JA260

Development of Rolling-Type Soil Crust Breaker

by
N.K. Awadhwal
Assistant Professor
Department of Agricultural Engineering
G.B. Pant University of Agriculture and Technology
Pantnagar U P., India

G.E. Thierstein
Principal Agricultural Engineer
ICRISAT Patancheru P O
Andhra Pradesh 502324, India

Abstract

Soil crusting or capping is a serious problem in arid and semi-arid regions; it restricts the emergence of crop seedlings. A mechanical, rolling-type soil crust breaker was designed, developed, and tested in the field. The equipment is of simple construction and breaks the soil crust effectively, improving emergence without any damage to crop seedlings. It can be manually operated as a single-row unit, or a multiple row unit and can be pulled by animal draft power or a small tractor.

Introduction

Soil crusting or capping is a world-wide problem and occurs under a wide range of soil and climatic conditions (Carnes, 1934, Hillel, 1959, 1960; Williams, 1963, Heinonen, 1965; Cary and Evans, 1974, Prihar, 1974; Gupta and Yadav, 1974, 1978). Soil crust offers mechanical resistance to emerging seedlings. If the young seedling lacks the energy to break through the crust, the seedling becomes bent just beneath the crust and dies. Failure of seedling emergence is a common problem in sandy and loamy soils of many arid and semi-arid regions of the world (Miller and Gifford, 1970: Hoogmoed, 1980), where the rapid drying of soil results in faster development of strong soil crust. The crops that are usually affected by crusting are pearl millet (Pennisteum americanum L.), cotton (Gossypium lirulum L.), grain sorghum (Sorghum bicolor L), soybean (Glycine max L.) guar (Cyamopsis tetragonoloba), carrot (Daucus carota L.), and other small grains (Richards, 1953, Hanks and Throp, 1957: Cary, 1967 Chaudhry and Das, 1980; Genard, 1980).

Once crust is formed, it should either be wetted frequently or should be broken mechanically. Moreover, application of water is often impractical because of the limited availability of water in the arid and semi-arid regions and the labour requirement and its cost. Heinonen recommended shallow cultivation to break the crust, which loosens the top soil surface and leaves it open for faster infiltration of water. But shallow cultivation cannot be used over seed rows that are ready for emergence because the cultivator may seriously injure young seedlings just below the soil crust.

So far no equipment is available that can be used by small farmers for breaking the soil crust over the rows of germinated seeds to help seedling emergence.

A piece of equipment called the rolling-type mechanical crust breaker was developed and tested at ICRISAT for breaking the soil crust over the rows of germinated seeds to improve the emergence of seedlings.

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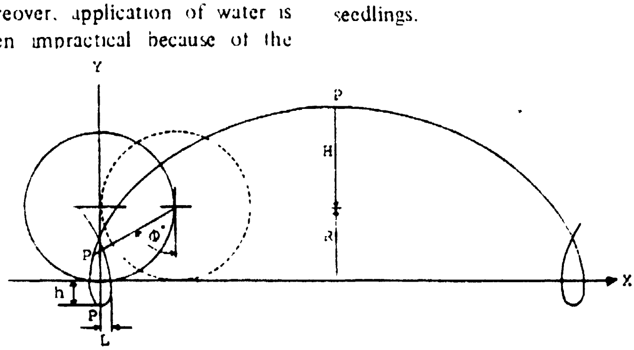

Fig. 1 Trajectory of a spike tip(p) when the drum rolls on a flat surface.

Working Principle

The trajectory of a point P at a distance H from the center of a circle of radius R is described by the following equations when the circle rolls on a straight line:

$$X = R\Phi - H \sin \Phi$$

$$Y = R\Phi - H \cos \Phi$$

where X and Y are coordinates of the point P and r is angle of rotation of the circle from the vertical. In the case of $R < H$, the point will trace a curve called the prolate cycloid, as shown in **Fig. 1**. Thus if spikes of length h are fixed radially on the surface of a drum of radius R (so, $H = R + h$) and the drum is rolled on the soil surface, then the spike will excavate the top layer of soil to a certain depth. The maximum depth of excavation will be equal to h and the bite length equal to 2L, where L is given by the following equation:

$$L = R \cos^{-1}(R/H) - H \sin(\cos^{-1} R/H)$$

Design and Construction

Small seeds such as pearl millet and cotton are generally planted at a depth of about 30 mm from the soil surface, so the spike length should be less than 30 mm. In a survey of soil crusts at ICRISAT Center, the crust thickness was found to be about 15 to 20 mm. Thus the optimum length of the spike lies between 20 and 30 mm.

An average spike length of 25 mm was selected. The diameter of the rolling drum was selected as 150 mm, based on the ease of fabrication and of manually-operated equipment. For this combination of drum size and spike length, the value of L was calculated as,

$$L = 75 \cos^{-1}(75/25) - 25 \sin(\cos^{-1}[72/25])$$

$$= 11.93 \text{ mm}$$

The inter-row spacing of the spikes was kept equal to 2L, i.e., 24. mm, because this should theoreti-

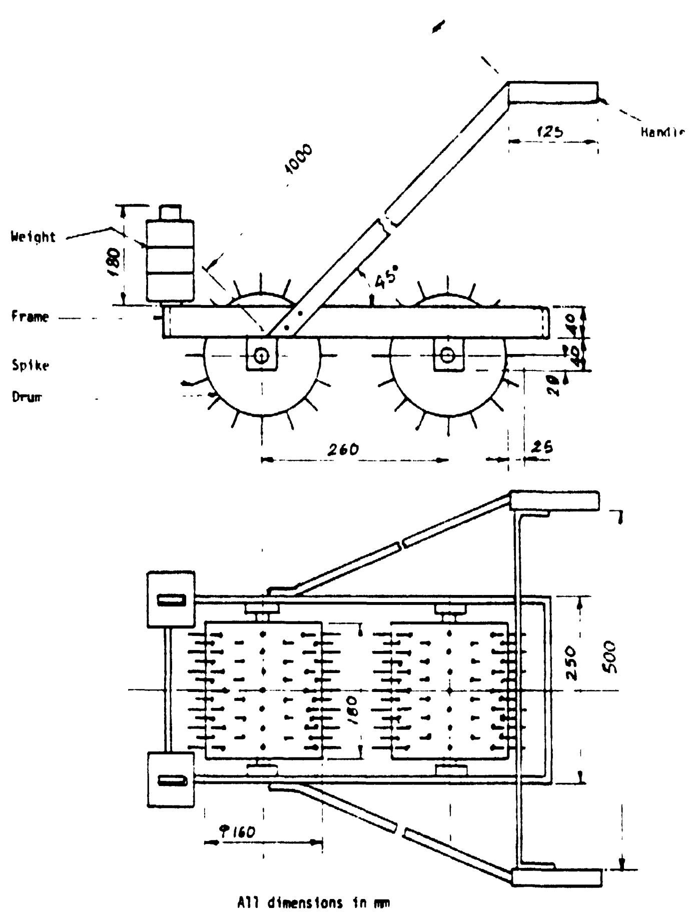

Fig. 2 Rolling type soil crust breaker (manually-operated).

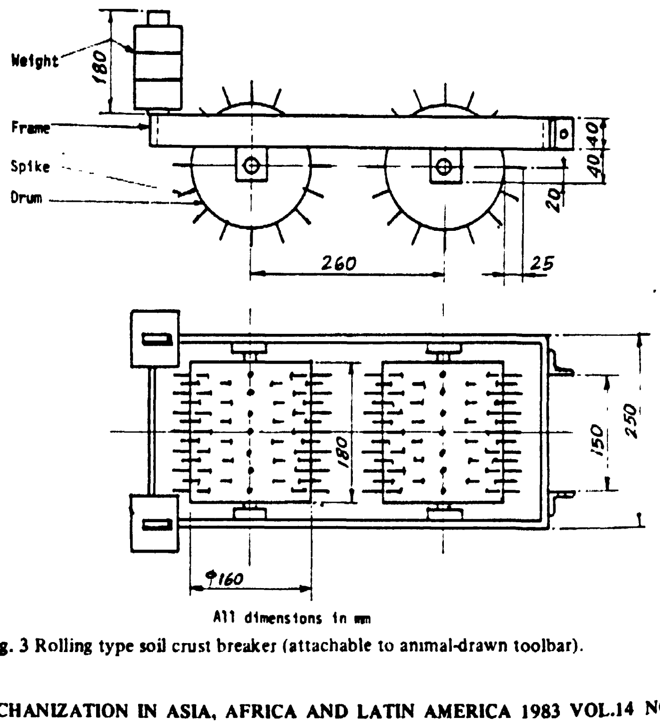

Fig. 3 Rolling type soil crust breaker (attachable to animal-drawn toolbar).

cally leave no crust unbroken at the soil surface The same distance was selected for spike spacing within rows.

Prototypes of the rolling-type crust breaker were fabricated and mounted on two different types of frames one for manual operation and the other for attachment on the bullock-drawn toolbar, as shown in **Figs. 2** and **3**, respectively The estimated cost of one crust breaker unit is about Rs.120 ($15).

Performance Evaluation

The performance of the rolling-type crust breaker was evaluated in Alfisol fields with a range of sandy, sandy loam, and sandy clay soils. A split-plot design in five replications with crust and broken crust conditions in main plots and different millet/sorghum genotypes in subplots was repeated three times. The pearl millet and sorghum genotypes were planted manually, and about 35 mm of water was applied by sprinkler from a height of 2 m. This produced a reasonably uniform and hard crust

On the day prior to the expected emergence the crust surface was dry and its strength, measured with a pocket penetrometer, was in the range of 2.0 to 2.5 kg per cm^2. The average moisture content in the top 10 cm of the soil was 8%, and the soil temperature was in the range of 35 to 37°C. These temperature and moisture conditions were judged to be favorable for emergence.

The rolling-type crust breaker was used to break the soil crust on the seeded rows one day prior to the day of expected emergence. The emergence count was taken one week after breaking the crust. Operation of the manually operated and the bullock-drawn crust breaker is shown in **Figs. 4** and **5**, respectively. The manually-operated crust breaker covers about 0.1 ha/h, and the bullock-drawn tool carrier with three crust breaker units can cover approximately 0.4 ha/h The seedling emergence in both the crusted plots and the plots with broken crust were noted.

The data given in **Table 1** indicate that the seedling emergence under crusted condition was very poor and the use of the crust breaker increased seedling emergence significantly when soil moisture was not a limiting factor. The CV values are generally high, possibly due to random selection of seeds for the experiments from the bulk.

Conclusion

The rolling-type crust breaker performed well in experimental fields. It broke the crust over seeded rows without any visible physical injury to the young seedlings just below the crust and improved seedling emergence significantly

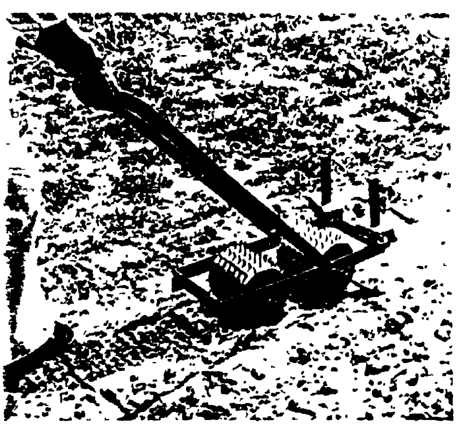

Fig. 4 Manually-operated rolling type soil-crust breaker

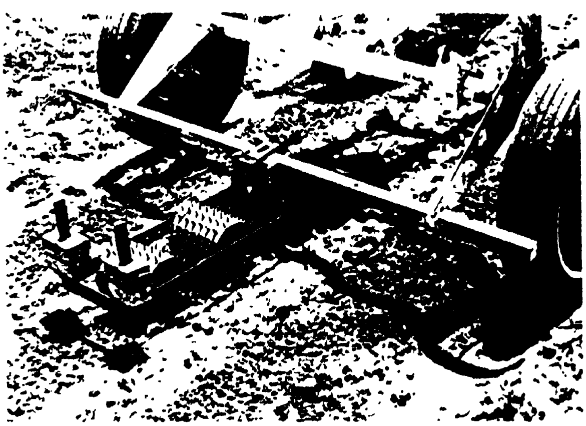

Fig. 5 Bullock-drawn rolling type soil crust breaker.

Table 1 Seedling Emergence under Crusted and Mechanically Broken Crust Conditions of Soil (Unit Percent)

Treatment	Sorghum			Pearl millet									
	IS462-1	IS8129	IS35-1	WC C 75	ICMS 7703	D2-395	SC2-191	ICMS7703	WC-C-75	D2-99	MLC91	SSC93	WC-C-7
Crust	8.7	37.7	17.3	28.6	1.7	0.0	0.0	0.0	3.3	3.3	1.7	3.4	3.3
Crust broken	45.0	96.3	43.0	43.3	50.0	23.3	55.0	50.0	26.7	45.0	36.7	50.0	33.3
CV %	77	32	14	21	78	119	76	74	93	82	90	60	42
F value	9.2	22.2	105.5	11.3	17.2	8.5	20.9	22.1	8.5	13.4	12.5	25.8	45.0
Significance	*	**	**	*	**	*	**	**	*	*	*	**	**

* Signficant at 5%   ** Significant at 1%

compared to emergence in crusted conditions.

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