LA NECESIDAD DE CAL EN SUELOS ACIDOS DEDICADOS AL CULTIVO DE PASTOS EN LA PROVINCIA DE SALAMANCA

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SUMMARY.—The lime requirements of 166 pasture soils of the Salamanca province have been studied, the mean value found being 9.5 t/ha of CaCO₃.

These soils are acid, with a mean pH value of 5.63; they have a mean organic matter content of 3.18 % and light texture, with a mean clay content of 17.4 %. They have low Calcium content, 62.6 % of them having less than 1,000 ppm of CaO.

The buffering capacity is weak, with a mean index of 2.84.

There exists a very significant correlation between the lime requirement and the organic matter and clay contents, pH and buffering index. The correlation with Calcium is not significant.

RESUMEN.—Se estudia la necesidad de cal en 166 suelos de la provincia de Salamanca dedicados al cultivo de pastos, siendo el valor medio encontrado de 9.5 Tm./Ha. de CO₃Ca.

Dichos suelos, son ácidos con un valor medio de pH de 5.63; de contenido medio en materia orgánica de 3.18 % y una textura ligera con valor medio de arcilla de 17.4 %. Son bajos en Calcio, con un valor inferior a 1,000 ppm de CaO para el 62.6 % de los suelos estudiados.

Hay correlación muy significativa entre la necesidad de cal y el contenido en materia orgánica, arcilla, pH e índice de amortiguación, siendo no significativa la correlación con el Calcio.

INTRODUCCION

Una manifestación de la acidez del suelo, a veces de forma muy acusada, es la falta de Calcio. La ausencia de este elemento, da lugar a circunstancias desfavorables en el suelo: mala estructura, lenta descomposición de la materia orgánica, problemas debidos a la fijación del Fósforo, aprovechamiento...
inadecuado de microelementos, deficiente actividad microbiana, asimilación irregular de Potasio, Sodio, Magnesio, etc. Existen por tanto, muchas razones por las que es aconsejable añadir Calcio al suelo, además de las convenientes para remediar la acidez.

La mayor parte de los cultivos, se acomodan a pH cercanos a la neutralidad; sin embargo para algunos, el rendimiento puede ser muy deficiente cuando el pH del suelo alcanza valores muy bajos, en suelos ácidos faltos de cal.

El conocimiento del pH para determinar la acidez del suelo y las enmiendas calizas a realizar, necesarias para conseguir su modificación, no son suficientes. Además conviene saber el poder de amortiguación del suelo, que será un índice tanto más elevado cuanto más alta sea la resistencia que ofrece a modificar su pH. Dicho índice, orienta sobre las formas de cal más convenientes a emplear; así para suelos con valores inferiores a 4.0, deben emplearse calizas o margas de acción lenta, pudiéndose usar formas rápidas derivadas de la cal viva para suelos con índices superiores.

En cuanto a los suelos de la provincia de Salamanca se refiere, la reacción que presentan corresponde a valores de pH inferiores a 6.5 para un 71.0 % de suelos de cultivo (3), por lo que nos encontramos frente a una zona ácida con los inconvenientes citados.

Puesto que además la zona dedicada al cultivo de prados y pastos, representa el 49.5 % (1) de su extensión total, es importante conocer la incidencia que podría tener la reacción ácida de estos suelos sobre dichos cultivos.

En la actualidad, no existe para los suelos de esta provincia, datos concretos de recomendaciones prácticas de enclavado y únicamente hasta ahora se han basado en los ensayos hechos en otros países, como por ejemplo, los efectuados por Magny, Baur (4), etc.

El objeto del presente trabajo, es estudiar la reacción de los suelos de la provincia de Salamanca, dedicados al cultivo de pastos, dar a conocer sus necesidades de cal, índices de amortiguación y correcciones calizas convenientes.

Del resultado de estas correcciones, será posible un desarrollo más racional y rentable de los pastizales, así como la incidencia que puede tener en una mejora de la ganadería.

PARTE EXPERIMENTAL

Muestras y métodos de análisis

Se han recogido 166 muestras de suelos pertenecientes a la capa arable (20 cm.), en la zona de la provincia de Salamanca de mayor dedicación al cultivo de pastos.

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Una vez preparadas las muestras, se procedió a su análisis empleando las técnicas siguientes:

- **pH**: Determinación en agua y solución de CIK 1 N, según método de la "pasta saturada.
- **Necesidad de cal e índice de amortiguación**: Método seguido por GUTIÉRREZ-CARBALLAS (2).
- **Materia orgánica**: Método de WALKLEY y BLACK.
- **Calcio**: Extracción con acetato amónico 1 N pH = 7.0 y determinación por fotometría de llama.
- **Análisis Granulométrico**: Método internacional de la pipeta de ROBINSON.

El cálculo del pH y necesidades de cal estimados teóricamente, se hace según (4) y (5).

**RESULTADOS Y DISCUSION**

Los resultados se incluyen en la Tabla I.

En ella, además de los datos analíticos de los suelos, figuran:

1. pH del suelo determinado en solución de p-nitrofenol-acetato cálcico.
2. pH del suelo estimado-teórico, según su contenido en arcilla de acuerdo con los límites dados por MAGNY y BAUR (4) y en limo, teniendo en cuenta la influencia que ejerce en el suelo.
3. Necesidad de cal, determinada en el laboratorio (L. Tm/Ha. CO₃Ca).
4. Necesidad de cal teórica, calculada, en función del contenido en materia orgánica y arcilla y materia orgánica, arcilla + limo (T. Tm/Ha. CO₃Ca).
5. Índice de amortiguación (β).

Los suelos estudiados presentan un carácter marcadamente ácido, con un pH con relación al agua, de valor medio de 5.63. Se exceptúan los suelos 23, 29, 41, 42, 106, 110, 111 y 166, que son neutros o ligeramente alcalinos.

Predominan los de textura ligera, siendo el contenido medio en arcilla del 17.4 %. El contenido en materia orgánica es aceptable: 3.18 % de valor medio, encontrándose valores extremos de 0.43 % y 24.00 %.

El contenido en calcio asimilable es bajo, el 62.6 % de los suelos presentan valores inferiores a 1.000 ppm y aún los valores más altos no exceden del 5.4 % de los suelos estudiados.

En el histograma de la Fig. 1, se representa la frecuencia de los índices de amortiguación y necesidad de cal.

El poder de amortiguación es débil, siendo el índice medio de 2.84. Este
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valor manifiesta una baja capacidad de oposición del suelo a transformar su pH en valores altos por efecto de la adición de sustancias encalantes.

La necesidad de cal, determinada experimentalmente en el laboratorio, da un valor medio de 9.5 Tm/Ha. de CO₃Ca. Este valor es superior al calculado teóricamente.

Ante estos resultados, se observa que los suelos estudiados necesitan una enmienda caliza fundamentalmente para conseguir la elevación del pH. Sin embargo al ser bajo el poder de amortiguación, dicha enmienda es aconsejable hacerla de forma muy escalonada, puesto que una adición global podría alterar las propiedades del suelo y ser contraproducentes para el desarrollo de los pastos.

En general, puede aconsejarse una enmienda máxima por año de 3.000 Kg/Ha. de caliza molido para los suelos muy deficiences en cal y de acuerdo con el contenido medio que presentan en materia orgánica y arcilla.

No obstante, este resultado se confirmará experimentalmente con los ensayos de campo que actualmente se llevan a cabo.

**Correlaciones**

A continuación se estudian las correlaciones entre la necesidad de cal teórica (T), necesidad de cal determinada en el laboratorio (L) y el índice de amortiguación (β), así como con las variables del suelo más responsables que determinan la necesidad del encalado: pH (H₂O), Calcio, materia orgánica, arcilla y (arcilla + limo).
Se correlacionan de forma lineal y en el caso de T-L según $y = a + bx + cx^2$.

Los resultados se expresan en la Tabla II.

**Tabla II**

**RELACION DE LA NECESIDAD DE CAL DETERMINADA EN EL LABORATORIO Y ESTIMADA TEÓRICAMENTE, CON LAS VARIABLES DEL SUELO:**

<table>
<thead>
<tr>
<th>β, pH, materia orgánica, calcio, arcilla y arcilla + limo</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Tm/Ha CO₂Ca</th>
<th>β</th>
<th>pH</th>
<th>M.O. %</th>
<th>CaO ppm</th>
<th>Arcilla %</th>
<th>Arci+limo %</th>
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</thead>
<tbody>
<tr>
<td>(L) b</td>
<td>3.2903</td>
<td>-3.8547</td>
<td>0.3286</td>
<td>0.0001</td>
<td>0.22147</td>
<td>0.2612</td>
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<tr>
<td>a</td>
<td>0.0823</td>
<td>30.3691</td>
<td>0.5732</td>
<td>9.0205</td>
<td>5.7384</td>
<td>4.4810</td>
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<tr>
<td>r</td>
<td>0.8146</td>
<td>0.4291</td>
<td>0.3944</td>
<td>0.0147</td>
<td>0.3936</td>
<td>0.4572</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Tm/Ha CO₂Ca</th>
<th>b</th>
<th>pH</th>
<th>M.O. %</th>
<th>CaO ppm</th>
<th>Arcilla %</th>
<th>Arci+limo %</th>
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<tr>
<td>(T) b</td>
<td>3.1983</td>
<td>-4.9747</td>
<td>1.8281</td>
<td>0.0030</td>
<td>0.6401</td>
<td>0.4572</td>
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<td>a</td>
<td>-2.2805</td>
<td>33.9898</td>
<td>1.2315</td>
<td>3.9235</td>
<td>-3.4214</td>
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<tr>
<td>(arcilla) r</td>
<td>0.4891</td>
<td>0.3471</td>
<td>0.5335</td>
<td>0.3961</td>
<td>0.7187</td>
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<table>
<thead>
<tr>
<th>β</th>
<th>pH</th>
<th>M.O. %</th>
<th>CaO ppm</th>
<th>Arcilla %</th>
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<tr>
<td>b</td>
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<td>0.0478</td>
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<tr>
<td>a</td>
<td>1.5736</td>
<td>1.9625</td>
<td>1.8025</td>
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<tr>
<td>r</td>
<td>0.6712</td>
<td>0.3082</td>
<td>0.3562</td>
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</tbody>
</table>

(T) Tm/Has CO₂Ca (Arc. + limo) — (Arc. + limo)

b = 0.6178   a = 4.0199   r = 0.7474***

(L) Tm/Ha CO₂Ca — (T) Tm/Ha CO₂Ca (arcilla)

b = 0.4846   a = 5.9444   r = 0.7132***

(L) Tm/Ha CO₂Ca — (T) Tm/Ha CO₂Ca (Arc. + limo)

b = 0.4758   a = 5.8582   r = 0.7371***

a = 4.4766   b = 0.7925   c = 0.0091   r = 0.7919*** (y = a + bx + cx²)

(1) b = 0.7509   a = 4.4905   r = 0.8475**

(2) a = 3.6688   b = 1.0186   c = 0.0146   r = 0.8533***

(1) y (2) ecuaciones donde no se han tenido en cuenta ciertos valores desviados. Fig. 2.

a, b, c = parámetros. r = coeficiente de correlación.

* - ajuste no significativo
** - ajuste significativo
*** - ajuste muy significativo

300
Nivel de significación

Lineal:

\[ r < 0.17 \] no hay ajuste significativo *.
\[ r \sim 0.17 - 0.23 \] ajuste significativo, al 95 % de probabilidad **.
\[ r > 0.23 \] ajuste muy significativo, con el 99 % de probabilidad ***.

Cuadrática:

\[ r < 0.241 \] no hay ajuste significativo *.
\[ r \sim 0.241 - 0.297 \] ajuste significativo con probabilidad del 95 % **.
\[ r > 0.297 \] ajuste muy significativo con probabilidad del 99 % ***.

Según estos límites, los valores de la correlación \( r \), que se muestran en la Tabla II, corresponden a niveles de significación definidos como muy significativos, excepto en el caso de la necesidad de cal determinada en el laboratorio (L) y contenido en Calcio del suelo, que no es significativo.

Dentro de esta significación alta, hay que destacar la del índice de amortiguación del suelo (L) y con el contenido en materia orgánica del suelo; también (T) y el contenido en materia orgánica y arcilla, así como entre T y L que dan una alta correlación.

Hay que destacar el aumento en el nivel de significación, conseguido al tener en cuenta el contenido en limo, fracción activa del suelo.

Las correlaciones más significativas se representan en la gráfica 2.

En ella, se hace también el estudio del intervalo de confianza de la ecuación lineal correspondiente a la correlación T-L, donde el intervalo para una probabilidad del 95 % es de 2 a 10 en el eje de abscisas (T en función de limo + arcilla). Para trabajar en el campo, es posible admitir hasta una probabilidad del 85 %, con lo que el intervalo se incrementaría hasta englobar a casi todos los valores observados. Por otra parte, con la probabilidad del 95 % quedarán englobados el 90 % de los valores estudiados.

El incremento en la significación del ajuste que se consigue con la ecuación cuadrática, en el caso de la correlación T-L no es muy grande, por lo que se recomienda tomar la relación lineal como más sencilla. Si en esta correlación no se tiene en cuenta los valores desviados que se encierran en un círculo, figura 2, la correlación aumenta considerablemente.

Por lo tanto finalmente, diremos que la necesidad de cal L, está correlacionada muy significativamente con las variables del suelo estudiadas, excepto con el contenido en calcio. Destaca la alta correlación obtenida con el
FIG. 2

Correlaciones más significativas
índice de amortiguación y la necesidad de cal (T), calculada a partir de la materia orgánica y arcilla + limo, que en este último caso quedarían ligadas por la ecuación lineal:

\[ y = 4.4905 + 0.7509 \times x \]

siendo \( x = (T) \) e \( y = (L) \).

En un siguiente trabajo, se podrán correlacionar estos resultados con los obtenidos en la experimentación de campo, que actualmente se están realizando y poder así encontrar un factor de corrección que facilite en la práctica los niveles de enmiendas calizas más convenientes para cada tipo de suelo.

Además, se podría pensar en una correlación alta existente entre la necesidad de cal determinada en el laboratorio y contenido en materia orgánica, limo + arcilla que estarían ligadas mediante una ecuación cuadrática múltiple.

**CONCLUSIONES**

1. Los suelos estudiados son en su gran mayoría ácidos, pobres en Calcio y con un índice de amortiguación de 2.84 de valor medio.
2. El promedio de la necesidad de cal para elevar el pH hasta valores deseados, de acuerdo con el contenido en materia orgánica y arcilla, es de 9.5 Tm/Ha. de CO₂Ca, recomendándose adicionar anualmente una cantidad media de 3.000 Kg/Ha. de caliza, dado el débil carácter de amortiguación de estos suelos.
3. Es manifiesta la influencia activa de la fracción limo.
4. Se recomienda tomar la ecuación: \( y = 4.4905 + 0.7509 \times x \) entre L y T (arcilla + limo) como orientación práctica para dar la necesidad de cal de un suelo.

**BIBLIOGRAFÍA**