QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

DIVISION OF PLANT INDUSTRY BULLETIN No. 809

CORRELATIONS BETWEEN INFILTRATION, EMERGENCE, CRUST STRENGTH AND PHYSICAL AND CHEMICAL SOIL PROPERTIES OF IRRIGABLE SOIL OF THE MACINTYRE BROOK, QUEENSLAND

by J. E. McAllister, B.Agr.Sc., Dip.Agric.Ec.; and J. L. Gunton, Q.D.A., M.Agr.Sc.

SUMMARY

Relationships between infiltration, seedling emergence (of *Phaseolus vulgaris* L.) and crust strength were correlated with soil physical and chemical properties for 50 sites adjacent to the Macintyre Brook, Inglewood in southern Queensland.

Regression techniques were used to determine the relationships between site response and pH, electrical conductivity, total exchangeable cations, and percentages of sodium, carbon, sand, silt and clay. The regressions indicated that high inter-correlation existed between soil properties measured.

Infiltration was significantly correlated with specific conductivity, clay, sand, carbon and coarse sand, and emergence was significantly correlated with carbon and coarse sand. Crust strength was significantly correlated with clay, carbon, sand, sodium, silt and pH.

An increase in percentage carbon through organic matter management may be the simplest solution to overcoming infiltration, emergence and crusting problems in the soil examined.

I. INTRODUCTION

Soils along the Macintyre Brook are difficult to crop because crusting reduces infiltration and seedling emergence (Isbell 1957).

It is not known if these problems can be alleviated by management practices. This study examined the effect of some soil chemical and physical properties on infiltration, seedling emergence and crust strength to indicate if management practices can modify soil behaviour to improve these major problems.

II. METHODS AND MATERIALS

In 1968, 25 pairs of cultivated and uncultivated sites were chosen adjacent to the Macintyre Brook which flows through Inglewood (28·5°S) in southern Queensland. The sites were selected to provide a range in texture of the main three alluvial soils described by Isbell (1957). Soil texture ranged from sandy loam to clay loam.

Field infiltration study

Three measurements (Marriott bottles) were made at each site using the technique of Keefer and Ward (1963). Paired sites were measured concurrently and all sites were measured in as short a period as possible to reduce variation in antecedent moisture.

Pot tests

EMERGENCE

A sample of 0 to 10 cm soil was removed from near each infiltrometer site. These samples were placed in bands in galvanized iron trays and samples were separated by wooden panels. Each soil sample band was 106 cm long, 25 cm wide and 15 cm deep. The soil samples were exposed to weather over several wetting and drying cycles to provide a seed bed. Weeds were removed by hand.

Graded navy bean seeds (99% germination) were planted on 25 February 1969, 5 cm deep in a well prepared seed bed. A hand operated tyne was used to place seeds every 7·5 cm along the middle of the soil sample band (14 seeds were planted).

After planting, 5 mm of simulated rainfall were applied through a hose sprinkler, held 60 cm above the soil surface. A standard 'five-inch' rain gauge was used to record the amount and intensity (12·7 cm h^{-1}) of the application.

When necessary the soil bands were protected from rainfall by plastic covered frames.

Emergence counts were taken daily. Emergence at day 14 was used in all correlations.

PENETROMETER TESTS

Two soil penetrometers were used to measure crust strength.

Falling weight of penetrometer. A silver steel rod 6·35 mm in diameter was the shaft of this instrument down which a weight (73·1 g) was dropped a fixed distance. The total mass of the instrument was 364 gm. The number of drops of the weight were recorded that were necessary to drive the shaft 2·5 cm deep. Eight replicate readings were taken for each soil sample.

Pressure gauge penetrometer. This apparatus used a conical tip. A distortion meter mounted in a spring steel ring provided a force reading (kg W) as the tip was pushed into the soil. The reading was recorded when the base of the cone was level with the soil surface.

Soil analyses

Soil samples were taken from the bulk samples used in the pot tests. The following analyses were carried out:

1. pH—1:2·5 suspension in water.
2. Mechanical analysis—clay, silt, fine and coarse sand percentage (International particle size, Marshall 1947).
3. Electrical conductivity (μ S cm^{-1}).
4. Exchangeable sodium (as percentage of total exchange capacity).
5. Organic carbon percent (Walkley and Black).
6. Total exchangeable cations (HCl Leach).

Analysis of data

Regression of mean and median values of infiltration on time were estimated at each site. The R^2 values for the means were slightly higher than for the medians hence mean values were used in the equation $I = at^b$ where I = infiltration and t = time. For each site the relevant equation was used to provide an estimate of infiltration at time = 3600s.

In the regression analyses soil properties were assigned $x_1 \ldots x_8$ the independent variables while soil response (infiltration etc.) $y_1 \ldots y_3B$ the dependent variables. The symbols for these variables are shown in table 1.

TABLE 1

VARIABLES AND THEIR SYMBOLS IN THE REGRESSION ANALYSES

Symbol	Variable
X_1	pH (1 : 2·5 suspension in H_2O)
X_2	Exchangeable sodium percentage
X_3	Electrical conductivity (micro siemens)
X_4	Organic carbon percentage (Walkley and Black)
X_5	Sand (percentage)
X_5A	Coarse sand (percentage)
X_5B	Fine sand (percentage)
X_6	Silt (percentage)
X_7	Clay (percentage)
X_8	Total exchangeable cations (HCl leach) (milli equivalents percent)
Y_1	Infiltration (I) where $I = at^b$ (cm)
Y_2	Emergence (number at day 14)
Y_3A	Falling weight penetrometer measurement
Y_3B	Pressure gauge penetrometer measurement

III. RESULTS

The range and mean values of all variables over all sites is given in table 2. The low level of clay in the soil is indicative of the soil types encountered.

Correlation coefficients between all parameters measured are shown, where $P < 0 \cdot 05$, in the correlation matrix (table 3).

Multiple regressions of soil properties on infiltration, emergence, falling weight penetrometer and pressure gauge penetrometer were fitted by a systematic step-wise procedure. Many significant equations were revealed by this procedure. Equations with high R^2 values, and those significant equations with a low number of X's have been included in table 4. Other equations have been included that are useful in later discussion.

TABLE 2

MEAN AND RANGE OF VARIABLES IN ALL SITES

Symbol	Variable	Mean	Range
X_1	pH	6·5	5·6—7·5
X_2	Sodium %	9·4	4·0—28·4
X_3	Electric Conductivity	77·3	23–297
X_4	Carbon %	1·12	0·4—2·7
X_5	Sand%	54·8	38—81
X_5A	Coarse Sand %	11·5	2—39
X_5B	Fine Sand %	43·2	31—64
X_6	Silt %	28·2	10—45
X_7	Clay %	17·1	9—31
X_8	T.E.C.	15·2	8·1—31·2
Y_1	Infiltration	12·8	1·3—50·1
Y_2	Emergence	10·3	2—14
Y_3A	Falling Weight Penetrometer	3·4	0·1—27·4
Y_3B	Pressure Gauge Penetrometer	15·7	2—84

IV. DISCUSSION

We do not intend to provide a treatise on the various correlations among the X variables. However, because so many of the X variables are correlated, the later results in multiple regression must be carefully examined before any conclusion can be drawn. For example, in equation 11 (table 4) there are nine X variables with an R^2 at 90%. However in table 3, pH (X_1) is correlated with percentage sodium (X_2) and percentage silt (X_6), while percentage sand (X_5) is correlated with percentage clay (X_7). Therefore an alternative equation containing clay, carbon, sodium or pH could be more readily used. Equation 9 contains these X variables (with six factors) and maintains an R^2 of 84%.

The simple correlations shown in table 3 indicate the relations between X's and Y's. From the soil texture variables, a point of interest was the gradational array between sites such that they may be regarded as samples from a continuum and can be combined satisfactorily in the regression analyses performed.

In the following section we consider all 50 sites as combined data.

Infiltration (Y_1)

The simple correlations imply some correlation between infiltration and electrical conductivity (–ve), total sand (+ve), coarse sand (+ve), silt (–ve) and clay (–ve). There seems no basis in soil chemistry to suggest the negative correlation between specific conductivity and infiltration (K. Coughlan personal communication). However, as specific conductivity and clay are highly correlated, specific conductivity may not have a direct effect on infiltration. The other factors appear to be satisfactory and the trend indicates a physical difficulty in increasing infiltration in these soils.

TABLE 3

CORRELATION COEFFICIENTS BETWEEN X'S AND Y'S FOR ALL SITES (50)

—	X_1	X_2	X_3	X_4	X_5	X_5A	X_5B	X_6	X_7	X_8	Y_1	Y_2	Y_3A	Y_3B
X_1	1·00													
X_2	−0·4374	1·00												
X_3	..	0·4936	1·00											
X_4	..	−0·3256	..	1·00										
X_5	..	..	−0·3096	−0·3910	1·00									
X_5A	..	..	−0·3102	..	0·8010	1·00								
X_5B	..	..	..	−0·3486	0·6096	..	1·00							
X_6	..	..	..	0·3689	−0·9509	−0·7305	−0·6210	1·00						
X_7	..	..	0·5167	0·3290	−0·7512	−0·6621	−0·3799	0·5197	1·00					
X_8	..	..	0·3161	0·3591	..	−0·3218	..	..	0·4023	1·00				
Y_1	..	..	−0·3361	..	0·5477	0·5696	..	−0·5529	−0·3025	..	1·00			
Y_2	..	..	..	0·3882	..	0·3606	..	..	..	..	0·3103	1·00		
Y_3A	−0·3017	0·6568	0·5533	−0·3031	−0·3645	−0·3010	..	..	0·4946	..	−0·3438	−0·4142	1·00	
Y_3B	−0·3298	0·5697	0·4649	−0·2835	−0·3034	−0·2899	..	..	0·3245	..	−0·4065	−0·3887	0·8400	1·00

All correlation coefficients shown are significant at $P < 0·05$ (0·279). ($P < 0·01 = 0·362$).

TABLE 4

MULTIPLE REGRESSIONS BETWEEN X AND Y VARIABLES FOR ALL SITES

No.	Regression (b Values Omitted)	R^2	
1	$Y_1 = + X_{5A}$	(99%)	0·3244
2	$Y_1 = + X_{5A} + X_7 - X_3 + X_{5B}$	(95%)	0·4606
3	$Y_1 = - X_3 - X^2_{5B} - X_{5A} + X_7 + X_5 + X_4 + X^2_5$	(95%)	0·5828
4	$Y_2 = + X_4$	(99%)	0·1507
5	$Y_2 = + X_4 + X_{5A}$	(99%)	0·3643
6	$Y_{3A} = + X^2_7$	(99%)	0·3584
7	$Y_{3A} = + X^2_7 - X_4$	(99%)	0·6336
8	$Y_{3A} = - X_4 + X^2_7 - X_7 - X^2_5$	(99%)	0·7648
9	$Y_{3A} = - X_1 + X^2_1 - X_4 + X^2_7 + X^2_4 - X_7$	(95%)	0·8353
10	$Y_{3A} = - X_4 + X^2_7 - X_7 - X^2_5 - X_1 + X^2_4 + X^2_1 - X^2_6$	(99%)	0·8686
11	$Y_{3A} = + X^2_7 - X_7 - X_4 - X^2_5 + X^2_2 - X^2_6 + X^2_4 + X_1 + X^2_1$	(95%)	0·8963
12	$Y_{3B} = + X^2_7$	(99%)	0·1781
13	$Y_{3B} = + X^2_7 - X_7$	(99%)	0·3208
14	$Y_{3B} = + X_3 - X_4 - X_1$	(99%)	0·4686
15	$Y_{3B} = + X^2_7 - X_7 - X_4 - X^2_5$	(99%)	0·5792
16	$Y_{3B} = + X^2_7 - X_7 - X^2_5 - X_4 + X_5 + X^2_4$	(99%)	0·6961
17	$Y_{3B} = + X^2_7 - X_7 - X^2_5 - X_4 + X_5 + X^2_4 + X^2_6$	(95%)	0·7359

The multiple regression equation (2) accounts for 46% of the variation. This indicates that more X variables than measured are influencing this parameter. The strongest single X variable measured is coarse sand (R^2 = 32%)—an expected result.

In the quadratic regression equations, R^2 was improved to 58% (equation 3) by including fine sand $\%^2$, total sand %, carbon % and total sand $\%^2$ to electrical conductivity, coarse sand and clay.

All these results indicate that there seems little hope of improving infiltration in those soils *en bloc* except by the highly impracticable way of changing the textural characteristics. The only possibility arises in equation 3 where percentage carbon occurs. However, this may come about by its correlation with the fine particles—clay and silt. Whether increasing percentage carbon would increase infiltration, as such, is doubtful from these equations alone. To verify the suggested relationship more refined experiments using a range of percentage carbon would be needed, keeping all other variables constant. However, results from work on irrigated pasture in these soils indicate that an increase in infiltration has occurred and may be due to, or associated with, a large increase in organic matter.

Emergence (Y_2)

The only variables significantly correlated with this parameter are percentage carbon (+ve) and coarse sand (+ve). These variables are not significantly intercorrelated, and may be acting independently. An increase in either should produce an improvement in emergence. Obviously, percentage carbon is the variable which can be managed through organic matter build up. The multiple regression expresses this relationship in equation 5 with an R^2 of 36%.

Crust strength (Y_3)

Of all the Y variables, this parameter was significantly correlated with the greatest number of X's. The significant correlations were such that (regardless of which measure was used) crust strength increases with increasing electrical conductivity, percentage sodium and clay and decreases with increasing pH, and carbon, sand and coarse sand percentages. Many correlations among the X variables are acting in these X vs. Y correlations, as may be seen by the large number of variables in the most significant regression.

FALLING WEIGHT PENETROMETER (Y_3A)

The multiple regressions are numerous, the highest R^2 value of 90% is given by equation 11 (table 4). However, as for reasons previously mentioned, equation 9 may be just as meaningful though the R^2 is reduced to 84% where pH, carbon and clay are involved. Again carbon (through organic matter) appears the most feasible variable to manage and improve the crusting problem.

PRESSURE GAUGE PENETROMETER (Y_3B)

The multiple regression with highest R^2 value (74%) is shown in equation 17 (table 4). This equation uses a similar range of variables to that on which the falling weight penetrometer measurement depended. Again, increasing carbon seems to be the most feasible way of decreasing crust strength.

The intercorrelations between the various Y values are indicated in table 3 for all sites. All Y values were significantly correlated with each other. The two crust strength measurements were also highly correlated.

The correlations between the Y variables give some hope that an improvement in one parameter *per se* may lead to an improvement in the others. Hence, if increasing organic matter (percentage carbon) can improve crust strength and emergence, some improvement in infiltration may also occur.

The overall implication of the correlations is that the soils along the Macintyre Brook present infiltration, emergence crusting problems mainly because of their particle size distribution (texture). The best means of practical improvement is to increase the percentage carbon through management of soil organic matter.

V. ACKNOWLEDGEMENTS

The authors wish to thank the staff of the Agricultural Chemical Branch and the Biometry Branch of the Queensland Department of Primary Industries for their co-operation in the running of this trial.

We are also grateful to Mr. P. Loxton for his efforts in carrying out the field measurements.

REFERENCES

ISBELL, R. F. (1957).—Soils of the Inglewood-Talwood-Tara-Glenmorgan Region, Queensland. Technical Bulletin No. 5. Queensland Bureau of Investigation.

KEEFER, G. D., and WARD, D. K. (1963).—Irrigation characteristics of soils in the Mareeba-Dimbulah Area of North Queensland. 3. Infiltration characteristics of three major soil types. *Queensland Journal of Agricultural Science* 20:437-445.

MARSHALL, T. J. (1947).—Mechanical composition of soil in relation to field descriptions of texture. Commonwealth Scientific and Industrial Research Organisation Bulletin (Aust.) No. 224.

(Received for publication 23 January 1976)

The senior author is a former Agronomist, Queensland Department of Primary Industries, now Research Fellow, Melbourne University, Victoria, Mr Gunton is an Agronomist, Queensland Department of Primary Industries, and is stationed at Hermitage Research Station near Warwick, Q. 4370.