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# EFFECTS OF IRANIAN PETROLEUM MULCHES ON SOME PHYSICAL PROPERTIES OF A CALCAREOUS SOIL. II. CRUST STRENGTH[1]

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## ABSTRACT

Low stability, physical degradation and high strength of surface soil result in lower seedling emergence. Use of chemical soil conditioners may improve the physical properties of soils. This experiment was conducted to study the effects of three National Iranian Oil Company petroleum mulches (cationic, anionic and clay emulsions) at surface application rates of 0, 2000, 4000 and 6000 L/ha and at incorporation application rates of 0, 0.5, 0.10 and 0.15% (dry weight basis of soil) on the crust strength of a Calcixerollic Xerochrept silty clay soil under the greenhouse and the field conditions. Furthermore, in the incorporation application study, Krilium Merloam (a copolymer of vinyl acetate and maleic acid) was used as a mulch with the same rates of application. In pot experiments, crust strength was significantly decreased by surface application of 6000 L/ha of anionic and cationic mulches but other rates and the clay emulsion had no effect. In the same study, all incorporation applications increased crust strength. The crust strength enhancements resulted from incorporation of the petroleum mulches and Krilium were dependent mostly on the mean weight diameter of the soil aggregates. In the field experiment, all rates of petroleum mulches applied on the soil surface significantly reduced crust strength. However, the incorporation treatments of the anionic and cationic emulsions had no effect on crust strength, except at 6000 L/ha where crust strength was reduced. Moreover, clay emulsion when incorporated had little or no effect in the field. Significant correlation was obtained between the crust strength and the percent seedling emergence of sugarbeets (*Beta vulgaris* L.) in both the greenhouse and field experiments.

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**اثرات مالچهای نفتی ایرانی برروی بعضی ازخواص فیزیکی یک خاک آهکی**
**۲ ـ سفتی سله خاک**

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**خلاصه**

ناپایداری، تخریب فیزیکی وسفتی خاکهای سطحی سبب کاهش سربرآوردن نهال ها از خاک میشود. کاربرد اصلاح‌کننده‌های شیمیائی میتواند خواص فیزیکی اینگونه خاکها را بهبود بخشد. اثرات سطح‌پاشی سه‌نوع مالچ‌نفتی ساخته‌شده درشرکت ملی‌نفت ایران (امولسیونهای کاتیونی، آنیونی‌ورسی) با مقادیرپاشش صفر، ۲، ۴ و ۶ هزار لیتردرهکتار و عمق پاشی با مقادیرپاشش صفر، ۰/۰۵، ۰/۱۰ و ۰/۱۵ درصدوزن خاک خشک برروی سفتی سله‌خاک رس لیمونی درآزمایش گلخانه‌ای وصحرائی موردمطالعه قرارگرفت. ضمنا "ماده‌شیمیائی "کریلیوم مرلوم" (کوپلیمری از وینیل استات و اسیدمالئیک) نیزبا مقادیرپاشش مشابه مالچهای نفتی دربررسی های عمق پاشی درگلخانه موردمطالعه ومقایسه قرارگرفت. سطح پاشی مالچهای نفتی آنیونی وکاتیونی فقط بمقدار ۶ هزار لیتردرهکتار درگلخانه بطور چشمگیری سبب کاهش سفتی سله‌خاک گردیددرحالیکه مقادیرپاشش غیرازآن وهمچنین سطح‌پاشی مالچ‌نفتی امولسیون رسی بی‌اثربودند. برعکس، عمق پاشی مالچهای نفتی وکریلیوم درشرائط گلخانه سبب افزایش سفتی‌سله‌خاک شد. مطالعه همبستگی های موجود بین سفتی سله‌خاک وسایرخواص فیزیکی خاک نشان میدهدکه درشرائط گلخانه‌ای سفتی سله‌خاک حاصل ازعمق پاشی مالچهای نفتی وکریلیوم ممکنست که‌با ثبات خاکدانه‌ها ارتباط بیشتری داشته‌باشد. سطح‌پاشی مقادیرموردمطالعه از مالچهای نفتی درشرائط مزرعه بطورچشمگیری سفتی سله‌خاک راکاهش داده‌است. اما عمق پاشی مالچهای نفتی درمزرعه اثری برروی کاهش سفتی سله‌خاک نداشت مگرمالچهای نفتی آنیونی وکاتیونی با مقدارپاشش ۶ هزارلیتردرهکتار. بین سفتی سله‌خاک ودرصدجوانه‌های سربرآورده ازخاک چغندرقنددرشرائط مزرعه وگلخانه‌ای همبستگی معنی داری مشاهده‌شد.

## INTRODUCTION

A hard soil surface layer (crust) hinders the emergence of small seedlings (3). Surface application of water asphalt emulsion at the rate of 1400 L/ha and incorporation application of Krilium at 1008 kg/ha reduced crust strength and promoted good germination and seedling emergence of cotton (*Gossypium hirsutum* L.) (4). Parker and Taylor (10) reported that 10 days after planting, 50% emergence of grain sorghum (*Sorghum bicolor* L. Moench) seedlings had occurred at the soil strength of 14.4, 13.2 and 9 bars with the respective soil moisture tension of -1/3, -1 and -2 bars. Jamison (7) showed that incorporation and surface applications of hydrolysed incorporation and surface application of hydrolysed polyacrylonitrile (HPAN) at 0.1% followed by a period of heavy rainfall increased the modulus of rupture of the soil crust and consequently repressed seedling emergence.

However, the incorporation application of Krilium at 7000 kg/ha followed by low intensity of sprinkler increased the seedling emergence of cotton and reduced the crust strength (4). Similarly, Ahmad and Roblin (1) showed that emergence of lettuce seedling was increased by incorporation application of soil aggregates (1-3.5 mm) with 0.05% Krilium. They wetted the soil by capillary action.

The effects of Iranian petroleum mulches on crust strength of soil has not been reported. Therefore, the same set of experiments as reported by Moosavi and Sepaskhah (8) was used to study the effects of four rates of three types of Iranian petroleum mulches applied on the surface and/or incorporated on the crust strength under greenhouse and field conditions. Moreover, in the incorporation study, Krilium Merloam was also used for comparison with the same rates of petroleum mulches.

## MATERIALS AND METHODS

The experimental procedures in the greenhouse and the field have been described previously by Moosavi and Sepaskhah (8). Anionic, cationic and clay petroleum mulches were sprayed on the surface of seeded pots at the rates of 0, 2000, 4000 and 6000 L/ha in the greenhouse experiment. The design of the experiment was a completely randomized design with a 3x4 factorial arrangement and three replications. Incorporation experiment was conducted in the greenhouse with the three mentioned mulches along with Krilium at the rates of 0, 0.05, 0.10 and 0.15% (soil dry weight basis) mixed to a depth of 15 cm of soil in the pots.

The experimental design in the field was a split-split plot design with 4 replications. It consisted of three main plots (three petroleum mulches), four subplots (four rates of application 0, 2000, 4000, and 6000 L/ha of treated area). Each subplot consisted of two sub-subplots, one for surface application in strips of 15 cm wide over the rows of planted seeds and the other for incorporation of mulches to a depth of 15 cm in strips of 25 cm wide.

Greenhouse Experiment

Four days after the first irrigation of the pots in the emergence experiment the amount of water lost by evaporation from each pot was determined by weighing. At this time, when the soil surface was dry and apparently a hard crust was formed on the soil surface, unconfined compressive strength of the crust was measured by a pocket penetrometer (Model GL-700, Soil Test Inc., Chicago, U.S.A.). The piston needle of the penetrometer (0.65 cm in diameter) was pushed with a steady pressure, vertically into the soil surface until penetration reached the calibration groove (approximately 6.3 mm). The unconfined compressive strength, in $kg/cm^2$, was read on the penetrometer scale.

The number of emerged seedlings of sugarbeet (*Beta vulgaris* L.) was also recorded at the time of penetration measurement for both methods of application.

Field Experiment

In the field experiment, crust strength was measured in all sub-subplots by means of the pocket penetrometer 3 days after fourth irrigation (19 days after sowing the seeds) using the same procedure as described previously. The average of penetrometer readings on three central rows was used as a single observation. At the time of crust strength measurement, soil samples were taken from the three cm surface layer of the crust by means of a soil tube. Moisture content was determined by gravimetric procedure and bulk density by the procedure as described by Fox and Page-Hanify (5). The number of emerged seedlings per unit area was also recorded at this time.

## RESULTS AND DISCUSSION

### Greenhouse Experiment

Surface application. The effects of surface application of petroleum mulches on crust strength are shown in Table 1. The average crust strength of the three petroleum mulch treatments was significantly reduced from 1.68 to 0.88 $kg/cm^2$ by application of 6000 L/ha whereas smaller rates of application did not have any significant effect. The results of analysis of variance showed a positive interaction between the type of mulches and the rates of application. Application of 6000 L/ha of anionic and cationic emulsions was required to reduce crust strength significantly. Clay emulsion had no significant influence on the crust strength at any rate ( Table 1 ). This anomalous result could be due

Table 1. Unconfined compressive strength ($kg/cm^2$) of surface crust as affected by surface application of various rates of petroleum mulches (pot experiment).

| Rate of application L/ha | Type of mulch | | | |
|---|---|---|---|---|
| | Anionic emulsion | Cationic emulsion | Clay emulsion | Mean |
| 0 | 1.95ab* | 2.03a | 1.07a | 1.68a |
| 2000 | 2.38a | 1.73a | 1.25a | 1.78a |
| 4000 | 1.43b | 1.27ab | 1.33a | 1.38a |
| 6000 | 0.53c | 0.97b | 1.17a | 0.88b |

*Means followed by the same letter in each column are not significantly different at 5% level of probability (Duncan's Multiple Range Test).

to the low measured crust strength of control pots with clay emulsion treatment as compared to those of the anionic and cationic treatments (1.07 $kg/cm^2$ vs. 1.95 and 2.03 $kg/cm^2$, respectively).

Fig. 1 shows the correlation (significant at $P<0.01$) between the mass of water lost by evapotranspiration four days after watering the pots to the field capacity and the unconfined compressive crust strength. The data reported in Fig. 1 refer to all mulch treatments. Crust strength was higher at the greater water loss from the soil. Although the weight of water loss form the whole soil of the pots does not reflect, directly the true moisture content of the crust, it can be used as an index for crust moisture content (3). Therefore, reduction of the crust strength resulted from petroleum emulsions applied on the soil surface was probably due to the effects of these materials on the prevention of evaporation from the soil surface. Bennett *et al.* (4) showed a similar correlation between moisture content of the surface 7.5 cm of the soil and the crust strength.

The increase in seedling emergence resulted from the surface application of petroleum mulches was directly related to the effects of these materials on the crust strength. A negative correlation ($r=-0.589$; $P<0.01$) was found between % seedling emergence four days after sowing and the crust strength (Fig. 2). The results obtained in this experiment indicated that the surface application of petroleum mulches prevented crust formation and reduced the crust strength through its effects on reducing evaporation from the soil surface. Due to this effect on the crust strength, petroleum mulches greatly increased the emergence of seedlings before the crust could be formed.

Incorporation application. The effects of incorporation of petroleum mulches and Krilium at various rates on the crust strength are shown in Table 2. Incorporation of petroleum mulches and Krilium had an adverse effect on the crust strength.

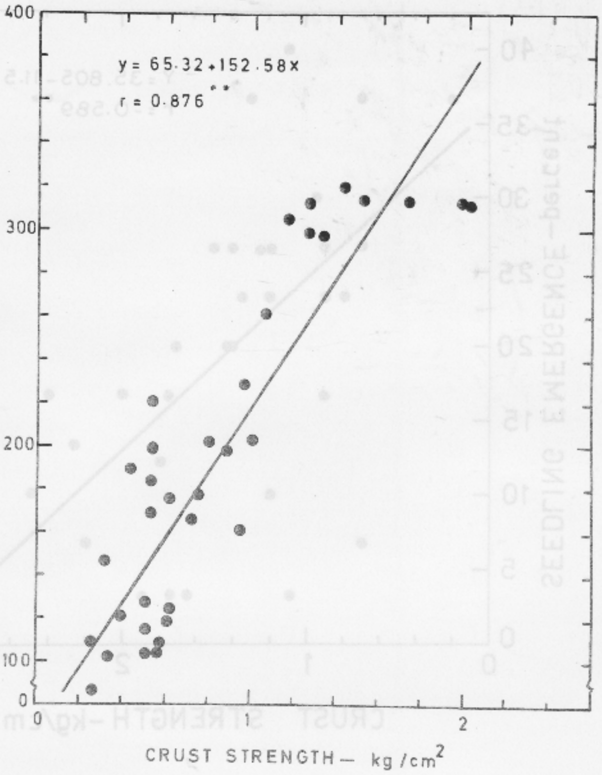


Fig. 1. Relationship between the amount of water loss and the crust strength in the surface application in the greenhouse.

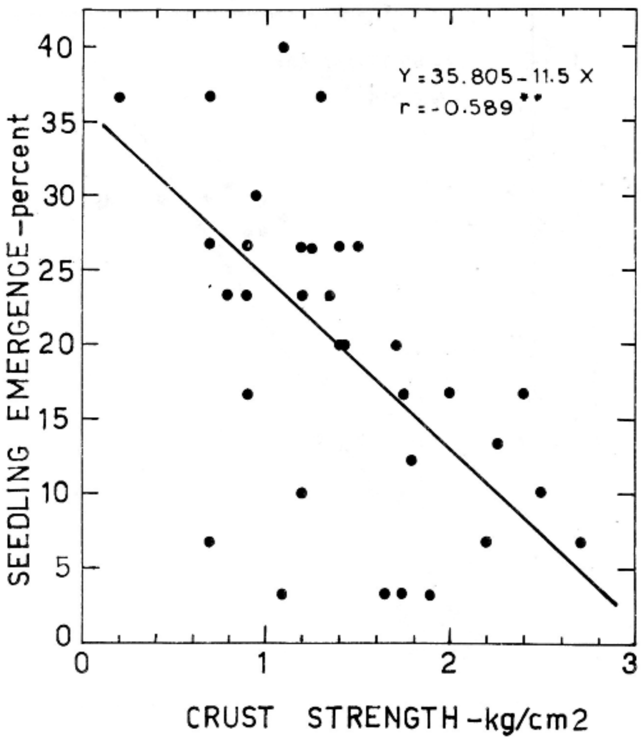


Fig. 2. Relationship between the % seedling emergence of sugarbeet and the crust strength in the surface application in the greenhouse.

Table 2. Unconfined compressive strength ($kg/cm^2$) of surface crust as affected by incorporation application of various rates of petroleum mulches and Krilium (pot experiment).

| Rate of application % | Type of mulch | | | | |
|---|---|---|---|---|---|
| | Anionic emulsion | Cationic emulsion | Clay emulsion | Krilium | Mean |
| 0 | 1.08 | 1.73 | 1.28 | 1.22 | 1.33c* |
| 0.05 | 3.12 | 2.43 | 2.42 | 1.52 | 2.37ab |
| 0.10 | 1.80 | 2.20 | 3.12 | 1.98 | 2.78a |
| 0.15 | 1.53 | 2.92 | 1.87 | 1.63 | 1.99b |
| Mean | 1.88ab | 2.32a | 2.17a | 1.58b | |

*Means followed by the same letter in each column or row are not significantly different at the 5% level of probability (Duncan's Multiple Range Test).

Increasing application rates increased crust strength averaged over all mulches significantly. An average increase of 80% in crust strength was obtained from the treated soils compared to that of the control. The effect of petroleum mulches on the increase of crust strength was greater than the Krilium. Interaction between the types of emulsion and the rates of application was not significant. The relationships between crust strength and the mean weight diameter (MWD) of the soil aggregates as reported by Moosavi and Sepaskhah (9) are shown in Fig. 3. Significant correlations were observed between the crust strength for petroleum mulches ($r=-0.77$, $P=0.01$) and Krilium ($r=0.79$, $P<0.01$) and MWD. These analyses indicated that enhancement of crust strength was a result of an increase in MWD of aggregates.

Fig. 4 shows a negative correlation ($r=-0.716$ $P<0.01$)

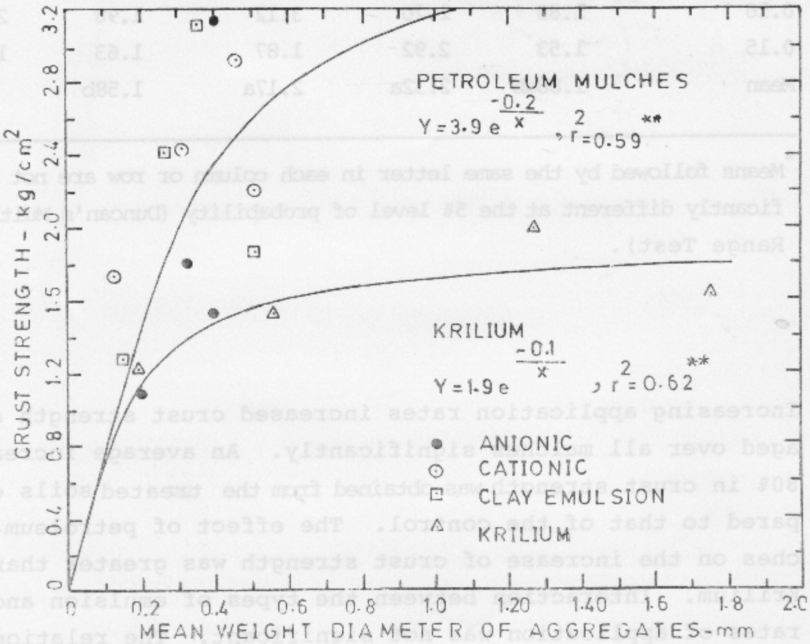


Fig. 3. Relationship between the crust strength and the mean weight diameter of soil aggregates for all petroleum mulches and Krilium.

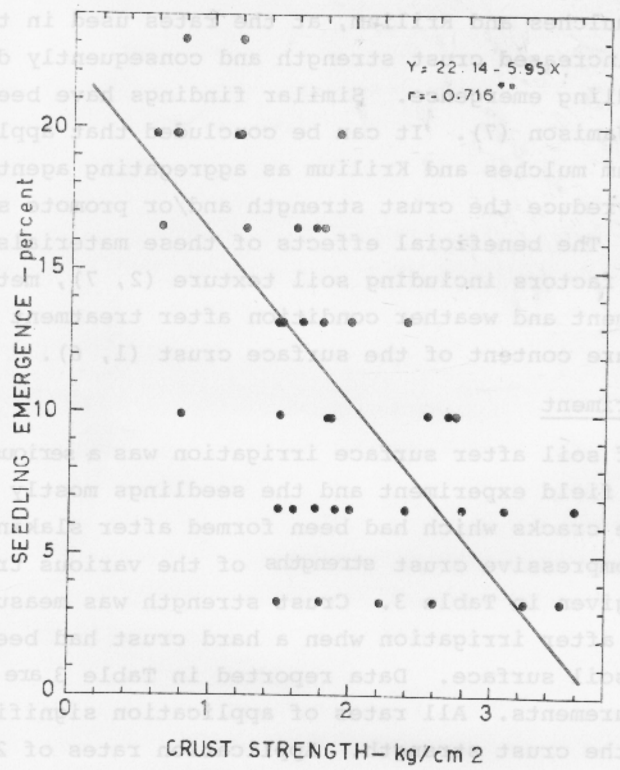


Fig. 4. Relationship between % seedling emergence of sugarbeet and the crust strength in the incorporation application in the greenhouse.

between % seedling emergence four days after sowing and the crust strength. The negative correlation together with the results shown in Table 2 indicate that incorporation of petroleum mulches and Krilium, at the rates used in this experiment, increased crust strength and consequently decreased the seedling emergence. Similar findings have been reported by Jamison (7). It can be concluded that application of petroleum mulches and Krilium as aggregating agents does not always reduce the crust strength and/or promote seedling emergence. The beneficial effects of these materials depend on various factors including soil texture (2, 7), method of soil treatment and weather condition after treatment (7) and also moisture content of the surface crust (1, 6).

Field Experiment

Crusting of soil after surface irrigation was a serious problem in the field experiment and the seedlings mostly emerged through the cracks which had been formed after slaking. Unconfined compressive crust strengths of the various treatments are given in Table 3. Crust strength was measured three days after irrigation when a hard crust had been formed on the soil surface. Data reported in Table 3 are averages of 12 measurements. All rates of application significantly decreased the crust strength. Application rates of 2000 and 4000 L/ha of emulsions had similar effect in reducing the crust strength but were significantly less effective than 6000 L/ha rate. The effect of anionic and cationic emulsions were not statistically different, but both of these emulsions were more effective than clay emulsion.

The results of the analysis of variance showed a positive interaction of methods X rates of application. Surface application of petroleum mulches was more effective than incorporation application. In the case of incorporation application of cationic and anionic emulsions, 6000 L/ha was required to reduce crust strength significantly, while in surface application, all rates decreased the crust

Table 3. Unconfined compressive strength ($kg/cm^3$) of surface crust as affected by surface (S) and incorporation (I) application of various rates of petroleum mulches.

| Rate of application L/ha | Method of application | Type of mulch | | | Mean | |
|---|---|---|---|---|---|---|
| | | Anionic emulsion | Cationic emulsion | Clay emulsion | Type of mulch | Method of application |
| 0 | S | 3.6 | 3.6 | 3.7 | 3.0a* | 3.6a |
| | I | 3.4 | 3.8 | 3.6 | 3.6a | |
| 2000 | S | 2.4 | 2.8 | 3.0 | 2.7bc | 3.1b |
| | I | 3.0 | 3.5 | 3.7 | 3.4a | |
| 4000 | S | 2.1 | 2.2 | 3.1 | 2.5c | 3.0b |
| | I | 3.1 | 3.4 | 3.6 | 3.4a | |
| 6000 | S | 2.0 | 2.2 | 2.9 | 2.4c | 2.7c |
| | I | 2.6 | 2.8 | 3.3 | 2.9b | |
| Mean | | 2.8b | 3.0b | 3.4a | | |

*Means followed by the same letter in each column or row are not significantly different at the 5% level of probability (Duncan's Multiple Range Test).

strength significantly. Furthermore, the incorporation of the clay emulsions had little or no effect. On the average, surface application of petroleum mulches at 2000, 4000, and 6000 L/ha decreased the crust strength by 25, 31 and 33 %, respectively.

It was hypothesized that lower crust strength in treated soils was related to higher moisture content of the crust. To test this hypothesis, moisture content at the 0-3 cm depth of soil was determined gravimetrically. Analysis of variance showed that rates and methods of application of petroleum mulches had no effects on the moisture content (data are not shown). The correlation coefficient between moisture content and crust strength was not significant, due to small variations in the moisture content of 0-3 cm depth of soils.

Percent seedling emergence, determined at the time of crust strength measurement, was negatively correlated ($r=-0.88$; $P<0.01$) with the crust strength (Fig. 5). In order to study the effects of surface and incorporation applications of petroleum mulches on the compaction of the soil, bulk densities of the treated and untreated soil samples taken from 0-3 cm depth were measured. No significant differences were observed (1.44 $g/cm^3$ vs. 1.48 $g/cm^3$, respectively).

In general, clay emulsion was less effective in reducing crust strength in the field studies. In contrast to the greenhouse experiment, incorporation of the highest rate of emulsions significantly decreased crust strength in the field experiment (Table 3). In the field experiment, the soil was workably moist at the time of incorporation of petroleum mulches and irrigation was done 24 hr after treating the soil. These conditions were suitable for slower and better completion of the reaction between soil and petroleum emulsions (7, 11). On the other hand, the impact effect of water during surface irrigation of the plots was less effective compared with irrigating the pots. The latter was done by pouring water on the soil surface.

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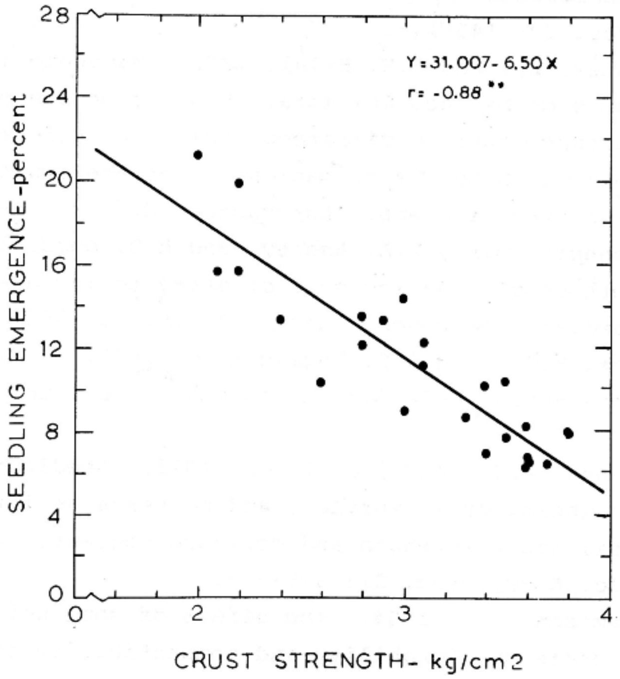


Fig. 5. Relationship between the % seedling emergence of sugarbeet and the crust strength in field experiment.

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