CHARACTERIZATION OF ALKALI BEE NESTING SITES

by

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INTRODUCTION

Alfalfa seed production is an important enterprise in several western states, but a problem confronting the seed producer is that of proper pollination. Alfalfa is a self-sterile species, but cross-pollination cannot be accomplished by wind because a thin membrane holds the petals together and the pollen inside the blossom. The alkali bee ruptures this membrane while seeking pollen and nectar, thus tripping the flower. It has been established that the alkali bee (Nomia melanderi) is very effective in pollination of alfalfa, tripping most flowers that it visits while the honey bee trips only one or two per cent. Certain leaf-cutter bees are also efficient pollinators, but due to their small numbers they are much less important than the alkali bee as alfalfa pollinators. While collecting pollen and nectar, the alkali bee is not discouraged by the sharp blow it receives when tripping the flower. The honey bee is primarily interested in nectar, and it soon learns to avoid the blow of the tripper by entering the flower at the base without rupturing the membrane. Higher seed yields are associated in every case with the abundance of alkali bees. In areas where bees are absent, the average yield of clean seed is 175 to 200 pounds per acre while in areas of high bee population, growers claim an average of 1000 pounds of clean seed per acre.

The adult female bee lives about five weeks during which time she lays up to 25 eggs at a depth of three to ten inches below the soil surface. Each egg is provisioned with a ball of pollen, which is consumed by the larva. The bee overwinters in the soil as a prepupa becoming an adult bee and emerging anytime between June and August. Certain soil conditions appear to be necessary before the alkali bee chooses a nesting site; however, there are comparatively few sites acceptable for bee nests. While more land is being devoted to alfalfa seed production, the number of natural bee nesting sites are decreasing due to land reclamation. In an attempt to check this decrease in the alkali bee population, artificial sites have been constructed, and natural nesting areas are being renovated. Only a small per cent of these attempts have been successful. It has been observed that a nesting site supporting a good bee population may revert to a condition where few or no bees are present, yet the moisture level remains satisfactory. The usual appearance of such a site is a loose powdery surface high in salts. In a few cases a site may become very hard making it difficult for bees to penetrate below the surface.

If one could clearly characterize alkali bee nesting sites, correlations may be made between soil chemical and/or physical properties and the quality of the bee bed. A soil test could then be used with this correlation to determine the proper quantity and type of soil amendment needed to maintain existing beds, renovate poor sites or make artificial beds.

The specific objectives of this investigation are:

1. To characterize soils from alkali-bee nesting sites by physical and chemical analyses.

2. To relate the above analyses to the quality of the bee beds.

LITERATURE REVIEW

Stephen (4,5) has conducted several experiments attempting to characterize the soil properties of alkali bee domiciles. One such study concerned soil texture and moisture. It was found that a relationship did not exist between the quality of a site and per cent sand, silt or clay; however, good beds were correlated to those soils having 8 per cent or less clay-sized particles when per cent clay-sized particles was determined by the usual hydrometer method of mechanical analysis. Pretreatment of the soil did not involve the removal of salts or organic matter. For this reason, it was more a measure of flocculation or dispersion. It was inferred that a better correlation may be found from kinds and amounts of salts since these affect flocculation and dispersion.

Stephen made the following conclusions regarding the moisture studies that were carried out periodically throughout the season:

1. Good beds maintained a uniform moisture percentage throughout the entire season.

2. Poor beds lost moisture rapidly in the dry

months.

3. Adequate moisture was the most important factor affecting bed quality. The moisture usually remained at 20 to 25% in the surface of excellent beds.

Stephen also conducted preliminary investigations on the effect of salts on nesting sites. The results of these chemical analysis showed better beds had a pH of slightly above 7.0. Sodium in the 0-6 inch depth of good quality beds was high in relation to the divalent cations. The effect of NaCl on the rate of capillary rise and the influence of salts on structure were studied. The NaCl effects were proportional to the depth that the salt was tilled into the bee bed. The four inch depth was the most satisfactory, providing a compacted and dispersed surface and leaving the subsurface flocculated for adequate moisture conditions; however, the soil eventually reverted to an undesirable flocculated condition by the divalent cations carried to the surface by capillarity. Stephen suggested that some relational balance must exist between monovalent and divalent cations above which dispersion will occur and below which flocculation can be effected.

Similar investigations were also conducted in Wyoming by Fronk and Painter (2). Samples were taken from eleven nesting areas and from adjacent areas that lacked bee nests. The conclusions based on physical and chemical analysis of these samples were: (1) Sites in which bees were present had approximately 75% sand, 17% silt and 8% clay. (2) The chief factor affecting bed quality was soil moisture. (Optimum moisture was 12 to 14% as compared to 20 to 25% in the silty soils of Oregon.) (3) Scattered vegetation encouraged nesting, but it was not absolutely necessary. (4) Acceptable beds were high in soluble salts, but it was of little importance as far as site selection was concerned. Salinity and soluble Na were higher in nesting sites than non-nesting areas. The exchangeable Na % was higher in non-nesting areas. Fronk and Painter inferred that the only effect salts have on bed quality is through their influence on water holding capacity and vegetation of the soil.

Frick, Potter and Weaver (1) of Washington maintained that salts were not an important requirement of good beds; however, the moist soil conditions attractive to bees frequently have high amounts of salts, incidental to bed quality, deposited by capillarity and surface evaporation. According to these workers there are four basic requirements a site must satisfy to support a good bee population: adequate moisture, little or no vegetation, near a pollen source, and a location close enough to other sites so there is a source of bees to nest in the site.

METHODS

Method of Sampling

The major alfalfa seed producing area in Oregon is centered near Ontario. Most of the samples for this study were taken from this area by the author, with W. P. Stephen providing a few from the Boise area of Idaho.

It has been observed (5) that the top few inches of soil determines whether a bee will accept or reject a particular site for nesting; therefore, one sampling depth included that portion above the nesting zone (0-3 inches), while the other depth included the brood level (3-8 inches).

As each sample was taken, the quality of the bed was recorded. It was assumed the surface tunnels per square foot was a measure of the bed quality since each female bee burrows a single entrance tunnel and lays an average of 15 eggs per season.

Most of the samples for this study were taken wherever beds could be found that contain a satisfactory moisture level. Each of the beds sampled was generally uniform in the number burrows per square foot. They ranged in quality from 0 to 70 burrows/ft^2. Approximately 35 samples were taken by this procedure. Each sample represented a composite of about 10 borings.

A second sampling procedure was used on three beds which were not uniform in quality. Samples were taken from a poor portion, a good portion and in a transition zone in each of the three different beds. Previous workers (5) felt that factors other than those which would be measured by the first sampling procedure might affect the quality of a nesting site. These factors were: (1) location and distance of a bed with respect to the pollen source, (2) tendency of bees to group themselves in a corner or portion of a bed that is uniform in chemical properties, (3) amount of vegetation on a bed and (4) distance to other beds. The second sampling procedure was used to minimize these factors.

Natural nesting sites are normally found in slick spots or salt deposits which are not representative of the soil series in the surrounding fields; therefore, series descriptions were not included.

Each sample was air dried at room temperature and crushed to pass a 2 mm sieve, then stored in a paper carton. The per cent moisture of the air dried samples was determined by drying at 105°C for 24 hours.

Chemical Analysis

Soil Reaction. The pH values of the soils were determined on a 1:1 soil-water paste using a Beckman pH meter with a glass electrode.

Cation Exchange Capacity. For cation exchange capacity determinations, a 5 gram sample was weighed into a 50 ml polyethelene centrifuge tube and rinsed with 4, 30 ml portions of N NH_4OAc adjusted to pH 7.0. The excess NH_4OAc was removed with 3, 30 ml rinsings of ethyl alcohol. The exchangeable NH_4 was replaced with 3, 30 ml portions of 0.1 N HCl. The NH_4 was distilled into boric acid then titrated with standard acid.

Ammonium Acetate Extractable Cations. NH_4OAc extractable Na, K, Ca and Mg were determined in the NH_4OAc rinsings saved from the CEC determinations. Sodium and potassium were determined by use of the

Beckman Model B flame spectrophotometer. The concentration of Na and SO_4 ions was too high to permit Mg and Ca determinations by use of the flame spectrophotometer; therefore, EDTA titrations were used. Aqua regia was added to an aliquot of the NH_4OAc extract followed by evaporation on a hot plate to remove organic matter and NH_4. Then, the residue was brought back to 50 ml and titrated with EDTA. (3)

Water Soluble Cations. Water soluble Na, K, Ca and Mg were determined in a 1:1 soil-water extract. The 1:1 paste was stirred and allowed to stand for six hours; then, the extract was obtained with a suction apparatus and water aspirator. Na and K were determined with a flame photometer, while Ca and Mg were determined by EDTA titrations. Exchangeable Na was found by subtracting the water soluble Na from the NH_4OAc extractable Na.

Electrical Conductivity. Electrical conductivity was measured on the same 1:1 soil-water extract obtained for soluble cations. A model RD-26 Solu-Bridge was used.

Water Soluble Anions. An estimate of chlorides and sulfates was made on the 1:1 soil-water extract using the procedures outlined in the Agricultural Handbook

No. 60 (3). Chlorides were determined in an aloquot of the 1:1 extract by titrating with 0.005 N $AgNO_3$ using potassium chromate indicator. Sulfates were found by precipitation with barium then turbidimetrically comparing the resulting solutions to standard solutions. A simple visual comparison was made for the presence of carbonates by adding HCl and comparing the degree of effervesence of one soil to the next. A large amount of effervesence was denoted by four "x" signs, while a small amount was one "x" sign.

Physical Analysis.

Mechanical Analysis. The per cent sand, silt and clay was determined by the hydrometer method in which 50 gm of soil is digested with H_2O_2 to remove organic matter. The soluble salts were drawn off in 1000 ml of distilled water using a Pasteur-Chamberlin filter and suction apparatus. Calgonite was added as dispersing agent, then the sample was transferred to a Bouyoucos cylinder and shaken. Hydrometer readings were made at the appropriate time for calculating the per cent clay and silt.

Particle Size Analysis. An approximation of the extent of surface soil flocculation was made by a modification of the Bouyoucos Hydrometer method referred to as "particle size analysis." Fifty grams of soil were placed in a 500 ml Erlenmyer flask containing 10 ml of 5% calgon and allowed to stand for 30 minutes. The flask and contents were shaken in a mechanical shaker for 5 minutes at a slow speed then transferred to a Bouyoucos cylinder where the proper dilutions and hydrometer readings were made to obtain the per cent sand, silt and clay sized particles. Since neither soluble salts nor organic matter are removed by this procedure, the extent of flocculation is estimated.

Moisture is the most important factor affecting the quality of a bee bed. Studies have been conducted, and poor to satisfactory moisture levels have already been established for beds of the Ontario area of Oregon; therefore, this study is concerned mainly with texture and kinds of amounts of salts. According to Stephen (5), the beds from which samples were taken for this study contained sufficient moisture to support a good bee population. Stephen correlated good beds to those sites which maintain 20 to 25% moisture during the summer months. These moisture studies were carried out in the same general area that samples for this study were taken.

RESULTS

Chemical Analysis

Salts are carried to the surface of bee beds by capillarity and are deposited there by surface evaporation. Such salt accumulations are hindersome to bee nesting, and a bed us eventually abandoned when these deposits overtake a nesting site.

Characterization of beds may reveal some consistent difference in chemical properties between good and poor beds. This information could then be used to predict the quality of a bed, or to make recommendations necessary to renovate a poor bed. The chemical properties and corresponding bed quality for each sample taken in the Ontario area are listed in tables 1 and 2.

Soil Reaction. It is seen that pH at the 0-3 inch depth ranged from 6.6 to 10.5. There was no consistent increase or decrease in the pH with an increase in the quality of bed. When the beds were averaged for each classification and compared it is noted that pH was slightly higher in poor beds than in good beds, but the

Table 1. Chemical analysis of alkali bee nesting sites of the Ontario Oregon area (0-3 inch depth).

Sample No.	Burrows per ft²	pH	CEC* me/100	Conductivity K x 10^3	SAR	ESP	Ammonium acetate extractable Na	K me/100 gm	Ca+Mg	Water Soluble Na	Ca+Mg me/100gm	Cl	SO_4	CO_3	O.M. %
							Poor								
1	0	8.5	18.9	148	238.0	82.5	156.0	7.9	54.9	140.0	6.9	40.6	95.0	xxx	0.8
3	0	8.0	18.4	88	86.8	68.5	82.6	9.0	41.7	70.0	13.0	41.0	49.0	0	1.3
5	0	8.4	15.8	20	54.8	51.3	23.6	1.7	32.7	15.5	1.6	13.9	3.8	xx	0.7
7	0	8.3	27.6	39	43.6	76.1	41.0	2.4	70.6	20.0	4.2	6.1	19.0	x	0.7
9	1	8.5	22.4	40	96.4	61.2	56.8	3.3	34.6	43.1	4.0	20.3	38.4	x	0.5
11	4	7.4	17.8	77	42.5	60.7	67.8	4.2	82.0	57.0	36.1	87.0	7.2	xxx	1.1
13	4	7.9	24.9	68	105.0	62.2	62.2	3.0	44.2	46.7	4.0	44.6	8.3	xx	0.7
15	5	7.5	29.6	94	50.1	39.9	73.8	5.8	91.0	62.0	30.6	78.9	5.0	x	1.4
Average		8.1	21.9	71.8	89.7	62.8	70.5	4.7	56.5	56.8	12.6	41.6	13.6		
							Fair								
17	7	7.7	17.8	75	38.4	69.1	78.3	3.9	99.0	66.0	59.3	109.1	7.3		1.6
19	8	7.6	27.4	75	80.0	58.4	80.0	3.1	78.6	64.0	12.8	73.6	7.6	x	0.8
20	8	8.2	27.9	58	160.0	60.9	91.0	3.5	67.1	74.0	4.3	59.2	17.5		
22	9	7.6	25.8	68	65.6	57.7	62.3	2.3	58.1	50.0	11.6	57.2	5.5	xx	0.7
24	9	7.6	21.4	50	53.5	70.1	64.5	5.5	46.7	49.5	17.1	48.7	23.8	0	1.1
26	10	6.8	16.6	62	14.7	63.3	29.5	6.0	70.0	19.0	33.6	68.5	5.2	0	2.3
27	11	7.6	27.7	130	78.9	50.5	79.0	4.4	54.6	65.0	13.6	101.5	10.0	x	0.9
29	12	7.6	19.8	72	65.9	63.6	66.1	8.5	52.3	53.5	13.2	56.5	9.9	0	2.9
31	15	10.2	22.8	26	220.0	52.6	34.0	8.0	29.9	22.0	0.2	0.9	6.0	xx	1.4
33	16	7.4	29.7	90	23.1	40.4	49.0	5.3	103.8	37.0	51.3	61.4	3.1	x	1.9
Average		7.9	23.0	68.4	86.3	59.6	65.0	5.1	66.0	51.4	18.4	63.7	9.6		
							Good								
35	21	7.2	18.9	44	38.5	58.2	61.0	5.3	56.8	50.0	33.7	79.7	6.5	0	1.3
37	21	8.5	17.7	92	165.0	67.2	92.9	0.7	45.9	81.0	4.8	47.4	44.3	xxxx	0.6
39	22	7.6	19.6	38	12.8	9.2	24.8	5.3	83.6	23.0	64.6	50.8	4.6	x	1.5
41	25	10.5	23.0	23	311.0	100.0	45.0	8.5	20.3	22.0	0.1	5.6	4.8	xxx	0.9
43	26	7.1	24.5	75	16.6	19.2	40.7	3.9	116.8	36.0	94.0	126.9	2.4	x	1.2
45	30	6.6	15.7	78	18.4	32.5	31.9	6.6	80.9	26.8	42.5	54.7	5.8	0	1.7
46	30	8.3	19.4	86	123.0	46.4	86.0	6.4	59.4	77.0	7.9	59.9	18.0	xx	1.4
48	45	8.5	13.3	12	25.0	24.1	12.2	2.8	21.0	9.0	2.6	0.8	6.5	0	0.6
50	70	7.3	16.9	150	33.5	24.3	64.1	7.5	79.0	60.0	64.0	128.3	4.4	x	1.7
52	72	7.2	26.9	65	34.6	49.4	66.3	5.0	85.5	53.0	47.0	87.8	3.7	x	1.6
Average		7.8	20.5	68.4	72.9	42.8	52.2	5.2	64.9	43.2	37.5	64.2	6.3		

* Notations for cation exchange capacity, sodium adsorption ratio and exchangeable sodium percentage are CEC, SAR and ESP respectively.

Table 2. Chemical analysis of alkali bee nesting sites of the Ontario, Oregon area (3-8 inch depth).

Sample No.	Burrows per ft^2	pH	CEC me/100	Conduc-tivity $K \times 10^3$	SAR	ESP	Ammonium acetate extractable: Na (me/100gm)	K (me/100gm)	Ca+Mg (me/100gm)	Water Soluble: Na (me/100gm)	Ca+Mg (me/100gm)	Cl (me/100gm)	SO_4 (me/100gm)	CO_3
						Poor								
2	0	8.5	19.9	32	61.5	64.8	37.9	4.0	62.4	25.0	3.3	12.1	15.3	xxx
4	0	7.8	18.2	30	36.8	54.9	30.0	5.8	22.6	20.0	5.9	12.7	11.1	0
6	0	8.0	15.8	76	110.0	38.0	70.0	3.2	42.2	64.0	6.8	61.0	5.7	xx
8	0	8.0	27.9	12	17.5	37.3	17.4	2.1	79.9	7.0	3.2	1.0	7.9	xx
10	1	8.2	23.4	20	43.8	44.0	27.0	2.7	36.3	16.3	2.9	3.6	15.3	x
12	4	7.8	17.6	20	29.8	78.4	30.5	2.7	47.7	16.7	6.3	19.2	5.3	xxxx
14	4	7.9	21.0	12	18.4	19.5	11.1	2.1	48.7	7.0	2.9	1.4	6.1	xxx
16	5	7.8	29.7	28	28.4	48.8	32.5	4.2	78.4	18.0	8.0	16.8	6.0	x
Average		8.0	21.7	28.8	43.3	48.2	32.1	3.4	52.3	21.8	4.9	15.9	9.1	
						Fair								
18	7	7.6	18.1	36	30.4	59.7	42.8	3.2	77.9	32.0	22.2	45.9	7.8	xxxx
21	8	8.1	29.9	24	49.9	49.2	38.3	3.1	57.2	23.6	4.4	13.0	11.0	x
23	9	7.6	28.1	34	29.4	45.2	30.7	2.4	71.0	18.0	7.5	22.9	4.3	xx
25	9	7.6	22.8	26	33.9	54.8	35.5	4.1	24.2	23.0	9.2	23.4	14.0	0
28	11	7.5	30.5	74	65.2	66.9	67.4	3.7	36.4	47.0	10.4	57.8	4.3	x
30	12	7.7	18.9	22	26.0	25.4	18.3	6.1	38.2	13.5	5.4	12.1	6.8	x
32	15	9.2	21.1	3	15.5	30.8	8.4	5.9	33.5	1.9	0.3	0.8	0.8	xxx
34	16	7.5	31.3	28	17.2	30.0	22.4	5.0	62.9	13.0	11.5	15.2	3.5	x
Average		7.9	25.1	30.9	33.4	45.3	33.0	4.2	50.2	21.5	8.9	23.9	6.6	
						Good								
36	21	7.3	19.6	12	29.5	31.1	18.1	3.5	13.3	12.0	3.3	14.5	1.4	0
38	21	8.6	19.4	24	94.5	92.3	35.6	0.4	47.0	17.7	0.7	6.1	11.9	xxxx
40	22	7.6	19.8	7	10.2	9.1	8.8	3.3	35.8	7.0	9.4	9.3	4.3	x
42	25	9.4	22.2	5	67.9	51.4	16.2	7.2	33.1	4.8	0.1		1.0	xx
44	26	7.4	32.3	30	15.2	18.0	22.5	3.8	70.5	16.7	24.2	23.1	3.7	x
47	30	8.2	20.3	44	87.0	62.1	49.0	5.1	51.0	35.9	4.2	27.4	10.6	xx
49	45	7.8	13.8	25	37.5	32.6	21.5	3.2	24.0	17.0	4.1	15.4	5.5	x
51	70	7.3	20.9	26	27.1	43.5	26.1	5.7	24.7	17.0	7.9	18.9	3.3	0
53	72	7.6	28.4	17	22.7	25.4	22.0	2.3	60.8	14.8	8.5	20.6	4.4	x
Average		7.9	21.9	21.1	43.5	40.6	24.4	3.8	40.0	15.9	6.9	16.9	5.1	

variation within a single classification was large in comparison to the variation between the average values.

pH of the 3-8 inch level ranged from 7.3 to 9.4. There was no significant difference in pH between the poor, fair and good beds. Poor sites averaged 8.0, while fair and good beds were 7.9.

Soluble Salts. Soluble salts were considered as to their effect on bed quality. As seen from table 1, there was no significant relationship between the electrical conductivity and the quality of a bee bed. For the 0-3 inch depth, poor beds averaged 71.8 mmhos/cm, while fair and good beds were 68.4 mmhos/cm. The variation within any one classification was comparitively large.

Since salt deposits were observed on the surface of poor beds, the lack of any relationship between conductivity and bed quality indicates that: (1) the same amount of salts were distributed evenly throughout the 0-3 inch depth in good beds, while they were concentrated on the surface of poor beds, or (2) the total amount of salts on the surface were not measured, because the electrical conductivity was measured on the 1:1 soil-water mixture which will not completely dissolve Ca and

Mg salts as carbonates and/or sulfates.

The conductivity at the 3-8 inch level was lower than at the 0-3 inch depth; it is believed that this was a result of continual removal of subsurface salts to the surface during capillary rise.

Exchangeable Cations. Ammonium acetate extractable Na was slightly higher in poor beds than in good beds, while Ca+Mg was lower in poor beds than in good beds. The same trend can also be seen for water soluble Na and Ca+Mg; however, it is unlikely that these relationships are significant because of the wide variation within any one classification.

A consistent difference in the exchangeable sodium percentage (ESP) values at the 0-3 inch depth could not be found with an increase in the quality of a bed, but average values for poor, fair and good beds showed a decrease in ESP with increasing bed quality.

Carbonates and sulfates were present in amounts which rendered it impossible to determine the exchangeable Ca+Mg. A larger amount of these carbonates and sulfates was dissolved by the ammonium acetate extraction than by the water extraction. In almost every case the exchangeable Ca+Mg would be greater than the CEC, if the value was obtained by subtracting water soluble Ca+Mg from NH_4OAc extractable Ca+Mg.

Anions. Although carbonates were not quantitatively measured, the per cent of beds in which carbonates were found was slightly higher in poor beds than in good beds. Similarly, sulfates were found to be higher in beds classified as poor. Of the soluble salts, chlorides were present in the largest amounts. In the 0-3 inch depth, they ranged from 0.8 me/100 gm to 128.3 me/100 gm. Poor beds averaged 41.6 while good beds contained an average of 64.2 me/100 gm.

Sodium Adsorption Ratio (SAR). It has been found that the ratio of monovalent to divalent cations is an important factor affecting the physical condition of a soil; therefore, the SAR was considered as to its effect on the quality of a bed.

The SAR values and corresponding bed quality are listed in tables 1 and 2. There is a wide variability within any one group of beds of similar quality; so, the tendency for a poor bed to have a higher SAR is not significant. Per cent clay and soluble salts as well as

SAR have an effect on the soil condition, but the wide SAR values for a given bed quality cannot be accounted for by comparing these quantities together (tables 1 and 3).

Physical Analysis

Physical measurements were made in an attempt to determine if the quality of a bee bed was affected by soil texture and by the degree of dispersion of the soil surface. These quantities were determined by mechanical and particle size analysis and are reported in table 3.

Mechanical Analysis. There was no relationship between the quality of a site and the per cent of sand or silt. The clay content of poor beds was 15.47% and 16.80% for good beds, but the range was from 10.21% to 19.17% for poor beds and from 10.18% to 21.09% for good beds.

Particle Size Analysis. It has been observed that bee activity is reduced by a soil surface that is highly compacted on one hand or extremely loose and powdery on the other; therefore, an attempt was made to relate the

Table 3. Physical analysis of alkali bee nesting sites of the Ontario, Oregon area. (0-3 inch depth)

Sample no.	Burrows per ft^2	Mechanical Analysis Sand %	Mechanical Analysis Silt %	Mechanical Analysis Clay %	Particle Size Analysis Sand %	Particle Size Analysis Silt %	Particle Size Analysis Clay %
				Poor			
1	0	26.31	56.20	17.49	26.27	47.00	26.73
3	0	21.21	62.39	16.40	21.64	63.02	15.34
5	0	25.20	61.58	13.22	29.16	59.84	11.00
7	0	26.42	56.71	16.87	36.75	52.52	10.73
9	1	53.06	36.73	10.21	49.99	39.60	10.41
11	4	21.88	63.18	14.94	24.06	68.27	7.67
15	5	23.98	56.85	19.17	28.69	62.87	8.46
Average		28.30	56.23	15.47	30.94	56.16	12.90
				Fair			
17	7	14.28	69.68	16.04	18.42	74.02	7.56
19	8	28.32	54.96	16.72	36.29	57.06	6.65
24	9	22.21	57.65	20.14	23.97	66.09	9.94
29	12	19.54	62.73	17.73	28.78	55.49	15.73
31	15	28.81	59.20	11.99	29.11	57.76	13.13
33	16	24.41	54.09	21.50	28.36	64.20	7.44
Average		22.64	60.84	16.52	27.32	62.08	10.60
				Good			
35	21	21.95	60.74	17.31	22.89	68.39	8.72
37	21	13.95	64.96	21.09	16.25	64.70	19.05
39	22	25.42	58.67	15.91	25.23	69.14	5.63
41	25	25.44	59.23	15.33	28.31	59.37	12.32
43	26	35.58	49.14	15.28	33.45	56.68	9.87
45	30	22.79	58.28	18.93	27.56	63.15	9.29
46	30	25.67	57.74	16.59	26.59	55.24	18.17
48	45	33.43	56.39	10.18	33.20	58.98	7.82
50	70	20.76	61.51	17.73	22.76	67.86	9.38
52	72	32.23	52.79	14.98	34.30	55.96	9.74
Average		25.60	57.60	16.80	27.17	62.15	10.68

degree of flocculation to bed quality. It was felt that the per cent sand, silt and clay as determined by particle size analysis would give an indication of the extent of flocculation.

Poor quality beds had a higher percentage of sand and clay sized particles than did good beds. The good beds contained an average of 10.68% clay sized particles, fair beds had 10.60%, while poor beds averaged 12.90%. Inspection of each sample reveals that the decrease in per cent clay sized particles is not necessarily in order when progressing from 0 to 72 burrow/ft^2. Samples 1, 31 and 46 show a larger value for per cent clay sized particles than for per cent clay as determined by mechanical analysis. Since this is not possible, incomplete dispersion in the mechanical analysis or undissolved $CaCO_3$ particles in the particle size analysis may account for this error. If sample number 1 (table 3), which is incorrect, is not considered, the average per cent clay sized particles for poor beds is very near the same for good beds.

In comparing particle size analysis to mechanical analysis it is seen that the per cent sand is higher and per cent clay is lower when determined by the particle size analysis. This is due to the flocculating effect of the salts and organic matter.

<u>Analysis of Beds Sampled by Second Procedure</u>

Chemical and physical analysis of three bee beds sampled by the second procedure, discussed earlier, are given in tables 4 and 5. It is seen that the analyses at the 0-3 inch depth are more closely related to bed quality than where sampling was done by the other procedure in that for a given bed there was a more consistent decrease in pH, SAR, and ESP as the quality of the site increased; however, the results for the good or poor portion of one bed do not correspond to those of another bed. Changes noted in the amounts of chlorides and sulfates may account for a more soluble form of Ca and Mg -- hence a lower SAR for the good portion in each bed. In bed No. 3, carbonates were much higher than in beds 1 and 2. It appears that the type of Ca and Mg salts account for the difference in SAR between the beds.

It has been reported that a poor bed may be improved

Table 4. Chemical and physical analysis for three bee beds sampled in a poor portion, a good portion, and a transition zone at the 0-3 inch depth.

Sample no.	Bed no.	Burrows per ft^2	pH	Conductivity	SAR	ESP	Per Cent Clay	Per Cent Clay Sized Particles	Chlorides me/100 gm	Sulfates me/100 gm	Carbonates
3		0	8.0	88	86.8	68.5	16.40	15.34	41.0	49.0	0
29	1	12	7.6	72	65.9	63.6	17.73	15.73	56.5	9.9	0
50		70	7.3	150	33.5	24.3	17.73	9.38	128.3	4.4	x
7		0	8.3	39	43.6	76.1	16.87	10.73	6.1	19.0	x
15	2	5	7.5	94	50.1	39.9	19.17	8.46	78.9	5.0	x
33		16	7.4	90	23.1	40.4	21.50	7.44	61.4	3.1	x
1		0	8.5	148	238.0	82.5	17.49	26.73	40.6	95.0	xxxx
37	3	21	8.5	92	165.0	67.2	21.09	19.05	47.4	44.3	xxx
46		30	8.3	86	123.0	46.4	16.59	18.18	59.9	18.0	xx

Table 5. Chemical analysis for beds sampled in a poor portion, good portion, and transition zone at the 3-8 inch depth.

Sample no.	Bed no.	Burrows per ft^2	pH	Conductivity mmho/cm	SAR	ESP
4		0	7.8	30	36.8	54.9
30	1	12	7.7	22	26.0	25.4
51		70	7.3	26	27.1	43.5
8		0	8.0	12	17.5	37.3
16	2	5	7.8	28	28.4	48.8
34		16	7.5	28	17.2	30.0
2		0	8.5	32	61.5	64.8
38	3	21	8.6	24	94.5	92.3
47		30	8.2	44	87.0	62.1

by removing the loose powdery salts. Chemical and physical analysis were made on two beds at the 0-3 inch depth after the surface salts were removed, but results were not significantly different from the average values given in table 1 for a poor bed.

Boise Area Study

Another soil condition, found in the Boise area of Idaho, which repelled bees was a highly compacted surface. While the problem in the Ontario area was one of salty surfaces, the Boise beds sometimes had the appearance of a Sodic soil. The surface was apparently too dispersed and hard to permit easy digging. Analyses of samples from one poor and four good beds from this area are given in table 6.

At the 0-6 inch depth there is a tendency for the SAR and ESP to increase as the number of burrows/ft^2 decreases. The per cent of clay and clay sized particles are also related in this way. It is known that a higher SAR will result in a more dispersed and compacted soil; therefore, the effect of SAR and clay content

Table 6. Physical and chemical analysis for alkali bee beds from the Boise area, Idaho, in which a compacted surface prevented nesting.

Sample no.	Burrows per ft²	Sampling Depth	pH	CEC	Conductivity Kx10³	SAR	ESP	NH_4OAc extractable Na	K	Ca+Mg	Water Soluble Na	Ca+Mg	Cl	SO_4	Clay %	Clay Sized Particles %
								me/100 gm								
54	25 good	0-6	7.5	10.0	24.0	26.9	11.0	17.8	0.4	24.1	16.7	7.7	45.8	0.5	10.09	5.06
55	25	6-12	7.4	11.7	8.5	20.4	10.3	7.8	0.4	10.6	6.6	2.1	8.7	0.1		
56	25	12-18	7.7	11.7	5.8	22.0	3.4	7.0	0.4	10.5	6.6	1.8	7.9	0.3		
57	20 good	0-6	7.4	10.9	26.0	40.8	2.8	18.8	0.4	11.5	18.5	4.1	29.3	0.3	9.85	8.30
58	20	6-12	8.0	10.5	4.0	20.4	5.7	5.6	0.3	19.8	5.0	1.2	7.0	0.3		
59	20	12-18	7.8	10.5	6.0	13.6	12.4	5.5	0.3	21.0	4.2	1.9	7.1	0.3		
60	15 fair	0-6	6.5	12.0	30.0	57.3	53.3	31.4	0.6	8.4	25.0	3.8	31.5	0.8	15.16	13.40
61	15	6-12	6.4	12.2	15.0	58.0	45.9	23.0	0.6	8.4	17.4	1.8	19.3	0.4		
62	15	12-18	6.7	12.0	14.0	36.7	40.0	15.5	0.5	7.9	10.7	1.7	15.9	0.1		
63	15 fair	0-6	5.9	11.7	41.0	32.5	68.4	35.0	0.5	19.4	27.0	13.8	44.7	0.7	13.22	10.50
64	15	6-12	6.2	12.0	11.5	22.4	33.3	14.5	0.4	12.1	10.5	4.4	15.9	0.1		
65	15	12-18	7.0	12.0	15.0	17.9	30.8	11.7	0.4	13.2	8.0	4.0	13.0	0.5		
66	0 poor	0-6	6.7	13.0	29.0	80.8	56.2	27.9	0.6	5.9	20.6	1.3	21.7	0.8	15.19	13.38

could account for the highly compacted surface. It was also noted that the per cent moisture of the poor site was 5.8% as compared to 10.5% in the good bed.

If the bed is poor due to a lack of sufficient moisture or a highly compacted surface, either condition could be improved by the usual procedures for reclaiming saline-sodic soils. The proper rate of gypsum could be estimated by comparing the ESP of the poor and good portions. On the basis of this study, additions of gypsum until the ESP was reduced to 10% would be adequate.

CONCLUSIONS

Alkali bee nesting sites of the Ontario area, Oregon, were characterized by comparing the chemical and physical analyses of various quality beds. No consistent increase or decrease was noticed with corresponding increases in the quality of a bed. The relationships are too poor to be of use for predicting the quality of a site on the basis of a soil test; however, certain tendencies were noticed by classifying the nesting sites and obtaining average values for chemical and physical analyses. pH, SAR, ESP and sulfates were higher in poor sites than in good sites, while chlorides were lower in poor beds. The presence of more Ca and Mg chlorides and less carbonates in good beds accounts for the greater solubility of Ca and Mg -- hence a lower SAR.

From the results of this study it is felt that the important factor is whether or not salt deposits are on the surface of the soil. Changing the ratio of monovalent to divalent cations should have no effect on the quality of a bed through flocculation or dispersion of the surface except as it may affect the moisture status or the rate at which salts are deposited on the surface. The following points indicate that salts and not SAR or per cent clay sized particles are important in site selection: (1) Although certain soil properties could be related to bed quality by taking averages for a group of beds of similar quality, the variability for any chemical or physical property is very wide within any one group of beds. (2) Bees will not nest in sites containing surface salts. It was not known whether the bees were repelled by the loose salts falling into the entrance tunnel or whether the physical condition of the soil was unsatisfactory. (3) Stephen obtained a good bee population by merely removing the surface salts, but analyses conducted in this study of the 0-3 inch level (after removing the salt deposits) showed no difference from that of a poor bed. (4) The quality of a site has been improved by raking NcCl into the surface of a bed that contains adequate moisture. Average ESP and SAR values for beds classed as good and poor were compared in the text of this paper, and they indicate that NaCl applications would create conditions similar to those of a poor site. It is felt that the NaCl improved conditions by eventually dispersing the surface -- thus reducing surface evaporation and the formation of salt accumulations.

It is possible that digging is made difficult for bees in poor sites by a slightly compacted surface condition caused by the higher SAR and per cent clay sized particles; however, the points listed above lead one to believe otherwise. It seems that the physical condition of nesting sites in the Ontario area, Oregon, are satisfactory, even in poor nesting sites; therefore, applications of amendments to change the degree of flocculation would not be of any value where moisture was not a limiting factor. Any treatment one may make to arrest the movement of salts to the surface would be beneficial. Where salts do not cover the surface of a site containing a satisfactory moisture level, it is felt that the following factors may account for a poor quality bed: (1) distance and location of a bed with respect to the pollen source (2) tendency of bees to group themselves in a corner or portion of a bed that is uniform (3) amount of vegetation on a bed (4) distance to other beds.

It was pointed out by Stephen that moisture is an important factor affecting the quality of a bed. Since moisture was not a variable in this study, further work should be carried out with special emphasis being placed on the factors which influence the rate of water rise to the soil surface. Measurements would include per cent moisture at intervals throughout at least one season. One should also consider the various combinations of salts and particle sizes which would permit adequate moisture rise without large amounts of troublesome salts being deposited on the surface of the bed. Other measurements should include depth to water tables and restricting layers.

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