# Effects of lime and molybdenum on nodulation and nitrogen fixation of **Phaseolus vulgaris** L. in acid soils of Brazil*[1/]

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*R E S U M O*

*Foram conduzidos três experimentos em casa de vegetação para estabelecer a melhor fonte de Mo e melhor nível de calagem para máxima fixação de nitrogênio e produção de feijão* (Phaseolus vulgaris *L.) cv. 'Venezuela 350', efetivamente nodulado.*

*Molibdato de amonio e ácido molibdico mostraram ser igualmente boas fontes de Mo, enquanto a Mo-mono frit (Fritted trace element) mostrou se sem efeito. Em um solo Podzólico Vermelho-amarelo, pH 5,1, a calagem aumentou o crescimento, nodulação, fixação de nitrogênio e eficiência dos nódulos. Sem calagem as plantas fixaram pouco nitrogênio, cresceram pouco e não responderam a adição de Mo. Entre pH 5,3 e 6,0 houve resposta significativa da fixação de nitrogênio e crescimento das plantas a aplicação de Mo. Acima de pH 6.0, as plantas cresceram bem com abundante fixação de nitrogênio e não houve resposta a aplicação de Mo. Estes efeitos foram também observados em vários outros solos, onde outros fatores limitantes haviam sido completamente eliminados.*

## *Introduction*

BEAN (*Phaseolus vulgaris* L.) response to inoculation in the field is variable although high rates of acetylene reduction (80 μmoles per plant per hour) have been obtained under controlled conditions by Franco, and Munns, (unpublished). Poor response in the field may be due to physical and nutritional limiting factors specific to the bean symbiosis, or a lack of adaptation of either one or both symbionts to enviromental stress.

Most beans in Brazil are grown in acid soils, often high in aluminum, low in calcium, magnesium and phosphorus, and deficient in one or more micronutrients. Molybdenum is especially important for legumes dependent on $N_2$ for growth (4) and its deficiency is widespread in soils in Brazil (15, 3). Responses of beans to Mo application have been observed in some experiments (10, 5, 18, 13 and 20) and no or even negative responses in others (10, 12 and 20).

The availability of molybdenum and its uptake is pH dependent, and responses to liming in legumes are sometimes attributable to increased availability of Mo (1). However, this has not been carefully considered in the studies of bean response to molybdenum applications. While in some experiments the soils were limed to pH 6.0 (20) or to levels which eliminate aluminum toxicity (19, 10), some of the reported results do not mention soil pH (6, 13) or the study was carried out without *Rhizobium* inoculation (21, 5 and 12). The present study was to assess the extent to which the poor symbiotic performance of beans in acid soils can be attributed to problems in Mo nutrition.

## *Materials and methods*

All experiments had factorial randomized block designs and were done with *Phaseolus vulgaris* L. cv. 'Venezuela 350' in a glasshouse at EMBRAPA/SNLCS/PFN, Km 47, RJ, Brazil during the winter months when the temperature in the glasshouse was between 20 and 32°C and rarely exceeded 33°C. The inoculants in all experiments were *Rhizobium phaseoli* strains F300 and F310 (PFN/SNLCS/EMBRAPA, Km 47, RJ, Brazil), cultured separately on yeast mannitol agar

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Table 1.—Effect of lime and Mo on nodulation, nitrogen fixation and growth of *P. vulgaris* cv. Venezuela 350 on a Red-yellow Podzolic soil.[a]

| Mo source | Lime (ton $ha^{-1}$) | Soil pH at harvest | Nodule dry wt (mg. $pot^{-1}$) | $\mu$moles $C_2H_4$ per hour: per g nod dry wt | $\mu$moles $C_2H_4$ per hour: per pot | Plant dry wt. (g $pot^{-1}$) | Total plant N (mg $pot^{-1}$) | Total N fixed[e] (mg $pot^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Am. molybdate[b] | 0 | 5.0 | 128 | 10 | 2.1 | 2.79 | 35 | 2.9 |
| F.T.E.[c] | 0 | 5.1 | 141 | 23 | 5.3 | 2.92 | 45 | 13.3 |
| Molybdic acid | 0 | 5.0 | 77 | 23 | 2.6 | 2.82 | 36 | 5.1 |
| Control | 0 | 5.0 | 65 | 27 | 5.2 | 2.77 | 37 | 6.5 |
| Am. molybdate | 0.19 | 5.1 | 88 | 12 | 7.1 | 3.19 | 48 | 15.0 |
| F.T.E. | 0.19 | 5.2 | 142 | 31 | 4.7 | 2.72 | 37 | 8.7 |
| Molybdic acid | 0.19 | 4.9 | 137 | 112 | 15.7 | 3.83 | 79 | 47.0 |
| Control | 0.19 | 5.1 | 94 | 16 | 1.9 | 3.20 | 42 | 8.7 |
| Am. molybdate | 0.50 | 5.2 | 172 | 113 | 23.2 | 3.12 | 82 | 58.4 |
| F.T.E. | 0.50 | 5.4 | 175 | 31 | 5.0 | 3.13 | 44 | 44.3 |
| Molybdic acid | 0.50 | 5.4 | 161 | 95 | 15.3 | 3.77 | 76 | 12.7 |
| Control | 0.50 | 5.5 | 215 | 36 | 13.7 | 3.04 | 43 | 11.9 |
| Am. molybdate | 2.00 | 6.0 | 276 | 144 | 39.0 | 6.36 | 200 | 168.2 |
| F.T.E. | 2.00 | 6.0 | 241 | 94 | 20.5 | 5.08 | 118 | 86.4 |
| Molybdic acid[d] | 2.00 | 6.0 | 314 | 115 | 37.4 | 6.92 | 197 | 164.6 |
| Control | 2.00 | 6.1 | 374 | 41 | 19.8 | 6.48 | 135 | 102.4 |
| *F. values* | | | | | | | | |
| Molybdenum | | | — | 7.88** | 6.62** | 2.82* | 2.85* | 2.60 |
| Lime | | | 11.79** | 0.36 | 4.41** | 53.62** | 28.31** | 27.72** |
| Mo x Lime | | | 3.23* | 5.35** | 3.09** | 1.98* | 4.14** | 4.44* |
| V.C. (%) | | | 41 | 57 | 75 | 16 | 30 | 53 |
| l.s.d. ($p \leq 0.05$) | | | 87 | 37 | 11.2 | 0.77 | 27 | 26.7 |

[a] Each value represents a mean of 5 pots

[b] Ammonium molybdate at the rate of 0.75 kg Mo $ha^{-1}$

[c] Fritted trace element (0.2% Mo) at the rate of 40 kg $ha^{-1}$

[d] Molydbic acid at the rate of 0.25 kg of Mo $ha^{-1}$

[e] Total plant N of each treatment minus total plant N of unnodulated plants

* $p \leq 0.05$

** $p \leq 0.01$

After growth at 30°C for five days the bacteria were washed from the slopes, diluted to approximately $10^8$ cells $ml^{-1}$, mixed and one drop per seed inoculated at sowing.

Experiment 1 compared ammonium molybdate (0.75 kg $Mo.ha^{-1}$), molybdic acid (0.25 kg $Mo.ha^{-1}$) and fritted trace elements (40 $kg.ha^{-1}$ of FTE containing 0.2% Mo) and $CaCO_3$ at rates equivalent to 0.19, 0.5 and 2.0 ton per hectare (based on 2000 ton soil per ha). Red-yellow Podzolic soil collected from three sites at Santa Monica-RJ was sieved and mixed. After homogenizing the soil had pH 5.1, ppm, P, 78 ppm K, 4.1 mE $Ca^{++}$ + $Mg^{++}$ and 0.2 mE $Al^{+++}$ per 100 $cm^3$ of soil. Basic fertilization consisted of 40 ppm P, 52 ppm K, 15 ppm Mg, 16 ppm $CuSO_4.5H_2O$, 9 ppm $ZnSO_4.7H_2O$, 0.3 ppm $H_3BO_3$, 20 ppm $FeSO_4.7H_2O$ and 10 ppm $MnSO_4.H_2O$. The soil was distributed into pots (1.8 kg/pot) and lime additions were mixed with the dry soil pot by pot. The soil was then watered and allowed to stand for one week before molybdenum was added in the appropriate levels and forms. The soils was remixed prior to sowing, the plants thinned to three per pot and harvested at flowering.

Experiments 2 compared five levels of Mo (equivalent to 0, 0 25, 0.5 and 1 0 kg Mo.ha$^{-1}$ as molybdic acid) and four levls of line (Ca $CO_3$ equivalent to 0, 1, 2 and 4 ton. ha$^{-1}$) on the same soil used in experiment 1. Experimental procedure was the same as for exp. 1 for two harvest (flowering and pod filling stage). For an additional harvest at seed maturity pots of 25 c mdiameter containing 9 kg soil, were used.

Experiment 3 compared 3 soils from Rio de Janeiro State (Alluvial, Latosol and the Red-yellow Podzolic used in exp. 1 and 2); and 3 soils from the cerrado vegetational province at Sete Lagoas-MG (Dark Red Latosol-MG) and Brasilia-DF (Dark Red Latosol-DF and Red-yellow Latosol-DF). Two levels of Mo were applied (zero and the equivalent to 0.5 kg Mo. ha$^{-1}$ as molybdic acid) and 3 line levels (Ca $CO_3$ equivalent to 9, 3 and 10 ton. ha$^{-1}$). The Red-yellow Latosol-DF received an extra level of lime (1 ton $CaCO_3$ ha$^{-1}$). The same basic fertilization and experimental procedure were used as in exp. 1.

At harvest of all experiments soil pH was measured using 1:1 ratio of soil to distilled water. Nitrogenase activity was estimated by acetylene reduction assay as described by Franco, Fonseca and Marriel (11). Total nitrogen was determined by Kjeldahl digestion, steam distillation and titration.

## *Results*

Results of experiments 1 are presented in Table 1. Liming without molybdenum significantly increased nodule dry weight, total $N_2$–ase activity, plant growth and total nitrogen accumulated in the plant. At the higher pH, ammonium molybdate and molybdic acid increased the efficiency of the nodules in reducing acetylene (specific $N_2$–ase activity). The response to Mo fertilization was pH dependent: in unlimed soil there was no significant response to Mo of nodule dry weight, total and specific $N_2$–ase activity, plant dry weight and plant total nitrogen. With the lower level of lime (0.19 ton $CaCO_3$ ha$^{-1}$), which was not sufficient to change the pH appreciably, molybdic acid was a superior source of Mo (compare total $N_2$ fixed in Table 1) but at higher pH ammonium molybdate was equally effective. The F.T E. (Mo-mono frit) was apparently a poor source of Mo for *P. vulgaris* cv. Venezuela 350, at any pH. The slightly better availability of molybdic acid at lower pH justified its adoption as the sole Mo treatment in the subsequent experiments.

Figure 1 illustrates the response of $N_2$–ase activity and total plant N accumulation at flowering to pH and 0.5 kg Mo.ha$^{-1}$ in experiment 2. There was response to Mo at intermediate pH; but growth was poor at lower pH and good at pH above 6 regardless of Mo application. The complete set of results with statistical analyses are presented in Tables 2 and 3. Without lime and molybdenum plants had few, large, poorly

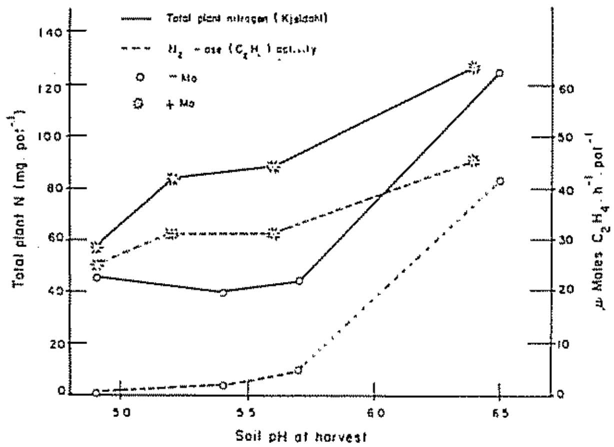


Fig 1.—*Effect of soil pH and Mo fertilization on $N_2$-ase ($C_2H_4$- reduction) activity and total plant nitrogen of* P. vulgaris *cv Venezuela 350 (Experiment 2, harvest at flowering).*

pigmented nodules. By flowering plants had developed little $N_2$–ase activity but by mid-pod fill, $N_2$–ase activity had increased to 12.5 $\mu$moles $C_2H_4$.pot$^{-1}$.h$^{-1}$. Addition of 0.25 kg Mo ha$^{-1}$ increased $N_2$–ase activity throughout the growth cycle but the N content of the plant was little changed. Levels of molybdenum of 0.5 kg ha$^{-1}$ and above increased $N_2$–ase activity and total N content of the plants (Table 2), percent N in beans and N-harvest index significantly, but had little effect on the seed dry weight (Table 3).

The plants growing at pH 4.9 with any level of Mo and the plants growing in pH 5.4 and 5.7 without Mo addition, tended to approach the best treatments in $N_2$–ase activity later in the plant cycle (compare harvest at flowering versus pod fill in Table 2) As a consequence the pattern of nitrogen accumulation up to pod fill was very similar in the treatmet without Mo for pH 5.4 and 5.7 or pH 4.9 with the higher levels of Mo. However, this was not reflected in seed yield (Table 3), indicating that the recovery was too late to benefit yield.

Experiment 3 confirmed that other soils of Brazil gave responses similar to Red-yellow Pódzolic soil from S Monica-RJ. The $N_2$–ase activity and total plant nitrogen response followed similar patterns and only the total nitrogen data are presented (Fig. 2).

The S. Monica soil was included in this experiment for comparative purposes. It is interesting that there was an increased nitrogen fixation between pH 6.1 and 7.6, when no Mo was added (Fig. 2a), in contrast to the results with pH 6.5 with and without Mo in experiment 2 (Table 2) indicating that the pH value at which no further response to Mo fertilization occurs with this soils is between 6.2 and 6.4

The Red Latosol from Rio de Janeiro with initial pH 5.7 gave good plant growth without liming, but Mo addition increased $N_2$–ase activity from 27 to 67 $\mu$moles $C_2H_4$.pot$^{-1}$.h$^{-1}$ and total plant nitrogen from 100 to 235 mg N.pot$^{-1}$. Liming in this soil resulted in

Table 2.—Effect of lime and Mo on the nitrogen fixation and growth of *P. vulgaris* cv Venezuela 350 on Red-yellow Podzolic Soil.[a]

| Lime (ton. ha⁻¹) | Mo kg ha⁻¹ | Soil pH at harvest | Harvest at flowering: Nodule dry wt (mg pot⁻¹) | Harvest at flowering: µmoles $C_2H_4$ . $h^{-1}$ pot⁻¹ | Harvest at flowering: Total plant N (mg pot⁻¹) | Harvest at pod filling stage: Soil pH at harvest | Harvest at pod filling stage: Nodule dry wt (mg pot⁻¹) | Harvest at pod filling stage: µmoles $C_2H_4$ . $h^{-1}$ pot⁻¹ | Harvest at pod filling stage: Total plant N (mg pot⁻¹) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 4.9 | 44 | 1.0 | 45.0 | 4.9 | 50 | 12.5 | 28.3 |
| 0 | 0.25 | 4.9 | 64 | 10.8 | 35.0 | 4.8 | 66 | 51.2 | 31.5 |
| 0 | 0.50 | 4.9 | 120 | 24.9 | 57.0 | 4.9 | 185 | 26.5 | 127.8 |
| 0 | 1.00 | 5.0 | 129 | 22.3 | 62.1 | 4.9 | 198 | 33.3 | 114.4 |
| 0 | 2.00 | 4.9 | 102 | 18.4 | 47.2 | 4.9 | 248 | 53.2 | 153.1 |
| 1 | 0 | 5.4 | 238 | 3.4 | 39.1 | 5.4 | 308 | 23.9 | 62.8 |
| 1 | 0.25 | 5.2 | 158 | 40.1 | 60.3 | 5.4 | 293 | 33.7 | 157.6 |
| 1 | 0.50 | 5.2 | 200 | 30.9 | 83.3 | 5.3 | 283 | 42.4 | 172.2 |
| 1 | 1.00 | 5.4 | 157 | 31.0 | 63.0 | 5.2 | 247 | 21.2 | 175.5 |
| 1 | 2.00 | 5.3 | 175 | 31.6 | 59.2 | 5.3 | 251 | 31.2 | 168.2 |
| 2 | 0 | 5.7 | 267 | 9.2 | 44.0 | 5.8 | 433 | 18.1 | 66.5 |
| 2 | 0.25 | 5.7 | 220 | 35.4 | 87.8 | 5.9 | 331 | 27.0 | 175.0 |
| 2 | 0.50 | 5.6 | 201 | 31.0 | 87.4 | 5.9 | 357 | 40.1 | 192.9 |
| 2 | 1.00 | 5.8 | 256 | 43.4 | 102.3 | 5.9 | 362 | 32.2 | 162.1 |
| 2 | 2.00 | 5.5 | 243 | 29.1 | 104.7 | 5.9 | 332 | 24.9 | 197.6 |
| 4 | 0 | 6.5 | 249 | 43.7 | 125.9 | 6.7 | 595 | 55.7 | 271.3 |
| 4 | 0.25 | 6.6 | 249 | 36.6 | 127.1 | 6.6 | 674 | 80.8 | 286.3 |
| 4 | 0.50 | 6.4 | 260 | 45.3 | 127.4 | 6.6 | 645 | 61.1 | 280.2 |
| 4 | 1.00 | 6.4 | 247 | 51.7 | 118.5 | 6.7 | 616 | 90.1 | 293.3 |
| 4 | 2.00 | 6.3 | 249 | 46.2 | 127.3 | 6.6 | 625 | 41.7 | 287.9 |
| *F. values* | | | | | | | | | |
| Mo | | | — | 5.23** | 2.27 | | — | 1.29 | 6.49** |
| Lime | | | 48.06** | 12.40** | 30.64** | | 99.25** | 7.85** | 33.40** |
| Mo x lime | | | 1.72 | 3.26** | 2.80** | | 1.69 | — | 5.60** |
| V.C. (%) | | | 24 | 27 | 20 | | 26 | 70 | 16 |
| l.s.d. ($p \leq 0.05$) | | | 66 | 11.8 | 22.7 | | 131 | 39.9 | 37.5 |

[a] Each value represents a mean of 4 pots with 3 plants each

* $p \leq 0.05$

** $p \leq 0.01$

no increase in growth or nitrogen fixation when compared with unlimed soil with Mo fertilization (Fig 2a).

The two Dark Red Latosols from the Cerrado behaved similarly (Fig. 2b). Without lime the few nodules formed had very little activity (less than 0.5 µmoles $C_2H_4$.pot⁻¹.h⁻¹). Although the plants were poorly nodulated, they were dark green and contained more nitrogen (68.3 and 55.5 mg N.pot⁻¹ respectively for the unlimed MG and DF soils) than those in Alluvial-RJ soil (24.1 mg N). This indicates the presence of available nitrogen in the soils. With 3 ton $CaCO_3$:ha⁻¹ both soils supported weakly nodulated plants and some nitrogen was fixed but there was little response to Mo. Ten ton $CaCO_3$.ha⁻¹ had no significant efect with or without Mo on total nitrogen content, but $N_2$–ase activity was significantly less indicating increased uptake of N from the soil and a corresponding reduction in the amount fixed in the nodules.

Table 3.—Effect of lime and Mo on the yield of *P. vulgaris* cv Venezuela 350 in a Red-yellow Podzolic soil.[a]

| Lime (ton. ha⁻¹) | Mo (ton ha⁻¹) | % N plants | Seed yield (g) (dry wt. pot⁻¹) | N-harvest index (%)[b] |
|---|---|---|---|---|
| 0 | 0 | 1.8 | 4.1 | 52 |
| 0 | 0.25 | 1.8 | 7.0 | 54 |
| 0 | 0.50 | 2.1 | 9.2 | 59 |
| 0 | 1.00 | 1.8 | 5.8 | 48 |
| 0 | 2.00 | 1.9 | 6.4 | 52 |
| 1 | 0 | 1.6 | 7.6 | 53 |
| 1 | 0.25 | 2.6 | 22.5 | 76 |
| 1 | 0.50 | 2.9 | 24.5 | 74 |
| 1 | 1.00 | 2.6 | 22.8 | 72 |
| 1 | 2.00 | 2.8 | 19.6 | 65 |
| 2 | 0 | 2.0 | 14.2 | 54 |
| 2 | 0.25 | 2.5 | 31.1 | 77 |
| 2 | 0.50 | 2.7 | 31.0 | 80 |
| 2 | 1.00 | 2.7 | 28.0 | 76 |
| 2 | 2.00 | 2.7 | 29.7 | 79 |
| 4 | 0 | 2.7 | 37.3 | 78 |
| 4 | 0.25 | 3.0 | 39.6 | 80 |
| 4 | 0.50 | 2.8 | 41.6 | 78 |
| 4 | 1.00 | 3.1 | 39.7 | 78 |
| 4 | 2.00 | 2.8 | 40.5 | 79 |
| *F values* | | | | |
| Mo | | 7.34** | 6.54** | 10.78** |
| Lime | | 30.47** | 89.10** | 61.06** |
| Mo x Lime | | 2.02 | 4.34** | 3.49** |
| V.C. (%) | | 22 | 14 | 9 |
| l.s.d. (p = 0.05) | | 0.3 | 4.4 | 6 |

[a] Each value represents a mean of 4 pots with 3 plants each.

[b] Total seed N x 100 divided by total plant N (including pod shells).

* $p \leq 0.05$

** $p \leq 0.01$

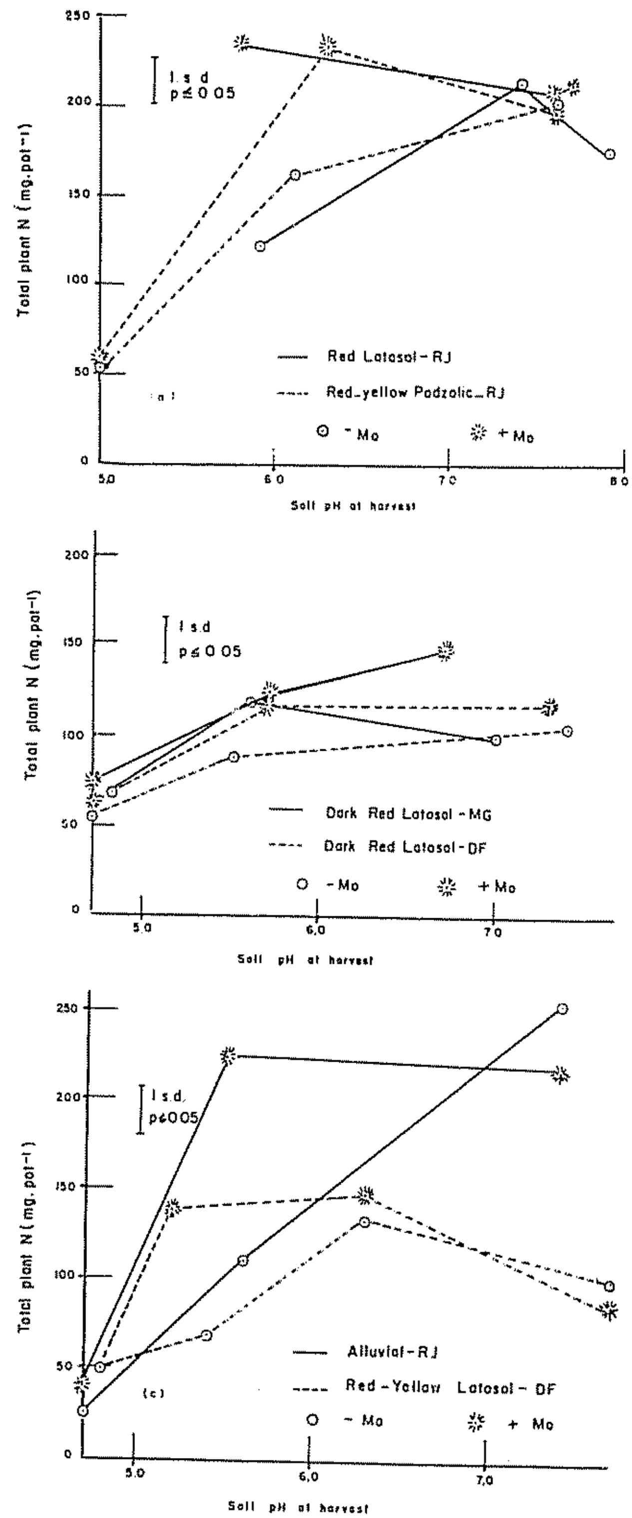


Fig. 2.—*Effect of soil pH and Mo fertilization on total plant nitrogen of P. vulgaris cv Venezuela 350 on six soils from Brazil (Experiment 3).*

The Red-yellow Latosol from Brasilia-DF received an additional treatment of 1 ton $CaCO_3$ ha⁻¹ (pH 5.2 and 5.4 in Fig. 2c) which was not included in the statistical analyses. However, this treatment was included in Fig. 2c to illustrate the response to Mo in this soil. At pH 6.4 there was no additional response to Mo and at pH 7.7 the plants showed severe signs of Mn deficiency (Döbereiner, J. personal commun.) which was probaly responsible for the poor nodulation and nitrogenase activity in this and perhaps the other cerrado soils.

The alluvial soil from Rio de Janeiro gave similar response to the S. Monica soil, but of greater magnitude (Fig. 2c).

## Discussion

All soils used in this study were severely Mo deficient confirming the widespread occurrence of Mo stress in many tropical soils (3, 15, Franco, A.A. and Laera, N.T., unpublished). Without lime, molybdenum fertilization had little effect on plant nitrogen or growth in any of the acid soils used, and increased both on a red latosol with pH 5.7. Santos *et al.* (20) studied three soils and observed that a soil with original pH 5.8 also responded up to 12.3 g Mo.$ha^{-1}$, while a soil with pH 5.5 responded linearly up to the highest Mo level used (16 g.$ha^{-1}$1) In another soil with originally low pH (4.7) liming to pH 6.0 in addition to Mo applications caused toxicity and decreased yield. These results agree with the high capacity of acids soils to adsorb Mo strongly below pH 5.5 but very little above pH 6.0 (22). The results of Smith and Leeper (23) with seven acidic soils indicate that Mo is rapidly fixed to the Fe and Al oxides and bound to organic matter. Also their studies indicated that leaching is not likely to move significant amounts of Mo through acidic profiles except perhaps in very sandy soils. This explains the lack of response to Mo in the acidic soils limed to pH 6.0 or more, observed here and by Santos *et al.* (20). The observation that Mo applications without liming increased significantly nitrogen fixation and yield of *Centrosema pubescens* grown in the same Red-yellow Podzolic soil from S. Monica, used in experiment 1 (8) stresses the differences between plant species in their response to Mo fertilization and soil pH, as indicated by Reisenauer, Tabikh and Stout (17).

Liming increased nodule growth at all levels up to 4 ton $CaCO_3$ $ha^{-1}$. At intermediate liming levels (1 or 2 ton $CaCO_3$ $ha^{-1}$) Mo fertilization reduced nodule production but increased nodule efficiency, total nitrogen fixed and plant growth. Increases of nodule mass as a response to low efficiency have been reported previously (9). At the high liming rate, plants grew well and did not respond to further Mo applications. This response pattern is similar to those obtained with subterranean clover (2, 16).

Ammonium molybdate and molybdic acid were both good sources of Mo for beans, but at lower pH levels molybdic acid seemed to be more available (Table 1). A specially prepared fritted trace element containing only Mo was of poor availability at all pH levels tested. A mixed fritted trace element preparation applied at higher doses to the same unlimed soil was able to supply the necessary micronutrients to *Centrosema pubescens* and *Macroptilium atropurpureum* (7). A later factorial experiment showed Mo to be, in fact, responsible for most of this response (8).

Kannan and Ramani (14) observed that $MoO_4^{2-}$ fed to the primary leaves of beans was transported readily to the roots. In one experiment (results not published) only sporadic improvement was obtained by either foliar application or seed imbibition.

The results reported in this paper indicate that *Phaseolus vulgaris* is unable to obtain the necessary Mo for $N_2$ fixation from the strongly acid soils studied. High levels of lime (to pH 6.0) or lower levels complemented with Mo seem necessary for nitrogen fixation. In slightly acid or neutral soils applications of Mo alone can solve the problem. Whether this effect is a direct effect of pH, interaction with Fe, Al, phosphate or sulphate and whether it is common in other bean varieties is currently under investigation.

## Summary

In three greenhouse experiments the effects of levels and types of molybdenum fertilizer on growth and nitrogen fixation of effectively nodulated *Phaseolus vulgaris* L. cv. Venezuela 350 were studied in acid and limed soils. Ammonium molybdate and molybdic acid proved equally good sources of Mo but fritted trace elements were of poor availability. In a Red-yellow Podzolic soil, pH 5.1, liming increased plant growth, nodulation, nitrogen fixation and nodule efficiency. Without lime, plants grew poorly, fixed little nirogen and did not respond to molybdenum. With low lime levels (to pH 5.3–6.0), molybdenum application significantly increased nodulation, nitrogen fixation and plant growth. Liming to a pH above 6.0 resulted in plants which grew well, fixed abundant nitrogen, and did not respond to molybdenum. These responses were similar in various soils, when other major limiting growing factors had been removed.

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# Notas y Comentarios

### *Seminario sobre conservación de la energía*

Un Seminario Internacional está organizándose por The Polytechnic of Central London, sobre "Conservación de la Energía y el uso de Energía Solar y otras Energías Renovables en Agricultura, Horticultura y Piscicultura", el que se celebrará del 15 al 19 de setiembre de 1980 El énfasis será en medidas y aplicaciones prácticas y en su eficacia dentro de un ambiente dado en la producción, procesamiento y mercadeo de alimentos humanos y animales.

El certamen tendrá lugar en el recinto del Politécnico Para detalles, incluso información sobre la presentación de los trabajos, se puede escribir a: Frederick Vogt, The Polytechnic of Central London, 35 Marylebone Road, London NW 15 LS La notificación de la intención de presentar un trabajo debe ser inmediata, *i e* a más tardar del mes de abril; los compendios deben ser sometidos en Mayo de 1980; los trabajos finales, en Agosto de 1980 Los anales serán publicados por Pergamon Press.

### *Reunión mexicana de control biológico*

La secretaría de Agricultura y Recursos Hidráulicos, de México, por conducto de la Dirección de Sanidad Vegetal y el Sector Agropecuario del Estado de Colima, han invitado a la VIII Reunión Nacional de Control Biológico, que se celebrará del 22 al 25 de abril de 1980, en la ciudad de Tecomán, Estado de Colima. Las sesiones de trabajo agruparán en: 1) control biológico de plagas principalmente mediante la entomofauna benéfica, 2) Microorganismos entomopatógenos, que abarca a virus, bacterias y nematodos, 3) centros de reproducción de insectos benéficos, y 4) coordinación del sector agropecuario con el gobierno.

El comité organizador está presidido por Carlos Aguayo Sierra, (Apartado Postal Nº 130, Tecomán, Colima) actuando como secretario Lorenzo Hernández Arregrin y como tesorero. Oscar Arredondo Gómez

### *Congreso Internacional de Horticultura*

Se ha distribuido el primer anuncio del XXI Congreso Internacional de Horticultura que tendrá lugar en Hamburgo, República Federal de Alemania, del 29 de agosto al 4 de setiembre de 1982. La invitación ha sido cursada por la International Society for Horticultural Science (I E H S ) y la Sociedad Alemana de Ciencias Hortícolas. También auspician el certamen el Ministerio Federal de Alimentación, Agricultura y Bosques, con sede en Bonn, y la Ciudad Libre y Hanseática de Hamburgo

El tema principal de la reunión será "La horticultura en la sociedad industrial" aunque tratará de otros aspectos de la ciencia hortícola, como la planta (genética, fisiológica, etc.), el ambiente ecológico y económico, la ingeniería hortícola, la protección vegetal, la postcosecha El lenguaje oficial será el inglés. Habrá giras por Hamburgo y alrededores, y algunas visitas a otras zonas de Alemania y países vecinos. La dirección del Secretariado es P. O Box 30 23 60, D-2000 Hamburgo 36, Alemania.

# Notas y Comentarios

*El vidrio y la biotecnología*

El que una firma productora de vidrio sea considerada como uno de los líderes en la biotecnología no es tan insólito como parece a primera vista si se tiene en cuenta que la firma en cuestión, la Corning Glass Works, es una de las empresas que mayor proporción de sus ingresos tiene invertido en investigación y desarrollo de nuevos productos

El romance de la Corning con la tecnología comenzó hace 100 años, cuando hizo el vidrio que sirvió para los primeros bombillos de luz de Edison Desde ese momento ha presentado una mayor innovación en cada década, constituyendo para *The Economist* (November 10, 1979, p 112), un paradigma de la industria dispuesta a correr los riesgos que toda innovación lleva consigo. Los éxitos mayores han compensado con creces los fracasos Los éxitos van desde el original vidrio Pyrex, pasando por el vidrio fotocrónico, un vidrio coloreado que se oscurece al aumentar la intensidad de la luz, hasta llegar en la actualidad a las fibras ópticas, un gran avance tecnológico que promete revolucionar las comunicaciones telefónicas en los novecientos ochenta

En la biotecnología, la firma ha gastado ya unos 20 millones de dólares. El descubrimiento de que había cierta relación entre el vidrio y la biología fue, como tantos hallazgos, fortuito. La compañía fabrica grandes cantidades de vidrio Pyrex para los laboratorios biológicos Notaba que las proteínas tenían el hábito inconveniente de pegarse al vidrio, por lo que se gastaba algún tiempo en tratar de refregar los utensilios. Entonces se dio cuenta que lo que había considerado un problema era realmente una solución selectiva: diferentes tipos de vidrio podían desarrollarse para hacer que se pegasen a ellos diferentes proteínas.

Una aplicación de esta propiedad es en estuches de pruebas para diagnosis de enfermedades, en los que el truco consiste en el uso de bolitas de vidrio especialmente diseñadas para que se adhieran a ellas anticuerpos específicos.

Una segunda aplicación del vidrio en la biotecnología es el uso de bolitas porosas las que adsorben enzimas particulares Estas enzimas "inmortalizadas" pueden ser utilizadas como catalizadores para acelerar reacciones químicas. Las ventajas de hacer que las enzimas se adhieran a las bolitas de vidrio son dos. Una es que el producto final no está contaminado y las enzimas pueden ser usadas una y otra vez

La primera reacción que la Corning ha decidido acometer comercialmente es una que se ocupa del suero del queso Por cada kilo de queso, se tienen como residuo indeseable ocho kilos de suero. La Corning ha desarrollado un proceso para convertir, mediante enzimas, el suero en subproductos útiles que pueden ser empleados por la industria de alimentos Se han completado en 1979, con éxito ensayos en Gran Bretaña y Francia, y ahora la compañía piensa construir plantas comerciales de 400,000 litros por día. Y esto se espera que sea sólo la primera de muchas aplicaciones de las enzimas inmovilizadas

*Publicaciones*

Cámara del Agro El primer número de una revista titulada *Cámara del Agro* ha aparecido en Guatemala con fecha marzo 1979. Es órgano de 13 entidades agrícolas guatemaltecas reunidas en un organismo, la Cámara del Agro, y está llamada a ser el vocero de anhelos, aspiraciones y críticas del sector agrícola. De periodicidad mensual el director del consejo editorial es César Bustamante Araúz. El primer número tiene información sobre poda del cafeto, la soya como alimento del ganado, y tratamiento del cólico del caballo. La dirección es la Reforma, 15 Calle "A" 7-65, Zona 9, Guatemala

*Anillo de plástico para prevención de la mastitis*

Un pequeño aro de plástico insertado en cada pezón de la ubre de una vaca puede prevenir la mastitis, dice Max Paape, un científico del Departamento de Agricultura de los Estados Unidos (*Agricultural Research*, September 1979). Con pérdidas a los productores de aproximadamente mil millones de dólares por año, la mastitis es la enfermedad más costosa del ganado lechero en ese país

William Kortum, un veterinario de California, desarrolló los anillos. Kortum también desarrolló un artefacto intrauterino par el control de la natalidad en vacunos (Cf. *Turrialba*, 16:5 1966).

Los anillos, que son abiertos, están hechos de un polietileno flexible similar al usado para frascos de medicina Una pieza de 11 cm del polietileno se inserta por el pezón mediante un catéter Una vez adentro el polietileno reasume la forma del anillo

El anillo funciona estimulando el mecanismo natural del animal de lucha contra las enfermedades El anillo produce una ligera irritación y en respuesta aumenta el número de leucocitos en la zona afectada Los leucocitos, o glóbulos blancos de la sangre, destruyen a la bacteria que causa la mastitis.

Normalmente, pasan unas 24 horas hasta que los leucocitos aumenten en número suficiente para destruir a las bacterias invasoras Para ese momento, las bacterias se han multiplicado en tal grado que la infección puede ya haberse establecido. El tener a los leucocitos presentes en ese momento, en respuesta al anillo, puede prevenir esta multiplicación. Además, el anillo "programa" a la ubre para responder más rápido en el caso de infección.

Las pruebas en Beltsville, controladas con ubres testigo han sido satsifactorias con toxinas de *Escherichia coli*, que causa un gran número de infecciones de mastitis Actualmente se están haciendo pruebas con infecciones con bacterias vivas de *E coli* y posiblemente con *Staphyloccus aureus*, otra bacteria causante de mastitis. Paape está siguiendo la investigación en Francia por un año, antes de que los anillos puedan recomendarse para la prevención de la mastitis y ponerlos a disposición de los productores de leche

El anillo no tiene aparentemente efecto en el número de leucocitos en la leche. El aumento en los glóbulos blancos fue evidente sólo en los primeros 20 mililitros de leche Esta cantidad es extraída normalmente antes del ordeño

*La fibra dietética reduce colesterol en los huevos*

Alimentar a las gallinas ponedoras con raciones ricas en fibras (fibra dietética) puede reducir el contenido de colesterol en la yema de los huevos en un 13 por ciento. James I. McNaughton, de la Science and Education Administration del Departamento de Agricultura de los Estados Unidos anota que no hay diferencias en la producción y en el peso de los huevos debidas a la ración rica en fibra. (*Agricultural Research*, April 1979) Como la mayor parte del colesterol en los huevos está localizada en las yemas, una reducción de 13 por ciento representa una reducción significativamente del colesterol de los huevos.

McNaughton, quien labora en Mississippi State, MS, alimentó a las gallinas ponedoras con fibra dietética en dos experimentos. Usó fibra de diversos orígenes, incluso maíz, soya, alfalfa, girasol, arroz y viruta de madera. La reducción más grande en el colesterol de los huevos (13,3%) ocurrió con la dieta con harina de girasol al nivel de 8,8 por ciento de la ración diaria. Las otras fibras tuvieron menor éxito, pero es interesante notar que el colesterol de la yema se redujo en un 10 por ciento cuando la ración contenía 10 por ciento de viruta de madera.

El científico no está seguro del porqué de la reducción en colesterol de la yema en una ración rica en fibra Aparentemente, opina McNaughton, los materiales gruesos fibrosos de la dieta causan un raspado del intestino delgado y la eliminación de células del vello intestinal, las que se sabe tienen una alta concentración de colesterol.