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Reducing Soil Crusting to Enhance Sesame Seedling Emergence

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REDUCING SOIL CRUSTING TO ENHANCE SESAME SEEDLING EMERGENCE

by

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Gustavo Campero

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ABSTRACT

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Sesame Seedling Emergence

by

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In Venezuela rainfall-induced crust is the main problem in obtaining adequate stands of sesame (*Sesamum indicum* L.) The effectiveness of seven commercially available soil conditioners to prevent soil crusting and their influence on sesame seedling emergence was tested on Parlo silt loam. The chemicals were sprayed on the soil surface at different rates and dilutions. The rates were established to give about the same treatment cost.

Two chemicals: a polyvinyl alcohol (Elvanol 71-30) and an anionic asphalt emulsion (Humofina B-2864) gave the greatest increase in sesame seedling emergence. Thereafter, the two chemicals were tested on two Utah soils (Parlo silt loam and Nibley silty clay loam) and four Venezuelan soils. Three of the Venezuelan soils (Turen silt loam, Nontilled Turen silt loam, and Agua Blanca silty clay loam) were sampled in areas actually being used for sesame production, but with problems of soil crusting. The fourth Venezuelan soil (Guanipa sand) was collected in an area where sesame has recently been introduced.

The experiments were carried out under greenhouse conditions. Soil samples were brought to a matric potential of about -3 bars, sieved through an 8-mm sieve, and placed in pots. Four sesame seeds were sown in each pot and immediately afterward the surface treatments were applied. The amount and dilution of a particular soil conditioner utilized on a pot constituted a treatment. The treatments were replicated eight times. Two days after sowing, crust formation was induced by a simulated rainfall of 50 mm/hour intensity during a 30-minute period. A control and a subwatered control treatment were simultaneously carried out with each replicate. The time required to reach ponding was recorded as an index of aggregate breakdown and surface sealing.

Sesame seedling emergence was recorded daily. When no additional counts occurred in a 24-hour period, the experiment was considered concluded. At this time, measurements of crust impedance and resistance to penetration were taken. In each experiment, half of the pots were provided with plastic guided tubes to allow a probe with a hemispherical cap to penetrate the soil crust from below. The force required to cause this penetration was called crust impedance. In the other half of the pots, a measurement was made of the resistance to penetration of the crust from above the soil surface using a pocket penetrometer.

In the screening test, the seven chemicals tested on Parlo soil did not show clear evidence of reducing soil crust formation, but they increased the time required to reach ponding. In the chemical treatments as compared with the control, a slightly higher sesame seedling emergence was obtained.

In all of the soils, Elvanol 71-30 and Humofina B-2864 prolonged the time required to reach a ponded condition. The effect of these chemicals on sesame seedling emergence was more variable. Thus, in Guanipa soil, high rates of Elvanol 71-30 or Humofina B-2864 lowered seedling emergence. Practically no effect was observed in Turen and Nontilled Turen soils. Only Elvanol 71-30 increased seedling emergence in Agua Blanca soil. But, in Parlo and Nibley soils, both chemicals were effective.

Most of the treated samples of the finer textured soils (soils other than Guanipa) showed higher crust impedance, higher resistance to penetration and higher sesame seedling emergence than the control. A shorter time to reach ponding conditions in the control, indicated a more extensive aggregate breakdown in the soil surface. This might, in turn, cause the formation of a hard crust section in the very surface of the soil. Although such crust section was not detected by the impedance or resistance to penetration measurements, it could be responsible for the low sesame seedling emergence percentage obtained in the control.

The results suggest that the evaluation of a soil crust strength based only on crust impedance and resistance to penetration determinations may lead to erroneous interpretations. The seedling itself is the best indicator of the soil mechanical strength influencing its emergence.

(108 pages)

INTRODUCTION

Sesame (*Sesamum indicum* L) is one of the oldest and most important oil crops of traditional agriculture in Asia and Africa. The seeds contain 45-55 percent of an edible oil which is rich in polyunsaturated fatty acids and has a very pleasant flavor. In addition, its high content of a strong antioxidant known as sesamol gives sesame oil the greatest resistance to oxidation of any of the vegetable oils. The seeds also contain 19 to 25 percent protein that is rich in the amino-acid methionine; consequently, sesame meal is an excellent source of protein for both human and animal consumption.

For 1972 the world production of sesame seed was about 2 million tons and the yield averaged 320 kg/ha (M.A.C., 1975). In the last few decades, sesame has been grown in some areas of Latin America. Today the Latin American yields are higher than those of Asia and Africa.

In the past, yields of 1,000 to 2,000 kg/ha have been reported in commercial plots in Venezuela (Leon, Mazzani, and Gomez, 1972). However, in the last 20 years, the average sesame seed yields for this country varied between 363 kg/ha and 704 kg/ha. Since there are adaptable varieties which have the potential to yield 2,000 kg/ha, the present yields could be greatly increased by resolving agronomic problems found in the management of the crop. Among the unsolved problems that affect sesame yields in Venezuela is the difficulty in obtaining adequate stands of sesame because of soil crusting (Mazzani, 1971).

In Venezuela, sesame is grown in the Western Plains of the country where about 150,000 hectares are dedicated to this crop (M.A.C., 1975). It is grown as a dryland crop and, consequently, its growth depends on the water stored in the soil at the time of sowing, and on the precipitation that infiltrates into the soil during the crop season. In these conditions sesame has been an excellent complimentary crop to plant after harvesting corn (*Zea mays* L.) or rice (*Oryza sativa*). Sesame makes effective use of stored soil moisture and also allows utilization of labor and agricultural machinery in a period of low activity. The stability of this management system, however, is precarious because soil crusting problems are annually increasing, partially due to progressive shattering of soil aggregates by the instruments used in seedbed preparation.

In many instances, even a light rain (15 mm) can cause a hard soil crust to form that greatly effects sesame seedling emergence. This is particularly true if the rain occurs a few days after planting and is followed by a dry spell. As a consequence of the resulting poor stand, the farmer must again prepare the seedbed and replant the sesame.

During the years 1970-74, sesame farmers in Venezuela had to plant sesame an average of 2.4 times to obtain a relatively satisfactory sesame stand (Mazzani, 1977). Crust formation has increased costs for sesame production and reduced the profit margin of the crop. Economically feasible agronomic practices could be used on the soils of the Western Plains of Venezuela to reduce soil crust formation and thus enhance sesame seedling emergence.

This research aims to test under greenhouse conditions the possibility of using surficial chemical treatments to reduce soil crust strength and enhance sesame seedling emergence.

Objectives

1. To characterize the temporal rainfall distribution at a location near the center of the sesame growing region in Venezuela by apportioning the rainfall incurred in the following periods.

   a. May 1 to the planting date.

   b. January 1 to the last day of February.

   c. The 20 days following the planting date.

2. To correlate sesame yields with the timing of precipitation for the location chosen for Objective 1.

3. To characterize two Utah soils and four Venezuelan soils by the following parameters:

   a. Particle size distribution.

   b. Water characteristic curve.

   c. Mineralogical composition of the clay-sized fraction.

   d. Percentage of organic matter.

   e. Electrical conductivity, pH, and sodium adsorption ratio in saturated extract.

   f. Aggregate stability.

4. To correlate aggregate stability with particle size distribution in the above characterized soils.

5. To screen seven commercially available soil conditioners for their effectiveness in reducing crusting when applied to Parlo series

at different rates and dilutions. The effectiveness will be assessed by determining the influence of treatments on:

a. Time required for ponding when the soil is under a simulated rainfall intensity of 50 mm/hour.

b. Evaporation.

c. Impedance to rupturing the crust from below by a probe that simulates an emerging plant.

d. Resistance to penetrating the crust from above with a commercial penetrometer.

e. Percentage of sesame seedling emergence.

f. Aggregate stability.

6. To further evaluate, at different rates and dilutions, the three soil conditioners that proved to be effective in the screening test of Objective 5. Such evaluation will be done on Parlo series by assessing the effects of soil conditioners on the first five parameters indicated in Objective 5.

7. To expand the evaluation of the best performing soil conditioners by testing them on two Utah soils and four Venezuelan soils. The evaluation will be done at several rates and dilutions by studying the effect of the soil conditioners on the six parameters indicated in Objective 5.

8. To correlate soil crust impedance (rupture from below) and soil crust resistance (penetration from above), with the sesame seedling emergence percentages.

9. To evaluate, under field conditions, the effect of the soil conditioners that showed the best performance in the screening test. The evaluation will be done on Roshe Springs silt loam to determine the influence of treatment on seedling emergence. (Reported in Appendix A.)

LITERATURE REVIEW

Sesame Characteristics

The genus *Sesamum* is a member of the Pedaliaceae family, a small family of annual and perennial herbs occurring mostly in the Old World tropics and subtropics (Purseglove, 1968). Sesame is a crop of the dry tropic and warm temperate regions. Once established, it can tolerate periods of drought, but it is intolerant of waterlogging. Arnon (1972) indicated that sesame gives a good crop even when grown on stored soil moisture alone--considering that a winter rainfall of 400 mm is sufficient to ensure a good dry land crop in the Mediterranian region. The crop grows slowly in the early stages, and is greatly susceptible to weed competition during that period.

Depending on the cultivar, sesame takes between 80 to 150 days to reach maturity. It grows to about 1.4 m and bears its flowers in short pedicels in the axils of the leaves. The seeds are small, about 2.5 mg/seed, and are found enclosed in capsules having dorsal dehiscence and a length of up to 40 mm. The seeds are easily dispersed by wind and other agents. Flowering is continuous so maturation of the capsules is not simultaneous. The plants must be harvested before the onset of dehiscence, otherwise grave loss of seed may occur (Tribe, 1967).

For harvesting, the plants are cut below the lowest fruiting point and fastened into bundles, which are left in the field to dry for about 15 days. Afterwards, the bundles are threshed. Harvesting has been an important factor limiting introduction of the crop into areas where labor is expensive (Yermanos, Edwards, and Hemstreet, 1964).

Mechanical harvesting has allowed sesame to be grown in new regions. In Venezuela, cutter-binders are used to cut the plants, and modified grain combines to thresh them. Now attempts are being made to dry the crop, without cutting, by using chemical defoliators or driers. This would permit direct harvesting of sesame with improved grain combines (FONALI, 1974).

The relation of sesame seed yield with plant population has been studied in several investigations. Mazzani and Cobos (1956) varied the distance between rows from 500 to 900 mm and the distance between plants in the row from 100 to 300 mm in two branched sesame varieties. Maximum sesame seed yield was obtained in the highest population density (200,000 plants/ha). The same relation was found for a nonbranching variety (Mazzani and Cobos, 1958).

Gerakis and Tsangarakis (1969) found that in sandy soils of the savannah belt of the Central Sudan the yield of nonirrigated sesame was increased when the maximum plant population commonly used in the area (80,000 plants/ha) was increased by 50 percent. Further increases in plant population resulted in yield decreases, and a population of 200,000 plants/ha was as productive as that of 80,000 plants/ha. El Nadi and Lazim (1974) studying the effects of varieties and populations on the yield of irrigated sesame in the Sudan determined that the increase in plant density from 143,000 to 238,000 plants/ha increased seed yield.

Delgado and Yermanos (1975) used a branched variety of sesame in an investigation to evaluate yield components of sesame under different population densities. Rows were 600 mm apart and spacing between plants in the row varied from 25 to 300 mm (667,000 to 56,000 plants/ha). More branches were produced at lower densities. Number of capsules and sesame seed yield decreased at plant spacings greater than 75 mm (222,000 plants/ha).

Sesame Production in Venezuela

About 95 percent of the sesame production in Venezuela is concentrated in Portuguesa State and particularly in the Turen region (M.A.C., 1975) which is located in the middle of the Western Plains of Venezuela. The Western Plains of Venezuela are situated south and west of the Andes ridge, and cover about six million hectares. The area has a high agricultural potential. The soils are recent alluvials, and tropical forest is the natural vegetation. Inceptisols, alfisols, vertisols, and entisols are the common soil orders in the area (M.O.P., 1973). The elevation is less than 250 m above sea level. The monthly average temperature fluctuates from 26 C to 28 C; and the annual precipitation is about 1,400 mm. Based on rainfall, the year can conveniently be divided into three periods: a dry period from January through April, a wet period from May through September, and a transitional period from October through December. These periods account, respectively, for less than 10 percent, more than 70 percent, and about 15 percent of the total annual precipitation. Evaporation from a Class A pan is about 6.0 mm/day during the dry period, 4.0 mm/day during the wet period, and 4.5 mm/day during the transition period (Gasperi, 1974).

Sesame is sown after the wet period crop (corn or rice) has been harvested. At planting time, the soil must be dry enough to be workable with machinery. However, because a minimal amount of precipitation is expected during the growing season of the crop, moisture in the soil profile must be high enough to supply adequate amounts of water for germination and further growth of sesame. Bascones (1967), working in the area, found that sesame grown after fallow showed higher yield than sesame grown after corn. He considered that those differences were a consequence of the higher levels of soil moisture in the profile of the fallow plots at the time of planting.

For 1968 in Portuguesa State, the percentages of the total area successfully sown and established during the planting period were as follows: 0.23 percent in September, 1.74 percent in October, 33.37 percent in November, 60.62 percent in December, and 3.70 percent in January (Leon, Mazzani, and Gomez, 1972). The varieties used in the region require 90 to 106 days from planting to complete harvesting, which must be done timely and in dry conditions. In one out of three years, appreciable precipitation occurs as early as late March or early April, making it impossible or very difficult to complete harvesting. Thus, in this region, it is not recommended to delay sesame planting until January 1. The nonobservance of such recommendation has caused severe economic losses in some years.

Sesame needs a finely prepared seedbed which is obtained in the region by going over the land with a disk tiller four or more times. In addition, just before planting, a tree trunk or other compacting device is pulled over the land by a tractor to increase the capillary rise of soil water to the seed depth (Leon et al., 1972). The soil is not fertilized at the time of planting. However, sesame makes use of the residual fertilization remaining in the soil after harvesting the preceeding crop. Rice planters are used to sow the sesame. The distance between rows ranges from 600 to 900 mm, and the amount of seed used ranges from 3 to 4 kg/ha, this is between 1.2 and 1.6 million seeds per hectare. For optimum yields, the recommended population density for established sesame plants in the region is about 325,000 plants/ha. Higher population densities creates excessive competition among plants and results in nonuniform maturity and decreased yields (FONALI, 1974). The depth of planting varies from 20 to 50 mm. A uniform depth of planting is recommended for a more uniform maturity.

Low aggregate stability in water and compaction tendency of soils in the region have been related to the abundance of particles in the size range of silt and fine sand (Pla and Campero, 1971). The most damaging crusts are found during the planting period of sesame. During this period, the prevailing soil and climatolological conditions are such that the soil surface dries rapidly after a rain and greatly enhances the soil crust strength. Thus, if a rain occurs in the first 14 days after sesame is planted, there is high probability that a hard soil crust will be formed and that the sesame seedlings will be unable to emerge through it. Even if the seedlings emerge, they may be seriously damaged by mechanical girdling of their stems at the crust level (Mazzani, 1971).

If a soil crust develops, the farmers usually prepare the seedbeds again and replant sesame. At least two passes of a disk tiller and one pass of a soil surface compactor are needed to reprepare the seedbed. The repreparation cost is about \$18/ha. The cost of the sesame seed and the planting would average about \$12/ha. Thus, the total cost involved in repreparing the seedbed and replanting sesame is about \$30/ha.

Due to the crusting problems in the period 1970 to 1974, only one out of 2.4 sesame plantings was successful (Mazzani, 1977). Thus, any practice that would ensure adequate stands of sesame by resolving the crusting problems could be economically justified if its cost were lower than the cost of 1.4 sesame plantings (\$42/ha).

By controlling soil crust formation, a successful sesame planting could be obtained earlier in the planting period, when more available soil moisture is in the profile. In this condition, higher sesame yields could be expected. However, the financial benefit of early planting has not been evaluated.

Seed Germination and Soil Water Content

Most of the plants show optimal seed germination in very moist soils. However, many seeds can achieve some germination in very dry soils. Doneen and MacGillivray (1943) distinguished some vegetable seeds able to germinate in soil at the wilting point. Wheat seeds (*Triticum aestivum* L. showed almost 100 percent germination at -20 bars water potential (Owen, 1952). With sesame, better seed germination is obtained between -3 and -6 bars soil water potential (Durand, personal communication).

Hadas (1975), working with chickpea (*Cicer aeritinum* L.) found that reducing soil water potential or the conductivity to water postpones germination, as expected, but to a lesser extent than contact impedance does. For dry farming, he recommends that the aggregates in the seedbed be no larger than one-fifth the seed size so as to ensure good seed-soil water contact. If small seeds, such as sesame, are to be sown, this recommendation cannot be met without pulverizing the soil.

Soil Crusting

Once seeds start to germinate, emergence must occur within a short time, before metabolic reserves are exhausted. Soil crusting is one of the main factors that reduces emergence of young seedlings. It acts by creating mechanical resistance for the seedlings' emergence and by decreasing soil aeration.

The flexibility of fine seedling stems is high. This reduces the axial force that can be exerted for given tissue pressures. Thus, when a soil crust is present, fine seedlings are more affected than coarse seedlings (Arndt, 1965b). In the case of dicotyledonous seedlings, emergence requires the rupturing of the soil surface in a dome or cone that is large enough to accomodate the cotyledons. Consequently, dicotyledons are more affected by soil crusting than monocotyledons (Morton and Buchele, 1960; Arndt, 1965b).

Soil crusts are also problematic after emergence has occurred. If a crust is formed around the base of a young seedling, it can cause the seedling's death by heat girdling (Arndt, 1965a).

Soil crusts result from the soil structure breakdown caused by raindrop impact (McIntyre, 1958) or by a slaking process, consisting of minor explosions of air entrapped in the previously dry aggregates (Emerson, 1956; Hillel, 1960). The fine particles are washed into and fill the interaggregate space in the immediate surface of the soil. The deposition of suspended material and the orientation of the clay particles may be factors in crust formation (McIntyre, 1958).

Crusts show a lower degree of aggregation, a greater bulk density, and a higher proportion of particles smaller than 0.10 mm in diameter than the underlying soil (Lemos and Lutz, 1957). Therefore, they exhibit higher mechanical strength than the same surface soil in a non-crusted condition.

Crusts reduce water infiltration, increase runoff and soil erosion, and decrease water use efficiency in both irrigated and nonirrigated conditions. Under wet conditions, crusts decrease gaseous diffusion causing poor soil aeration (Domby and Kohnke, 1956; Hanks and Thorp, 1957). However, it is considered that the most important detrimental effect of soil crusts is the mechanical obstruction to the emergence of seedlings (Miller and Gifford, 1975; Chaudhri, Brown, and Holder, 1976).

The modulus of rupture was studied by Richards (1953). Since that time, the factors involved in the crusting phenomenon have been somewhat clarified. The modulus of rupture is an index of strength. It is used widely to determine the breaking force and to compare the binding strength of structural materials.

Working with fine sandy loam soil, Richards (1953) reported that as the soil crust strength, measured by modulus of rupture, increased from

108 to 273 millibars, the emergence of bean seedlings decreased from 100 to 0 percent. Allison (1956) studied modulus of rupture of soil crusts in a loam soil. For seedling emergence, he found that the limiting value was between 1,200 and 2,500 millibars. Both investigators dried the artificial soil crusts at 50 C.

Hanks and Thorp (1956) showed that wheat seedling emergence was reduced when oxygen diffusion rate was below 75 to 100 x 10^{-8} $g/cm^2/min$; when crusts were present and no soil cracking was allowed, this corresponded to an air pore space less than 17 percent in a silty clay loam soil and less than 26 percent in a fine sandy loam soil. For wheat seedling emergence, they found that the limiting modulus of rupture of the soil crust was between 200 and 500 millibars, and appeared to decrease as the proportion of the available moisture decreased.

Hanks and Thorp (1957) used a technique which allowed independent variation in soil crust strength, soil moisture at the seed depth, and soil type. They found that emergence of wheat seedlings through a crust was influenced by the strength of the crust immediately around the growing tip and not by the strength of the entire crust. No relation was found between wheat seedling emergence and seed spacing. Thus, they considered that modulus of rupture is a reliable measure of soil crust strength with respect to seedling emergence of wheat and probably of similar plant seedlings such as grain sorghum (*Sorghum vulgare* L.). They indicated that increments in soil crust strength from 0 to 1,400 millibars resulted in reduction of seedling emergence for wheat, grain sorghum and soybeans (*Soja max* L.).

Lemos and Lutz (1957) reported that in artificially prepared soil crusts, the modulus of rupture was increased: by compacting the soil in the molds used to prepare the artificial soil crust, by the moisture content of the soil at the time of compaction, by the beating effect of raindrops, by puddling the soil before putting it in the molds, and by longer periods of drying at 105 C. There was a decrease in the modulus of rupture with successive cycles of wetting and drying. These authors tested nine soils with known type of clay and mechanical composition. They remarked that when only a small fraction of 2:1 type clay was present, the modulus of rupture was more closely related to the silt content than to any other fraction or group of fractions, but as the content of 2:1 type of clay increased it became the regulating factor affecting the strength of the soil crusts.

Hanks (1960) used the same technique reported by Hanks and Thorp (1957) for crusting studies, but measured the modulus of rupture for crusts dried at 50 C rather than at 105 C. Hanks studied varied crust strength from 0 to 11,200 millibars in a silt loam soil, and found it difficult to fix a limiting value of soil crust strength for emergence of wheat, grain sorghum and soybeans. The limiting value increased as the soil moisture content at the seed level increased. The soil crust strength increased as the moisture content of the crusts, at the time crusts were broken, decreased. He also noticed that in four tested soils, a one-hour application of rain at an intensity of about 47.5 mm/hour increased the soil crust strengths more if the soils were air dry than if the soils were previously wet.

Hillel (1960) carried out a soil crust study in conditions where disturbance by rainfall was absent. For a loessial soil from the arid Negev of Israel, he found a high correlation between the degree of saturation at wetting and the degree of densification upon drying. He pointed out a conceivable identification of the zone of crusting with the zone of saturation in the infiltration process. Crusting was recognized to be a positive function of wetting duration. However, the rate of slacking appeared to decrease with time.

In a field experiment, Bennett, Ashley, and Doss (1964) determined the force required to pull a fishing line through a soil crust. They used the force requirement as an index of soil crust strength. Their measurements were negatively related to cotton (*Gossypium herbaceum* L.) seedling emergence.

Parker and Taylor (1965) compressed six different sandy soils. For two of them they found that increments of soil crust strength increase, measured by a soil penetrometer, caused progressive decreases in sorghum seedling emergence. In the other four soils, crust strength induced decreases in sorghum emergence when its value was higher than 3 bars. In the six soils they studied, sorghum seedling emergence was absent when the soil crust strength reached 18 bars. Soil temperature, in a range of 21 C to 35 C, did not affect emergence of sorghum. They determined that increases in planting depth slightly reduced sorghum seedling emergence, but markedly reduced guar (*Cyamopsis tetragonolobus*) seedling emergence.

Wanjura, Hudspeth and Kirk (1966) conducted a field experiment on a loam and a fine sandy loam soil in which compaction, resulting from the surface presser wheels during cotton planting, was measured by penetrometer. They noticed that maximum soil strength usually took place 2 days after planting, and that maximum soil strength pressures as low as 1.4 bars reduced final cotton emergence 10 percent below the nonpressed treatment.

Arndt (1965a) considered that the mechanics of seedling emergence is too variable and complex to be expressed by modulus of rupture determinations. Arndt, after field observations of seedlings that failed to emerge, developed a device for direct measurements of the mechanical impedance of soil crust from below--an approach that he estimated was in accordance with field experience.

Holder and Brown (1974) recognized that a direct measurement of the mechanical impedance of soil crusts from below is a realistic approach to achieving a comprehension of the factors regulating soil crust impedance. They improved the method proposed by Arndt (1965a) for measuring soil crust impedance. Soil was placed in boxes that were fitted with guided tubes to permit a probe to penetrate the soil crust from below. The crusts were formed by simulated rain. They remarked that for the loam soil that they studied, crust impedance increased as the soil dried, then decreased upon further drying as cracking increased. Maximum impedance occurred when the soil crust moisture was about 2.5 percent.

Hadas and Stibbe (1977) measured the resistance, from underneath, of natural soil crusts by using a pocket penetrometer. Their results indicated that the crusts formed on disked fields were nearly twice as resistant to penetration as those formed on plowed fields. In the studied area, impaired emergence of wheat was attributed to soil crusting. However, no relation between wheat stand 3 weeks after rainfall and the crust resistivity to penetration was found. They suggest the impaired wheat stand might be due to the fact that the seedling coleoptile reached the crusted top soil after drying time was enough to increase the soil crust strength.

Increasing Seedling Emergence in Crusting Soils

The literature gives several physical and chemical management techniques which in particular conditions have improved seedling emergence in crust-susceptible soils.

For cotton on the Texas High Plains, a shallow planting depth (25 to 50 mm) is recommended to reduce the time between planting and emergence. Thus, if it rained after planting, seedlings were less affected by soil crusts (Jones, Hudspeth, Ray, Thaxton, Walker, Owen, and Lane, 1956).

Carnes (1934) pointed out that the injury to cotton seedling stands, caused by crust formation can be avoided by proper preparation of the seedbed before and at the time of planting. For planting cotton he recommended some compaction of soil around the seed to provide a firm footing for the seedling in breaking through the crust and a more efficient use of moisture present in the soil. His recommendation was supported by laboratory studies conducted by Morton and Buchele (1960). For highest seedling emergence, they recommended the development of planters able to: pack the soil below the seed level, press the seeds into this soil layer, and then cover the seeds with loose soil.

Previously soaked seeds may exhibit a more rapid seed germination (Morton and Buchele, 1960). With the soaking procedure, adequate seedling emergence could take place before the soil crust dries.

Kemper and Miller (1975) expressed that one possibility for obtaining emergence through crusts was that of planting the seeds more dense than the desired stand. With this method, more seedlings may emerge through cracks or may develop cracks by group force.

In a fine sandy loam soil with crusting tendency, Bennett et al. (1964) determined that altering the geometric characteristics of the soil surface resulted in a moderate increase in cotton seedling emergence. Cotton emergence increased from 10 percent in the flat conventional planting to 35 percent when cotton was planted between ridges perpendicular to the wind.

Cary (1967) found in greenhouse and field experiments that satisfactory stands of lettuce (*Lactuca sativa*) and carrot (*Daucus carota*) could be obtained by planting single seeds in holes, as deep as 60 mm, punched through soil crusts. He recommended the punch planting method in areas where a stable soil crust forms and where heavy rains are not expected during the germination and emergence period. Heinemann, Cary and Dilworth (1973) designed an experimental machine for punch planting of small seeded row crops. They also determined, in a greenhouse study, that the soil surface around the holes could be further stabilized if the seed row was shaped into a convex form about 13 mm high and then a soil stabilizer was applied.

Hanks (1960) pointed out that methods to minimize soil drying, such as a stable mulch, could be appropriate to reduce crust strength and increase seedling emergence. Bennett et al. (1964) tested several physical and chemical methods of reducing the soil crusting that resulted when simulated rain was applied. He found that cotton seedling emergence was greatest where a black plastic film was placed over the row for 5 days after the seeds were sown. Sale and Harrison (1964) reported that a wet crust did not affect emergence of spinach (*Spinacia oleraceae*), beet (*Beta vulgaris*) and lettuce. They also pointed out that smaller waterdrops caused little or no soil crusting and tended to increase seedling emergence.

Light and frequent irrigations with sprinkler systems may be practical during the emergence period of weak seedlings. This practice helps to reduce the soil crust strength by keeping the soil surface moist. Kemper and Miller (1975) reported that in the Imperial Valley, California, it was a common practice to plant lettuce and other high-value crops in beds and to keep the soil moist using portable sprinkler systems for the 7 to 10 days needed for emergence. After seedling emergence had been completed, furrow irrigation was used.

Hoyle, Yamada and Hoyle (1972) found that by rototilling wet soils, a homogenous mixture of new aggregates was formed. This method of preparing seedbeds, called aggresizing, reduced the size of large clods and former larger aggregates from fine dust by puddling it.

In field experiments on Panoche clay loam, in which watering was supplied with furrow irrigation at weekly intervals, emergence of several vegetable crops in aggresized soil was greater, more uniform and 3 to 5 days earlier than in nonaggresized soil. These effects were related to a slower crust formation in the aggresized seedbed (Hoyle and Yamada, 1975). Aggresizing may not be useful in soils where aggregates readily slake when wet.

Addition of organic matter to soils has long been recognized as a beneficial practice in the management of soil structure. Its effects are derived from its conversion to organic bindings substances which are predominantly responsible for the stabilization of soil surface aggregates (Harris, Chesters and Allen, 1966). Nuttall (1970) reported that peat, manure, straw and sawdust ammendments, applied to a soil low in organic matter at a rate of 2.5 percent by weight, reduced the soil crust strength and increased the emergence of rape (*Brassica napus* L.) in a growth chamber.

Plant residues used as surface mulchs absorb part of the energy of the falling raindrops; thus, they may reduce soil crust formation (Carpenter and Watson, 1954). Ahmad and Roblin (1971) indicated that baggase (sugar cane pulp) and pen manure used as surface mulches increased water infiltration but were not effective in improving lettuce seedling emergence.

Qashu and Evans (1967) found that black granular coke material applied on the soil surface resulted in a friable soil crust as compared with a hard crust on the bare soil.

Many low-strength materials have been used in the soil immediately over the seed row to increase seedling emergence in crust susceptible soils. In an emergence study of direct-seeded tomatoes (*Lycopersicon esculentum* L.) in a clay loam soil, Ells (1967) found that using perlite in the seed furrow was a more practical method of increasing emergency than either sand in the seed row or asphalt emulsion sprayed over the seed row. Perlite, at a rate of 25 cm^3 per m of row, induced a fissure line in the seed row and a concomitant increase in seedling emergence. While planting lettuce seeds in soil depressions on a 13 mm square grid, Ririe and Huffman (1969) noticed that covering the seed with vermiculite or coke instead of soil improved lettuce stands and offered better possibilities for precision planting. Ririe and Hills (1970) trying to obtain satisfactory sugar beet (*Beta vulgaris* L.) emergence in soils with crusting problems, found that vermiculite in the seed row was more effective than coke. In the two above studies, vermiculite was sprayed with polyvinyl acetate to prevent it from blowing or washing away.

Wilcox and Johnson (1971) developed integrated equipment for direct seeding of tomatoes in the humid midwestern United States on soils with crusting tendencies. A strip of soil ahead of the seeding unit was rototilled to a 25 mm depth to keep moisture moving up to the seed by capillarity. Plant population was controlled by releasing seeds in clumps at the required distances. Starter fertilizer was sprayed on the seed; and anticrustant was applied on the seed furrow at a rate of 160 cm^3/m of row. The anticrustant was then firmed against the soil by a press wheel with a concave surface. In a field experiment, these authors found that vermiculite, sawdust compost, and petroleum coke were more effective as anticrustants than perlite.

Chaudhri et al. (1976) worked with a fine sandy loam and a silty clay soil in a greenhouse in which crusting was produced with simulated rain. They noticed that when manure was added in a 25 mm band over the row and mixed with the soil, cracks opened as the soil dried and the impedance to penetration of the crust from below was reduced.

Johnson and Law (1967) reported that in calcareous soils concentrated sulfuric acid applied in 40 to 50 mm bands over the planted row resulted in 42 to 54 percent increases in sugar beet emergence. A thin friable film of gypsum was formed in the treated band which completely prevented soil crust formation. However, these authors pointed out that there were many dangers and hazards in applying concentrated sulfuric acid. Robbins, Carter and Leggett (1972) found that dilute phosphoric acid sprayed over the seed row on a calcareous silt loam soil increased sugar beet seedling emergence by reducing soil crusting. An application of 69 kg/ha of elemental P--applied as phosphoric acid diluted with 650 to 1,300 liters of water was effective in reducing soil crusting and also supplied the phosphorus needed for the crop. The increased water stability of the soil aggregates in the treated bond was believed to result from the slightly soluble Ca and Mg phosphates formed which acted as cementing agents.

Hemwall and Scott (1962) determined the ability of a chemical, 4-tert-butylpyrocatechol, as a fracturing agent in crusting soils. They reported that rates between 150 to 200 ppm of the chemical in the seed row caused self-mulching (intense microcracking) of the crusts and increased emergence of radish (*Raphanus sativus*) seedling. Bennett et al. (1964) indicated that a soil fracturing agent was very effective in improving cotton seedling emergence in a fine sandy soil with crusting tendency.

Crusts that form above young seedling can be mechanically disrupted by shallow cultivation with crust-breaking equipment such as a cultipacker, rotary hoe, finger weeder, or a spring-tooth harrow.

Cultipackers have been the most successful as crust breaker equipment (Kemper and Miller, 1975). The cultipacker is formed by a series of narrow, toothed wheels placed over a smaller supporting tube. The loose arrangement of the toothed wheels allows only the weight of each individual toothed wheel to press on the soil surface. This breaks the surface crust but eliminates excessive packed areas and reduces soil movement to the lowest possible degree. This crust breaking practice is of little value if the soil crust is severe and/or the seedlings are very weak.

Effect of Synthetic Soil Conditioners

Since soil conditioners (chemical materials used to improve soil physical conditions) were introduced in the early 1950's, a good correlation has been found between the increased aggregate stability and reduced soil crust strength (Allison and Moore, 1956; Myhrman and Evans, 1969).

Reduction in soil crusting and increased seedling emergence have been reported along with sharp yield increases in vegetable crops when synthetic soil conditioners were applied (Allison, 1956). However, the costs of commercial applications at the rates used in these early experiments was prohibitive for agricultural purposes.

New and cheaper soil conditioners, with a wider range of usefulness, have been developed in the last several years. In relation to these new possibilities, Gardner (1972, p. 1053) gave the following recommendation:

> It may be well to concentrate major research and development efforts in areas where the best chance for economic application may be anticipated and to avoid the over-extension and over-enthusiasm which helped to speed the decline in interest in soil conditioners of the late 1950's.

Bennett et al. (1964) reported that in a fine sandy loam soil with crusting problems, asphalt emulsion sprayed on the planted seed row at the rate of 115 liter/ha, after dilution of 1:5 in water resulted in a greater reduction in soil crust strength and a greater increase in cotton seedling emergence than the incorporation of Krilium (Vinyl acetate-maleic acid copolymer) at a rate of 2,450 kg/ha into the top 25 mm of soil before planting. Ells (1967) indicated that asphalt emulsion sprayed on the soil surface increased emergence of direct seeded tomatoes in a clay loam soil with crusting problems, but perlite in the seed furrow was a more effective treatment.

De Boodt (1972) considered that in many agricultural soils there is a lack of bonding between clay domains and sand particles, and that stability of the soil aggregates could be increased by creating such bonds. When emulsions are applied to a soil, the micelles migrate to the points of contact between the soil particles, particularly between sand particles or between clay domains and sand particles. Thus, emulsion-based soil conditioners could be effective in creating such bonds. He explained the interest in the use of asphalt emulsions as soil conditioners on the basis that asphalt is a cheap product which can be easily emulsified.

Asphalt emulsions may have different charges depending upon the emulsifier used. If the applied asphalt emulsion is more anionic, the water-soil contact angle is greater, making the soil more hydrophobic. Gabriels (1972) conducted a laboratory study in which water was applied with a rainfall simulator. He observed that when an anionic asphalt emulsion was sprayed over loam soil aggregates of two size ranges

(20-8 mm and 8-2 mm) the water infiltration remained high and the aggregates did not rupture. When asphalt emulsions were mixed with 2-8 mm aggregates, the aggregates were so hydrophobic that no water infiltration occurred, and small stable aggregates were carried in the runoff water. Similar results were obtained by Gabriels, Moldenhauer and Kirkam (1973).

Gabriels, De Boodt and Minjauw (1974), in a laboratory experiment, found that anionic asphalt emulsion, polyacrylamide (with cross-linkage) and polyvinyl acetate used at optimal rates stabilized a dune sand against raindrop impact. Optimal rates were sensibly lower in surface applications than in incorporated treatments (0-50 mm depth); and the most economical treatment was anionic asphalt emulsion. They pointed out that the amount of the chemicals that must be applied to give satisfactory stabilization can be reduced by treating only the soil over the seed row.

In recent trials conducted in Belgium, Indonesia, Malaysia, Thailand, Iran and Tunesia, De Boodt (1977) found that in almost all cases, seed germination (emergence) increased when an anionic asphalt emulsion (Homofina B-2864) was applied to the soil.

Surface applications of petroleum resin-in-water emulsion were recognized in California as beneficial in promoting early germination and establishing stands in several vegetable crops. The mechanism for the beneficial effect was thought to be an increase in soil temperature and a reduction in water evaporation (Takatori, Lippert and Whiting, 1963). Lyles et al. (1969) found that a petroleum resin-in-water emulsion (Coherex) in dilution of 1:4 in water was a very effective and economical temporary treatment for wind erosion control, and also increased bean seedling emergence.

Lange (1971) tested polyacrylate, asphalt emulsion and oil-latex emulsions as surface stabilizers against water emulsion. Independent of soil type, oil-latex emulsions were the most effective treatments. Armbrust and Dickerson (1971) indicated that a styrene-butadiene copolymer latex emulsion (SRB Latex S-2105) diluted 1:10 with water was a practical treatment for wind erosion control.

Polyvinyl alcohol (PVA) has been recognized by a number of workers as an effective compound for stabilizing soil aggregates. Emerson (1956) pointed out that the attachment between clay surfaces and PVA is apparently by hydrogen bonding between the oxygens in the clay surface and the hydroxyl groups of the PVA. Stefanson (1973) studying PVA as a surface soil stabilizer found that the most effective soil stabilization was obtained by use of optimal-sized PVA (molecular weight about 70,000) and by applying when the soil was wet. When applying under these conditions, it is probable that a better distribution of PVA in the pore system was obtained.

Carr and Greenland (1973) observed that PVA with a lower molecular weight was able to penetrate deeper in large aggregates of a heavy clay loam soil, but PVA with a higher molecular weight was more effective in improving stability of the soil aggregates. Stefanson (1974) reported that in a fine sandy loam soil the strength of a wet crust presumably decreased wheat seedling emergence, but applications of PVA at rates as low as 150 kg/ha increased seedling emergence from 35 to 90 percent. Oades (1976) stabilized the surface soil of a fine sandy loam throughout the growing season by spraying the soil with an aqueous solution of PVA at rates of 80-100 kg/ha. Crust formation was prevented and wheat seedling emergence was increased. Carr and Greenland (1975) found that PVA in 0.02 M $CaCl_2$ solution was more effective for structural improvement of sodic soils than PVA in aqueous solution.

A diluted polyvinyl acetate (PVAc) emulsion at a rate of 500 liters/ha sprayed on the surface was able to stabilize a dune sand against the impact of raindrops (Gabriels et al., 1974). Carr and Greenland (1975) reported that in a sandy loam soil, the lowest application rate of four PVAc emulsions (0.03 percent on a weight basis) increased ryegrass (*Lolium perenne*) seedling emergence from 41.7 to about 70.0 percent.

Armbrust and Dickerson (1971) found that a protein colloid (Technical Protein Colloid 5-V) sprayed on the soil surface at a rate of 120 kg/ha effectively controlled wind erosion and showed an appreciable resistance to natural weathering.

Myhrman and Evans (1969) indicated that addition of 0.4 percent (by weight) of dry, powdered hexadecanol decreased the modulus of rupture by 57 percent in a silt loam soil and by 65 percent in a sandy loam soil. Lower rates and emulsified hexadecanol showed less effect.

Polyacrylamide (PAM) solutions at rates of less than 500 kg/ha have proven effective in achieving good soil aggregation and stabilization (De Boodt, 1972). In silty loess soils over Northwestern Europe, poor sugar beet seedling emergence is obtained because of soil crust formation. In that region 0.2 percent PAM solution sprayed in 100-mm bands over the seed rows has promoted good sugar beet stands by reducing crust formation (De Boodt, 1975).

MATERIALS AND METHODS

Relationship between Precipitation and Yield of Sesame in Venezuela

Precipitation data (mm) obtained from the Colonia Turen meteorological station (Portuguesa State, Venezuela) were related to the national yearly sesame seed production per unit of area (kg/ha) for the period 1957-1976. The Colonia Turen meteorological station is located in the middle of the productive sesame area in Venezuela (09°16' N, 69°06'W; 150 m above mean sea level).

In this analysis the precipitation data were classified in relation to four planting dates selected arbitrarily as typical of the area. These were November 30, December 5, December 10, and December 15. Two multiple linear regression equations (referred to here as equations 1 and 2) were calculated to fit the 20 years of data for each planting date.

The first equation relates the annual sesame yield to two precipitation variables: (1) the accumulated precipitation from May 1 to planting date and (2) precipitation for the period January 1 to the last day of February. The second equation relates the annual sesame yield to the same two precipitation variables included in equation 1 plus an additional term, the accumulated precipitation for the 20-day period following the planting date.

The determination coefficients (r^2) obtained for the two equations were compared to each other. Such comparisons indicate the relative importance of the precipitation that falls in the 20-day period immediately following seeding in affecting sesame yields. This precipitation is, in turn, associated with soil crusting problems.

Soils Used and Their Characterizations

The study was conducted on surficial samples (0-200 mm) of two Utah soils and four Venezuelan soils. The two Utah soils were selected because their textures resemble those of the soils commonly used to produce sesame in Venezuela. Three of the Venezuelan soils were obtained from the sesame production area and the fourth Venezuelan soil sample came from an area in which sesame culture has recently been introduced.

One of the Utah soils was Parlo silt loam (Calcic Argixerolls) whose surficial color is classified as dark grayish brown (10 YR 4/2) dry, and very dark brown (10 YR 2/2) moist. The other Utah soil was Nibley silty clay loam (Aquic Argiustolls). Its surface color is classified as light brownish gray (10 YR 6/2) dry, and very dark grayish brown (10 YR 3/2) moist (Erickson and Mortensen, 1974).

Two Venezuelan soil samples were silt loam with surface color categorized as grayish brown (10 YR 5/2) dry, and very dark gray (10 YR 3/1) moist. These samples were taken in the Turen region in the Western Plains of Venezuela, a few kilometers southwest of the town of Villa Bruzual. The two samples were collected about 30 m apart. They differ in the fact that one soil has been in crop production for 30 years and the other has remained under natural forest. These two soils are termed here as Turen and Nontilled Turen.

The third Venezuelan soil sample (here named Agua Blanca) was collected in Foremaiz Experimental Field, Agua Blanca, located in the Western Plains of Venezuela. The soil is a silty clay loam classified as Aeric Tropaquepts. The surface color is dark grayish brown (10 YR 3/2) moist (M.O.P., 1972). This soil has been in agricultural use for the last 30 years.

The fourth Venezuelan soil sample, here termed Guanipa, was obtained in the Mesa de Guanipa Agricultural Experiment Station in the Eastern Plains of Venezuela. This soil has been dedicated to crop production for about 15 years, and its original pH has been modified by continuous liming. Guanipa is a sandy soil and its surface color is categorized as yellowish red (5 YR 4/6) dry, and dark reddish brown (5 YR 3/3) moist.

Mechanical analysis was run in triplicate on each soil using the hydrometer and wet sieving methods (Day, 1965). A soil water characteristic curve was determined for each soil using pressure plates (Soil Moisture Equipment Corp., Santa Barbara, California). The pressures applied were 0.01, 0.10, 0.33, 0.50, 0.75, 1.00, 2.00, 5.00, 10.00 and 15.00 bars.

Organic matter was determined by the Walkey and Black modified method (Walkey and Black, 1933) and pH was measured on saturation extracts by standard methods. Calcium and magnesium were determined on the saturation extract with EDTA, and sodium was measured with a flame photometer (U.S. Salinity Lab. Staff, 1954). Based on these data, the sodium adsorption ratio (SAR) for each soil sample was calculated.

Soil Conditioning Experiments

Seven commercially available soil conditioners were tested for their effectiveness in reducing soil crusting and their influence on sesame seedling emergence. The soil conditioners are described in Table 1. The experiments were conducted under greenhouse conditions in hard plastic pots and wooden boxes during the period March 21 to June 22, 1977. Daily evaporation was measured with a 152.5 mm diameter free evaporating surface. Evaporation data are shown in Appendix B (Table 19).

Pot Experiments

Square plastic containers (78 mm on the bottom edge, 94 mm at the top edge, 78 mm deep, and having four lateral holes for drainage) were used. The bottoms of the containers, including the lateral holes, were lined with four sheets of newsprint. An 80 g sample of air dried coarse sand was placed in the bottom of each pot--this formed a 7 mm layer. Samples of the test soils that had been equilibrated to a soil matric potential of about -3.0 bars and sieved through an 8 mm square-hole sieve were weighed and placed in the pot. The weight of the test soil used was sufficient to produce a 40 mm layer in the pot.

In preliminary studies conducted with Parlo soil, it was found that sowing of 8 or more scattered sesame seeds per pot resulted in the crust being lifted by the combined effort of the emerging seedlings. Because of this, a density of four seeds per pot was selected as adequate for this study. The four sesame seeds (variety Aceitera) were placed on the soil surface, each one at a point halfway between one

Table 1. List of soil conditioners, manufacturers, characteristics, and market prices[a]

Material	Manufacturer	Type of material	Particle charge	Market price $/kg or $/l
AMSCO Res 4072	Union Oil Company of California, LaMirada, California	Liquid, styrene-butadiene copolymer, latex-in-water emulsion	None	1.18
Aerospray 70	American Cyanamid Co., Wayne, New Jersey	Liquid, polyvinyl acetate, resin-in-water emulsion	Cationic	1.08
Cationic Asphalt Emulsion	Bitumeca S.A., Caracas, Venezuela	Liquid, cationic asphalt emulsion	Cationic	0.19
Coherex	Witco Chemical Corporation, Bakersfield, California	Liquid, petroleum resin-in-water emulsion	None	0.24
Elvanol 71-30	du Pont de Nemours and Co., Inc., Universal City, Cal.	Powder, polyvinyl alcohol, solution in water	None	1.93
Humofina B-2864	Labofina S.A., Brussels, Belgium	Liquid, anionic asphalt emulsion	Anionic	0.23
Technical Protein Colloid 5-V	Swift Chemical Co., Chicago, Illinois	Dry granular, protein colloid, 15-16 % N, solution in water	Cationic	1.58

[a]This information is included for convenience of readers and not to imply endorsement by the author.

corner and the central point of the pot. The seeds were covered with a weighed soil sample sufficient to make a 20 mm layer. Each soil layer was packed by gently shaking and tapping the pot.

Estimations of the initial soil bulk densities in the pots indicated the following values in g/cm^3: 1.44 in Guanipa, 0.99 in Turen, 0.91 in Nontilled Turen, 0.91 in Agua Blanca, 0.96 in Parlo, and 0.95 in Nibley.

Pot Experiment 1. This experiment was carried out on Parlo soil. Each treatment consisted of an amount and a dilution of a particular soil conditioner applied on a pot. A list of the soil conditioners is given in Table 1. Products such as Elvanol 71-30 and Technical Protein Colloid 5-V, which are sold in the solid state, needed to be dissolved. Water heated to 90 C was used as the solvent. Once dissolved, these solutions were stable at ambient temperature.

The treatments were applied immediately following planting. Twenty-six treatments, replicated eight times were performed. The treatments are given in Table 2. The chemicals were applied on the soil surface using a hand pump sprayer.

The pots were placed side by side and their location randomized within each replication. Two days after sowing, all of the treatments, except the subwatered control treatment, were subjected to a 50 mm/hour intensity simulated rain for 30 minutes. The control subwatered treatment was watered by placing the pots in a tray containing water; thus, the soil was wetted from the bottom. The pots were left in the tray until the soil surface looked saturated.

The simulated rain was provided by a rainfall simulator described by Malkuti (1975, p. 22) as follows:

Table 2. List of treatments in Pot Experiment 1

Chemical	Treatment No.	Rate per m^2	Dilution ratio[a]	Diluted volume l/ha[b]	Chemical cost $/ha[b]
None - Control	1				
Subwatered control	2				
Technical Protein	3	3 g	1:100	500	7.90
Colloid 5-V	4	6 g	1:100	1000	15.80
Coherex	5	20 ml	1:10	333	8.00
	6	40 ml	1:10	667	16.00
AMSCO Res 4072	7	4 ml	1:50	333	7.87
	8	8 ml	1:50	667	15.74
	9	4 ml	1:100	667	7.87
	10	8 ml	1:100	1333	15.74
Aerospray 70	11	4.5 ml	1:50	375	8.10
	12	9.0 ml	1:50	750	16.20
	13	4.5 ml	1:100	750	8.10
	14	9.0 ml	1:100	1500	16.20
Elvanol 71-30	15	2.5 g	1:100	417	8.04
	16	5.0 g	1:100	833	16.08
	17	2.5 g	1:200	833	8.04
	18	5.0 g	1:200	1667	16.08
Humofina B-2864	19	25 ml	1:10	417	9.58
	20	50 ml	1:10	833	19.17
	21	25 ml	1:20	833	9.58
	22	50 ml	1:20	1667	19.17
Cationic Asphalt	23	25 ml	1:10	417	7.92
Emulsion	24	50 ml	1:10	833	15.83
	25	25 ml	1:20	833	7.92
	26	50 ml	1:20	1667	15.83

[a]Chemical-to-final volume ratio.
[b]Values are referred to application on 1/6 of the total surface.

1. Water chamber--60.92 centimeter (2 feet) by 60.92 cm by 2.54 cm (one inch) box made of plexiglass.
2. Flow meter--which is attached to the reservoir to measure the rate of flow regulated by the tubing clamp.
3. Reservoir--5 gallon polyethylene container which provided distilled water to the water chamber through a small tube.
4. Electric motor--powered by a 6 volt battery to rotate the water chamber for better distribution of the rain drops.
5. Hypodermic needles--517 stainless steel tubes with 0.159 millimeters (0.00625 inches) wall thickness, 0.635 mm (0.025 inches) outer diameter, projecting 3.175 mm (1/8 inch) above and 9.525 mm (3.8 inch) below the plexiglass.

In this study, the reservoir was filled with tap water instead of distilled water. The apparatus produces water drops 2.5 mm in diameter. The vertical falling distance of the water drops was regulated at 1.05 m which gave an impact velocity of about 4.5 m/sec at the soil surface. Since the rain was applied at 50 mm/hour intensity for a 30-minute period, the kinetic energy of the rainfall was 253 joules/m^2.

Using this apparatus, it was possible to water 25 pots simultaneously. The pots were placed on a flat wooden board that was rotated by hand to improve the distribution of the raindrops. The time necessary to reach ponding conditions in each treatment was recorded.

Five days after the first irrigation, the pots were weighed and a slight watering was given to all the treatments. The pots were set in a pan and water was added to the pan to form a layer 30 mm deep. Each pot was allowed to soak up water until its weight was 10 g greater than its weight at the beginning of the experiment. This method of watering the soil did not disturb the soil crust that had formed.

Seedling emergence counts were taken daily until no additional emergence occurred in any of the pots for a 24-hour period. When seedling emergence stopped, the surface crust strength was measured mechanically. In four of the eight replications, the soil crust strength was measured using a modified version of the Arndt method (Arndt, 1965a) (see Figure 1). For the other four replications, the soil crust strength measurement was made using a pocket penetrometer (Model CL-700, Soiltest Inc., Chicago, Illinois). (See Figure 2.)

In the modified Arndt method, a measurement is made of the energy required for a hemisphere-shaped cap, 9 mm in diameter, to pierce the crust from 15 mm below the soil surface. That energy is termed impedance. To accomplish the measurement, pots were provided with a hard plastic tube in the center of the container. The tube was opened at both ends and held a plastic rod with a cap.

The device used to measure impedance consisted of a simple beam with equal size arms (250 mm). One end had a probe attached to push the plastic rods that were installed in the individual pots. A 1-liter container was hung on the other end. Water was added to the container until the crust broke. The weight of the water needed to break the crust was recorded as soil impedance. In this experiment, the device was slightly modified from that used by Arndt. A microswitch was used to activate a normally-open water valve. When the crust ruptured, the beam hit the microswitch which, in turn, closed the valve that supplied water to the container. The addition of the microswitch increased the precision of the measurement.

In the penetrometer method, the soil crust strength was measured in terms of the pressure needed to vertically penetrate the first 6 mm of the soil surface. The penetrometer tip had a diameter of 6 mm and the readings could be made in a range of 0.2 to 4.5 kg/cm^2. A single measurement was made in the center of the soil surface on each pot.

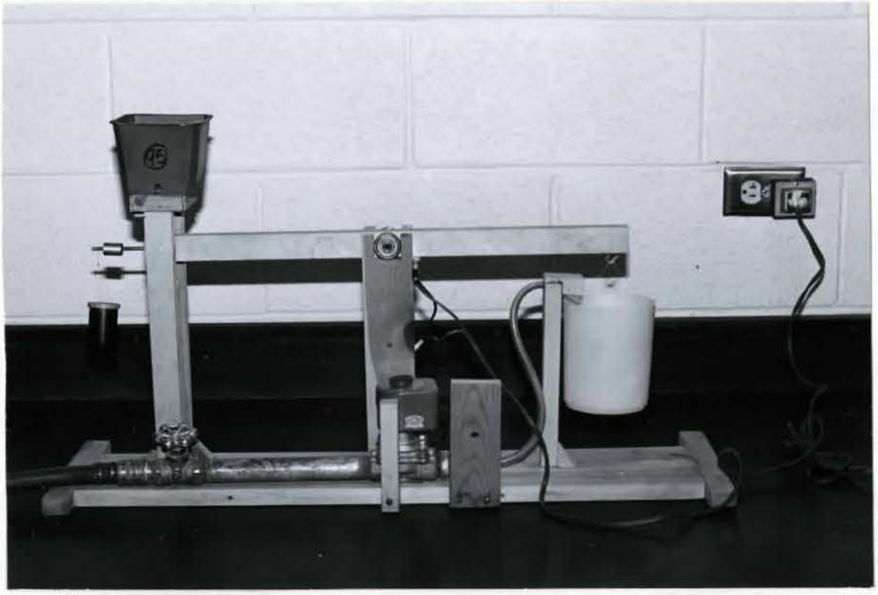

Figure 1. Apparatus that was used for soil crust impedance measurements. (Modified from Arndt, 1965a.)

Figure 2. Pocket penetrometer that was used for measurement of soil crust resistance to penetration.

Pot Experiment 2. Twenty-five treatments were applied on Parlo soil. At this time it was intended to recheck the behavior of three of the chemicals that showed a relatively great enhancement to sesame seedling emergence in Experiment 1. The treatments are shown in Table 3. The procedure was essentially the same as that followed in Experiment 1. Treatments 3 and 4, however, were different because the chemical was not sprayed on the soil surface as before. Instead, a previously prepared soil-chemical mix was substituted for the top 10 mm of soil in the pot. The mix was made by applying the chemical to the moist soil at a specified rate. The soil was allowed to dry, then brought to a matric potential of about -3 bars and passed through an 8 mm square-hole sieve. Finally the mix was placed by weight on the top of the soil in the pot.

Pot Experiment 3. From Pot Experiments 1 and 2, two chemicals were selected which had given good performance in increasing seedling emergence. In this experiment such chemicals were simultaneously tested on the six soils in the study. The treatments applied on each soil are given in Table 4. Two replications per treatment were carried out at the same time, one for impedance measurement and the other for resistance to penetration. For the control treatment the replications were two-fold, thus two measurements of impedance and resistance to penetration were taken. Limitations of materials and of time to prepare the pots made it difficult to run more replications at one time. However, the procedure was repeated four times to complete eight replications per treatment.

Preparation of the pots with the different soils was essentially the same as in Pot Experiment 1. The exception was the Guanipa soil

Table 3. List of treatments in Pot Experiment 2

Chemical	Treatment No.	Rate per m^2	Dilution ratio[a]	Diluted volume l/ha[b]	Chemical cost $/ha[b]
None - Control	1				
Subwatered control	2				
Elvanol 71-30 1 cm layer 0.02%	3	1.82 g	1:400	1200	5.80
Humofina B-2864 1 cm layer 0.40%	4	36.40 ml	1:20	1200	14.00
Elvanol 71-30	5	1.25 g	1:100	20	4.02
	6	1.25 g	1:200	417	4.02
	7	1.25 g	1:400	833	4.02
	8	2.50 g	1:100	417	8.04
	9	2.50 g	1:200	833	8.04
	10	2.50 g	1:400	1667	8.04
Technical Protein Colloid 5-V	11	3.0 g	1:50	250	7.90
	12	3.0 g	1:100	500	7.90
	13	3.0 g	1:200	1000	7.90
	14	6.0 g	1:50	500	15.80
	15	6.0 g	1:100	1000	15.80
	16	6.0 g	1:200	2000	15.80
Humafina B-2864	17	25.0 ml	1:5	208	9.58
	18	25.0 ml	1:10	417	9.58
	19	25.0 ml	1:20	833	9.58
	20	50.0 ml	1:5	417	19.17
Humofina B-2864	21	50.0 ml	1:10	833	19.17
	22	50.0 ml	1:20	1667	19.17
	23	75.0 ml	1:5	625	28.75
	24	75.0 ml	1:10	1250	28.75
	25	75.0 ml	1:20	2500	28.75

[a]Chemical-to-final volume ratio.
[b]Values are referred to application on 1/6 of the total surface.

Table 4. List of treatments in Pot Experiment 3

Chemical	Treatment No.	Rate per m^2	Dilution ratio[a]	Diluted volume l/ha[b]	Chemical cost $/ha[b]
None - Control	1				
Subwatered control	2				
Elvanol 71-30	3	4 g	1:150	1000	12.87
	4	8 g	1:150	2000	25.73
	5	12 g	1:100	2000	38:60
	6	4 g	1:300	2000	12.87
	7	8 g	1:300	4000	25.73
	8	12 g	1:200	4000	38.60
	9	16 g	1:100	2667	51.47
Humofina B-2864	10	40 ml	1:15	1000	15.33
	11	80 ml	1:15	2000	30.66
	12	120 ml	1:10	2000	46.00
	13	40 ml	1:30	2000	15.33
	14	80 ml	1:30	4000	30.66
	15	120 ml	1:20	4000	46.00
	16	160 ml	1:10	2667	61.33

[a]Chemical-to-final volume ratio.
[b]Values are referred to application on 1/6 of the total surface.

pots; due to the sandy texture of the soil, the sand layer was not placed in the bottom of the pots.

In some treatments on Turen soil, Nontilled Turen soil and Agua Blanca soil, the impedance was greater than 1,000 g, hence the measurement could not be made using the simple beam as before. In these cases the impedance was measured by hand pressing the plastic rod installed in the pots against a probe mounted over a 10,000 g precision top loading balance. The soil impedance was recorded by noting the highest reading before the very sharp decline in scale reading when the crust was broken. The measurement may be criticized for the use of the hands to exert the pressure, but care was taken to apply the pressure slowly, thus minimizing the error in the measurement.

In the last run, the evaporation was extremely high. The soils dried out so rapidly that there was no sesame seedling emergence. This run was concluded 6 days after rewatering and soil crust strengths were measured at that time.

Box Experiments

Square wooden boxes 520 mm in width and length and 120 mm deep were used to study the effect of the chemicals on a larger surface area and with the sesame planted in rows (this more closely approximates field conditions). Drainage was prevented by sealing the joints of the boxes. The soils tested were previously brought to a matric potential of about -3 bars and sieved through a 8 mm square-hole sieve. The seeds were planted 20 mm deep in the soil in a single row running diagonally across the box with a plant density of 100 seeds/m (72 seeds in the diagonal row).

<u>Box Experiment 1</u>. Eight boxes were prepared with Parlo soil. On each box, a diagonal furrow 100 mm wide at the top and with a base about 35 mm deeper than the original soil surface was formed. A 90 degree angle wood piece was used to shape the furrow. The seeds were buried 20 mm below the bottom of the furrow. After planting, one treatment per box was applied directly over the furrow space. The treatments are given in Table 5.

Table 5. List of treatments in Box Experiment 1

Chemical	Treatment No.	Rate per m^2	Dilution ratio[a]	Diluted volume l/ha[b]	Chemical cost $/ha[b]
None - Control	1				
Tech. Prot. Colloid 5-V	2	6 g	1:100	1000	15.80
Coherex	3	40 ml	1:10	667	16.00
AMSCO Res 4072	4	8 ml	1:50	667	15.73
Aerospray 70	5	9 ml	1:50	750	16.20
Elvanol 71-30	6	5 g	1:100	833	16.08
Humofina B-2864	7	50 ml	1:10	833	19.17
Cat. Asph. Emulsion	8	50 ml	1:10	833	15.83

[a]Chemical-to-final volume ratio.
[b]Values refer to application of 1/6 of the total surface.

Two days after seeding, each box was subjected to a 50 mm/hour intensity simulated rain for 30 minutes. In each treatment, the time to reach ponding conditions on the furrow and on the flat surface was recorded. No additional water was applied during the rest of the test. Seedling emergence was recorded daily. When no more seedlings emerged in a 24-hour period, the study was concluded. A total of ten penetrometer readings was made perpendicular to the furrow. An equal number of readings was also taken on the adjacent flat surface.

The treatments were replicated at a different time following the same procedure.

Box Experiment 2. In this experiment the effectiveness of ground corncob in increasing sesame seedling emergence was tested in two ways, (1) corncob alone on the seed row, and (2) corncob on the seed row stabilized with one of the two chemicals. Eight boxes were prepared with Parlo soils. In two boxes the seeding was done in a flat surface diagonal line and in the rest of the boxes the seeding was done in diagonal furrows. The treatments (shown in Table 6) were repeated at a different time.

The procedures followed for watering, recording the sesame seedling emergence, and making measurements of crust resistance to penetration were the same as used in Box Experiment 1.

Box Experiment 3. Five boxes were prepared with Parlo soil and three with Agua Blanca soil. Planting was done on flat surface diagonal rows. The treatments (Table 7) were applied on the entire soil surface of the box. The treatments were not replicated. The rest of the procedure was the same as that followed in Box Experiment 1.

Table 6. List of treatments in Box Experiment 2

Material	Treatment No.	Surface shape	Rate /m^2	Dilution ratio[a]	Diluted volume l/ha[b]	Chemical cost $/ha[b]
None - Control	1	flat				
None - Control	2	furrow				
Elvanol 71-30	3	flat	4 g	1:300	2000	12.87
Elvanol 71-30	4	furrow	4 g	1:300	2000	12.87
Humofina B-2864	5	furrow	40 ml	1:30	2000	15.33
Ground corncob[c]	6	furrow				
Ground corncob[c] + Elvanol 71-30	7	furrow	4 g	1:300	2000	12.87
Ground corncob[c] + Humofina B-2864	8	furrow	40 ml	1:30	2000	15.33

[a] Chemical-to-final volume ratio.
[b] Values refer to application on 1/6 of the total surface.
[c] 50 cm^3/m linear row.

Table 7. List of treatments in Box Experiment 3

Chemical	Soil	Treatment No.	Rate per m^2	Dilution ratio[a]	Diluted volume l/ha[b]	Chemical cost $/ha[b]
None - Control	Parlo	1				
Elvanol 71-30	Parlo	2	4 g	1:300	2000	12.87
Humofina B-2864	Parlo	3	40 ml	1:15	1000	15.33
Elvanol 71-30	Parlo	4	2 g	1:300	1000	6.44
Humofina B-2864	Parlo	5	20 ml	1:30	1000	7.67
None - Control	Agua Blanca	6				
Elvanol 71-30	Agua Blanca	7	4 g	1:300	2000	12.87
Humafina B-2864	Agua Blanca	8	40 ml	1:15	1000	15.33

[a]Chemical-to-final volume ratio.
[b]Values are referred to application on 1/6 of the total surface.

Aggregate Stability

Samples of all soils under study were brought to a matric potential of about -3 bars, and then sieved through an 8 mm square-hole sieve. Parlo soil was divided into eight fractions, seven of which were treated with different chemicals and one was not treated, to be used as a control. Soil samples other than Parlo were divided into three fractions, two of which received either Elvanol 71-30 or Humofina B-2864 and the third was nontreated.

The chemicals were sprayed on the soils at the rates and dilutions specified in Table 8. Immediately after spraying, the soil and chemical were gently mixed by hand to improve the distribution of the chemical. Treated and nontreated soil samples were air dried and again passed through a 8 mm square-hole sieve.

Table 8. List of treatments with soil conditioners used to evaluate aggregate stability

Chemical	Treatment No.	Rate % by weight	Dilution ratio[a]	Cost $/ton of soil
None	1			
Elvanol 71-30	2	0.05	1:400	0.97
Humofina B-2864	3	0.50	1:40	1.15
Aerospray 70	4	0.09	1:250	0.97
AMSCO Res 4072	5	0.08	1:250	0.94
Cationic Asphalt Emulsion	6	0.50	1:40	0.95
Coherex	7	0.40	1:50	0.96
Technical Protein Colloid 5-V	8	0.06	1:300	0.95

[a]Chemical to final volume ratio.

Subsamples (80 g for Guanipa soil and 40 g for other soils) of each treatment were used to determine the percentage of the silt plus clay fraction remaining as water-stable aggregates with a diameter > 0.05 mm. These determinations were made in triplicate at two different times:

1. The soil sample was added to a 1-liter cylinder containing distilled water, and then the water level was brought to the 1,000 ml mark. After the soil sample had soaked 15 minutes the cylinder was turned end over end a total of 10 times per minute and placed upright. Then the hydrometer method (Day, 1965) was used to determine the percentage of silt plus clay (based on total soil dry weight) that was detached from aggregates > 0.05 mm diameter. Hydrometer readings were taken at 30, 40 and 60 seconds.

2. After the first determination, an additional 15-minute soaking was given to the soil sample. Then the cylinder was turned end over end a total of 20 times in 2 minutes and placed upright. Again hydrometer readings were taken. This series of readings was then taken to obtain the percentage of silt plus clay detached from aggregates > 0.05 mm diameter when the soil was subjected to a longer time of soaking and shaking.

The total amount of silt plus clay in the soils (based on total soil dry weight) had been determined previously by a standard mechanical analysis technique (Day, 1965).

The percentage of the silt plus clay fraction remaining in water-stable aggregates with a diameter > 0.05 mm was calculated each time by subtracting the silt plus clay detached from aggregates > 0.05 mm diameter from the total amount of silt plus clay. Then this difference was divided by the total amount of silt plus clay and expressed as a percentage.

RESULTS AND DISCUSSION

Relationship between Precipitation and Yield of Sesame in Venezuela

Annual sesame yield in Venezuela for the period 1956-1976, and May through February precipitation data for the same period obtained from the Colonia Turen meteorological station (Portuguesa State, Venezuela) are summarized in Table 9. The precipitation data--corresponding to four planting dates--are summed for three time periods as follows.

X_1 is the accumulated precipitation (mm) from May 1 to the planting date. This precipitation is related to the soil moisture in the profile at the time of planting.

X_2 represents the accumulated precipitation (mm) from January 1 to the last day of February. This precipitation occurred after the seedling period and before the cutting of the plants.

X_3 is the accumulated precipitation (mm) for the 20 days following the planting date. This is the precipitation that falls shortly after planting and is related to the problem of soil crusting.

Two multiple linear regression equations were calculated to fit the data in Table 9. The regression coefficients for each equation are given in Table 10. The coefficients obtained for X_1 and X_2 showed that the precipitation which fell from May 1 to the planting day and from January 1 to the last day of February increased sesame yields. The negative signs of the X_3 coefficients indicate that the accumulated

Table 9. Annual sesame yield in Venezuela (kg/ha)[a] and precipitation data (mm) obtained from Colonia Turen meteorological station (Portuguesa State, Venezuela)[b] referred to four planting dates. X_1, X_2, and X_3 denote rainfall incurred in the periods May 1 to the planting date, January 1 to the last day of February, and the 20 days following the planting date, respectively.

Harvest year	Sesame yield	Planting dates: November 30 X_1	X_2	X_3	December 5 X_1	X_2	X_3	December 10 X_1	X_2	X_3	December 15 X_1	X_2	X_3
1957	530	1138	0.3	6.3	1139	0.3	5.7	1144	0.3	0.0	1144	0.3	0.0
1958	522	1215	0.0	48.6	1232	0.0	31.5	1232	0.0	31.8	1261	0.0	1.3
1959	398	1131	0.3	4.3	1131	0.3	21.3	1131	0.3	21.3	1135	0.3	17.0
1960	363	1489	14.8	14.0	1498	14.8	8.3	1498	14.8	49.6	1498	14.8	49.2
1961	461	1272	0.0	36.7	1308	0.0	0.2	1308	0.0	0.0	1308	0.0	0.0
1962	495	1340	0.1	25.3	1365	0.1	0.3	1365	0.1	0.2	1365	0.1	0.2
1963	502	1207	9.7	3.4	1207	9.7	3.4	1211	9.7	0.0	1211	9.7	1.6
1964	681	1439	2.0	3.7	1439	2.0	3.7	1442	2.0	1.0	1443	2.0	0.0
1965	621	1250	13.2	5.4	1256	13.2	0.0	1256	13.2	0.0	1256	13.2	0.1
1966	634	1671	17.8	1.1	1671	17.8	1.2	1671	17.8	2.1	1672	17.8	8.5
1967	604	1203	3.5	27.5	1205	3.5	23.4	1228	3.5	2.1	1228	3.5	2.1
1968	544	1295	5.0	59.3	1295	5.0	59.6	1327	5.0	28.2	1327	5.0	28.2
1969	538	1370	23.5	37.1	1672	23.5	38.8	1379	23.5	31.1	1379	23.5	34.2
1970	705	1296	67.6	43.6	1299	67.6	41.1	1326	67.6	14.1	1337	67.6	2.8
1971	555	1400	13.7	46.1	1423	13.7	27.5	1435	13.7	16.9	1441	13.7	16.4
1972	550	1180	40.3	14.0	1180	40.3	14.0	1184	40.3	20.2	1184	40.3	22.4
1973	519	1411	0.0	72.0	1421	0.0	62.5	1471	0.0	16.3	1483	0.0	2.2
1974	413	1222	8.5	33.8	1222	8.5	43.2	1256	8.5	9.6	1256	8.5	9.6
1975	536	1078	0.6	4.1	1078	0.6	4.1	1082	0.6	0.1	1083	0.6	0.0
1976	484	1455	0.1	50.8	1455	0.1	51.2	1485	0.1	22.6	1505	0.1	2.9

[a]Source: Leon, Mazzani and Gomez (1972), MAC (1975), FONALI (1976). [b]Source: Oñate J. (1977).

Table 10. Regression coefficients obtained by regression of 20 years of sesame yield data (kg/ha) against 20 years of precipitation data (mm). Equation 1 includes only two precipitation variables (X_1 and X_2 of Table 9) and thus has only three regression coefficients (b_0, b_1 and b_2). Equation 2 has an additional precipitation variable (X_3 of Table 9) and, consequently, an additional regression coefficient (b_3).

Date	Equation	Regression coefficients				Determination coefficients
		b_0	b_1	b_2	b_3	(r^2)
Nov 30	1	401.5	0.08	2.23		0.21*
	2	399.3	0.09	2.23	-0.34	0.22*
Dec 5	1	449.2	0.04	2.25		0.20*
	2	448.6	0.05	2.30	-0.50	0.22*
Dec 10	1	410.5	0.07	2.25		0.21*
	2	357.0	0.15	2.71	-3.45	0.52***
Dec 15	1	408.6	0.08	2.25		0.21*
	2	346.4	0.14	2.93	-3.71	0.52***

*Significant at the 5 percent level.
***Significant at the 0.1 percent level.

precipitation for the 20 days following the planting day caused a detrimental effect on the sesame yield. Later in the planting season (December 10 and December 15) this effect was even greater. Two facts may explain these results: (1) at the later dates, a greater number of hectares have already been planted, and a lesser proportion of the crust affected area is replanted; and (2) late in the planting season the dry season is more advanced, the soil surface is drier, and even a slight precipitation can result in the formation of a hard soil crust.

Let us consider a hypothetical situation in which no precipitation falls in the 20 days following planting and furthermore, the planting date is either December 10 or December 15. Based on equation 2, it can be speculated that sesame yields would be an average of about 40 kg/ha greater than the average actual yield.

Soil Characteristics

Particle size distribution (expressed as percent of dry soil) and texture of the soils used in the study are summarized in Table 11. Even though the sampling distance between Turen and Nontilled Turen soils was only 30 meters, their particle size distributions were noticeably different.

Soil water characteristic curves for all the study soils are shown in Figure 3. It is clear that between -0.1 and -15.0 bars much less water was released by the Guanipa soil than by the other soils. Undoubtedly, this was a consequence of its very low silt plus clay content.

Chemical characteristics of the soils are given in Table 12. The soils did not present problems of either salinity or alkalinity. Since liming is a common practice in the management of Guanipa soil, the pH of native soil would undoubtedly be lower than that of the farmed soil used in this study. The reddish color of this soil and the fact that most of its clay-sized materials seem to be amorphous suggest the abundance of iron oxide and hydroxide compounds.

Table 11. Particle size distribution (in dry soil percentage) and soil texture

Soil name	Particle size range (μm)												Soil texture
	Sand						Silt					Clay	
	2000 - 1000	1000 - 500	500 - 250	250 - 100	100 - 50	2000 - 50	50 - 20	20 - 10	10 - 5	5 - 2	50 - 2	< 2	
Guanipa	7.2	13.8	23.0	35.2	14.3	93.5	1.5	.7	.5	.3	3.0	3.5	Sand
Turen	0	0	0.8	10.7	16.5	28.0	28.0	14.3	8.5	6.2	57.0	15.0	Silt loam
Nontilled Turen	0	0	0.7	6.6	9.7	17.0	19.0	18.5	12.2	13.3	63.0	20.0	Silt loam
Agua Blanca	0	0.6	1.6	4.4	5.6	12.2	15.2	14.6	11.6	12.6	54.0	33.8	Silty clay loam
Parlo	0	0	0.8	1.4	6.8	9.0	18.7	17.3	14.0	15.6	65.6	25.4	Silt loam
Nibley	0	0	0.4	2.6	7.0	10.0	16.0	15.2	14.6	15.6	61.4	28.6	Silty clay loam

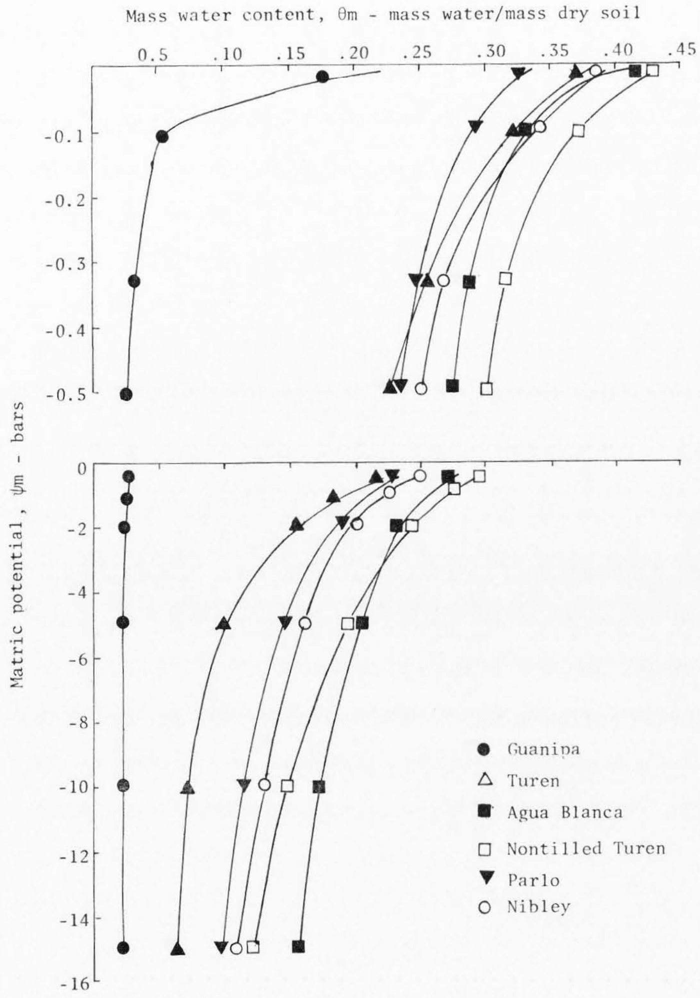

Figure 3. Soil water characteristic curves for the six soils used in the study.

Table 12. Some chemical characteristics of the soils used in the study

Soil name	Organic matter %	Saturated extract pH	Saturated extract EC millimhos/cm	Saturated extract SAR	Mineralogical composition of clay-sized fraction[a]
Guanipa	0.31	7.3	0.34	1.00	Amorphous material and Kaolinite
Turen	3.35	7.8	0.71	0.63	Illite > Kaolinite
Nontilled Turen	8.83	7.9	1.02	0.40	Illite > Kaolinite
Agua Blanca	5.79	7.7	0.68	0.67	Illite >> Kaolinite > Smectite
Parlo	6.60	7.6	0.57	0.36	Kaolinite ≃ Illite > Smectite
Nibley	5.83	8.0	1.03	0.42	Illite > Kaolinite

[a]X-ray diffraction analysis obtained by Utah State University Geology Department.

Aggregate Stability

The percentages of the silt plus clay fraction remaining in water stable aggregates with a diameter of > 0.05 mm are illustrated in Figure 4 for treated and nontreated soil samples.

For each soil, the treated samples showed higher percentages of silt plus clay aggregation than the nontreated samples. Such increases were as great as 100 percent in the soil with the lowest silt plus clay aggregation (Turen soil). In Parlo soil, in which seven soil conditioners were tested, the polyvinyl alcohol (Elvanol 71-30) and the anionic asphalt emulsion (Humofina B-2864) treatments showed the highest aggregate stability. Practically no change in aggregate stability was obtained in this soil when treated with either Coherex or Technical Protein Colloid 5-V. In each one of the soils, Elvanol and Humofina produced similar increases in aggregate stability.

Determinations of the silt plus clay aggregation percentages after 30 minutes soaking and 3 minutes shaking were lower than those in which 15 minutes soaking and 1 minute shaking were given. The decrease in aggregate stability was about the same in each case, i.e., it was independent of the soil and the treatment.

An examination of the organic matter content of the soils (Table 13) and the aggregate stability of nontreated soil samples (Figure 4) does not indicate any correlation. In fact, the soils with the least organic matter content, Guanipa and Turen, have the highest and the lowest aggregate stability, respectively. The cementing action of amorphous material, very common in Guanipa soil, may explain the high aggregate stability exhibited by this soil.

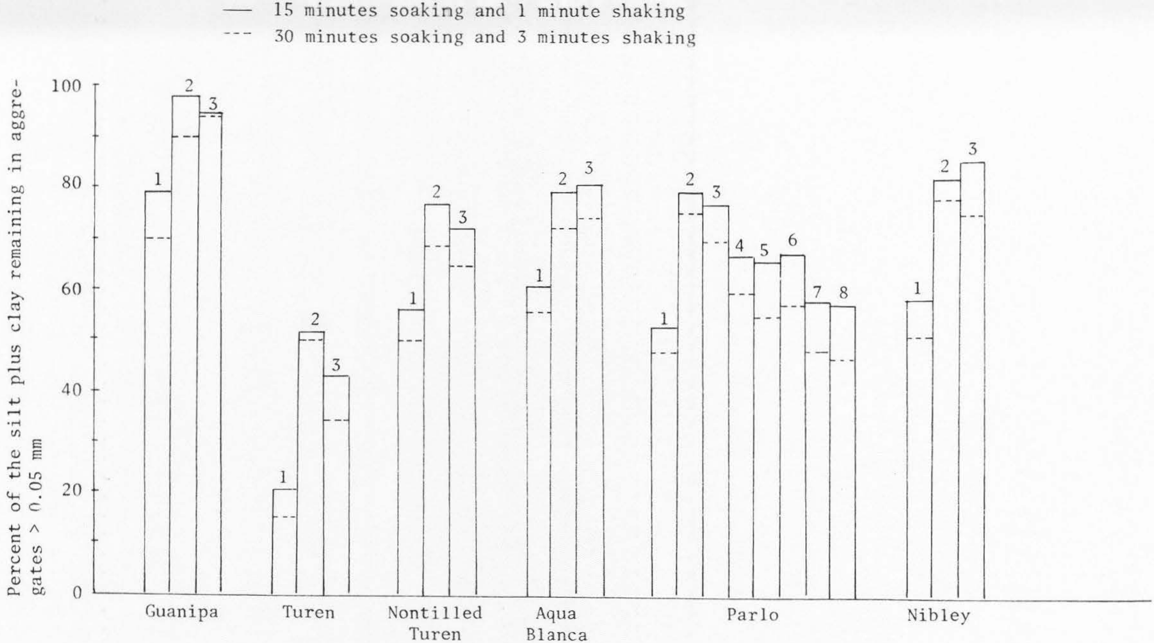

Figure 4. Percentage of the silt loam plus clay soil fraction remaining in water stable aggregates with diameter > 0.05 mm as influenced by treatments with soil conditioners. Numbers on the bars denote the treatments as follows: 1) None, 2) 0.05 percent Elvanol 71-30, 3) 0.5 percent Humofina B-2864, 4) 0.09 percent Aerospray 70, 5) 0.08 percent AMSCO Res 4072, 6) 0.50 percent Cationic Asphalt Emulsion, 7) 0.40 percent Coherex, and 8) 0.06 percent Technical Protein Colloid 5-V.

Table 13. Regression coefficients obtained by regression of the percentage of the silt plus clay fraction that remained as stable aggregate > 0.05 mm (after 15 minutes soaking and 1 minute shaking) against the content of a given size of particles (in percent of dry soil).

Particle fraction (mμ)	Regression coefficients		Determination coefficients (r^2)
	b_0	b_1	
50 - 2 (silt)	78.2	-0.46	0.34
< 2 (clay)	59.0	-0.20	0.01
< 50 (silt + clay)	73.8	-0.27	0.21
100 - 5	91.7	-0.61	0.49
100 - 10	104.2	-1.24	0.85**
100 - 20	88.42	-2.05	0.87**
50 - 20	103.9	-1.86	0.95***

**Significant at the 1 percent level.
***Significant at the 0.1 percent level.

Correlations were computed to test if aggregate stability depends on soil particle distribution. Percentage of the silt plus clay fraction forming aggregates > 0.05 mm--determined in nontreated soil samples after 15 minutes soaking and 1 minute shaking--was correlated with seven ranges of particle size. Ranges of particle size and results are given in Table 13. The aggregate stability was negatively correlated to the content of very fine sand plus coarse silt. However, the aggregate stability was more closely related to the content of particles in the size range 50 - 20 μm than to any other fraction. The low cohesion among silt particles and fine sand causes the few aggregates that are formed, in soils with abundance of these particles, to be easily disrupted by water action

Pot Experiment 1

Figure 5 illustrates the results obtained on Parlo soil in Pot Experiment 1. The time required for ponding, the relative evaporation incurred during the 5 days following watering to soil field capacity, and the percentage of sesame seedling emergence are represented by bars. Each bar is the average of eight replications. The relative evaporation incurred during the 5 days following wetting of the soil to field capacity was determined as follows: the weight of the pots, determined 5 days after watering, was subtracted from the estimated pot weights when the soil was at field capacity. The evaporation was expressed in relation to the mean evaporation obtained in the control treatment. In some of the figures, it is indicated that the average time required to ponding could be higher. Where this is indicated,

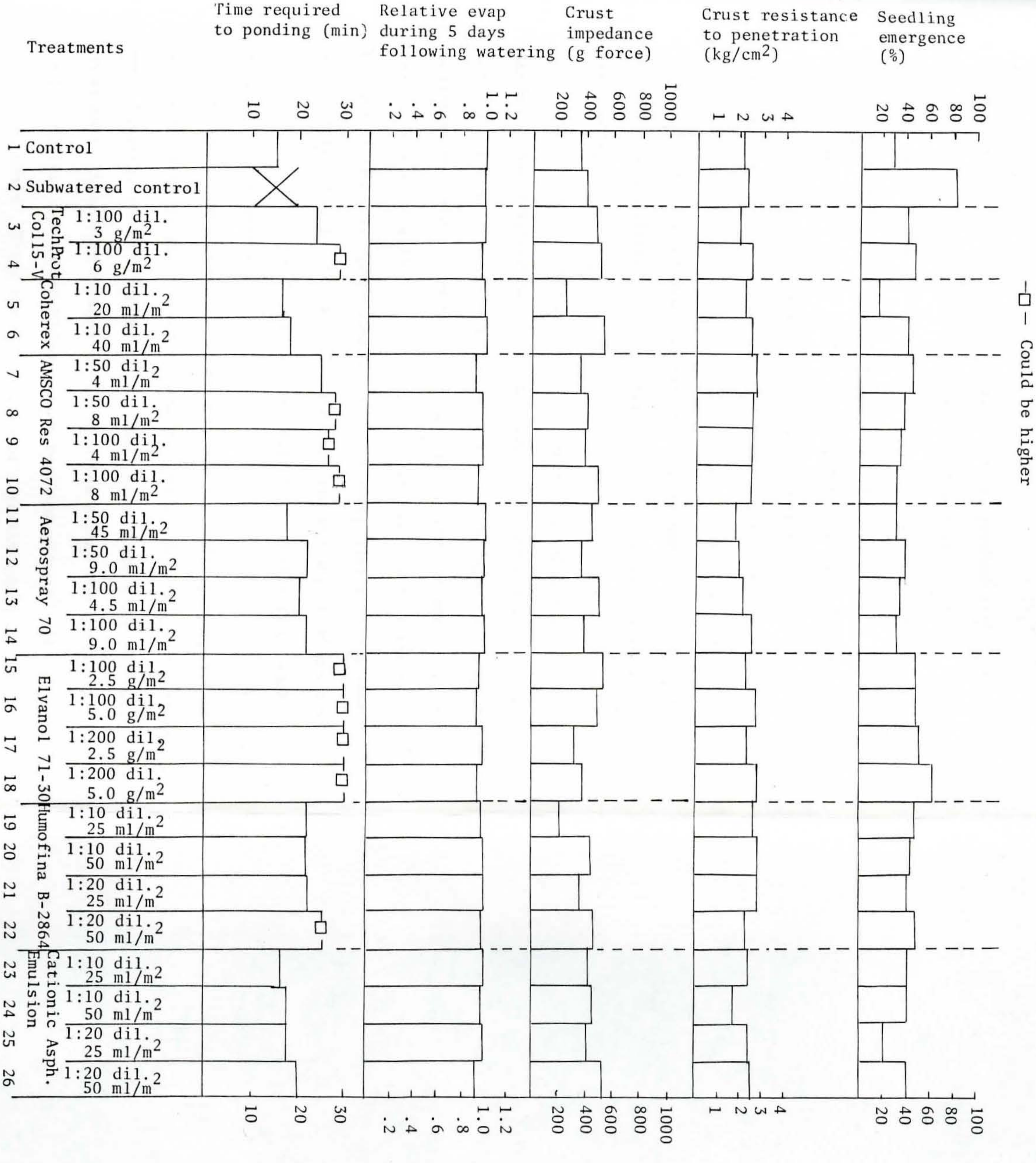

Figure 5. Pot Experiment 1: evaluation of soil crusting in Parlo soil in response to soil surface treatments.

it signified that at least in one replication, ponding conditions were not reached during the 30 minutes of simulated rain. The bars representing crust impedance and crust resistance to penetration are based on the mean obtained from four pots (replications).

During the 30-minute period in which the rain was applied, ponding conditions were not reached in the Elvanol treatment. All of the other chemical treatments delayed the ponding to a certain degree. The effect was a function of the total amount of chemical applied and of its dilution. Coherex and Cationic Asphalt Emulsion showed less effectiveness. No appreciable differences were observed in evaporation among the treatments.

Crust impedance and resistance to penetration showed a general tendency toward higher values in the chemical treatments than in the control. Visual inspection of the crusts after impedance measurements indicated that the crusts formed in the control were thinner than those in the treatments with soil conditioners. It could be that the disruption of soil aggregates caused by the raindrop impact in nontreated soil samples lowered the water infiltration and the degree of wetting of the soil. This resulted in a lower degree of densification upon drying and a thinner soil crust.

In most of the chemical treatments, sesame seedling emergence was higher than in the control treatment. The subwatered control treatment, however, resulted in the highest emergence. Among the chemical treatments, those with Elvanol 71-30, Humofina B-2864 and Technical Protein Colloid 5-V showed higher sesame seedling emergence than the other treatments. There was no evidence of a relationship between sesame seedling emergence and the soil crust strength measurements (impedance and resistance to penetration).

Pot Experiment 2

The graphs illustrating the results for this experiment (Figure 6) follow the same general patterns shown in Pot Experiment 1. Treatments with Elvanol or Humofina previously incorporated into the top 10 mm of soil (Treatments 3 and 4) reached ponding conditions almost at the same time as that of the control. The subwatered control treatment (Treatment 2) and the treatment with the highest rate of Humofina at low dilution (Treatment 23) exhibited lower evaporation than the other treatments.

Most of the treatments reflected lower impedance than the control, while resistance to penetration measurements showed an inverse situation. Treatments in which Elvanol was previously incorporated into the soil showed the lowest value of soil impedance. No relationship could be established between impedance and resistance to penetration.

The percentages of sesame seedling emergence was higher in the treatments in which Elvanol or Humofina were sprayed on the soil surface. As in Pot Experiment 1, the highest percentage of sesame seedling emergence was observed in the subwatered control treatment. Evidently this was associated with the fact that this treatment was not subjected to the raindrop impacts.

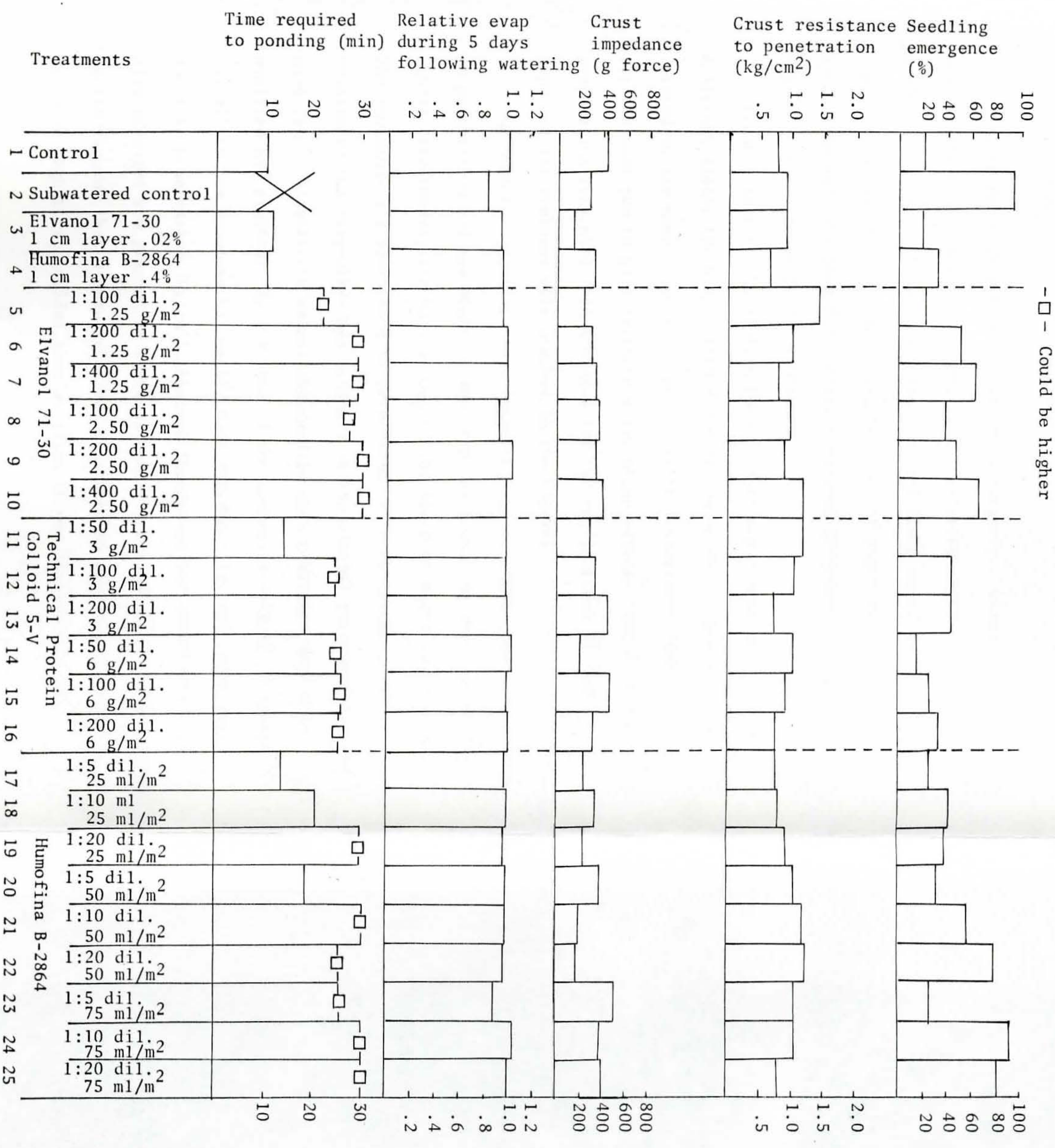

Figure 6. Pot Experiment 2: evaluation of soil crusting in Parlo soil in response to soil surface treatments.

Pot Experiment 3

Results for each soil were graphed separately. In each of these graphs, the time required for ponding and relative evaporation incurred during the 5 days following watering to soil field capacity are illustrated by bars, each one expressing the mean of eight replications. Exceptions were the bars for control treatment (Treatment 1), which represent the mean of 16 replications.

Because some of the replications of this experiment were run at different times, the evaporation for each run of the treatments was related to the mean evaporation of the control treatment (four pots) for the same run to give relative evaporation values. The relative evaporation data were then averaged for the replications of each treatment and the averages were graphed in the figures.

The bars for relative crust impedance and relative crust resistance to penetration are the means of four replications. In the case of the control treatments, the bars represent the means of eight replications. The impedance and resistance to penetration in each treatment were related to the respective measurements in the control treatment for the same run. The relative values obtained in each treatment were then averaged and graphed. In the case of the control treatment (Treatment 1), all of the absolute values of crust impedance (g) and crust resistance to penetration (kg/cm^2) obtained throughout the experiment were also averaged and graphed to serve as comparisons. Where it is indicated on the figures that a mean relative resistance to penetration value could be higher, it implies that at least in one replication the absolute measurement of resistance to penetration exceeded the measuring capacity of the penetrometer.

Guanipa soil

Results in Guanipa soil (Figure 7) indicated that ponded conditions were not reached either in the control or in any of the chemical treatments. Due to its texture, this soil has a naturally high water infiltration rate which was not modified by the soil conditioners.

High rates of Elvanol or Humofina formed a film on the soil surface that decreased the relative evaporation, although it had no appreciable effects on water infiltration. Moreover, high rates of Humofina at high dilutions (Treatments 14, 15, and 16) practically abolished evaporation even after the soil was watered to field capacity.

The highest impedance was obtained with the intermediate rate and high dilution of Humofina (Treatment 15). Observations of the soil crusts after impedance measurements indicated a thicker crust in this treatment than in the others. Apparently Humofina created interaggregate linkages that result in a greater thickness of the soil crust.

Most of the chemical treatments caused an increased resistance to penetration compared to the control. For a given chemical the resistance to penetration increased at higher rates of the chemical. Control subwatering (Treatment 2) indicated higher resistance to penetration than the control treatment. This may be due to a higher degree of wetting in the subwatered control than in the control treatment during the watering.

In general, the chemical treatments exhibited about the same sesame seedling emergence percentage as the control. The highest rate of Elvanol

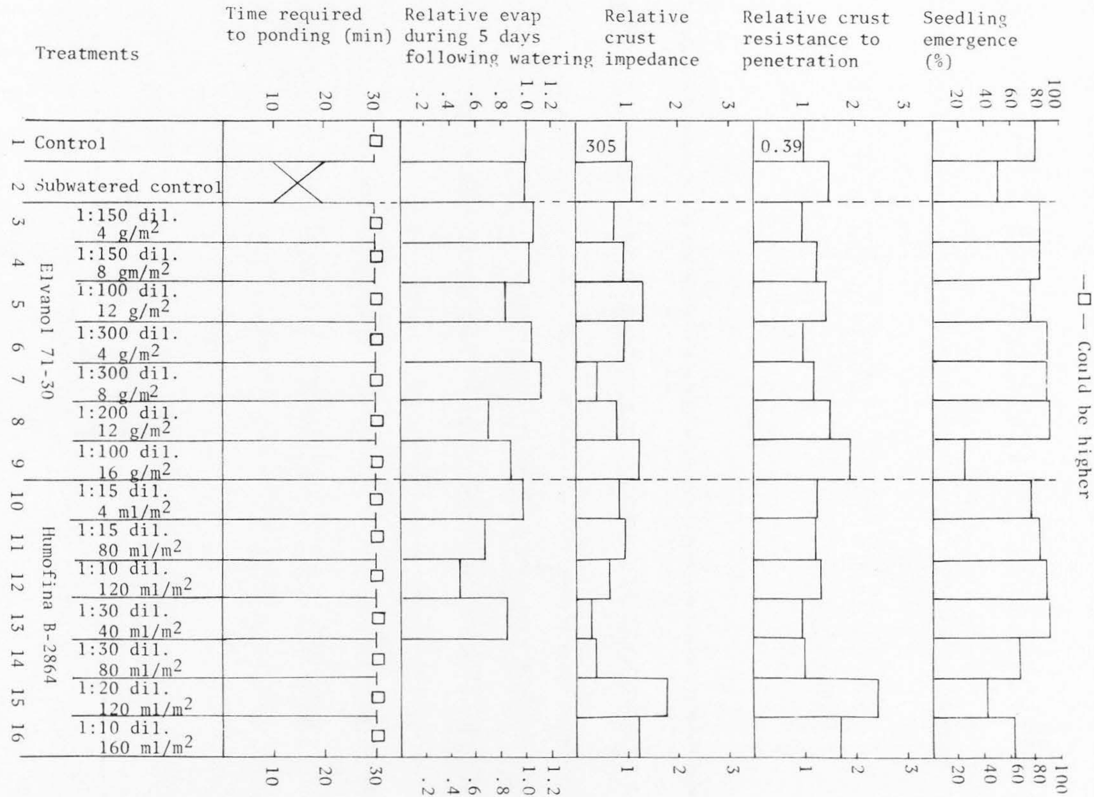

Figure 7. Pot Experiment 3: soil crusting evaluation in Guanipa soil.

(Treatment 9) and high and intermediate rates of Humofina at high dilutions (Treatments 14, 15, and 16) reduced sesame seedling emergence. Such reduction was correlated with high values of soil crust strength. The control subwatered treatment had a lower seedling emergence percentage than the control treatment.

Turen soil

Originally this soil had a low hydraulic conductivity but it was increased by the chemical treatments--as was evidenced by the long time required to reach ponding (Figure 8). In general, the time required for ponding increased as higher rates of chemicals were used; the increment was somewhat independent of the dilution. Humofina treatments showed greater effectiveness than Elvanol in delaying ponding conditions. All of the chemical treatments had similar evaporation. Control and subwatered control treatments showed the highest and the lowest evaporation rate, respectively.

In the impedance determinations, no definite pattern was observed. The chemical treatment impedance were not very different from those of the control and subwatered control treatments. Resistances to penetration were greater in the subwatered control and chemical treatments than in the control.

Seedling emergence was practically prevented in all the treatments. The weak structural stability of this soil (see Figure 4) seemed to be the predominant factor in limiting the effectiveness of the two soil conditioners (Elvanol and Humofina) in enhancing sesame seedling emergence.

Nontilled Turen soil

The low infiltration rate characteristic of this soil was increased

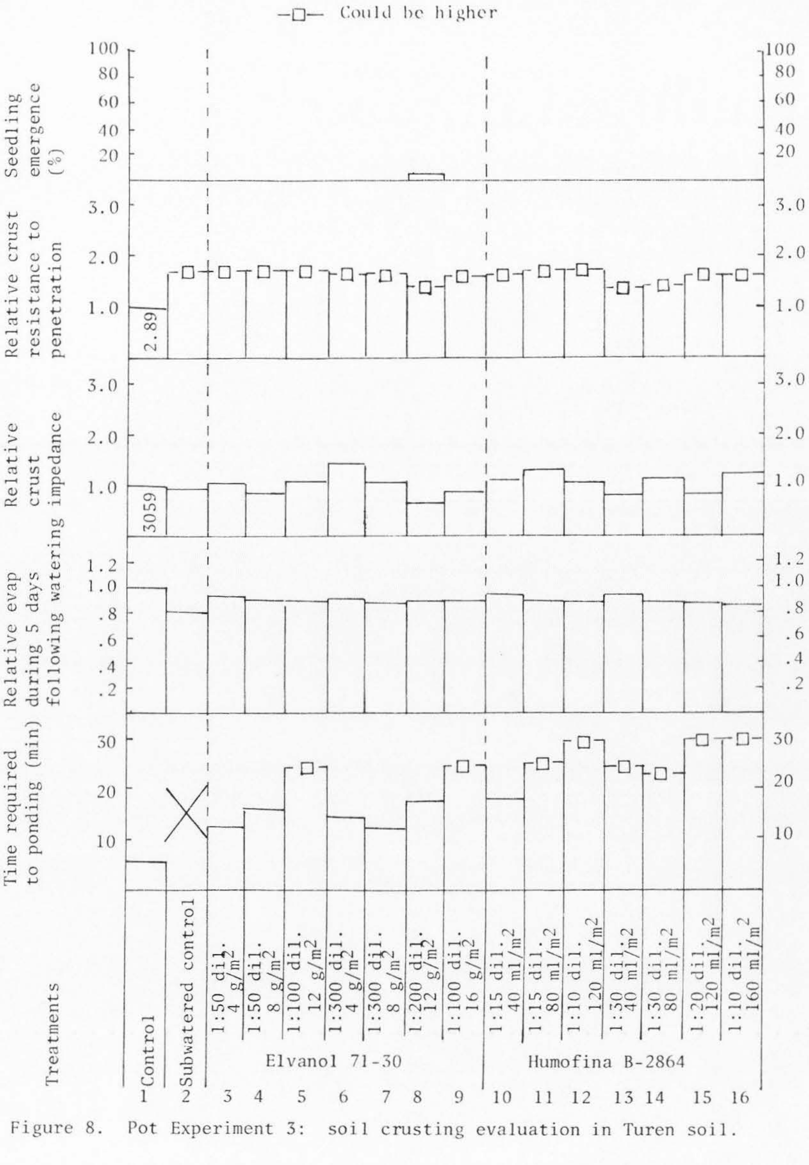

Figure 8. Pot Experiment 3: soil crusting evaluation in Turen soil.

by the chemical treatments--the treatments with Humofina being more effective than those with Elvanol (Figure 9). The soil conditioners slightly lowered the evaporation in relation to the control, but the lowest evaporation was exhibited by the subwatered control treatment.

Chemical treatments reflected higher impedance than the control; exceptions were the higher and intermediate rates of Elvanol at high dilutions. Subwatered control and chemical treatments showed higher impedance than the control treatment.

No seedlings emerged in the control and the subwatered control. Almost all the chemical treatments exhibited some sesame seedling emergence, but without following a definite pattern.

Agua Blanca soil

The results are illustrated in Figure 10. The chemical treatments markedly prevented ponding conditions, but Elvanol was slightly more effective than Humofina. A comparison of the chemical treatments with the control indicated that evaporation was somewhat reduced by the soil conditioners. The lowest evaporation was obtained in the subwatered control treatment.

The soil crust impedance was greatly lessened by the chemical treatments, with Elvanol showing more effectiveness than Humofina. At a given rate, the Elvanol effectiveness in reducing impedance seemed to increase at higher dilutions. Crust resistances to penetration in the chemical treatments were close to those of the control. When the chemical dilution was higher, however, the resistance to penetration decreased.

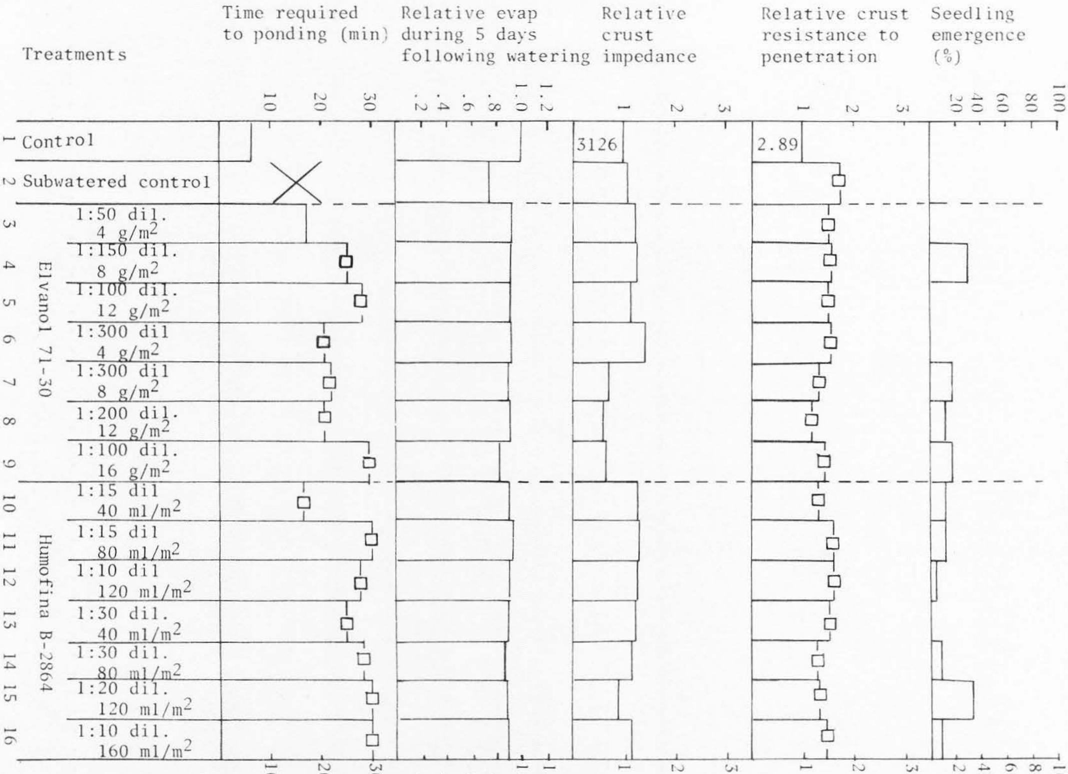

Figure 9. Pot Experiment 3: soil crusting evaluation in Nontilled Turen soil.

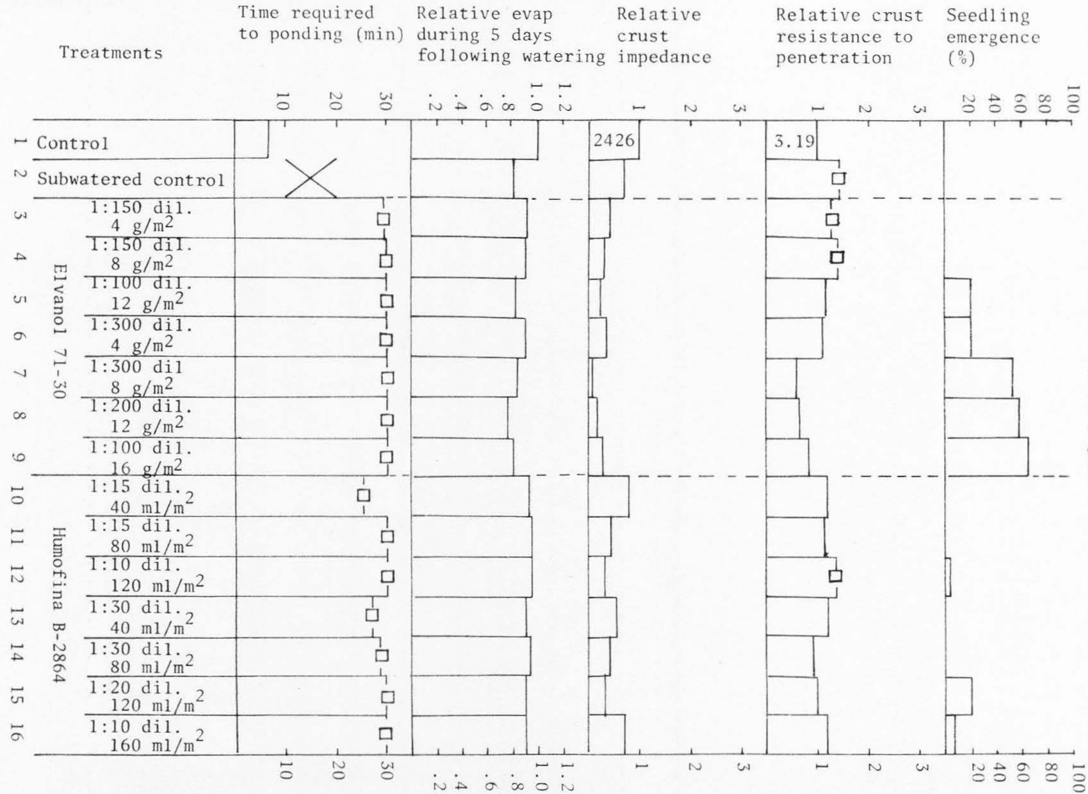

Figure 10. Pot Experiment 3: soil crusting evaluation in Agua Blanca soil.

No sesame seedling emergence occurred either in the control or in the subwatered control treatment. Intermediate and high rates of Elvanol at high dilutions (Treatments 7, 8 and 9) sharply increased seedling emergence. Apparently, these results were associated with the effect of Elvanol in reducing soil crust impedance.

Parlo soil

An examination of Figure 11 shows that Elvanol treatments (Treatments 3 through 9) completely prevented ponding conditions. Low dilutions of Humofina (Treatments 10, 11, 12, and 16) were more efficient in preventing ponding than the treatments with the same chemical at high dilutions. In general, the chemical treatments slightly reduced the evaporation but Elvanol was more effective than Humofina.

The highest impedance and penetrometer readings were observed in the subwatered control. Humofina treatments reflected a higher impedance than those with Elvanol. However, in most of the Elvanol treatments, as in the case of Humofina treatments, the crust impedance measurements were higher than those in the control. The chemical treatments exhibited lower resistance to crust penetration than the control. That reduction was especially marked for intermediate rates of Elvanol at high dulution (Treatment 7 and 8).

The soil conditioners greatly increased sesame seedling emergence as compared with the control. Different rates and dilutions of Elvanol had about the same effect in increasing seedling emergence, while Humofina treatments showed greater variability.

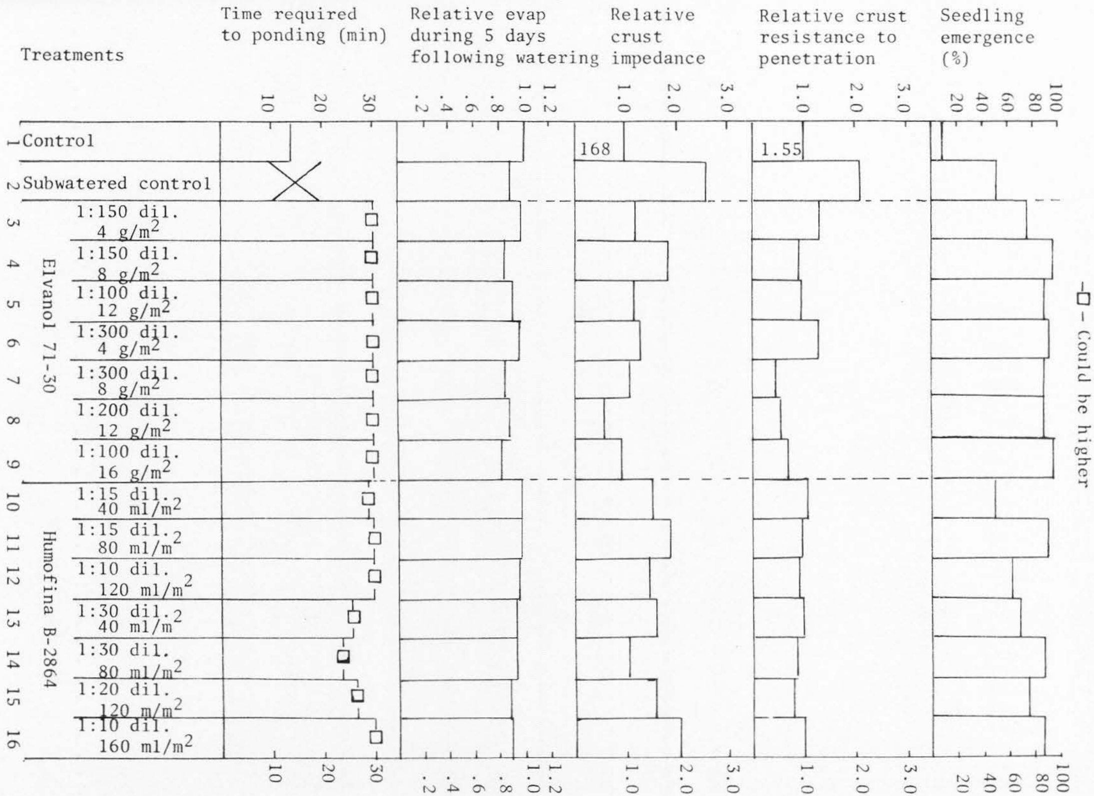

Figure 11. Pot Experiment 3: soil crusting evaluation in Parlo soil.

Nibley soil

Results are illustrated in Figure 12. The chemical treatments delayed ponding, their effect being similar to those in Parlo soil. Rates and dilutions of Elvanol showed the same pattern in reducing evaporation. Results of evaporation from Humofina treatments indicated a higher variability.

No definite tendency was obtained in crust impedance measurements with both types of chemicals. The highest impedance and resistance to penetration were obtained in the subwatered control treatment. Perhaps a greater degree of wetting was reached during the watering in this treatment than in the other treatments. The treatments with soil conditioners indicated penetrometer readings close to the control treatment; but at higher rates and dilutions of the chemicals, a definite tendency to lower values was evident.

In comparison with the control, the chemicals increased the sesame seedling emergence. Their effectiveness was greater at higher dilutions. Elvanol treatments exhibited a slightly greater sesame seedling emergence than Humofina treatments.

Sesame Seedling Emergence in Relation to Crust Impedance and Crust Resistance to Penetration

Relative crust impedance and crust resistance to penetration were plotted against sesame seedling emergence percentage using the data obtained with the chemical treatments in Pot Experiment 3 (except Turen soil). They are illustrated in Figures 13 and 14.

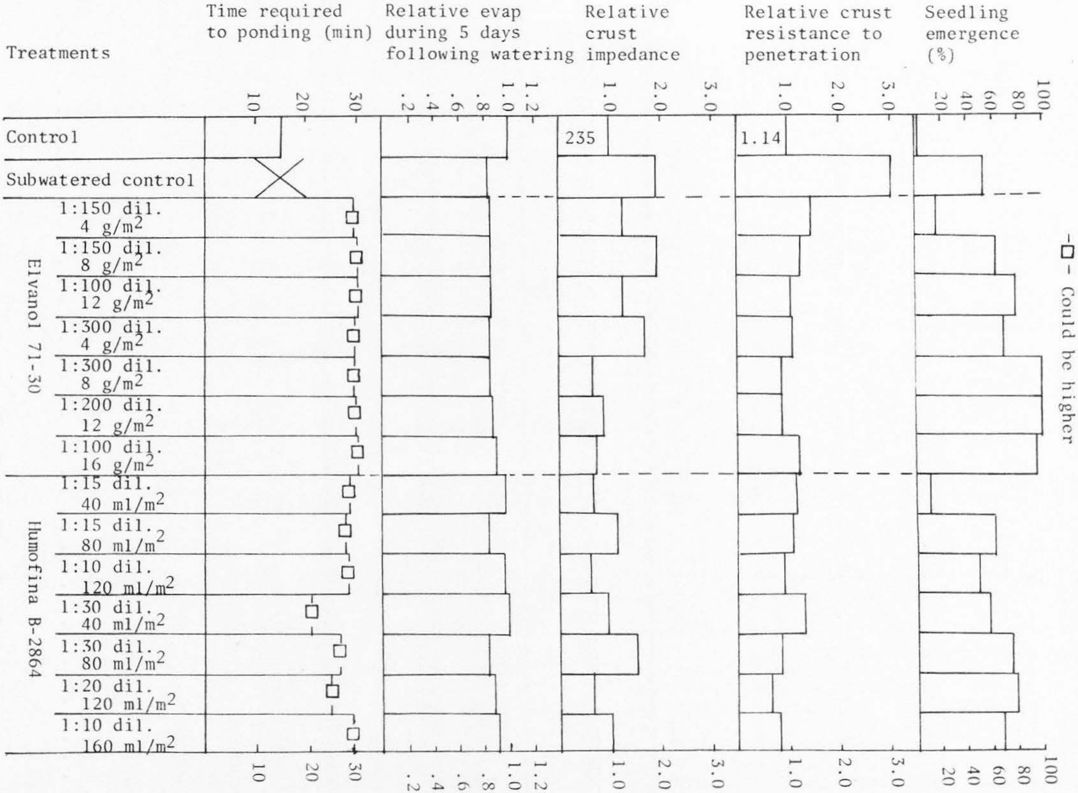

Figure 12. Pot Experiment 3: soil crusting evaluation in Nibley soil.

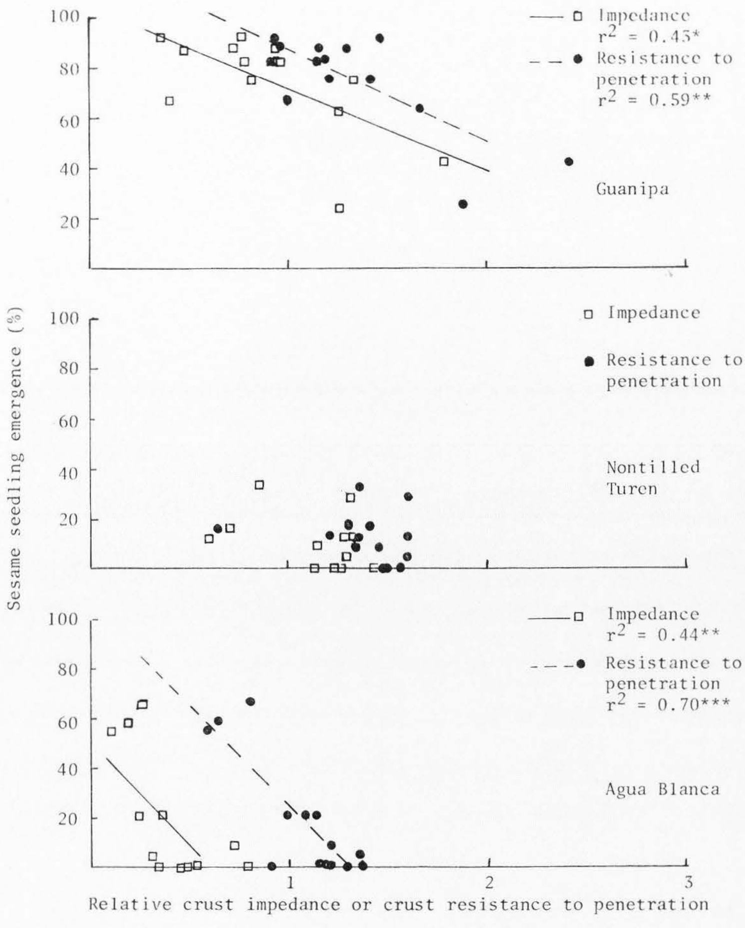

Figure 13. Relationship between relative crust impedance or crust resistance to penetration and sesame seedling emergence for Guanipa, Nontilled Turen and Agua Blanca soils.
*Significant at the 5 percent level.
**Significant at the 1 percent level.
***Significant at the 0.1 percent level.

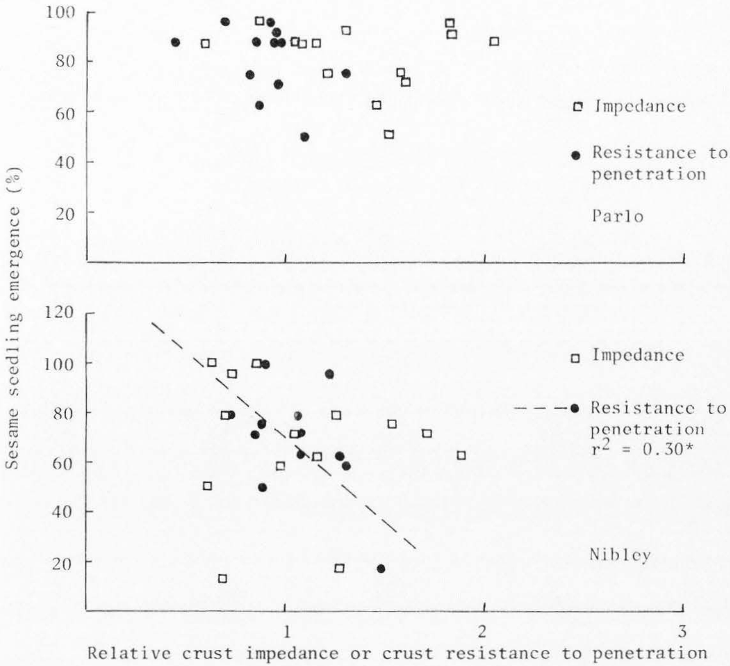

Figure 14. Relationship between relative crust impedance or crust resistance to penetration and sesame seedling emergence for Parlo and Nibley soils.
*Significant at the 5 percent level.

In Agua Blanca and Guanipa soils there was a definite tendency for sesame seedling emergence to decrease as impedance and resistance to penetration increased. No such tendency was obtained in Parlo and Nontilled Turen soil; i.e., the sesame seedling emergence seemed to be independent of soil crust strength. In Nibley soil, however, sesame seedling emergence decreased with an increase in resistance to penetration.

Box Experiments

The results of Box Experiment 1 are summarized in Table 14. The soil conditioner effects generally agree with those obtained in Pot Experiments 1 and 2, as is evidenced by the data for the time required to reach ponding and the sesame seedling emergence percentages. Again, Humofina and Elvanol were more effective than other chemicals in increasing seedling emergence. However, the crust resistance to penetration measurements did not indicate appreciable differences among the treatments.

The results of Box Experiment 2 are given in Table 15. Comparison of the sesame seedling emergence percentages obtained in the control treatments indicates that a lower emergence occurred in the furrow planting as compared to flat surface planting. It is suggested that the aggregates on the soil surface were disrupted by the effect of raindrops. The sediment thus formed was washed into the bottom of the furrow where it formed a thicker soil crust and decreased seedling emergence. In a flat surface, such a situation is not present.

Applications of ground corncob to the furrow slightly increased seedling emergence as compared with the furrow planted control.

Table 14. Box Experiment 1: evaluation of soil crusting in Parlo soil in response to soil surface treatments

Treatment	Time to reach ponding (min)						Crust resistance to penetration (kg/cm^2)						Sesame seedling emergence (%)		
	Furrow			Flat surface			Furrow			Flat surface					
	Replication			Replication			Replication			Replication			Replication		
	1	2	Ave	1	2	Ave	1	2	Ave	1	2	Ave	1	2	Ave
Control	16	13	14.5	16	13	14.5	2.2	2.2	2.2	2.8	2.5	2.65	44.4	44.4	44.4
Tech. Prot. Coll. 5-V 1:100 Dil 6g/m^2	>30	>30	>30	16	14	15.0	2.2	2.2	2.2	2.6	2.5	2.55	47.2	33.3	40.3
Coherex 1:10 Dil 40 ml/m^2	20	26	23	17	12	14.5	2.2	2.2	2.2	2.7	2.5	2.6	43.1	44.4	43.8
AMSCO Res. 4072 1:50 Dil 8 ml/m^2	28	21	24.5	15	13	14	2.5	2.2	2.35	2.8	2.5	2.65	38.9	19.4	29.2
Aerospray 70 1:50 Dil 9 ml/m^2	26	20	23	17	11	14	2.5	2.2	2.35	3.0	2.4	2.7	27.8	47.2	37.5
Elvanol 71-30 1:100 Dil 5 g/m^2	>30	>30	>30	15	13	14	2.2	2.2	2.2	2.8	2.5	2.65	83.3	58.3	70.8
Humofina B-2864 1:10 Dil 50 ml/m^2	>30	>30	>30	15	13	14	2.2	2.2	2.2	2.8	2.5	2.65	68.1	56.9	62.5
Cat. Asph. Emuls. 1:10 Dil 50 ml/m^2	>30	27	>28.5	14	13	13.5	2.7	2.3	2.5	3.0	2.5	2.75	41.7	27.8	34.7

Table 15. Box Experiment 2: evaluation of soil crusting in Parlo soil in response to soil surface treatments

Treatment	Surface shape	Time to reach ponding (min)						Crust resistance to penetration (kg/cm^2						Sesame seedling emergence (%)		
		Furrow Replication			Flat surface Replication			Furrow Replication			Flat surface Replication			Replication		
		1	2	Ave	1	2	Ave	1	2	Ave	1	2	Ave	1	2	Ave
Control	Flat	--	--	--	15	15	15	--	--	--	1.6	2.2	1.9	73.6	51.4	62.5
Control	Furrow	15	14	14.5	15	16	15.5	1.2	1.6	1.4	1.4	2.0	1.7	68.1	37.5	52.8
Elvanol 71-30 1:300 Dil 4 g/m^2	Flat	--	--	--	>30	>30	>30	--	--	--	0.8	1.4	1.1	88.9	59.7	74.3
Elvanol 71-30 1:300 Dil 4 g/m^2	Furrow	>30	>30	>30	15	16	15.5	0.9	1.2	1.1	1.4	1.8	1.6	88.9	63.9	76.4
Humofina B-2864 1:30 Dil 40 ml/m^2	Furrow	20	>30	>25	16	15	15.5	1.0	1.7	1.4	1.4	2.1	1.7	94.4	41.7	68.0
Ground corncob	Furrow	18	14	16	16	15	15.5	1.2	1.8	1.5	1.6	2.2	1.9	72.2	45.8	59.0
Ground corncob + Elvanol 71-30 1:300 Dil 4 g/m^2	Furrow	>30	>30	>30	15	16	15.5	0.9	1.4	1.2	1.5	1.9	1.7	87.5	45.8	66.7
Ground corncob + Humofina B-2864 1:30 Dil 40 ml/m^2	Furrow	19	>30	>24.5	15	16	15.5	1.0	1.7	1.4	1.4	2.0	1.7	73.6	51.4	62.5

The soil conditioners prevented ponding conditions and hence prevented the ground corncob from being washed out by the rain. Upon drying, however, it seemed that the soil conditioners increased the mechanical strength of the ground corncob. As a consequence, the treatments in which the chemicals were sprayed on ground corncob showed a lower seedling emergence than those in which the chemicals were applied alone.

Table 16 summarizes the results of Box Experiment 3. In Parlo and Agua Blanca soils, those treatments in which either Humofina or Elvanol were applied on the entire flat surface, sesame seedling emergence increased. Elvanol treatments were more effective than Humofina treatments. Such differences were especially marked in the Agua Blanca soil. These results agree very well with those obtained in Pot Experiment 3.

Table 16. Box Experiment 3: evlauation of soil crusting in Parlo and Agua Blanca soils in response to soil surface treatments

Soil	Treatment	Time to reach ponding (min)	Crust resistance to penetration (kg/cm^2)	Sesame seedling emergence (%)
Parlo	Control	16	2.2	23.6
	Elvanol 71-30 1:300 Dil 4 g/m^2	>30	2.5	45.8
	Humofina B-2864 1:15 Dil 40 ml/m^2	>30	2.3	47.2
	Elvanol 71-30 1:300 Dil 2 g/m^2	>30	2.7	58.3
	Humofina B-2864 1:30 Dil 20 ml/m^2	>30	2.4	27.8
Agua Blanca	Control	8	>4.5	0
	Elvanol 71-30 1:300 Dil 4 g/m^2	>30	>4.5	33.3
	Humofina B-2864 1:15 Dil 40 ml/m^2	>30	>4.5	11.1

SUMMARY AND CONCLUSIONS

An analysis of precipitation data and annual sesame yield in the production area of Venezuela indicated that the precipitation occurring shortly after planting decreases the sesame yield instead of producing an increase as would be expected. Because precipitation is related to soil crusting problems, these results suggest that the use of an efficient practice, designed to prevent soil crusting, could reduce or eliminate the need to replant and could also increase sesame yields.

One of the main objectives of this study was to determine whether soil crusting can be reduced by spraying the soil surface with some of the commercially available soil conditioners. Parlo soil was used in a test designed to screen seven chemicals. The screening tests showed Elvanol and Humofina to be the most effective. All of the chemicals that were sprayed on this soil increased the time required to reach ponding albeit to different degrees (Figures 5 and 6). This indicates that the chemicals lessened the breakdown of soil aggregates by raindrop impact. In other words, the chemicals contributed to a greater aggregate stability in the soil surface. This is evidenced by the fact that the chemically treated soils showed a higher percentage of silt plus clay aggregation than untreated samples (Figure 4).

Elvanol and Humofina were incorporated into the surface layer of Parlo soil. Incorporation resulted in less aggregate stability than spraying the chemicals on the surface. This is evidenced by the fact that incorporation failed to delay ponding, whereas ponding was delayed by spraying (Figure 6).

The greater aggregate stability of the sprayed soil could probably be attributed to a greater concentration of the chemical in the soil surface. Due to its greater stability, this layer could receive the raindrop impact without serious aggregate disruption.

The time required for ponding, the evaporation, the resistance to penetration, and the sesame seedling emergence indicated that the way a soil responds to Elvanol and Humofina is largely dependent on the physical characteristics of the soil.

Evaporation was greatly reduced by the soil conditioners only in the light textured soil (Guanipa soil). Reduced evaporation in Guanipa soil could be indirectly due to the scarcity of colloid in this soil. The lack of colloid may have caused the sprayed chemical to concentrate as a continuous film on the soil surface. In the Guanipa soil, high rates of Elvanol or Humafina decreased sesame seedling emergence. Consequently, in this soil, the use of these two chemicals would be justified only to reduce evaporation.

In the Agua Blanca soil it would be legitimate to consider the use of Elvanol to enhance sesame seedling emergence. In Turen soil, however, the chemicals did not increase seedling emergence. If Nontilled Turen soil were brought into agricultural use, the soil would change within a few years and would then produce a response similar to that of Turen soil. Therefore, the use of Elvanol or Humofina is considered unjustified in both Turen soil and Nontilled Turen soils.

In all the soils, with the exception of Guanipa soil, Elvanol and Humofina appreciably increased the time required to reach ponding. This suggests the possibility of using Elvanol or Humofina to improve permeability of heavy soils in field conditions.

Most of the treated samples of the finer textured soils (soils other than Guanipa) exhibited higher crust impedance, resistance to penetration and sesame seedling emergence than non treated samples. Nevertheless, the chemical treatments increased the time required to reach a ponded condition and in some cases they prevented ponding. It could well be that by prolonging the time to reach ponding the chemicals increased the opportunity for a high degree of wetting to occur several centimeters below the soil surface. Since the degree of densification upon drying is directly dependent on the degree of wetting during watering (Hillel, 1960), the high mechanical strength measured in treated samples may be a logical consequence.

In the case of nontreated samples, the aggregates on the soil surface, whose stability was lower than that of the treated samples, could be disrupted by the raindrop impacts . Thus, the infiltration was reduced which, in turn, may have prevented a high degree of wetting deep in the soil. The aggregate breakdown and subsequent sedimentation of the detached material resulted in the formation of a hard crust section on the very top of the soil. Although such a crust section was not detected by the crust impedance or resistance to penetration measurements, it could be responsible for the large reduction in sesame seedling emergence observed in the control.

According to Hanks and Thorp (1957) the emergence of seedlings such as wheat is influenced by the strength of the crust immediately around the growing tip and not by the strength of the entire crust.

Hanks and Thorp's (1957) findings are probably also applicable to dicotyledonous plants such as sesame. To emerge, dicotyledonous seedlings must rupture the soil surface in a dome or cone large enough to accomodate the cotyledons. Thus, a hard crust on the very top (the surface) is particularly harmful.

For treated soil samples, correlations between impedance or resistance to penetration and sesame seedling emergence were poor (Figures 13 and 14). The poor correlations may be caused by differences in application of the rupturing force. The mechanical instruments apply a force that increases rapidly until it ruptures the crust--rupture involves a short time interval. The seedling, on the other hand, applies a relatively constant force that may persist for days. This suggests that the seedling itself is the best indicator of the soil mechanical strength influencing its emergence. Impedance and resistance to penetration measurements, when taken alone to evaluate soil crust strength, may lead to erroneous interpretations.

Future Research Needs

Since the amount of foreign soil allowed to be introduced into the USA is limited, the screening test of soil conditioners was conducted on a Utah soil (Parlo silt loam). Based on the results of this test, only two chemicals (Elvanol 71-30 and Humofina B-2864) were selected and tested on Venezuelan soils. It would be desirable, however, to perform a screening test with the seven soil conditioners in Venezuela using Agua Blanca soil. In this way, it could be clearly established whether some of the other conditioners are more effective in increasing sesame seedling emergence on Venezuelan soils than the two conditioners that were tested on these soils.

In the greenhouse, it is difficult to simulate the variations of soil water normally found in the seedbed. Since the seedling emergence is highly dependent on soil water content, the results here obtained cannot be literally extrapolated to field conditions.

Two modifications might, in part, correct this problem in future greenhouse studies. First, use of a considerably deeper pot would give a thick layer of soil from which water could be moved upward into the soil zone in which the seeds are emerging. Second, an increased humidity in the greenhouse, particularly at night, would slow down the rate of evaporation. As a result of these modifications, the soil water profile in the pots would more nearly approximate that found in the field at the time of sesame seedling emergence.

Field experiments are needed to determine the feasibility of using soil conditioners and their effect on soil crusting and seedling emergence in extensive areas. Even with good greenhouse studies, it is wise to verify the results under field conditions.

Inasmuch as it is known that the precipitation is a major factor in determining soil crusting, it becomes obvious that improved long range weather forecasts are needed for the sesame growing region. A more precise prediction of the precipitation during the planting season would help the sesame farmers to anticipate, with a greater degree of accuracy, the best time to plant.

In some cases, the soil conditioners increased the time required for ponding, but also increased the crust impedance and crust resistance to penetration. This suggests that further investigation is needed to clarify the relation between the soil mechanical strength and the degree of wetting at different depths of the surface soil layer shortly after watering.

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APPENDIXES

Appendix A

Seedling Emergence Study under Field Conditions

The field experiment was conducted on Roshe Springs silt loam (Typic Calciaquolls). The plot had been in fallow for the last 2 years. The seedbed preparation consisted of rototilling the soil and packing it with a wooden flat board. Four blocks, each containing three 1.5 x 0.6 m plots, were delineated and sown to sesame on June 13, 1977. The seeds were placed in rows located centrally in, and parallel to the long dimension of the plots. The seeds were planted at 25 mm depth with a density of 100 seeds per meter.

Three treatments were randomized within each block. The treatments were: control (Treatment 1), Elvanol 71-30 applied at 4 g/m^2 in a 1:300 dilution (Treatment 2), and Humofina B-2864 applied at 30 ml/m^2 in a 1:30 dilution (Treatment 3). Immediately after sowing, the chemicals were sprayed on the entire surface of the plot with a hand pump sprayer. The day after sowing, the blocks were irrigated with low pressure sprinklers for 1 hour at an intensity of 25 mm/hour.

Sesame seedling counts were taken daily along the entire seedrow in each plot. The experiment was terminated on June 24, 1977. This was the first day for which there had been no additional emergence in any of the plots for a 24-hour period. During the experiment no precipitation was recorded in the area.

The sesame seedling emergence data obtained at the end of the experiment, expressed in percentages, are shown in Table 17.

Table 17. Percentage of sesame seedling emergence for the different plots under field conditions

Treatment	Block 1	Block 2	Block 3	Block 4	Mean
Control	69.33	40.00	58.00	50.67	54.50
Elvanol 71-30 4 g/m^2 1:300 dil.	70.67	49.33	40.00	66.00	56.50
Humofina B-2864 40 ml/m^2 1:30 dil.	75.33	52.00	46.67	68.00	60.50

An analysis of variance for seedling emergence (Table 18) indicated that there were no significant differences among treatments, but that differences among blocks were significant at the 5 percent level. These results suggest that in the soil where this experiment was conducted, crusting is not a major factor affecting seedling emergence. Visual inspections of the soil surface, however, indicated that there was less disruption of the aggregates on the plots that were treated with the two chemicals.

Table 18. Analysis of variance for emergence of sesame seedlings under field conditions

Source of variation	Degrees of freedom	Mean square	F
Total	11		
Blocks	3	416.24	6.88*
Treatments	2	37.34	.62
Error	6	60.46	

*Significant at the 5 percent level.

Appendix B

Evaporation Data for Greenhouse Studies

Table 19. Daily evaporation obtained under greenhouse conditions from March 21 to June 22, 1977

Date	Pan evap. (mm)	Date	Pan evap. (mm)	Date	Pan evap. (mm)	Date	Pan evap. (mm)
3-21-77	4.1	4-14-77	4.5	5-8-77	5.5	6-1-77	7.7
22	5.3	15	8.7	9	4.9	2	8.2
23	7.1	16	6.7	10	5.4	3	8.5
24	3.3	17	6.0	11	6.7	4	9.0
25	3.6	18	5.4	12	8.1	5	10.9
25	5.1	19	7.1	13	6.2	6	10.5
27	4.6	20	8.1	14	1.9	7	11.3
28	2.8	21	7.3	15	7.3	8	7.9
29	4.1	22	7.6	16	2.3	9	8.6
30	4.2	23	9.0	17	3.8	10	7.6
31	5.4	24	9.7	18	3.5	11	10.8
4- 1-77	3.8	25	8.2	19	2.6	12	10.3
2	3.6	26	7.6	20	5.5	13	9.2
3	6.7	27	7.4	21	9.0	14	12.1
4	6.2	28	7.2	22	5.1	15	10.3
5	5.8	29	6.9	23	5.8	16	9.0
6	7.1	30	7.2	24	2.9	17	10.5
7	7.3	5- 1-77	3.8	25	3.6	18	9.5
8	9.2	2	5.4	26	3.5	19	9.0
9	9.0	3	5.1	27	4.4	20	6.7
10	9.1	4	2.6	28	6.8	21	8.2
11	7.4	5	3.8	29	6.4	22	9.7
12	7.7	6	5.1	30	8.7		
13	6.7	7	5.4	31	8.1		