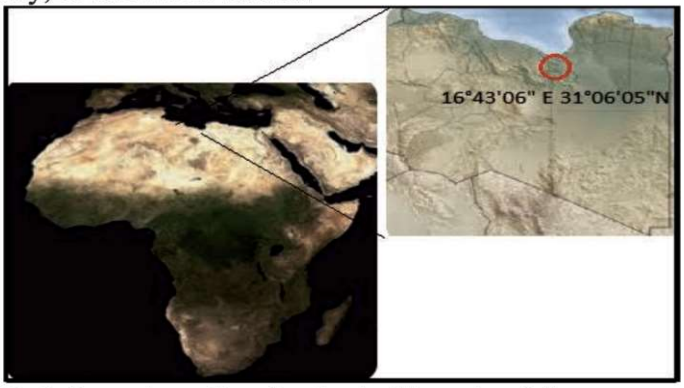

Fig1. Location of study site in Sirte city, Libya.

Table1. Monthly average air temperature and relative humidity in Sirte ,Libya.

Months	Climate mean values, 2023				Climate mean values, 2024			
	T MAX C°	T MIN C°	T Mean C°	WIND Km/h	T MAX C°	T MIN C°	T Mean C°	WIND Km/h
March	22	11	16.5	10-20	19	12.5	15.7	10-20
April	26	15	20.5	10-20	21	41	17.5	30-20
May	30	18	24	20-30	26	15	20.5	30-20
June	32	20	26	20-30	30.5	21	25.7	30-20
July	33	22	27.5	20-30	33.5	24.3	30	20-30
August	34	23	28.5	20-30	33.5	24.9	29.2	20-30
September	33	22	27.5	20-30	28	21.2	24.6	20-30
October	29	19	24	20-30	27.8	19.6	23.7	20-30

Source: National Center of Meteorology

TMAX: Maximum Air Temperature. TMIN: Minimum Air Temperature. TMean: Average Air Temperature. , WIND: Wind Speed (Km/h),

2. Quality of Irrigation Water

A water sample was collected from a well located in the experimental area for analysis. Laboratory tests were performed to determine the electrical conductivity (EC) and pH level, following standard procedures. The EC was found to be 4.4 dSm^{-1}, and the pH was 7.6. According to the FAO classification system proposed by Ayers and Westcot (1985), this water falls into the third category, indicating that it has moderate salinity and is suitable for irrigation of crops that are moderately salt-tolerant, although its use should be monitored carefully to avoid adverse effects on plant growth.

3. Initial Soil analysis and its properties

The physical and chemical analyses were conducted following the methods outlined by Dane and Topp (2020) and Sparks et al., (2020), with the results of these analyses presented in Table 2. A soil sample was collected from the study area at depths ranging from 0 to 20 cm. The soil was air-dried for 24 hours, sieved with a 2 mm diameter mesh to remove non-soil components, and then oven-dried at 105°C for 24 hours. After cooling, the sample was passed through a series of sieves arranged in descending order from 2 mm to 0.002 mm. The sieving process was conducted using a shaker for 7 minutes. The particle size distribution (%) was measured:

Table 2. Characteristics of initial soil.

Characteristics		Values
Particle size distribution (%)	Sand	67.0
	Silt	32.3
	Clay	0.70
Textural class is sandy		
Hydraulic conductivity, cm/hr		9.00
Field capacity,%		15.4
Saturation, %		30.0
Wilting point,%		7.50
EC dSm^{-1}		4.3
pH		7.5
SAR		0.287
ESP		2.476
Cations, meq/100g	Na^+	1.4
	K^+	0.4
	Ca^{++}	16
	Mg^{++}	15.6
Anions, meq/100g	CO_3^-	Nile
	HCO_3^-	3.2
	Cl^-	3.2
	SO_4^{--}	27

The hydraulic conductivity of the soil was measured using a column method. A cylinder with a diameter of 5 cm was filled with soil, and the water column was set at a height of 45 cm. After saturation, the time taken for 38 ml of water to pass through the soil was recorded (8 minutes). Darcy's Law was applied to calculate the hydraulic conductivity:

$$K\ (cm/h) = \frac{Q \times L}{H \times A \times T}$$

The field capacity of the soil was determined by saturating 100 gm of soil placed in an open-ended cylinder. After 24 hours of saturation, the excess water was drained, and the weight of the moist soil was recorded as 115.4 g. The field capacity was calculated using the formula:

$$\text{Field Capacity} = \left(\frac{\text{Weight of Moist Soil-Weight of Dry Soil}}{\text{Weight of Dry Soil}}\right) \times 100$$

The saturation percentage was estimated by gradually adding distilled water to a 100 g sample of air-dried soil until the surface appeared glossy. The saturation water was then measured. The saturation percentage was calculated as follows:

$$\text{Saturation Percentage} = \left(\frac{\text{Weight of Saturation Water}}{\text{Weight of Dry Soil}}\right) \times 100$$

The wilting point was derived from the saturation percentage using the following equations: Wilting Point = Saturation percentage / 4. Soil pH was measured using a pH meter (model HANNA HI83141) on the saturated soil paste extract. The electrical conductivity of the soil was measured using a conductivity meter (model JENWAY 4520) to estimate the dissolved salts. The standard methods were used to estimate the cations and anions in the soil. SAR (Sodium Adsorption Ratio) and ESP (Exchangeable Sodium Percentage) were calculated using the following formulas, respectively:

$$SAR = \frac{Na^+}{\sqrt{\left(\frac{Ca^{2+} + Mg^{2+}}{2}\right)}}$$

$$ESP = \frac{Na^+}{CEC} \times 100$$

4. Experimental Design and Setup

A completely randomized block design with three replicates was applied. The treatments included:

-T_1 **(Control):** No mulching.

-T_2**:** One black plastic mulch (1m width, 1mm thickness, 6 holes of 2 cm diameter) on the soil surface.

-T_3**:** One black plastic mulch covered with soil.

-T_4**:** Two black plastic mulches layered with soil and a 2 cm airspace between them.

The treatments were applied in adjacent plots with the same soil type. Mulching was initiated in early February 2023 and continued until October 2024. The three mulching treatments were applied within a 1.0 m^2 circle around the base of each tree. Ten trees were assigned to each treatment, with five randomly selected trees from each treatment group for measurement. After mulching, no additional management practices were applied to the treatments until the empirical indicators were measured. The same amount of water was applied to all four treatments. Soil moisture levels were measured using a tensiometer at a constant temperature of 32°C, and the number of days the soil retained the required moisture level was recorded.

5. Data Collection

-Vegetative Growth: Bud count, bud length and bud thickness were measured in October 2023 and 2024.

-Yield and Quality: Total yield (kg/tree) and average fruit weight (g) were recorded.

Results And discussions:

Table 3 illustrates the impact of different soil mulching types on the duration of soil moisture retention. The un-mulched control treatment **(T_1)** retained moisture for the shortest period, lasting only 6 days. Introducing one layer of uncovered black plastic mulch **(T_2)** improved moisture retention to 8 days. Covering the black plastic mulch **(T_3)** further extended the retention period to 11 days. The most effective treatment **(T_4),** using two layers of black plastic mulch, significantly increased moisture retention, maintaining the required moisture level for 15 days. This demonstrates a clear trend where increased mulching enhances soil moisture conservation.

Table 3. The duration of soil moisture retention.

Character of plant	Soil mulching type			
	T_1 Un-mulched (control)	T_2 One black plastic mulch uncovered	T_3 One black plastic mulch covered	T_4 Two black plastic mulch
Number of days the soil retained the required moisture level	6 days	8 days	11days	15days

Table 4 provides key metrics on the impact of different soil mulching types on the growth, yield and fruit quality of pomegranate trees for the 2023/2024 growing season. It compares four treatments: un-mulched (control), one black plastic mulch uncovered, one black plastic mulch covered with soil, and two black plastic mulches. Each treatment's impact is measured across several plant characteristics: bud number, bud length, bud thickness, total yield, and average fruit weight.

Table 4. The impact of different soil mulching types on the growth, yield and fruit quality of pomegranate trees for the 2023/2024 growing season.

Character of plant	Soil mulching type			
	T_1 Un-mulched (control)	T_2 One black plastic mulch uncovered	T_3 One black plastic mulch covered	T_4 Two black plastic mulch
Average integer of buds / tree 2023/2024	70 / 65	69 / 70	70 /79	85/87
mean vernal buds length, cm 2023/2024	16 / 14	15/18	20/24	23/25
bud thickness flush, cm 2023/2024	0.7 / 0.8	1 /1.1	1.2 / 1.4	1.3/1.6
total yield, kg 2023/2024	20 / 22	28 / 30	35 / 34	42/48
Average fruit weight, g 2023/2024	150 / 158	198/ 180	250 / 244	246/243

Average number of buds / tree

The number of buds per tree is a crucial indicator of a plant's potential for vegetative growth and future fruit production. The un-mulched control showed a decline from 70 buds in 2023 to 65 in 2024, which is typical of non-mulched treatments that are susceptible to environmental stress such as water loss and temperature fluctuations. Conversely, the two-layer plastic mulch treatment (**T_4**) demonstrated the most significant increase in bud numbers, from 85 in 2023 to 87 in 2024, suggesting enhanced growth conditions. The additional layer of mulch likely created a more stable microenvironment, conserving soil moisture and moderating temperature, which in turn supported better bud development.

Vernal bud length (cm)

Bud length is an indicator of the overall vigor and health of the plant. Pomegranate trees under mulching treatments consistently showed improved bud length compared to the control group. In the case of the two-layer plastic mulch treatment, the bud length increased from 23 cm in 2023 to 25 cm in 2024, significantly outperforming the control (16 cm in 2023 and 14 cm in 2024). This improvement can be attributed to the enhanced moisture retention and temperature regulation provided by the mulch, which supports better physiological functions in the plant. Similar results have been reported in studies of soil mulching, where improved water retention and reduced soil stress led to increased bud development and overall plant growth.

Bud thickness flush (cm)

Bud thickness is often used as an indicator of the plant's response to environmental conditions and its ability to allocate resources for growth. The thickness of the buds showed a similar trend to bud length, with the two-layer plastic mulch treatment showing the greatest increase in bud thickness, from 1.3 cm in 2023 to 1.6 cm in 2024. This thicker growth may be associated with improved nutrient and water availability, as the mulch treatment prevents excessive evaporation and helps maintain adequate soil moisture. In contrast, the un-mulched treatment showed the lowest bud thickness, likely due to the combined stress of water scarcity and high evaporation.

Total yield (kg)

Yield is the ultimate measure of the plant's productivity, and in this study, mulching had a clear positive effect on yield. The un-mulched control showed the lowest yield of 20/22 kg per tree. The one-layer plastic mulch uncovered **(T_2)** and covered **(T_3)** treatments both resulted in higher yields, with **T_3** showing a yield increase of 35/34 kg per tree compared to the control. However, the most significant yield improvement occurred with the two-layer plastic mulch **(T_4),** with yields reaching 42/48 kg per tree. This dramatic increase in yield can be attributed to the improved soil moisture retention and reduced soil temperature fluctuations, which are essential for pomegranate fruit development, particularly in arid environments.

Average fruit weight (g)

Fruit weight is an important indicator of fruit quality, and the results indicate that mulching significantly improved fruit size. The control treatment produced fruits with an average weight of 150/158 g. In contrast, the two-layer plastic mulch treatment **(T_4)** produced fruits with an average weight of 246/243 g, which is considerably larger. The increased fruit size is likely a result of better water availability and more consistent growing conditions provided by the mulch. Previous research has shown that soil mulching not only improves fruit yield but also increases the size of individual fruits, which is crucial for enhancing marketability and quality.

The observed results can be explained by several scientific factors related to the effects of soil mulching on plant growth and development. Mulching, particularly with plastic materials, helps conserve soil moisture by reducing evaporation. This moisture retention prevents the soil from drying out, ensuring that the roots have access to sufficient water, which is vital for their physiological processes. Furthermore, plastic mulches regulate soil temperature by providing a barrier that shields the soil from excessive heat during the day and cold at night, creating a more stable environment for root growth. The reduction in soil temperature fluctuations promotes better nutrient uptake and enhances plant growth, as seen in the increased bud and fruit development. Additionally, the physical properties of mulches, such as the coverage of soil, prevent weed growth, which could otherwise compete with the plants for water and nutrients. The observed increase in bud length, bud thickness, yield, and fruit size in mulched treatments is consistent with findings from previous research, which has demonstrated that mulching can significantly improve plant productivity under water-limited conditions. Our results align with studies by (El-Taweel & Farag, 2015; Bombino et al., 2021; El-Beltagi et al., 2022; Beelagi et al., 2023), who reported similar positive effects of mulching on fruit yield, quality, and overall plant performance in arid environments.

Conclusion:

This study highlights the significant role of soil mulching in conserving water, reducing evaporation, and improving the growth and productivity of pomegranate trees in arid conditions like those in Libya. The results clearly demonstrate that mulching with plastic covers, particularly double-layered mulching, not only enhances soil moisture retention but also promotes better vegetative growth and higher fruit yield. The highest yields were observed with the two-layer plastic mulch treatment, which underscores the potential of this technique in optimizing water use and improving crop performance in water-scarce regions. Based on these findings, it is recommended that farmers in arid regions, particularly in Libya, adopt soil mulching practices as a sustainable water-conservation strategy. The use of plastic mulches, especially double-layered, could be an effective solution to mitigate the challenges posed by limited water resources and high evaporation rates. Furthermore, further research could explore the long-term effects of different mulch materials, their environmental impact, and the potential integration of mulching with other water-saving technologies to maximize agricultural productivity and ensure food security in such regions.

References:

Ayers, R.S., & Westcot, D.W. (1985). Water quality for agriculture (Vol. 29, p. 174). Rome: Food and agriculture organization of the United Nations.

Beelagi, R., Singh, V.P., Jat, R., Singh, P.K., Rai, R., Singh, A., ... & Kumar, P. (2023). Enhancing the Fruit Yield and Quality in Pomegranate: Insights into Drip Irrigation and Mulching Strategies. Plants, 12(18), 3241.

Bombino, G., Denisi, P., Gómez, J. A., & Zema, D.A. (2021). Mulching as best management practice to reduce surface runoff and erosion in steep clayey olive groves. International Soil and Water Conservation Research, 9(1), 26-36.

Dane, J.H., & Topp, C.G. (Eds.). (2020). Methods of soil analysis, Part 4: Physical methods (Vol. 20). John Wiley & Sons.

El-Beltagi, H.S., Basit, A., Mohamed, H.I., Ali, I., Ullah, S., Kamel, E.A., ... & Ghazzawy, H.S. (2022). Mulching as a sustainable water and soil saving practice in agriculture: A review. Agronomy, 12(8), 1881.

El-Taweel, A.A., & Farag, A.A. (2015). Mulching implication on productivity and fruit quality of pomegranate grown in a sandy soil. Egypt J. Hortic, 42, 367-391.

Ghosh, A., Singh, A.K., Kumar, S., Manna, M.C., Jha, P., Bhattacharyya, R., ... & Kumar, R.V. (2021). Do moisture conservation practices influence stability of soil organic carbon and structure?. Catena, 199, 105127.

Hamad, J.R.J., Hanafiah, M.M., & Yaakob, W.Z.W. (2017). Water resources management in Libya: Challenges and future prospects. Malaysian Journal of Sustainable Agriculture, 1(2), 2-5.

Liu, J., Yang, H., Gosling, S.N., Kummu, M., Flörke, M., Pfister, S., ... & Oki, T. (2017). Water scarcity assessments in the past, present, and future. Earth's future, 5(6), 545-559.

Noureddine, G., Eslamian, S.A.E.I.D., & Katlane, R. (2021). Status of water resources and Climate change in Maghreb regions (Mauritania, Morocco, Algeria, Tunisia and Libya). International Journal Water Sciences and Environment Technologies. Scientific Press International Limited, 6(4), 67-94.

Sparks, D.L., Page, A.L., Helmke, P.A., & Loeppert, R.H. (Eds.) (2020). Methods of soil analysis, part 3: Chemical methods (Vol. 14). John Wiley & Sons.

Volschenk, T. (2020). Water use and irrigation management of pomegranate trees-A review. Agricultural Water Management, 241, 106375.