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A FIELD TECHNIQUE TO SCREEN SEEDLING EMERGENCE OF PEARL MILLET AND SORGHUM THROUGH SOIL CRUSTS†

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SUMMARY

A field technique to screen large numbers of pearl millet and sorghum lines for seedling emergence through soil crusts is described. Seeds were sown on raised broad beds in an Alfisol field. The beds were smoothed after sowing with a bed shaper. Thirty five mm of water was applied from two parallel lines of sprinklers at a rate of 14 mm per hour. A crust of relatively constant strength in different tests developed as the surface dried out. The crust was broken in the control treatment with a crust breaker. The ratio of emergence under crust to that under control (c/u ratio) was used to classify the test materials.

Peacock (1979) reported soil crusting as a major factor causing poor seedling establishment in sorghum. In the semi-arid tropics sorghum and millet are generally grown in soils of poor physical structure, for example Alfisols, which are prone to form crusts as reported by Hoogmoed (1983). The crusting problems of West African soils of the semi-arid tropics are reported in an extensive review by Jones and Wild (1975). Compaction from rain drops and the subsequent drying of the compacted surface soil results in a soil crust (Cary and Evans, 1974). The small seed size (100 seeds weigh between 0.5 and 4.0 g) of sorghum and millet is an additional factor (Taylor 1962), increasing the adverse effects of soil crusts on seedling emergence. The effect of crusting on seedling emergence was reviewed recently by Goyal (1982).

Previous work at ICRISAT (Maiti *et al.* in press) strongly suggests that there is genetic variation among sorghum lines in their ability to emerge through crusts. An important objective of that work was to develop a technique which was simple, repeatable, inexpensive and capable of screening large numbers of germplasm and breeder's lines for such variation. The technique, which used a roller to form a flat compacted surface, had some major problems: (i) it was difficult to obtain an even soil surface, (ii) the unevenness coupled with poor drainage produced crusts which were not consistent over the experimental area and (iii) the lack of a control (no crust) treatment made it difficult to interpret the data.

In the technique described here crusting was induced on raised broad beds with furrows to facilitate drainage. The surface was smoothed after sowing with

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a bed shaper, and a crust breaker (Awadhwal and Thierstein, 1983) was used to break the crust in the control treatment.

MATERIALS AND METHODS

The Alfisol at the ICRISAT Research Center (Udic Rhodustalf, Patancheru series) selected for this work has 54% coarse sand in the upper 100 mm (Table 1). It forms a crust naturally when rainfall is followed by bright sunshine. However, for experimental purposes the unpredictability of this sequence of conditions in the rainy season makes it necessary to simulate conditions in the summer when rain or cloudy conditions are rare.

The field was irrigated to let the weeds germinate and then ploughed. These operations were repeated twice before the experiment began. The soil was then disced and rotavated. Ten broad beds each 1.5 m wide were prepared between the sprinkler lines and smoothed with a bed shaper. A light irrigation (10 mm) was applied over the beds from two parallel lines of sprinklers spaced 15 m apart. The sprinklers were mounted on tripods 3 m above the soil surface. This irrigation settled the surface and facilitated the sowing.

Two metre-long plots with a 0.5 m path between plots were laid out along each broad bed. Seeds were then sown at a depth of 30 mm for millet and 50 mm for sorghum. A John Deere 7100 planter with four planters spaced 30 cm apart was used for sowing.

After sowing the beds were again smoothed with the bed shaper to make the soil surface even. Thirty five mm of water was then applied at a rate of 14 mm per hour when the wind speed was at a minimum. An even application of water over the ten broad beds was achieved by using the two parallel sprinkler lines kept at the appropriate distances.

After this irrigation the plots were left to dry for three days. By this time the surface was firm enough to break the crust in the control treatments without damaging the plumules of germinating seeds, which were still more than 15 or 20 mm below the surface.

Two preliminary trials were conducted in summer 1982 with a limited number of sorghum genotypes. These were done in two Alfisol fields, RCE23 and RCE22, which differed in soil texture, RCE23 being sandy and RCE22 loamy sand in the top 100 mm. In 1983 another two experiments with a large number of genotypes of both sorghum and pearl millet were conducted in RCE23. The

Table 1. *Textural composition of soil from the field (RCE 23) where the trials were conducted in 1983*

Depth (mm)	% clay (< 2 μ)	% silt (2-20 μ)	% fine sand (20-200 μ)	% coarse sand (200 μ-2 mm)	% gravel (> 2 mm)	Soil type
0-100	8	4	23	54	9	sand
100-150	6	6	22	64	2	sand
150-300	8	4	24	55	9	sand

results of the genetic differences in emergence response and the associated environmental factors of the 1983 trials are reported here to illustrate the technique.

THE ENVIRONMENT

Crust strength

Crust strength was measured using a pocket penetrometer (Soil Test Model, CL-700). Fifteen measurements were made daily at random locations on each broad bed until the day of emergence.

Bulk density

Soil bulk density was taken as a measure to indicate the repeatability of the operations in different trials The bulk densities of the surface (0-25 mm) and seed zone (25-50 mm) were estimated for each bed using a core sampler

Soil moisture

The moisture of the soil was estimated gravimetrically. A 10 cm column of soil was collected using a core sampler fitted with four internal aluminium rings each 25 mm long so that soil from each ring could be emptied into a container for drying. Ten samples, one from each bed, were taken each day until the seedlings emerged.

Soil temperature

The trials were conducted between April and June when temperatures were high. Soil temperature was measured at 20 mm depth at 1400 h using a thermocouple probe attached to a digital recorder. Fifteen measurements were made on the crust and control treatment in each replicate. Measurements were made each day until the seedlings emerged.

Seed material

The technique has been developed mainly for sorghum (*Sorghum bicolor* (L.) Moench) and pearl millet (*Pennisetum americanum* (L.) Leeke). Two trials were conducted between April and June 1983. Trial I consisted of 285 pearl millet germplasm entries and Trial II of 82 germplasm and 44 breeding lines of sorghum from the ICRISAT breeding programme. Seed for these trials was produced during the post monsoon season of 1982 and stored at 4°C. Fifty seeds were sown for each plot in a 2 m row, with three replicates in a randomized block design.

RESULTS AND DISCUSSION

The crust strengths measured from the four trials are shown in Figs 1a and b. These trials showed that uniform crust strengths can be developed by systematically following the preparatory steps described. In 1983 the crust strength

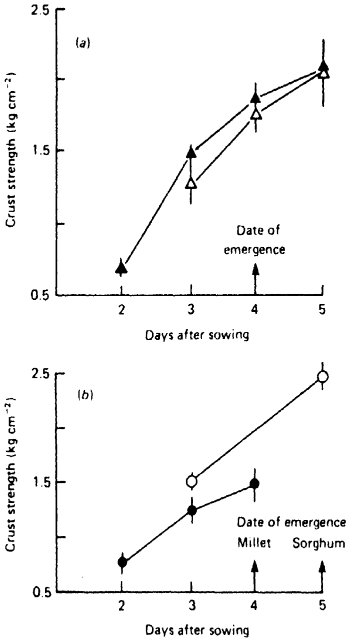

Fig. 1. Crust strength from trials in (a) 1982 and (b) 1983; (△) field RCE 22, (▲) field RCE 23, (○) sorghum trial and (●) millet trial. Vertical bars denote SD.

for the millet (Trial I) was less than that for the sorghum (Trial II). This could be attributed to the relatively lower temperature experienced in Trial I (air temperature 35.4°C) than in Trial II, (39.1°C) and because sorghum emerges a day later than millet. However, crust strength did not vary significantly among the beds in Trial I, 1983 (Table 2). The strength of the crusts

Table 2. *Crust strength developed in different broad beds for Trial I, 1983*

Broad bed no.	Crust strength ($kg\ cm^{-2}$)† Day 2	Day 3	Day 4
1	0.68	1.05	1.53
2	0.85	1.20	1.55
3	0.75	1.20	1.40
4	0.80	1.25	1.70
5	0.73	1.15	1.40

† SE (difference between means), 0.13.

Table 3. *Mean bulk soil densities for the two 1983 trials*

Depth (mm)	Bulk density (g ml⁻¹)† Trial I	Trial II
0-25	1.23 (0.05)	1.13 (0.06)
25-50	1.36 (0.03)	1.40 (0.04)

† SE in parenthesis.

developed in the trials seemed to be adequate to differentiate genotypes, and closely resemble those from Alfisol fields when the crusts are formed naturally by rainfall, these ranging from 1.5-2.5 kg cm^{-2}.

The bulk density of the surface soil (0-25 mm) and seed zone soil (25-50 mm) did not vary between the 1983 trials (Table 3). This indicated that the various steps in machine operation maintained the same degree of soil packing in each test.

The depletion pattern of moisture at various depths is shown in Fig. 2. The surface soil (0-25 mm) dried rapidly. The open pan evaporation rates were high during the experiment period (12.5 mm day^{-1} for April). This was probably an advantage allowing a fast development of a surface crust which could be broken in the control treatment before plumules reached the soil surface. The daily increase in crust strength was closely associated with the drying pattern of the surface soil. The seed zone (25-50 mm) contained 8% moisture on the second day after sowing. The lower two zones (50-75 and 75-100 mm) dried more slowly, ensuring that there was adequate moisture for germination and emergence of the seedlings which did not show any wilting for a period of 15 days after emergence. The 35 mm water applied initially thus not only helped form the crust but ensured adequate moisture for germination and emergence.

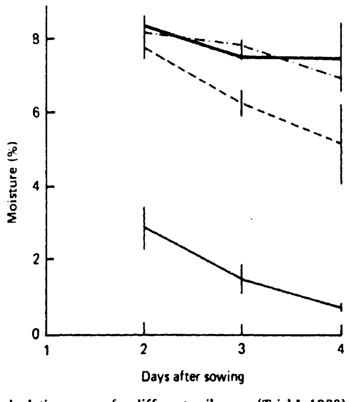

Fig. 2. Moisture depletion curves for different soil zones (Trial I, 1983); —— 0-25 mm, – – – 25-50 mm, –·–· 50-75 mm and ▬▬ 75-100 mm. Vertical bars denote SD.

Table 4. *Mean soil temperature (20 mm deep) at 1400 h for crust and control treatments from Trial I, 1983*

	Mean soil temperature (°C)†	
Days after sowing	Crust	Control (crust broken on day 3)
1	33.2 (0.5)	33.4 (0.6)
2	39.6 (0.7)	39.8 (0.8)
3	43.4 (0.3)	43.8 (0.3)
4	42.0 (0.2)	45.1 (0.2)

† SE in parenthesis.

Soil temperature measured at 20 mm depth at 1400 h daily increased with drying (Table 4). There was little difference in the temperature of the soil at 20 mm depth in the crust and control beds until the crust was broken when that of the control beds rose, possibly due to exposure of the fresh soil to radiation once the crust had been broken. Soil temperatures in this range did not inhibit seedling emergence in millet and sorghum when soil moisture was adequate (unpublished data).

In both 1983 trials there were highly significant differences ($P<0.01$) in seedling emergence between the two treatments and between genotypes (Table 5). Emergence in the control treatment, where the crust was broken, was always higher than the emergence through the crust. The ratio of the number of seedlings emerged in the crust treatment to the number emerged in the control (c/u ratio) was used to evaluate and classify the genotypes. The performance of 285 germplasm lines of millet on the basis of this ratio is shown in Fig. 3a. Only three millet entries had a c/u ratio of more than 0.8 while that of more than 50% of the entries was less than 0.2. Among the sorghum genotypes tested only

Table 5. *Emergence of selected pearl millet germplasm lines following soil crust and broken crust treatments*

Entry name	Mean of the number of seedlings emerged under crust (c)	Mean of the number of seedlings emerged under control (u)	C/u ratio
Zimbabwe-6QQ	22.0	26.0	0.85
Sudan 15K	18.0	21.5	0.84
Togo P-3271	13.7	17.0	0.80
Niger-D102C-1	16.7	22.3	0.75
Sudan 31K	17.3	23.0	0.75
Senegal 1517	15.3	22.7	0.68
Sudan 7KS	10.7	16.3	0.65
Sudan 36K	20.3	31.0	0.65
Sudan 10K	13.3	21.0	0.63
Niger 163C-2	21.0	33.7	0.62
Sudan 8K	11.7	19.0	0.61
Zimb-Rushmanbo (BKF)	12.7	26.7	0.47
Mean	16.1	23.4	0.69
SE	1.10	1.53	0.03

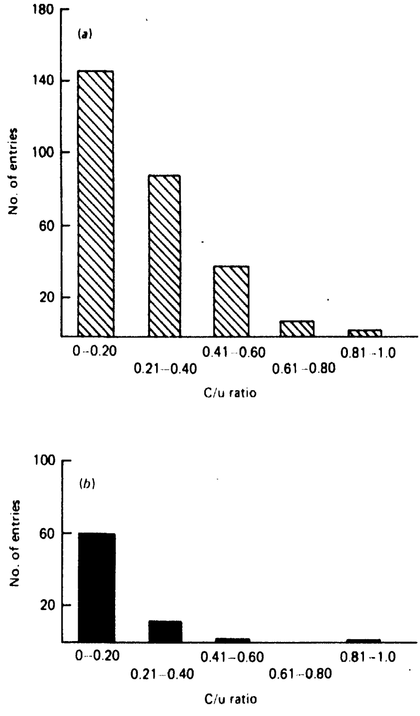

Fig. 3. Classification of germplasm lines on the basis of their emergence through a soil crust compared with no crust (c/u ratio); (a) 285 millet lines and (b) 82 sorghum lines.

one entry (IS 2877) had a c/u ratio of 1.0 and 60% of the entries failed to emerge (Fig. 3b). Only one of the ICRISAT breeders' lines showed more than 60% emergence through crust.

Seedlings emerge through soil crusts in various ways. Individual seedlings can exert sufficient pressure through a soil crust to emerge or groups of seedlings may crack the crust from below by cumulative force (Taylor, 1962). The additive effects of closely spaced plants emerging together through the crust were avoided in these experiments by the use of a precision planter and weed control. In cases where seedlings did not emerge, curved plumules or damaged whorls of the first leaf were observed when the surface crust was removed.

The technique is simple, relatively inexpensive and enables large numbers of lines to be screened simultaneously in a replicated trial. The environmental parameters relevant to the study are easily measured so that two to three such trials can be conducted in a season. The availability of land and sprinkler irrigation equipment can limit the number of genotypes included in a trial. An off-season rain can wash off the crust but the effect of this can be overcome by using a rain shelter.

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