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Optimizing Trocar Depth for Effective Land Reclamation in Karbala: Combating Waterlogging and Salinity

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Abstract. *This research explores the significance of field trocars in land reclamation within Karbala Governorate's Karta-10 area, caused by waterlogging and salinity. Implementing a detailed reclamation strategy, the study underscores the necessity of a 2 to 2.5 meters burial depth for trocars to prevent water and salt-related issues, aligning with industry standards. The investigation discourages reducing trocar depth to cut costs, as it can result in capillary action and salt build-up or require deeper drainage to manage seepage. Findings indicate that shallow trocars reduce water storage capacity, impacting irrigation and crop hydration, whereas deeper trocars offer better management of drainage flow and spacing efficiency. The study indorses a universal trocar depth of 2 to 2.5 meters, accommodating various crops, thus guiding optimal trocar design and placement for effective land reclamation.*

Keywords*: Field trocars; land reclamation; waterlogging; salinity; irrigation efficiency; drainage system; crop hydration*

Graphical abstract

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1. INTRODUCTION

In arid and semi-arid regions, land suffers from salt accumulation due to the absence of mechanisms to leach salts from the soil [1]. This salinity hampers plant growth and productivity, altering the soil physical, chemical, and hydraulic characteristics[2]. Implementing land reclamation strategies is crucial for addressing high soil salinity. A fundamental step in successful saline soil reclamation is establishing efficient drainage systems to remove salts and prepare the land for agricultural use. In the Governorate of Karbala, a dedicated team formulated a comprehensive plan to rehabilitate the saline lands. This initiative involved adopting advanced techniques and strategies to enhance soil quality and restore the land agricultural viability. In their attempt to address the pressing challenges of land reclamation, the work team in the Karbala Governorate encountered numerous obstacles in implementing their core principles and procedures aimed at combating soil salinity. Despite these hurdles, the team was committed to translating these principles into effective action on the ground.

One of the primary strategies involved the removal of salinity, which necessitated diverse approaches. A key method was washing the soil with fresh water, a technique proven to reduce soil salinity by up to 40%. Additionally, a thorough chemical analysis of the soil was essential, enabling the modification of its components to alleviate the adverse effects of salinity [3]. Effective water management was also critical. Saline lands demand robust drainage systems to manage the dual challenges of salinity and moisture [4]. Implementing surface and side drainage solutions helped evacuate excess water, maintaining optimal moisture levels for plant growth. Moreover, enhancing soil fertility was crucial, achieved by incorporating organic materials like compost and fine-tuning nutrient balances in the soil [5].

The team also explored biological solutions, employing vegetative techniques to bolster soil health. Selecting salt-resistant crops was another strategic choice, leveraging the natural resilience of certain plant species to thrive in saline conditions[6]. This approach ensured agricultural viability on reclaimed lands.

Managing salinity was an ongoing process, involving continuous monitoring of soil salinity levels, adjusting irrigation practices to meet crop-specific water needs, and minimizing the use of high-salinity water. By adhering to these meticulous practices, the team aimed to transform the saline lands of Karbala into productive agricultural landscapes, thereby overcoming the significant challenges posed by soil salinity.

2. METHODOLOGY

The work team engaged in the reclamation of saline lands in the Karbala Governorate faced significant challenges in applying their core work principles and procedures on the ground. Despite these obstacles, the team was determined to implement a series of strategic actions to address the issue of soil salinity effectively. A primary focus was the removal of salinity, which involved employing various methods. One effective approach was washing the soil with fresh water, a method proven to reduce soil salinity by up to 40%. Alongside this, the team conducted chemical analyses of the soil to identify and modify its components, thereby mitigating the negative impacts of salinity.

The team also recognized the critical need for efficient water drainage systems to manage the dual challenges of salinity and moisture in the soil. They implemented both surface and side drainage systems to remove excess water, ensuring that the plants received the appropriate amount of moisture for their growth [7]. Enhancing soil fertility was another key objective. The team achieved this by adding organic materials like compost to the soil and adjusting nutrient balances, which are essential steps in improving the soil health and its ability to support plant growth. Additionally, they employed vegetative techniques to further enhance soil quality and health [8].

The choice of crops was strategically aligned with the conditions of the saline land. The team selected for salinity-resistant crops and plants, which possess inherent mechanisms to cope with high salt levels in the soil, ensuring the sustainability of agricultural practices in these reclaimed areas [9]. Furthermore, the team placed a strong emphasis on salinity management. This involved regular monitoring of soil salinity levels, tailoring irrigation practices to meet the specific water requirements of the crops and minimizing the use of water with high salinity content. These carefully arranged measures were aimed at successfully reclaiming the saline lands of the Karbala Governorate, transforming them into productive agricultural areas and thus overcoming the salinity challenges that once plagued these lands.

2.1 Concept of trocar

The concept of a trocar is pivotal in agricultural practices, especially in managing excess water in soil environments where plant roots thrive [10]. Excessive water, whether above or below the ground surface, can significantly harm land quality and agricultural productivity. Understanding and implementing effective trocar systems are essential for preserving soil health and ensuring sustainable agricultural outputs. Trocar networks are generally categorized into two primary systems: vertical and horizontal drainage. Vertical drainage systems can be further divided into wells that require pumping and those that do not. Horizontal drainage, on the other hand, includes interception drains and regular drains, each designed for specific water management goals.

Covered trocars offer numerous advantages over open drainage systems. They allow for the full utilization of agricultural land since the area above the drainage system can be cultivated, saving an estimated 10-15% of land that would otherwise be lost with open drains [11]. Additionally, these systems reduce the need for extensive infrastructure like canals and crossings, prevent weed growth and the breeding of pests and pathogens, require less maintenance, and facilitate uninterrupted agricultural operations. The uniform drainage provided by covered trocars enhances soil water management, promoting efficient water infiltration [12].

In the context of Iraq, where water and agricultural resources are fundamental to life and economic development, the effective management of these resources is crucial. Water is a cornerstone for agricultural development, and its practical distribution is dynamic for the sustainability of the sector. Field pit projects in Iraq exemplify innovative efforts to improve water management and land reclamation, highlighting their importance in enhancing the nation agricultural landscape and overall economic progress.

2.2 Benefits of field trocars

Field trocars offer a multitude of benefits that significantly enhance agricultural practices and land utilization. One of the primary advantages is their ability to wash away salts from the soil, rendering previously barren and unproductive lands fertile and viable for cultivation. This desalination process enables farmers to invest in these reclaimed lands, diversifying their agricultural output by growing a variety of crops.

Moreover, field trocars contribute to water conservation. When used correctly, these systems prevent water wastage, allowing farmers to utilize every drop efficiently for irrigating various agricultural crops. This efficient use of water not only supports sustainable farming practices but also promotes the diversification of crops, enhancing agricultural productivity and biodiversity.

Economically, field trocars present a more viable option compared to traditional open pits. They require significantly less financial investment for maintenance and cleaning. For example, while the maintenance and disinfection of open pits can cost up to 4,000,000 dinars per kilometer annually, field trocars only necessitate around 500,000 dinars per kilometer every two to three years. This cost-effectiveness makes field trocars an attractive option for farmers looking to optimize their investment in land reclamation and agricultural operations.

Additionally, field trocars are designed to be space efficient. Unlike open pits, which consume considerable land area and render the land unusable for any other purpose, field trocars occupy minimal space. This efficiency allows for the maximization of available land for cultivation, further enhancing the economic and productive value of the land. Overall, the integration of field trocars into agricultural practices offers a sustainable, economical, and efficient solution for land reclamation and water management, fostering better outcomes for farmers and the agricultural sector.

2.3 Combined and field trocars project.

The "Combined and Field Trocars Project" addresses critical aspects of land management, specifically focusing on the concept of drainage, which is vital for optimizing land for various uses, be it agricultural or otherwise. Drainage involves the systematic removal of excess water from the soil, ensuring that the land is conducive to the activities intended for it. Waterlogging presents a significant challenge, manifesting when excess water accumulates either on the surface or below the earth's crust. Surface drainage comes into play when dealing with water that pools on the soil's surface, necessitating its removal to prevent potential damage to crops, infrastructure, and the soil's overall health. This process involves the careful design and implementation of channels and conduits to facilitate water flow away from the affected areas.

Conversely, issues arise when water collects beneath the surface, leading to elevated groundwater levels. Addressing this scenario requires a technique known as subterranean puncture or subsurface drainage, where pipes or other conduits are employed to lower the groundwater level, effectively mitigating the risks associated with waterlogging. The practice of puncturing, or creating drainage solutions, serves multiple purposes. Primarily, it aims to eliminate excess water within the root zone of plants, thereby enhancing soil structure and promoting better aeration. This improvement in the soil environment significantly benefits plant growth, as it ensures roots have access to the necessary oxygen, nutrients, and room for expansion. Ultimately, effective drainage contributes to the overall health of the ecosystem, supporting robust plant growth and sustainable land use[13].

2.4 Sustainability of soil productivity

Sustainability of soil productivity is a crucial aspect of modern agriculture, focusing on enhancing agricultural output while maintaining the health and viability of the soil[14]. A key component of this sustainability is the improvement of soil properties, particularly its physical characteristics, to support the cultivation of economically valuable crops. In regions like the Governorate of Karbala, characterized by its arid climate and sandy soil, innovative approaches are essential for sustainable agriculture. One such approach is the technique of puncturing, which offers several benefits crucial for maintaining soil productivity in these challenging conditions.

Penetrating helps in reducing the moisture content of the soil's surface layers by lowering the level of salty groundwater. This process is vital in arid regions where salt accumulation can be a significant problem, hindering crop growth. By washing away excess salts from the soil, particularly around plant roots, puncturing ensures that the soil remains conducive to agricultural use. Moreover, this technique plays a pivotal role in preventing the re-salination of the soil. It achieves this by maintaining a delicate balance between the salts introduced into the soil through irrigation and those removed via drainage, ensuring that the salt levels remain within a range that is not detrimental to crops.

In addition to these benefits, puncturing can be adapted for subterranean irrigation, providing a dual function that enhances soil moisture while controlling salinity. This innovative use of trocars not only addresses the immediate concerns of irrigation and drainage but also contributes to the long-term improvement of the soil's physical and chemical properties. Ultimately, the application of puncturing, particularly in areas with challenging soil conditions like Karbala, underscores the importance of tailored soil management practices in achieving sustainable agriculture. By enhancing soil properties and ensuring the balance of essential elements, such strategies pave the way for increased agricultural production and improved crop quality, essential for meeting the growing demands in these regions.

2.4 Types of trocars

Trocars, essential tools in the field of drainage, are categorized into various types to suit different environmental and agricultural needs. These include open trocars, covered trocars (which further divide into tube trocars and simple trocars), and vertical trocars, also known as puncture wells[15]. The open trocars are a traditional method involves creating deep, open channels to transport excess water. The technique that has been widely adopted globally due to its simplicity and effectiveness in certain contexts[16]. While field trocars aimed to design as parallel channels with a base width of around 30 cm, field trocars are engineered to remove excess water from smaller irrigation fields, effectively controlling the groundwater level. On the other hand, the combined trocars are known by specialized channels that gather water from field drains and channel it towards the main drainage systems [17]. They typically have a wider base, around 40 cm, to accommodate the increased volume of water.

While major trocars designed to serve a critical role, major trocars are the conduits that carry water away from the controlled area, often discharging into larger bodies of water like canals, rivers, or lakes[18]. Despite their utility, open trocars come with a set of disadvantages. They can lead to significant agricultural land loss, sometimes up to 15% of the area, due to the space the channels occupy. This loss is not just in terms of land area but also impacts the efficiency of agricultural machinery, hindering their operation across the fields. The open channels require regular maintenance and cleaning, adding to the cost and labor intensity of their upkeep. Moreover, the infrastructure necessary to cross these channels, such as bridges, adds additional complexity and expense. Environmentally, they can foster the growth of unwanted vegetation and become breeding grounds for pests, posing further challenges to both health and the economy.

2.5 Combined and field trocars project.

The Combined and Field Trocars Project in the Governorate of Karbala represents a significant and strategic initiative, marking a pioneering step in Iraq's agricultural and water management practices. For the first time in the nation, this project utilizes the covered trocar system, showcasing a modern approach to traditional agricultural challenges. Central to this initiative is the use of advanced leveling and adjustment techniques, employing laser-guided mechanisms to ensure precision and efficiency. This technological advancement addresses and rectifies many issues that were previously attributed to human error, thereby enhancing the overall effectiveness of the project.

The implementation of covered bundled trocars is a key feature of this initiative. These trocars are constructed using unplasticized polyvinyl chloride (uPVC) pipes, which are chosen for their durability and suitability for the task. The pipes have a diameter of 400 mm, can withstand a pressure of 6 bars, and each has a length of approximately 1500 meters. These dimensions are meticulously planned to cater to the specific requirements of the project. In terms of layout, each complex house is strategically placed with around 500 meters from one another, adhering to designs prepared by the Center for Studies and Designs of the Ministry of Water Resources. A total of 40 field houses feed into each complex house, connecting through an intricate network that includes circular concrete manholes, each 1 meter in diameter and 4 meters in height.

Additionally, covered field shunts are constructed using filtered plastic tubes with a 100 mm diameter, demonstrating a commitment to utilizing robust materials for long-term sustainability. The depth of these field houses varies between 1.8 m and 2.2 m, with an average length of 250 meters, ensuring comprehensive coverage and functionality across the irrigation fields. This project not only represents a technological leap in the region's agricultural practices but also serves as a model for sustainable water and land management in arid environments, underscoring the Governorate of Karbala's commitment to innovation and efficiency in its developmental initiatives.

2.6 Preventive maintenance

Preventive maintenance is crucial for ensuring the longevity and efficiency of drainage systems. When it comes to trocars, tube trocars stand out for their lower maintenance requirements compared to open trocars. For systems where the outlets discharge into an open drainage channel, it is essential to keep the channel clear of weeds, plants, and trees. Additionally, the outlet pipes should be equipped with a gate that permits only water to pass through, preventing rodents or other animals from entering the puncture tube. Cleaning the puncture tubes is an integral part of their maintenance to avoid blockages that can impair their functionality. Over time, these tubes can become filled with sediment or obstructed by plant roots. To address this, there are two main cleaning methods:

1. The use of a flushing machine, which involves pumping water at high pressure through a plastic pipe inserted into the puncture line from the outlet. Attached to the head of this plastic pipe is a jet nozzle designed to thoroughly wash the pipeline, effectively removing any obstructions or buildup.
2. The application of a washing column technique, where water is introduced into the house from the beginning of the system through a working column. This process allows the water to push the sediment toward the outlet, facilitating its removal and ensuring the tube remains clear for optimal operation.

3. Field trocars project

The field pits project in the Governorate of Karbala represents a significant and innovative venture, marking the first use of a system of covered pits in Iraq. This system, comprising underground trocars, includes field houses, group punctures, and main punctures, all concealed beneath the earth surface. Such a system is particularly beneficial in areas like Karbala, known for its arid conditions and sandy soil.

The adoption of this underground puncturing system brings multiple advantages. It helps reduce the moisture content in the soil surface layers by lowering the groundwater level, which is often high in salinity. This reduction in groundwater level curtails the accumulation of harmful salts in the vicinity of plant roots, prevents soil re-salination, and maintains a balanced salt concentration. This equilibrium is crucial for preventing damage to agricultural crops, achieved by managing the salts introduced through irrigation and those removed via drainage. Additionally, these trocars can serve as a means for subterranean irrigation, further enhancing their utility.

The advantages of this covered puncture system are manifold. Firstly, it eliminates the loss of agricultural land, allowing for cultivation directly above the system and saving 10-15% of land that would otherwise be unusable with open sewers. It obviates the need for extensive surface infrastructure like canals and crossings. Furthermore, by being underground, it reduces the opportunities for weed growth and the breeding of pests and pathogens. Covered trocars are also less maintenance-intensive compared to their open counterparts. They enable uninterrupted agricultural operations and promote more uniform land drainage, facilitating water entry and enhancing overall soil management efficiency.

3.1 Depth of burial of field trocars.

The proposal to reduce the depth of burial of field trocars focuses on a detailed examination of the design principles of field pits, emphasizing the correlation between the depth of these pits and the underground water layer. The primary objective was to position the water table below the root level of crops to enhance plant growth and productivity. The depth of the trocars varies depending on the crop type, with specific consideration given to soil aeration and the necessity to mitigate high salt concentrations. Figures 1-5 showed the depths were determined based on standard guidelines for the minimum permissible depths for various crops:

- Vegetables require a depth of 0.6 meters.
- Field crops need a depth of 1.0 meter.
- Legumes should have a depth of 1.2 meters.
- Orchards necessitate a depth of 1.4 meters.

For general design purposes, a standardized depth of 1.2 meters is recommended for a range of crops, including orchards.

Furthermore, in the context of Iraq's arid and semi-arid regions, managing the underground water table's level is crucial for controlling soil salinization and preventing capillary rise during the summer fallow. The water table should be maintained below a critical depth, which is typically set at 1.8 meters for the fine soil characteristic of Iraq. However, if there is significant water runoff during the fallow period, a deeper trocar depth between 2 to 2.2 meters may be necessary to facilitate a greater slope and ensure effective drainage.

The design principles of field pits have been extensively studied, highlighting their crucial role in agricultural productivity. The effectiveness of field pits is intrinsically linked to the depth of the underground water layer and the pits themselves. Proper management of the water table depth (WT.) is essential for promoting plant growth and enhancing productivity. It is critical that the WT. level is situated below the root zone of crops to ensure optimal growth conditions.

The requisite depth of these pits varies according to the type of crop being cultivated, as different crops have varying root depths and soil aeration needs. Additionally, the strategy for setting the depths is tailored to address the issue of salt accumulation in the soil, which can be detrimental to plant health.

In the specific context of Iraq's arid and semi-arid regions, managing the underground water table is crucial to prevent soil salinization and capillary rise during the dry, fallow periods [19]. The critical depth for the water table, especially in fine soils typical of Iraq, is usually set at 1.8 meters. However, if there's a significant risk of percolation runoff during the summer fallow, it may necessitate deeper field pits, ranging from 2 to 2.2 meters, to provide an adequate gradient for effective water drainage. This overview approach to pit depth is vital for maintaining soil health and ensuring sustainable agricultural practices [19].

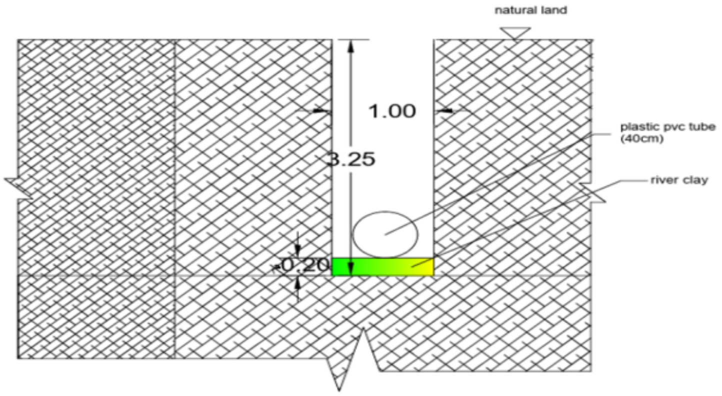
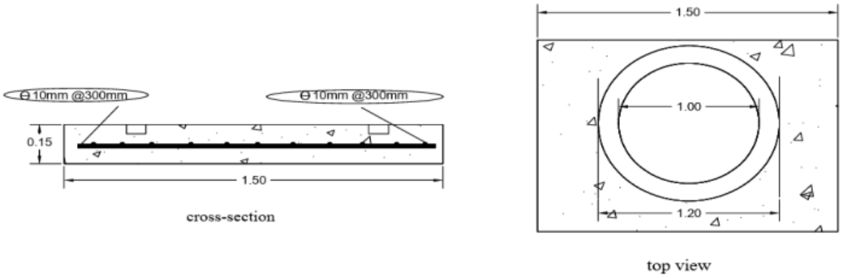


Figure 1. Cross section of the collecting trocar.



cross-section

top view

Figure 2. Reinforced concrete base for the manhole.

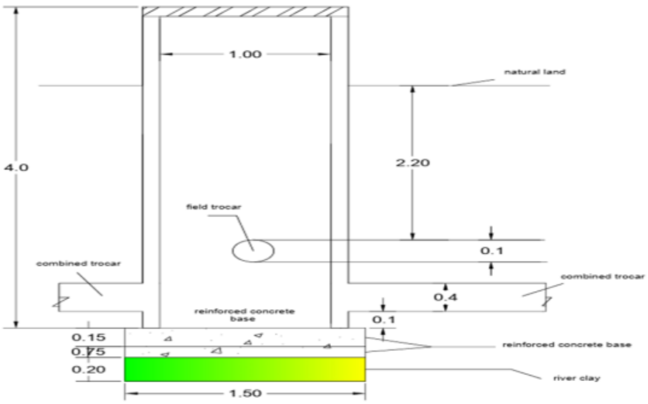


Figure 3. A diagram of the connecting manholes between the field trocar and the combined trocar.

Figure 4. Early Stages of Construction and Earthwork: Excavation and Smoothing

Figure 5. The trocar after completing the work of opening and casting.

3.2 Homogeneous soil:

Trocar depth is a critical factor in the design and efficiency of drainage systems, particularly when considering the type of soil. In homogeneous soils, the depth of drains plays a significant role in determining the water storage capacity of the soil located between the surface and the level of the field drains. Deep drains are advantageous as they allow for a larger volume of water to be stored, which can be particularly beneficial during periods of uneven water flow. Shallow drains, on the other hand, might not always match the permeation rate with the filtration rate, potentially leading to less efficient water storage and drainage [20].

Deep drains are designed to moderate fluctuations in water flow, resulting in a lower peak flow rate. This is especially useful in maintaining a consistent water level and ensuring that the soil's water storage capacity is utilized effectively. Moreover, with increased drainage rates, it's possible to space the field trocars further apart, which can contribute to a more efficient and cost-effective drainage system.

However, the depth of the trocars also influences the cost of the drainage system. While deeper drains offer numerous benefits, the construction costs rise with the increase in depth. There exists an "ideal economic depth" for installing field pits, typically between 2 to 2.5 meters. Within this depth range, the benefits of deeper drainage are balanced against the cost, providing an effective solution for controlling secondary salinization while ensuring the system is economically viable [21]. Achieving this balance is crucial for developing a sustainable and efficient agricultural drainage system.

3.3 Stratified soils:

In the Mesopotamian plain of Iraq, the earth stratification comprises silty layers and sedimentary basins, which significantly influence agricultural practices, particularly drainage[21]. This stratification typically consists of thin sandy soil layers, succeeded by thicker bands of clayey silt, and then silty clay. The thickness of these layers varies across different locations, leading to distinct variations in soil properties. A notable characteristic in these stratified soils is that horizontal permeability tends to be substantially higher than vertical permeability[22]. This disparity plays a crucial role in determining the interstitial distance for drainage, underscoring the importance of specialized knowledge in the field of drainage design and implementation [23].

When considering the depth of trocars in such stratified soils, it is essential to account for the hydraulic head. The hydraulic head evaluation is pivotal in defining the optimal depth for field trocars. Experimental findings suggest that the maximum discharge value decreases as the trocar depth increases. The relationship between the hydraulic head (h) and the discharge (q) relative to the trocar depth appears to be linear as shows in Table 1. In designing a drainage system, the hydraulic head used in the steady-state equation should be aligned with a pipe depth that is below the lowest water table level (WT.). Adjustments to this parameter should be made based on the crop type and the specific depth requirements, which are typically delineated in detail for various agricultural scenarios as example shown in Figure 6.

Table 1. Comparative Water Management Needs Across Crop Types

Crop	Average Drain depth, m		
	2.0	2.2	2.5
	Hydraulic head, m		
Vegetables	1.4	1.5	1.7
Field crops	1.0	1.1	1.25
Orchards	0.6	0.7	0.85
Mixed cropping	0.8	0.9	1.05
Alfalfa	0.8	0.9	1.05

Note: Mixed cropping is excluding orchards

Figure 6. Transformation the poor and unused land to productive agricultural fields

4. CONCLUSIONS

In summary, it has been established that the minimum advisable depth for installing field trocars should be 2 meters under standard conditions, with potential reductions only considered in urgent scenarios. The optimal economic depth for these installations' ranges from 2 to 2.5 meters, a standard that is widely recognized and adopted in current field trocar design practices. Attempting to decrease the depth solely for cost-cutting purposes is strongly discouraged due to the potential for significant adverse effects, including:

- Enhanced capillary rise of water during the summer, which can lead to salt accumulation in the root zone or cause substantial seepage flow, necessitating a greater depth for effective summer drainage.
- A reduction in the water storage capacity within the soil layer above the drains, compromising the available water reserve for crops between irrigation intervals.
- Shallow trocars may fail to stabilize water flow fluctuations and enhance drainage efficiency, unlike deeper installations, which facilitate lower peak drainage rates and allow for wider spacing between field trocars.

These considerations underscore the importance of a nuanced approach to trocar installation, necessitating expert analysis, especially given the complex stratification of soil layers and the pronounced difference between vertical and horizontal permeability. Additionally, the interaction between the hydraulic head and the crop's root zone depth indicates that a uniform trocar burial depth of 2 to 2.5 meters is advisable across various crop types to ensure effective drainage and optimal soil conditions.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18