دروس مستفادة في ترشيد استهلاك مياه الري لتحقيق الأمن المائي والغذائي وتعزيز الاستدامة البيئية في سورية

ديمه علي نبهان سلامه[1*]

[1*]مدرس – قسم المكننة الزراعية – كلية الهندسة التقنية – جامعة طرطوس.

الملخص:

يقدم البحث رؤية لتحقيق الاستدامة البيئية للموارد الطبيعية وتوفير الأمن الغذائي والأمن المائي في المناطق القاحلة وشبه القاحلة في سورية. يعد توفير مياه الري في المناطق ذات الترب الرملية مشكلة كبيرة، وغالباً ما يحدث فقد الكثير من مياه الري إما بالتبخر أو بتسرب المياه الى الطبقات السفلى من التربة دون أن يستفيد منها النبات لنموه، من أجل تعويض هذا الفاقد يتم استخدام كميات كبيرة من المياه مما يبدد الموارد المائية العذبة ويسبب هدرها. تم استخدام طرق مختلفة لضبط مشكلة هدر المياه غير أن معظمها مكلف كما قد تتسبب بحدوث مشاكل بيئية كبرى. من هنا تأتي أهمية البحث في الاستفادة من تجارب الدول العربية والأجنبية في هذا المجال والوصول الى طريقة تناسب الواقع في سورية تحقق ترشيد استهلاك مياه الري باستخدام مواد رخيصة ومتوفرة محلياً. يهدف البحث الى تسليط الضوء على جدوى استخدام الرمل المغلف بالشمع في تحقيق التنمية المستدامة المنشودة في المناطق القاحلة وشبه القاحلة في سورية، وذلك باعتبار أن الشمع متوفر حيث أنه منتج ثانوي لعملية تكرير النفط كما أنه مادة غير سامة صديقة للبيئة وفعالة في تخفيض نفاذية الرمل المنتشر بشكل واسع في سورية وبذلك يمكن استخدامه لتقليل استهلاك مياه الري. تتم عملية تغليف جزيئات التربة بطبقة من الشمع بصهر الشمع وتطبيقه على التربة بتقنيات خاصة، أثبت استخدام الرمل المغلف بالشمع تقليل بخر الماء من التربة العلوية، وزيادة رطوبة التربة، وكذلك زيادة غلة محاصيل النباتات ذات الجذور الضحلة وهذا يثبت جدوى استخدامه لتوفير مياه الري وتحقيق الأمن المائي والأمن الغذائي.

كلمات مفتاحية: الرمل المغلف بالشمع، ندرة المياه، الأمن المائي، الأمن الغذائي، التنمية المستدامة.

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Lessons learned in rationalizing irrigation water consumption to achieve water- food security and enhance environmental sustainability in Syria

Dima Ali Nabhan Salameh[1*]

[1*]Lecture-Department of Agricultural Mechanization-Faculty of Technical Engineering-Tartous University.

Abstract:

The research presents a vision of developing natural resources within the framework of environmental sustainability to achieve food and water security in arid and semi-arid regions in Syria. Providing irrigation water in sandy sites is a major problem, as often most of water are lost either by evaporation or by its seepage down into the subsoil without benefiting of it in the process of plant growth. Therefore, to ensure sufficient water availability to support plant growth, water is compensated by irrigation and this consumed freshwater resources and threaten water security. Various technologies for enhancing the water-use efficiency of irrigated agriculture have been used to control the problem of wasting water, but most of them are expensive and causing environmental problems. Hence, the importance of the research in benefiting from the experiences of Arab and foreign countries in this field, and finding a technology that suits the reality in Syria and satisfy rationalization of irrigation water consumption using cheap and locally available materials. The research aims to highlight the feasibility of using wax-coated sand in achieving the desired sustainable development in arid and semi-arid areas in Syria. Since wax is available as a by-product of the oil refining process, and it is non-toxic material, friendly environmentally, good water repellent and capable to reduce the permeability of sand which is widely spread in Syria therefore it is suitable to reduce irrigation water consumption in sandy sits. The coating process of sand particles with a layer of wax is done by melting the wax and applying it to the sand by using special techniques. In conclusion, the use of wax-coated sand on the surface of sand reducing water evaporation from the upper soil, increasing soil moisture the yield of crops of plants with shallow roots, and this proves the feasibility of using it to provide irrigation water and achieve water security and food security.

Key Words: Wax-Coated Sand, Water Scarcity, Water Security, Food Security, Sustainable Development.

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1.Introduction:

Irrigated agriculture plays an important role in achieving food security around the world, contributing (30-40) % of the total global food production.[26] Many lands have been invested as agricultural centres in arid and semi-arid regions by exploiting freshwater resources[25], and due to the large scale of agricultural operations, irrigation of crops consumes 70% of global freshwater withdrawals annually[4,12], which in turn poses the risk of depleting freshwater supplies around the world.[12,20]

Sandy soils are widespread in Syria, and arid and semi-arid areas suffer from water shortages when cultivated. Sandy soils are characterised by their low capacity to store water, as sand composed of hydrophilic silica attracts water and facilitates its flow in the ground [6,13], which negatively affects crops even with expensive irrigation systems such as sprinkling or drip [8]. High temperatures and dry winds in these areas also cause significant losses of irrigation water through evapotranspiration and evaporation without the plant benefiting from it for its growth, which requires compensation with additional irrigation processes that increase the consumption of freshwater stocks [20] In addition to the loss of irrigation water through evapotranspiration, it is also lost through leaching down to the root zone. Various methods have been used to increase the water retention capacity of sandy soils, but the emergence of some environmental issues when using them, in addition to their high cost, limited their application [14,15,18]. Based on the concern to preserve fresh water resources for irrigation, much attention has been directed to search for ways to control water waste and achieve water and food security through the application of sustainable technology to enhance water use efficiency in arid land agriculture [2,5,9]. Since transpiration is important for photosynthesis, it is counterproductive to minimise it, so attention has been focused on minimizing Leaching and evaporation. Leaching can be reduced by applying a water barrier layer below the root zone of the plant [8,13], but this method is expensive and labour intensive, so the best way to reduce water loss is to minimise evaporation. Applying a barrier to the topsoil to prevent evaporation enhances soil moisture content, promotes transpiration and improves plant root growth, which improves water and nutrient uptake from the soil as well as photosynthesis [7,23,26]. Low-density polyethylene mulching films with a thickness of 0.1 mm have been widely used in developed and developing countries around the world [10,27]. However, as plastics are non-biodegradable and have adverse effects on soil quality and microbial activity in the long term, their use is considered an unsustainable solution [24]. Therefore, it has become necessary to search for sustainable mulching technologies [2,15,20]. Recently, the use of hydrophobic sand has been emphasised [5,6], to reduce leaching and evaporation and mitigate irrigation water wastage [9]. Hydrophobic sand is obtained by treating sand with water-resistant materials or compounds that ensure that the sand particles adhere to each other and form a layer that does not allow water to seep through, but water droplets collect on the surface without penetrating it [2,519,22]. Waterproof sand is formed in different ways such as adding a chemical substance to the sand and allowing it to build chemical bonds between the sand particles (there is a special factory in the Emirate of Al Ain in the Arabian Gulf region where waterproof sand is prepared by treating sand with organic silica compounds)[1]. However, concerns about the risk of chemical contamination of soil and groundwater as a result of leaching of the chemical organic compounds used in sand encapsulation have limited its use[1,24]. Since wax is a low-cost, non-toxic and environmentally friendly material, interest has been directed to its use with sandy soils to improve their hydraulic properties and its use in agriculture to improve irrigation efficiency and alleviate the issue of wasting irrigation water and environmental issues, hence the importance of the research. The process of coating sand particles with a layer of wax is a physical process, and we get Wax-coated sand by melting the wax and applying it to sand with special techniques [3,11,17]. The research aims to evaluate the possibility of using wax-coated sand to control water wastage in areas with sandy soils in Syria by studying the results of research conducted in different regions in the Middle East and the world, which in turn constitutes a promising research topic of global importance to achieve sustainable development.

2. Research Objective and Importance:

The research aims to shed light on successful Arab and international experiences in the application of sustainable soil mulching technology to reduce water evaporation in arid and semi-arid land conditions, with the aim of reaching the most economically and environmentally appropriate method to be used in Syria, through which rationalising the use of irrigation water and increasing the required agricultural productivity through the use of cheap and locally available materials. The importance of the research comes in choosing the method of using sand coated with paraffin wax and evaluating its effectiveness in achieving the sustainability of food and water resources in a way that suits the specificity of local conditions, especially since sandy soils are widespread in Syria and wax can be extracted from the oil refining process in oil refineries in Syria, which is economically important from an economic point of view.

3. Materials and Methods:

This research is based on the results of international reference studies [6,12,16,18] and a pilot study conducted in laboratories in Saudi Arabia [8,16]. The wax-coated sand was prepared according to [9]. Clean silica sand with a grain size of 100-700 nm was used in the study, and paraffin wax was used. To prepare the wax-coated sand, the paraffin wax was melted in a container using a natural solvent (hexane) that was added to the wax, then the sand was added to the wax in a ratio of 1:600, the mixture was mixed and the wax-coated sand was formed. The solution (hexane) was then removed by reducing the pressure and increasing the temperature, leaving the wax-coated sand (the solution is retained to be reused again).

Figure 1: Wax-coated sand

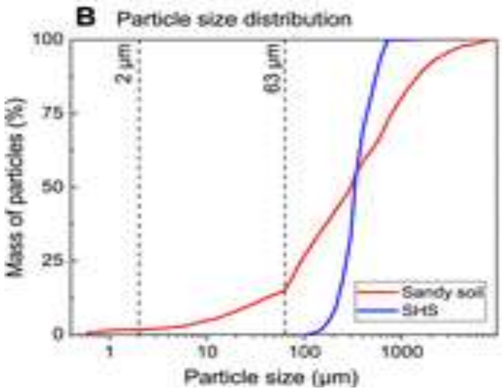

Figure 2: Grain gradient of sand and wax-coated sand

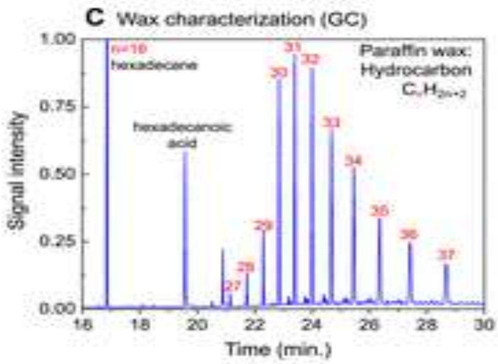

Figure 3: Characterisation of paraffin wax

We can also form wax-coated sand based on the reference study [21] where sand and wax with a wax ratio of 5% by weight of dry sand are placed in a container and the mixture is heated to a temperature above the melting point of the wax (°C62), after which it is mixed using an automatic mixer at 60 rpm for 15 minutes, then the heat source is removed and the mixing continues for a few more minutes until the mixture softens, forming wax-coated sand particles.

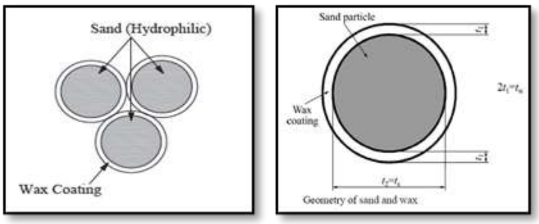

Figure 3: A thin layer of water-repellent wax encapsulates the sand particles

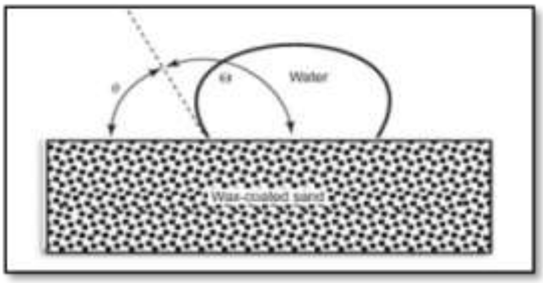

Figure 4: Stabilisation of a water droplet on the surface of a layer of wax-coated sand

To form the wax-coated sand according to the previous method, sand brought from the city of Latakia was used. A set of laboratory experiments were conducted on the sand, and as a result of the tests, the sand was classified according to the Unified Classification System (USCS) as poorly graded sand SP medium to well graded, and its specifications are shown in the following table:

Table 1: The properties of sand

Property	Quantity
Natural moisture content, (%)	5.8 – 6
Specific gravity, Gs	2.69 – 2.7
Natural density (KN/m^3)	17 – 17.1
Relative density D_d	Dry method ≈ 0.93 Wet method ≈ 0.56
Sand equivalent (%) SE	97.62 -98.4
Porosity coefficient e	0.64 – 0.65
Uniformity coefficient, Cu	2.1 - 2.3
Curvature coefficient, C_Z	0.74 - 0.94
Percent Passing through #200 sieve,(%)	1.28 -1.81

Paraffin Wax (FA 569) was used. Due to its availability, effective performance and low cost compared to other waxes, this research is oriented towards the use of wax from oil refining in the oil refineries located in Syria.

Figure 5: Some of the waxes tested in the research

Table 2: The properties of the wax used, Paraffin Wax FA 569

Testing Methods	Specification		ASTM Method
	Minimum	Maximum	
Physical State (25°C)	Solid		
Melting Point (°C)	60	62	D 87
Needle penetration (mm, at 25°c)	15	20	D 1321
Oil (%)		0.5	D 721

Figure 6: Method of forming wax-coated sand

To study the effect of covering the surface layer of sandy soil with a layer of wax-coated sand, based on the study conducted in the fields of King Abdullah University in Saudi Arabia [16], a set of samples was prepared as a study model where tomato seeds were planted in plastic pots placed in controlled rooms with ambient environmental conditions that mimic the environmental conditions in the desert areas to be cultivated and greened in sustainable ways to achieve food and water security. Half of the samples were covered with a 1cm thick layer of wax-coated sand, while the other half of the samples were not covered with this layer. Plant growth was observed with subsurface irrigation systems placed 10 cm below the surface of the cultivated soil.

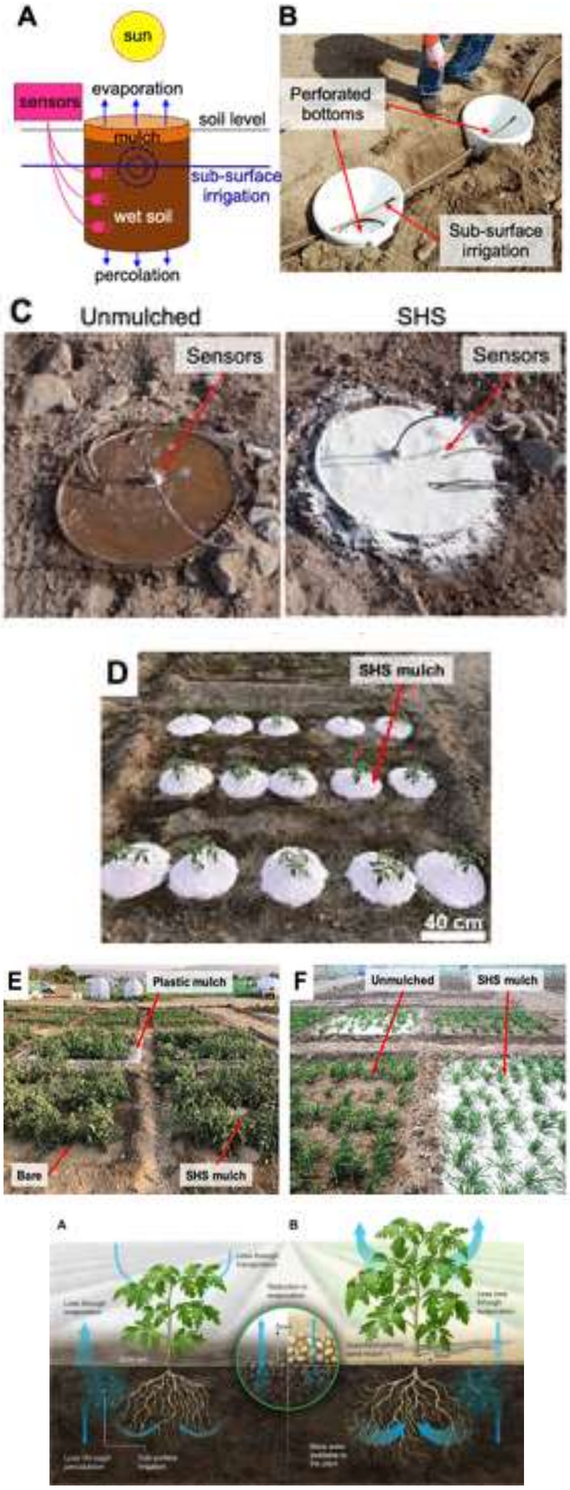

Figure 7: Stages of growing a plant with mulch, No mulch

4.Results and discussion:

Experimental results on plant growth, soil moisture, transpiration, evapotranspiration, evapotranspiration, leaching and plant productivity were observed with and without wax-coated sand mulching. The daily water loss through evaporation was estimated and the water content in the soil was measured using a special software and the data was analysed and averaged over time. The experiments showed the following results:

Applying a 5-10mm thick wax-coated sand surfacing layer resulted in:

-Root growth improved by 21% and larger woody vessels increased hydraulic conductivity by 23%.

-Improved plant growth as plant height significantly exceeded the maximum height and became larger and healthier than plants grown in unmulched soil.

-Reduced evaporation by 56-78% and increased moisture by 25-45%

-Increased crop yields by 17-73% using normal irrigation.

-Wax-coated sand shows great water retention capacity as a 2cm thick layer can maintain a water column height of 35cm.

-Wax-coated sand shows very high thermal stability when used for water storage.

-The wax melting test showed that during the summer the temperature can reach 70 degrees Celsius and more, which actually happened in the experiments. However, this did not affect the wax coating as the 20 nm thick wax films are bound to the silica granules by strong intermolecular bonds, which prevented melting, dripping or flowing.

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5. Conclusions and recommendations:

The study concluded with a set of conclusions, the most important of which can be summarised as follows:

-Wax-coated sand has great water resistance, which allows water to stay and flow on its surface without any moisture or leakage .

-The effectiveness of wax-coated sand in reducing the rate of evaporation, allowing the plant to benefit from irrigation water as required without the need to compensate for water loss, which in turn reduces the consumption of irrigation water and contributes to its rationalisation.

-The effectiveness of wax-coated sand in storing and transporting water in desert areas.

-The increased production achieved when using wax-coated sand confirms that the economics of its use is good.

-The paraffin used in the study is easily biodegradable and harmless to the environment, unlike plastic sheeting, and does not affect microbial communities in the soil, which encourages its use without fear of environmental issues .

As a result, the use of sand coated with a nanocoat of wax contributes to the rationalisation of irrigation water consumption in a sustainable manner in arid and semi-arid regions and can be proposed as a promising method in Syria to achieve food and water security.

As for the duration of the wax coated sand in the ground, there will be a need to change it with each plant at the time of planting seedlings, so it can be suggested to make the wax coating thicker or add materials to increase its lifespan in the ground.

In order to enrich this study to complete the research, it is recommended to complete the research with local field experiments in Syria that mimic those of Arab and foreign countries and verify its effectiveness in local conditions in Syria.

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6. References:

1. Alazawi, S. 2015, Hydrophobic Sand To Combat Water Scarcity – Properties And Possible Chemical Risk. Trita-Lwr. Master Thesis,Environmental Science And Engineering. Royal Institute Of Technology (Kth) . Stockholm, Sweden.
2. Atta. M.A; Abdulla.M.M.S , Al-Lohedan.H.A; Mohamed.N.H.2019,Coating Sand With New Hydrophobic And Superhydrophobic Silica/Paraffin Wax Nanocapsules For Desert Water Storage And Transportation. Coatings, 9(2), 124.
3. Bardet. J.P; Jesmani. M; Jabbari N; Lourences.D.N. 2014, Permeability And Compressibility Of Wax-Coated Sands. Geotechnique. Vol.64(9), 752-755.
4. Boretti. A; Rosa. L. 2019, Reassessing The Projections Of The World Water Development Report. Npj Clean Water, 2, Article No. 15.
5. Chen.L, Si. Y, Guo.Z, Liu.W.2017, Superhydrophobic Sand : A Hope For Desert Water Storage And Transportation Projects, Journal Of Materials Chemistry A 5(14).
6. Dao.M; Dell.B; Henry.J.D; Harper.J.R. Soil Water Repellency In Sandy Soils: A Review, 2024. In Book: Sandy Soils, 265-275.
7. Demo, A. H; Asefa Bogale, G.2024, Enhancing Crop Yield And Conserving Soil Moisture Through Mulching Practices In Dry Land Agriculture. Frontiers In Agronomy, 6, 1361697.
8. El-Saied, H.; El-Hady, O.A.; Basta, A.H.; El-Dewiny, C.Y.; Abo-Sedera, S.A.2016, Bio-Chemical Properties Of Sandy Calcareous Soil Treated With Rice Straw-Based Hydrogels. J. Saudi Soc. Agric. Sci. 15, 188–194
9. Gallo, A.; Odokonyero, K.; Mousa. M. A. A.; Reihmer, J.; Al-Mashharawi, S. ; Marasco, R.; Manalastas, E. ; Morton, M. J. L.; Daffonchio, D. ; Mccabe, M. F. ; Tester, M.; Mishra, H. 2022, Nature-Inspired Superhydrophobic Sand Mulches Increase Agricultural Productivity And Water-Use Efficiency In Arid Regions. Acs Agricultural Science & Technology. 2(2), 276-288.
10. Han, Y.; Hwang, G.; Kim, D.; Bradford, S.A.; Lee, B.; Eom, I.; Kim, P.J.; Choi, S.Q.; Kim, H. 2016,Transport, Retention, And Long-Term Release Behavior Of Zno Nanoparticle Aggregates In Saturated Quartz Sand: Role Of Solution Ph And Biofilm Coating. Water Res. 90, 247–257.
11. Jesmani. M; Bardet. J.P; Jabbari. N; Kamalzare. M. 2013, Hydraulic And Mechanical Properties Of Wax-Coated Sands. Journal Of Central South University.Vol.20(12), 3667-3675.

12. Koech, R.; Langat, P. 2018, Improving Irrigation Water Use Efficiency: A Review Of Advances, Challenges And Opportunities In The Australian Context. Water, 10, 1771.
13. Liao, R.; Wu, W.; Ren, S.; Yang, P. 2016, Effects Of Superabsorbent Polymers On The Hydraulic Parameters And Water Retention Properties Of Soil. Journal Of Nanomaterials, (1), 5403976.
14. Narjary. B.; Aggarwal. P.; Singh. A.; Chakraborty. D.; Singh. R. 2012, Water Availability In Different Soils In Relation To Hydrogel Application. Geoderma, 187, 94-101.
15.Nkurunziza, L.; Chirinda. N. ; Lana. M. ; Sommer. R.; Karanja. S. ; Rao. I. ; Romero Sanchez. M. A. ; Quintero. M. ; Kuyah. S.; Lewu. F.; Joel. A.; Nyamadzawo. G. ; Smucker. A. 2019,The Potential Benefits And Trade-Offs Of Using Sub-Surface Water Retention Technology On Coarse-Textured Soils: Impacts Of Water And Nutrient Saving On Maize Production And Soil Carbon Sequestration. Frontiers In Sustainable Food Systems, 3, 71. 10.3389/Fsufs.2019.00071.
16. Odokonyero, K; Gallo Jr, A; Dos Santos, V; Mishra, H. 2022, Effects Of Superhydrophobic Sand Mulching On Evapotranspiration And Phenotypic Responses In Tomato (Solanum Lycopersicum) Plants Under Normal And Reduced Irrigation. Plant-Environment Interactions, 3(2), 74-88.
17. Ovaskainen. L.; Olin. P.; Pettersson, T.; Wagberg. L.; Tuominen. M. 2017, The Effect Of Different Wear On Superhydrophobic Wax Coatings. Nordic Pulp Paper Res. J. 32, 195–203.
18. Polanowska. B.G, Garbowski. T., Michalczyk. D. B, Kowalczyk .A.2021, The Benefits Of Synthetic Or Natural Hydrogels Application In Agriculture: An Overview Article. Water And Land Development.21:208-221
19. Reihmer.W.2017, Synthesis Characterization, And Application Of Super Hydrophobic Sands In Desert Agriculture.Doctoral Dissertation, King Abdullah University Of Science And Technology.Thuwal, Kingdom Of Saudi Arabia.
20. Rodell. M.; Famiglientti. J. S.; Wiese, D. N.; Reager, J. T.; Beaudoing. H. K.; Landerer. F. W.; Lo, M. H. 2018, Emerging Trends In Global Freshwater Availability. Nature. 557, 651– 659.
21. Salameh.N.D. 2023, A Method Of Preparing Sand Treated With Wax For Impermeability Of Sandy Bases Of Sanitary Landfills.Patent N0. Us 7,160,379 B1, 4-6 .
22. Salem. M. A.; Al-Zayadneh. W.; Cheruth, A. J. 2010,Water Conservation And Management With Hydrophobic Encapsulation Of Sand. Water Resource Manage. 24,2237-2246.
23. Salem, M. A.; Al-Zayadneh. W.; Schulze. H. F.; Cheruth, A. J. 2014, Effect Of Nano-Hydrophobic Sand Layer On Bermudagrass (Cynodon Spp.) In Urban Landscaping. Urban Water J. 11, 167– 173.
24. Shah. F.; Wu. W. 2020, Use Of Plastic Mulch In Agriculture And Strategies To Mitigate The Associated Environmental Concerns. Advances In Agronomy, 164(164), 231–287.
25. Susnik. J.; Masia. S.; Teutschbein. C.2023, Water As A Key Enabler Of Nexus Systems (Water–Energy–Food). Cambridge Prisms: Water.; Vol.1:E1. Doi:10.1017/Wat.2023.1
26. World Water Assessment Programme (Nations Unites), The United Nations World Water Development Report 2018 (United Nations Educational, Scientific And Cultural Organization, New York, United States)
27. Zhang. P.; Wei, T.; Cai, T.; Ali, S.; Han. Q.; Ren. X.; Jia, Z.2017, Plastic-Film Mulching For Enhanced Water-Use Efficiency And Economic Returns From Maize Fields In Semiarid China. Front. Plant Sci. 8, 512 Doi: 10.3389/Fpls.2017.00512