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SOIL CRACKS, Causes, Significance and their effects on agricultural production: A Review

Yousif Hasan Al-Naser[1] **Khalid Anwer Khalid[2]**
[1,2] College of Agriculture and Forestry, University of Mosul/ Iraq
ORCID : https://orcid.org/0000-0001-8506-8693

*Correspondence to: Yousif Hasan Al-Naser, Email: alnaseryousif10@uomosul.edu.iq

Abstract
Soil cracking is a common physical property in Vertisols containing a high percentage of expansive clays of type 2:1, this phenomenon is accompanied by some morphological features such as Gilgai and silken sides as a result of the expansion and contraction that occurs to the soil after periods of wetting and drying. These soils are called inverted soils due to the occurrence of self-mixing because of rising apart of the soil to the top after the soil expansion phenomenon occurs. Some of these expansive clays have a high ability to hold water, as water films are generated on the internal and external surfaces of the layers of minerals that compose them, giving these soils a high property of expansion and plasticity. Under conditions of drought and high temperatures, water is lost from between the layers of clay minerals, which leads to shrinking the soil and causing it to crack. The cracks width and depth are proportional to quantity and type of the prevailing mineral, organic matter, calcium carbonate and other binding materials, Cracks can be reduced by improving soil structure and aggregates through the addition of soil amendments such as agricultural gypsum, organic matter, animal waste, and previous crop residues. Cracks can also be reduced using agricultural practices such as reduced tillage, water management, and modern irrigation methods, however, the study of cracks, directions and their impact on different land uses has not been well-documented or studied with regards to water and nutrients movement, and its transfer through these cracks. Therefore, this review aims to collect the literature and studies related to the subject of soil cracks, their causes, consequences and the mechanics of their formation in addition to the methods followed and appropriate in their management.
Keywords: Expansion, Morphological Features, Shrinkage, Soil Cracks, Vertisols

1. Introduction

Soil cracking is a characteristic feature of Vertisols soils, which are clayey soils that expand with moisture and contract during dry periods, forming cracks of varying depth and width depending on the type and quantity of expansive clays, especially thick clays (68). This shrinkage and swelling makes managing these soils difficult (78). Vertisols are sometimes called black soils (82), The colors of these soils range from gray or red to dark black based on the kind of parent material and the surrounding environment (59 and 17). The most common are "Black Earths" in Australia (74), "Black Gumbo" in east Texas, "Black Cotton" in east of Africa, and "turf soil" or "vlei soils" in the south of Africa. The primary regions with a high concentration of Vertisols are east of Australia, the Deccan Plateau in India, Most of Southern Africa, South America, most of south of America and eastern China, in addition to small and scattered areas of many countries in the world (77 and 38), including Iraq (6). Cracks affect the development and properties of soil to the point that it enters the highest level of soil classification, as it is considered an order within the USDA soil classification (36). Vertisols are naturally covered with grasslands, savannas, or grassy woodlands (4), and the heavy clay texture contains more than 35% clay, and the unstable behavior due to the turning and self-mixing of the materials of these soils makes it difficult for many species of trees and forests to grow in them (9). Vertisols are rich in Smectite and Montmorillonite clay minerals, which have shrinkage and expansion property (84). When these soils dry, they form deep and wide cracks from the surface to the bottom, ranging from 15-200 cm (11 and 88). Different morphometric composition is very common in such soils with expansive minerals and the high swelling and shrinkage potential of soils containing these expansive minerals leads to the formation of wide and deep cracks, where the cracks are closed after rainfall or irrigation (87 and 7), when these soils get wet, the clay minerals expanded and create high pressure inside the soil body, this internal pressure results in distinct aggregates in the surface soil and flat soil masses in the subsoil (84).

Vertisols are capable of rapid expansion and naturally shrink throughout the drying without allowing air to enter; on the other hand, many non-Vertisols also display expansive soil behavior (82 and 5). For example, the sodic alluvial soils of the Pampas region of Argentina exhibit similar behavior to Vertisols in terms of expansion but differ in that they expand as a result of air entrained in the soil after flooding (84 and 60). Volume changes occur upon drying or rewetting in all soils with high organic matter and/or clay content. In fact, crack development observed in fine sandy soils at larger volumes than in clay soils (57, 48 and 88).

[80] stated that most studies focused on the soil phenomenon of expansion and shrinkage and its effect on the development of cracks, as well as, its effect on the process of infiltration, while there are few studies focused on the morphology and distribution of these cracks (47). The process of cracking in the soils are complex that has many causes and affected by internal and external factors, that is difficult to study or trace its effects due to the occurrence of some phenomena, resulting from the expansion or shrinkage of soils (41), causing distinctive morphological features of Vertisols, including the development of micro-topography on the soil surface such as Gilgai, silken sides (43 and 40). The depth and width of soil cracks associated with the kind and quantity of clay minerals (16), the quantity and pattern of rainfall, as well as the kind and density of vegetation cover that associated with frequently of drought (39 and 37). In addition, the state of soil moisture, temperature, wet/dry cycles, and pressure of the air affect the state and position of cracks (18). Moreover, the characteristics of Vertisols cracks may vary depending on the properties of the soil itself, the local climate, topography (13), crop patterns, cultivated plants (14), and soil management practices (69).

[47]explained that when temperatures rise and there is no availability of irrigation water or rain, clay soils begin to dry out and lose water from between the layers of minerals that make them up (79). Causing the soil to shrink by an amount greater than or equal to the volume of water lost (49 and 84). The volume of the decrease recorded at 49% in some clay soils in the Netherlands. [95] also indicated that when the soil dries, great physical stresses are imposed on the soil aggregates, causing a continuous shrinkage in the volume of the soil to the extent of a tension of 15 bars. [51] stated that soil cracking occurs due to the soil being exposed to drought following heavy rain or irrigation.

[91] showed that the soil clod boundaries ridges are weak and easily separated from each other when the soil dries and shrinks, as soil cracks follow the boundaries of these ridges, and new cracks can form between natural ridges when drought increases (62). During long dry seasons, dry plant debris, harvest residues and dust fall into the wide cracks beneath the ground, where these cracks fill up .When rain falls and the soil expands and swells, this puts pressure on the materials in the cracks and on the sides of the cracks, eventually lifting the soil upwards, causing a surface morphological terrain called “Gilgai” (21). The process of expansion and upward movement of soil ridges causes friction between the faces of the ridges with neighboring ridges (24), causing these faces to be polished, which are called "Slickensides", the incorporation of soil particles at roughly the crack's depth, frequently preventing the development of a B-horizon (2).

Cracks develop in heavy clay soils that contain significant amounts of expansive minerals during the dry season, these silicate minerals are in the form of thin sheets that stack on top of each other, and when the soil moistened, water makes its way between these plates and causes them to expand (63), when the soil dries, the silicate plates collapse on each other and cause the soil to shrink, because the bonds holding the silicate molecules together are not strong enough to maintain this expanding structure. When the soil moistened again, the same process is repeated; causing the soil structure to expand and the cracks to close (55). [61] reported an inverse relationship between the density of clay cracks and their depth, as the density of cracks decreases with increasing depth of these cracks. [8] showed that physical changes such as (expansion, shrinkage, cracking and crack closure) in expansive clay soils that occur during and after a rainstorm have a significant impact on the movement of surface water or its penetration into the soil body (42).

2. Impact of cracks and fissures on soil management and uses

[26] indicated that soil cracks provide free paths for the movement of water, salts and nutrients away from the root spread area. Soil cracks have an impact on the physical characteristics of the soil (56), as well as the flow of air and water through the soil and their movement to the subsurface soil and groundwater, these eventually affected the soil's hydrological (24 and 66). The depth, width and density of cracks also play an important role in the rapid loss of moisture in cracked soil, and the physical movement of cracking may tear plant roots and expose small growing roots, which reduces the plant's ability to absorb water and nutrients (73). Additionally, deeper and wider cracks sometimes limit the efficient use of available resources for crop production and thus these soils need sustainable management (71).

[44] stated that soil cracking increases the low effect of temperature on plant roots, leading to an increase in symptoms of phosphorus deficiency because phosphorus called an energy element, and the plant consumes it quickly to confront the stress it is exposed to under these conditions (78).

Soil cracks have both beneficial and negative impacts on the use and management of Vertisols. As cracks develop, the area of open surface exposed to the atmosphere increases, and the amount of vapor from crack edges could match or surpass that of the surface soil (67 and 94). This leads to rapid drying of the soil, as the crack network develops, fine roots adjacent to the cracks are cut off, which leads to additional stress on the growing crop to absorb water and nutrients (67). In flat lands, the soil may suffer from a lack of ventilation due to water saturation and poor drainage. In field practices for managing cracking in Vertisols soils, farmers are concerned with keeping the soil from drying out excessively and reducing the temperature of wetness during the thaw process (44). The development and occurrence of cracks able to display good control in irrigated soils, but in rainy conditions, it becomes more difficult in the early stages of plant growth. However, as plant growth increases (58), the growing plants form a surface cover that reduces the occurrence of cracking (32). Leaving residues on the surface after harvest reduces surface evaporation; this prevents soil from drying out quickly and cracking (20). In natural pasturelands, overgrazing should be avoided because it leads to soil drying and thus cracking (13).

Cattle and sheep that graze on Vertisols may get damages if their hooves or feet fall into cracks that have developed during dry spells, and ungulates do not like to move on these soils when they are flooded (21). In addition to the negative effects of these soils from an agricultural perspective (27), the shrinkage and swelling of Vertisols can cause many problems for roads, buildings and structures built on them (98).

The benefits of the crack network represented in storing water efficiently at the beginning of rainfall because it provides rapid entry of water, especially in areas with scarce rainfall (33). In the Caribbean, sugarcane roots have been found to grow and concentrate where soil, air, and water interactions are good near the walls of former cracks. (25). Additionally, (91) observed that in Syria, roots of wheat grow more readily on the walls of internal cracks than on sandy soil. Cracks can be sign as a sign of the soil's rejuvenation, especially in compacted soils (21). These soils have poor permeability when filled with water, making them suitable for growing rice (55), but it is difficult to adopt rain-fed agriculture in these soils as they are extremely sticky when wet and extremely rigid when dry. However, these soils are interested in Australia because they do not suffer from a phosphorus shortage (20).

3. Factors affecting soil cracks

3.1. Effect of moisture content and dominant clay mineral

The process of drying out clay soils is closely associated with the formation of cracks because the soil loses water continuously and becomes dry during this time (52). Many factors, including decreased water phases, high temperatures, dry periods, a decline in vegetation cover, or the absence of plant remains on the soil surface, might cause this process (58).

The creation of soil crack patterns can also be greatly influenced by a variety of soil characteristics, including clay mineral composition, amount of clay present (3), bulk density, organic carbon, cation exchange capacity (CEC) (51), thickness and size of soil layers, boundary conditions and cycles of wetting\drying, etc. (68). The main factor influencing a soil's ability to separate after drying is its texture; the more colloid the soil contains, the more uniform its texture is, and the more likely it is to crack after drying. Simultaneously, a larger colloid content causes the soil to expand more while wet and to dry out more as it dries (65). Similar behaviors and effects on the creation and growth of cracks are seen by adsorption monovalent cations, particularly sodium (51). Shrinkage cracks are more prevalent and develop during drying in soils containing high Montmorilloniteic clay compared to Illite (4). Initial areas of weakness in the soil mass are wherever cracks appear, which decreases the soil's overall mechanical durability and increases the compressibility of the aggregates and the bulk of the soil (4). The shape of the cracks and their networks mostly determines the hydraulic characteristics of clay soils, as the size of the cracks (length, width and depth) (68). Water and dissolved materials move through the soil profile at different rates and speeds depending on the degree of crack twisting, and the arrangement and connectivity of cracks control the flow pathways, which in effect control the materials' diffusion within the soil body (86). Cracks can affect the water capacity (HC) of soil and the infiltration rate of rainwater or irrigating water in the soil body, increasing soil holding capacity will reduce the soil's shearing strength (44) (Fig. 1).

Fig. (1) Cracks in Vertisols 2 cm wide and 40 cm deep

[44] investigated the impact of soil type and soil moisture on cracking using laboratory tests, they combined Kaolin and Montmorillonite in varying amounts to create four soil samples, which they then repeatedly wet and dried. Their findings showed that when the moisture content reduces from 44.1% to 43.4%, cracking forms more slowly (65), and when it drops from 43.4% to 33.3%, cracks form more quickly. At this point, the cracks' opening width could grow from 2.7 to 6.1 mm. Based on these results, three stages are distinguished in their classification of the crack formation process: the first, precursor, and stable state periods. The first stage of slow cracking is caused by a reduction in the water content of the exposed soil surface alone (85). When evaporation occurs from the soil sample's surface as well as the crack perimeter (predecessor stage), the crack becomes more severe and noticeable, the development of cracks is sluggish and tends to attain a steady state when the soil sample's moisture content and the surrounding conditions are balanced (64).

3.2. Effects of Cropping and Paddling

According to (97), among the most important factors controlling cracking of Vertisols soils in rice fields are pond formation, agricultural practices, and water management. Since these practices are useful for sustainable management in such fields (58), they also have direct practical ramifications and solutions, they also observed in their research that, (1) Evaporation from rice grown in rows causes parallel (29), straight cracks to emerge throughout the rows at the middle of the row spacing, (2) As the space between the rice rows gets bigger, the cracks width increases, and (3) The development of straight cracks along the rows is facilitated by the frequency of ponding (fig. 2).

[6] reported that excessive moisture and high compaction on the soil surface produce larger, deeper cracks, and the breadth and depth of the cracks in these soils can be decreased by managing the soil by adding organic matter and gypsum at a rate of 10 Mg ha^{-1}. Studies by (72 and 15) indicated that cracks develop in the elevated areas between crop rows, and attributed this to the fact that cracks occur at the junction of points of lower resistance with areas of

higher moisture content. [12] conducted an analysis on the impact of crop spacing on crack patterns and observed that when the space between crop rows increases, the cracks become bigger, [91] ascribed the formation of cracks among rows of crops to the soil consolidation caused by crop roots.

In a lab experiment, (97) observed that bidirectional water circulation between crop rows increases the formation of inter-row cracks, and they supported their results with numerical simulations of effective moisture tensile stress. Their results showed that cracks occurred in the middle of the inter-row spaces due to water absorption by the plants, and they reported that the pattern of cracks varied depending on the time of field drying because the rate of transpiration varies with the stage of crop growth (10). Based on a study by (56), when soil is mechanically formed, cracks are wider under foot or wheel pressure.

Fig. (2) cracks in the rice field

3.3. Effects of Management and Tillage Practices

Soil cracks play an important role in agricultural farming systems because they allow water to resupply in insufficiently porous soils shortly after rainfall (76, 90 and , 93), and water loss from the crack by evaporation increases Along the front edge of the crack (74 and 95). As the crack width and length increase, Heat, solutes, air, and water in the soil all rise (Novak, et al., 2000), thus improving the yield of crops (28), and the potential in light of groundwater contamination (13, 10 and 45). Agricultural gypsum reduces soil cracks by binding clay particles together, thus improving soil structure. This increases water permeability, enhances aeration, and breaks down dense soil structures (92 and 7). Field operations, tillage, and the application of organic residue can all alter the patterns of soil cracks. According to a field experiment carried out in India, lantana (Lantana spp.) continuously applied to farmland within a wheat-rice cultivation cycle decreased surface area and crack density by 19%–37% and 36%–76%, respectively (14). The type of plants cultivated additionally impacts the formation of cracks since roots of plants play a major role in compaction of the soil and retention of humidity., thus affecting soil shrinkage (21, 37 and 61).

Soil tillage affects the physical properties of soils close to cracks. As an example, excessive tillage reduces exchangeable calcium, CEC (13), and calcium carbonate equivalent (48), increases organic carbon (SOC) (21), and has a higher plasticity limit in the vicinity of roots than in the rest of the soil body away from cracks (44). There are often differences in soil properties between the soils adjacent to cracks and the rest of the soil body in intensively tilled soils, but there are no differences between them in pasture and low-tillage soils, due to the presence of stable biopores in pasture and low-tillage soils (45). Additionally, cracks can enhance soil structure and make drainage and water infiltration easier (48 and 62), root distribution (64, 79 and 83), soil OM, and nutrients in the soil profile (27, 18, 8 and 88).

Sustainable soil management is applied to improve soil quality in Vertisols by planting crop varieties that increase and increase dryness and cracking of soil, like wheat (Triticum aestivum L.) (73), like Safflower (Carthamus tinctorius L.) subsequent to irrigated cotton (Gossypium hirsutum L.) (49 and 64). Additionally, soil cracking makes it easier for nutrients (67), insecticides (68), and herbicides to enter the soil (64 and 70). Because of their critical role in management processes (30), the physical and chemical properties of soils associated with cracks differ significantly from those of soils far from cracks within the soil body (72 and 18).

4. Significance of Cracks for Water Movement and Distribution within the soil

Water penetration into Vertisols soils and its redistribution after rainfall or irrigation is influenced by the distribution, width and depth of cracks (13, 10, 9). Naturally, water can reach a depth of nearly 50 centimeters through the soil's surface, and water can only reach deeper layers through cracks in the soil, where moisture is distributed along the sides of the cracks (7). Excessive moisture depletion in these areas leads to accelerated and extended cracking, more moisture loss through evaporation and plant absorption, and thus drier and harder surfaces around the crack area (53). Maximum root presence is observed next to cracked surfaces (4), due to the possibility of low bulk density and higher moisture content in nearby areas of cracks, which encourages root penetration.

Vertisols exhibit variation in the frequency and distribution of cracks and interpenetrating pores (96). Crop productivity is impacted by the quick evaporation of soil crack moisture from the surface during the post-rainy season, this process is important in scheduling irrigation because the presence of cracks increases the crops' requirements for irrigation during the initial irrigation scheduling (89 and 95). According to (88), more than 12% of the water required by rain-fed crops produced in Vertisols evaporates during the winter from non-irrigated agricultural soils. [1] reported that the reason for the differences in the pattern and distribution of cracks is caused by the moisture content, clay content, and clay mineral quality of the soil. Soil cracks help the movement of water, dissolved materials and gases preferentially into the soil body, and water is lost through evaporation (30). Water use efficiency is decreased by the cracks because they increase the surface area exposed to the atmosphere, which increases water losses through evaporation and preferred flow. In the Sudanese Gezira region, rainfall that accumulates up in the soil substrate during the soaking process permits the rapid movement of significant quantities of water into deeper layers before cracks seal (99). According to some studies, this procedure known as "bypass flow" or "short circuiting" (20), negatively affects crop production. Along with the possible loss of nutrients, this process also leaves the soil bed irregularly wet around cracks, the soil matrix unsaturated, and moisture unable to penetrate below the crop root zone (15), as well as water loss from deep, wide cracks that evaporated more readily, decreasing the crops availability of water (11 and 18).

In a study on Vertisols soils in northern Iran, (50) found that there was an 60% reduction in water use efficiency (WUE) when the crack width grew from 3 to 25 mm. [35 and 46] found that in broken soils, preferred flow is the primary factor causing water loss, low water usage efficiency, and problems with crop productivity and seedling emergence and growth. (100).

According to (19), there are differences in the dynamics of preferential flow under conventional and nonconventional agricultural management techniques, as well as a relationship between preferential flow and the soil matrix close to the cracks. [59] observed that in dry soils, where cracks are filled upon irrigation, preferential flow is reduced, thus being one option to reduce water requirements in later stages. In a weighing lysimeter under cracked soil, [78] assessed the effects of macropores/preferential flow and crack dynamics, they found that, despite surface runoff under the cracks, there was no drainage in the soil column during the first three of the six irrigation operations. Additionally, they noticed that soil cracks remained open in the subsurface layers for preferential flow despite their closure at the soil surface. In the case of flood irrigation, cracks recur in the same previous locations, while their locations change in the case of rainfall, which is what (2) and (7) found.

5. Cracks Measurement

Limited information is available on the measurements of cracks (length, width and vertical depth) in situ or in the field. There are several methods for measuring crack area and extent. [79 and 84] measured the coefficient of overall variation in Rajasthani Vertisols through investigating the dimensions of cracks and their horizontal extensions, [93 and 81] also created a quantitative index system based on the idea of crack geometry and network analysis, these indices are useful for evaluating the intricate details of the network structure of soil cracks. There are five classifications for the values of the morphological indices of cracks: fragile, tiny, mild, extreme, and very intense. In order to investigate the cracking phenomenon, [74] established the crack intensity factor, which serves as a description of the degree of surface cracking. They also proposed an image processing technique. Comprehensive techniques for crack characterization based on resistance, ultrasound, computing technology, flow of fluids, an ultrasound, theoretical calculations, and optical image analysis were also categorized by (74). [90] employed the principles of stereo photo science to derive three-dimensional crack pattern properties from two-dimensional measurements.

One method for measuring crack size is by the amount of sand needed to fill the crack (12). In order to determine the overall expansion coefficient and surface area using crack parameters like width, length and depth, [23] devised equations that assume a triangle shape:

(1) Total volume of cracks $V= \sum 0.5 wdl$

(2) Total area of the crack surface $SA = \sum 2cl$

Where d= refers for the average depth of a crack. (m), l= average crack length (m), and c= coefficient of dependence on w and d, which estimated as follows:

(3) c= 0.5 w2 + d21/2

6. Management of Heavy Cracking Clays

Tillage and cultivation systems, nutrient management and soil water management are particularly relevant in heavy, cracked clay soils (Vertisols) found in arid tropical and subtropical regions (31). Soil water management is closely related to soil management, especially in these regions, poor internal drainage and slow hydraulic conductivity lead to waterlogging of the soil (67). Due to the specific characteristics of these soils, tillage operations are carried out within a narrow range of moisture in soil. When the soil is wet, it becomes sticky, and the plow sticks to it during plowing (54), when dry, it forms large, clumps, hard and difficult to till (45). Despite the availability of nutrients in these soils, they sometimes suffer from fertility problems due to the low availability of phosphorus and micronutrients under sustainable high-input systems (1).These soils have micro-topography called Gilgai, which is formed as a result of expansion and contraction in addition to cracking of these soils (31) These soils are also characterized by the phenomenon of continuous mixing or turning, there is a constant need to benefit from rainwater for use by the crop, and surface drainage must be provided to avoid waterlogging of the soil, when cracks are closed and infiltration rates slow down (54). There are some benefits to soil cracking, including creating drainage channels in heavy clay soils, allowing air to move deeper into the soil, and incorporating organic matter into the subsurface soil (92), but these benefits are insignificant compared to the negative impact that contractile clay has on water loss, root damage and reduced crop yields (88). In a study conducted by (70) to investigate the effect of basalt fiber and various pozzolanic additives (lime, fly ash, and silica fume) on desiccation cracking behavior, the additives used proved effective in reducing cracking. Crack areas decreased when lime was added, and continued to decrease when fly ash or silica fume was added with lime. The results demonstrated that additives can be an effective solution for preventing desiccation cracks in clayey soils. In order to determine the causes and effects of cracking techniques in Vertisols soils, some research be conducted on such, which can be summarized below:

- Understand the characteristics of cracked soils.
- Determine the quantity of nutrients and water lost through cracks and the impact it has on the productivity of crops.
- Determine physical parameters such as deformation process, sheer strength, penetration resistance, bulk density and aggregate stability of soil adjacent to cracks.
- Understand the tendency and continuity of the crack network.
- Evaluate the degree of crop yield losses from cracking and root damage for various agricultural products and soil types.
- Establish sustainable soil management techniques through investigation that reduce the occurrence of cracks and increase crop yields.
- Evaluate the efficacy of organic fertilizers and soil-conditioning substances (such as residues of crops, gypsum, biofertilizers, and FYM) in the field to reduce the occurrence of cracks and enhance the physical properties of the soil through aggregate formation.
- Develop general models to predict and estimate the occurrence of cracks in soils.

7. Cracked Soil Management Procedures

Heavy clay soil cracking is a common problem on farms, and treating these cracks and their negative effects is necessary to maintain plant growth and agricultural fertility. To reduce soil cracking in arid regions, a few steps can be taken, including:

1- Frequent irrigation: To keep the soil from drying up and reduce cracking without drying, a sufficient quantity of water must be added to it on a regular basis.

2- Using gray water: Water used in homes for daily activities can be used for irrigation, instead of using other water sources, especially if this water is limited.

3- Choosing appropriate soil types: choosing soil types that tolerate drought and have a high ability to retain moisture.

4- Afforestation of the area: Trees and plants provide moisture to the soil and help stabilize and cohesion, which reduces the degree of cracking.

5- Dissolving salts in the soil: Salts in the soil may increase the cracking, so they should be dissolved by purifying the water before irrigation, or adding organic feed to the soil.

6- Soil Covering: Different covers can be used to cover the soil, such as plant leaves, crop residues, straw, stones or some plants to maintain soil moisture, reduce evaporation rate and reduce cracking.

7- Use dry, coarse soil, straw or sawdust to close cracks in the field.

8- Deep plowing: Deep plowing should be done periodically to maintain soil quality and repair soil cracks.

9- Use of organic materials: such as organic fertilizer or green manure can be added to the soil, as these materials help increase the moisture content and maintain soil structure.

10- Use of modern irrigation techniques: Modern irrigation techniques such as drip irrigation, sprinkler irrigation and regular irrigation can be used to provide adequate moisture for plants without wasting water.

8. Conclusions

Soil cracks in Vertisols are mainly caused by the expansion and shrinking of clay minerals 2:1, affecting soil aggregates, water and air movement. The severity of cracks depends on mineral composition and quality and quinttity of organic matter. Applying soil amendments and adopting proper tillage and irrigation practices can effectively reduce cracking. Further studies are needed to better understand crack behavior and its impact on soil productivity.

9. Disclaimer (Artificial Intelligence)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

10. Competing Interests

Authors have declared that no competing interests exist.

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