J. Agric. Sci. Mansoura Univ., 27 (6): 4249 - 4254, 2002

SOIL CRUSTING AND ITS EFFECT ON SEEDLING EMERGENCE

Al-Oud, S.S.
Soils and Water Dept., College of Agric. and Vet. Medicine, King Saud University Branch, AL-Gassim, Saudi Arabia

ABSTRACT

Crusting is commonly found in arid and semi-arid regions. As water evaporates, soil surface becomes charged with relatively high concentration of sodic salts, and consequently with a high ESP. The crust formation is due to two complementary mechanisms; (1) mechanical breakdown of soil aggregates by beating action of raindrop, followed by compaction of a thin layer at soil surface; and (2) chemical dispersion of clay which depends on soil ESP and electrolyte concentration of applied water. Low organic matter content, high ESP, and high silt content make soil surface sustainable to crusting. Soil crust has an adverse effect on soil characteristics such as; infiltration and gas exchange. It also restrict the emergence of seedlings.

Definition:

Soil crust is a hard compact of surface layer which cause a prominent effect on a number of soil processes such as, a reduction of infiltration and increase in runoff, a slowing of the soil atmospheric gas exchange and an interference with seed germination. Soil crusting has been widely blamed for poor aeration and simulated considerable interest of soil scientists and agronomists in its effect on the emergence and early development of seedlings.

Types and formation of soil crust:

Chen, et al. (1980) reported two types of crusts by their mechanisms of formation : (1) Those which formed as a result of water drop impact called structural crusts, and (2) those formed by translocation of fine soil particles and their deposition at a certain distance from their original location refereed to as depositional crust. The latter is mainly a function of Na which brings about dispersion of the soil. In the same citation, Chen, et al. (1980) reported that deposition was marked by the presence of a thin skin also about 0.1 millimeter thick.

McIntyre *et al.* (1958) found that the crust consists of two parts: an upper skin seal attributed to compaction of raindrop impact and a deeper "washed in" region of decreased porosity, attributed to fine particle movement and accumulation. He measured thickness of 0.1 mm and 2 mm for the skin seal and "washed in" zone, respectively. Bresson and Boiffin (1990) studied crust development on a loamy Aquic Hapludalf near Paris in an experimental field to which fertilizers and amendments had been applied. These treatments over the period of 57 years had induced a range of organic matter contents and exchangeable cation percentages. The macroscopic aspects of soil surface were closely monitored during crusting, and microscopic characterization was carried out at every main crust development stage.

Crusting followed the general pattern :1) sealing of the soil surface by a structural crust; 2) development of depositional crust. Even in the sodic plot where the depositional crust appeared early, the structional crust developed first. They concluded that the process of crust development was faster in a sodic soil, with the earlier and more rapid depositional crust development mainly due to more dispersion and thickening of the structural crusts.

Shainberg (1985), in his review on the effect of exchangeable sodium and electrolyte concentration on crust formation, summarized that crust formation is due to two complementary mechanisms: (1) mechanical breakdown of soil aggregates by the beating action of raindrops, followed by compaction of a thin layer at the soil surface; and (2) chemical dispersion of clay which depends on soils ESP and the electrolyte concentration of the applied water. With soils exposed to rain, 3-4% exchangeable Na is enough to cause clay dispersion, crust formation and very low infiltration. In this review, he further summarized that the crust consists of two distinct parts : (1) an upper skin seal attributed to compaction by raindrop impacts and (2) a "washed in zone" is prevented. Conversely, when the ESP of the soil >4-5, clay movement and the formation of the thick crust (washed in layer) are the dominate mechanisms.

Stroehlien and Pennington (1986) reported that sodic soils have more than 15% of the soil cation exchange sites occupied by Na^+ but in fine textured soil values as low as 7 may cause problems especially with low salt water and 2:1 swelling clays. Exchangeable sodium also cause high pH values. Miller and Gifford (1974) reported that the quality of irrigation water, as well as the method and rate of application influence the formation and hardness of a crust. The SAR, a measure of the hazard, is the most important water property related to crust formation. Some of the sodium salts in water are concentrated at the soil surface by evaporation. If enough sodium is adsorbed by the soil surface, it will disperse by irrigation or rain and the crust forms without any mechanical energy impute to arrange and compact the soil particles. They also stated that, the characteristics that make surface soil especially sustainable to crusting are low organic matter content, high exchangeable sodium and high silt content. These are all related to low structural stability, so that aggregates are easily broken down due to the impact of slaking action of water. A dense massive structure can result, and the soil forms into a hard crust upon drying.

Kemper and Noonan (1970) studied the effect of adding of calcium and sodium to the soil on infiltration and showed that both Ca and Na have important effects on infiltration. They concluded that, Na decreased infiltration because it allowed the aggregates to disperse while Ca prevented the dispersion and made the surface more stable. It was further reported that the decreased surface crusting and increased seedling emergence can be achieved by applying a narrow band of gypsum over the seeded row, using approximately 100 to 200 kg/ha.

Effect on seed emergence:

Hillel (1982) studied the effect of crusting on seedling emergence, crust formation and factors affecting crusting formation. He observed that soils exhibiting strong crusting restrict the emergence of seeds. The seedling emergence can only occur through cracks in the crust. However, the critical crust strength which prevents emergence obviously depends on crust thickness and soil wetness as well as on plant species and depth of seed placement. It was further noted that the crust strength increases as the rate of drying decreases and as the degree of colloidal dispersion increases. As water evaporates, the soil surface often becomes charged with relatively high concentration of sodic salts and consequently, with a high exchangeable sodium percentage. With further infiltration by rain or irrigation water salts are leached but the ESP remains high, which includes colloidal dispersion and contributes to the formation of a dense crust.

Taylor (1971) studied the emergence and early development of seedling in soil with a crust and reported that when an elongating shoot encounters a crust, that is too hard to break through, it may grow horizontally and sometimes emerge through cracks. Shiel and Yuniwo (1993) showed that soil crust, produced by applying 44 mm of distilled water at an intensity of 290 mm/hr using a rainfall simulator, was sufficiently rigid to significantly decrease emergence of barley from 76% to 40% and of oil seed rape from 82 to 61%. Also they added that if the crust was kept wet by regular application of water its strength would significantly decrease, but emergence would stay poor due to prolonged soil wetness. Further, they reported that spraying the crust surface just before emergence caused an increase in seedling emergence as compared to uncrusted control. They suggested that carefully timed fine spray watering would help in ensuring rapid seed emergence.

The morphological properties of the landforms also changed due to formation of surface crust and cavities in rocks. However, very severe impact of effluent on vegetation could not be observed. In irrigated crop lands, the cropping intensity, crop yield and crop residue declined up to 75 per cent while at some places the cultivation is completely stopped (Khan, 2001). Upadhyaya, et al. (1989) conducted a field study to measure the soil crust strength with a fully automatic, portable instrument which was developed to measure soil crust strength in shear, rupture, and resistance to penetration. Field tests revealed that the shear technique does not estimate the crust strength reliably. However, both maximum rupture force per unit width of the crust and maximum penetration force were correlated with crust thickness.

Prevention and controlling soil crust:

Crust formation primarily reduces infiltration and affects seedling emergence. The objectives of all management action have been to minimize the crust formation produced by either raindrop impacts or chemical dispersion of clay by sodium and to improve the infiltration rate. In this concentration a number of organic and inorganic chemicals has been studied by researchers and plant growers.

Cary and Evans (1974) presented a details discussion on prevention and management of crusted soil. In their review, three main factors were mentioned that are responsible for crusting includes low organic matter, high exchangeable sodium and high silt content. Their review of literature and research work showed that surface mulching, addition of organic matter, keeping soil moist during germination, and use of gypsum can prevent the effect of crusting on seed emergence by improving hydraulic conductivity.

Agassi *et al.* (1982) and Keren and Shainbeg (1981) reported that chemical dispersion of soil can be prevented by spreading phosphogypsum (or other readily available electrolyte source). In one of their studies Agassi et al., (1981) reported that addition of phosphogypsum at the rate of 5 tons/ha prior to the rain prevents the formation of the crust and improve infiltration rate. Phosphogypsum acted as a slow release salt (Keren and Shaniberg, 1981) supplying sufficient electrolytes to the rainwater and preventing clay dispersion. In their study, they further reported that phosphogypsum application increased the final infiltration rate of a sandy loam soil from 7.5 to 12 mm/hr for the sample with an ESP of 1 and from 0.6 to 10 mm/hr for a soil sample with an ESP of 11.6.

Kumar and Hazar (1989) studied the direct and indirect effect of soil crust strength, soil moisture content and soil management practices (tillatge, sowing rates, mulching and breaking soil crust with hand hoe) on seedling emergence of cluster bean growing under dry conditions. Both soil crust strength and soil moisture content showed a significance effect on seedling emergence, but their indirect effect via soil management practices was very low. Among soil management practices, mulching with dry grass at 5 tons/ha soon after sowing and subsequently removing the mulch 10 days later, was very effective in increasing seedling emergence. Loveday (1974) showed a general relationship between crust strength and seedling emergence. He reported on increase of 100% in emergence with gypsum treatment. Further researches by Shanmuganathan and Oades (1983) have confirmed the positive effect of gypsum on emergence and shown the importance of reducing clay dispersion in establishing good crop stands.

Miyamoto *et al.* (1975a,b, and 1986) extensively studied the effect of sulfuric acid on reclamation of sodic affected calcareous soil. They showed that sulfuric acid provided faster leaching and water movement than dose equivalent amount of gypsum. Sulfuric acid showed a greater removal of Na than gypsum and effectively prevented the crust formation. Kemper and Noonam (1970) reported that the use of gypsum application to sodium affected soils increases infiltration rate and helped in flocculation of the soil. Kemper and Miller (1974) reported that gypsum application increased the emergence of seedlings and decreased surface crusting. Sodium is one of the prominent factors in dispersing clay particles and formation of crust.

Alawi (1977) reported that gypsum can be effectively used in the reclamation of sodic and saline sodic soil, if these soils are not calcareous, but if there is calcium carbonate in soil, sulfuric acid will be more beneficial than gypsum. Ryan and Stroehlein (1973) reported that removal of bicarbonate from water by sulfuric acid improves nutrient uptake by corp/plants and can be beneficial in reducing soil crusting, where as precipitated calcium carbonate acts as a cementing agent and encourages crusting. Comparing with other management techniques available for amelioration of crusted seedbeds, carefully timed fine spray watering would help in ensuring rapid seed emergence as it showed by Shiel and Yuniwo (1993).

REFERENCES

Agassi, M., I. Shanibreg and J. Morin (1981). Effect of electrolyte concentration and soil sodicity on infiltration rate and crust formation. Soil Sci. Soc. Am. J., 45: 848-851.

Agassi, M., J. Morin and I. Shanibreg (1982). Infiltration and runoff control in semi-arid region of Israel. Geoderma, 28:345-356.

Alawi, B.J. (1977). Effect of irrigation water quality, sulfuric acid and gypsum on plant growth and on some physical and chemical properties of Pima soil. Ph.D. Dissertation Univ. of Arizona, Tucson.

Bresson, L.M. and J. Boiffin (1990). Morphological characterization of soil crust development stages on an experimental field. Geoderma, 47: 301-325.

Cary, W.J. and D.D. Evans (1974). Soil crusts, Ariz. Agric. Expt. Stn. Tech. Bull. 214.

Chen, Y., J. Tarchitzky, J. Brouwer and A. Banin (1980). Scanning electron microscope observations on soil crusts and their formation. Soil Sci,. 130: 49-55.

Hillel, D. (1982). Introduction to soil physics. Acadimic press., 51-52.

Khan, M. A. (2001). Pollution of water resources due to industrialization in arid zone of Rajastan, India. J. Environ. Sci., 13: 218-224.

Kemper, W.D. and D.E. Miller (1974). Management of crusting soil. Some practical possiblilities, In: Cary, W.J. and D.d. Evans 1874. Soil crusts. Ariz. Agric. Expt. Stn. Tch. Bull. 214.

Kemper, W.D. and L. Noonan (1970). Runoff as affected by salt treatments and texture. Soil Sci. Soc. Am. Proc., 34: 126-130.

Keren, R. and Shainberg (1981). Effect of dissolution rate on the efficiency of industrial and mine gypsum in improving infiltration of a sodic soil. Soil Sci. Soc. Am. J., 45: 103-107.

Kumar, A. and C.R. Hazra (1989). Quantification of direct and indirect influence of soil management practices on seedling emergence of cluster bean under dry-land condition. Annals agric. Research., 10: 262-269.

Loveday, J. (1974). Recognition of gypsum responsive soils. Aust. J. Soil Res,. 12: 87-96.

Miller, E.D., and R.O. Gifford (1974). Modification of soil crusts for plant growth. In Cary, J.W. and D.D. Evans (eds) Soil crusts. Arizona Agric. Expt. Stn. Bull., 214: p7-16.

McIntyre, D.S.; J. Loveday and C.L. Watson (1958). Field studies of water and salt movement in an irrigated swelling clay soil. 1. infiltration during ponding. 2. J. Soil Res., 20: 81-90, 90-99, 101-105.

Miyamoto, S. (1975). Sulfuric acid for controlling calcite precipitation. Soil Sci., 120: 264-271.

Miyamoto, S., S. Jryan and J.L. Stroehlein (1975a). Sulfuric acid and leaching requirements for reclaiming sodic-affected calcareous soil. Plant. Soil, 43: 573-585.

Miyamoto, S., S. Jryan and J.L. Stroehlein (1975b). Potentially beneficial uses of sulfuric acid in South West agricultural J. Environ. Qual., 4: 431-436.

Miyamoto, S. and J.L. Stroehlein (1986). Sulfuric acid effects on water infiltration and chemical properties of alkaline soils and water. Am. Soc. Agric. Eng., 219: 1288-1296.

Ryan, J. and J.L. Stroehlein (1973). Use of sulfuric acid on phosphorus deficient Arizona soil. Progressive Agric. Arizona, 25: 11-13.

Shainberg, I.R. (1985). The effect of exchangeable sodium and electrolyte concentration on crust formation. Advances in soil Vol. 1 by Springer-Verlag. New York. Imc., 102-122.

Shanmuganathan, R.T. and J.M. Oades (1983). Modification of soil physical properties by addition of calcium compound. Aust. J Soil Res., 21: 285-300.

Shiel, R.S. and E.C. Yuniwo (1993). Decreasing the impact of surface crusting on seedling emergence by spray wetting. British Scc. Soil Sci,. 9: 40-45.

Stroehlein, J.L. and D.A. pennington (1986). Use of sulfur compounds for soil and irrigation water treatments. In: sulfur in Agriculture, Agronomy Monograph n. 27 Madison WI. Pp. 433-453.

Taylor, H.M. (1971). Soil conditions as they effect plan establishment, root development and yield. In: Cary W.J. and D.D. Evans. 1974. Soil crusts. Ariz. Agric. Expt. Stn. Tech. Bull., 214.

Upadhyaya, S.K., K. Sakain, and J.L. Glancy (1989). In field measurement of soil crust strength. Amer. Soc. Agric. Eng., 89: 1101-1116.

تصلب سطح التربة وتأثيره على الأنبات

سعود سبيل العود
قسم التربة والمياه -كلية الزراعه والطب البيطري فرع جامعة الملك سعود بـالقصيم - بريـده
ص ب ٤٨٢، المملكة العربية السعودية

يتصلب سطح التربة فى المناطق الجافة وشبه الجافة احيانا مكونا قشرة متماسكة غير منفذة للماء والهواء. ويرجع السبب فى ذلك الى زيادة تركيز أملاح الصوديوم على السطح والذى ينتج من زيادة معدل تبخر الماء, والذى يعقبه عادة ارتفاع نسبة الصوديوم المتبادل. ويعزى تصلب سطح التربة الى ميكـانيكيتين رئيسيتين هما: (١) التكسير الميكانيكى للتجمعات الأرضية بفعل ارتباط قطرات المطر معها والـذى يعقبـه تضاغط طبقه رقيقه على سطح التربة, (٢) التفريق الكيماوى للطين والذى يرجع اساسا الى ارتفـاع نسـبة الصوديوم المتبادل والى نقص تركيز الألكتروليت فى مياه الرى. يؤدىكل من إنخفاض نسبة المادة العضوية, إرتفاع نسبة الصوديوم المتبادل, وإرتفاع نسبة السلت الى جعل سطح التربة اكثر عرضة للتصلـب. يؤثـر تصلب سطح التربة تأثيرا عكسيا على العديد من الخواص الأرضية مثل رشح الماء وتبـادل الغـازات مـع الهواء الجوى, وايضا الى اعاقة عملية الأنبات.