Perchlorate in Chilean Nitrate as the Cause of Leaf Rugosity in Soybean Plants in Chile

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ABSTRACT

Chilean sodium nitrate applications produced strongly crumpled leaves with burned tips, and reduced terminal growth of soybean plants. Potassium perchlorate, a component of Chilean nitrate, was found to be responsible for this disorder.

Residues of potassium perchlorate in the soil, originating from Chilean nitrate applied in previous seasons, caused leaf rugosity in nonfertilized commercial soybean plantings. However, a light degree of perchlorate injury in field-grown soybean plants affected neither yield nor chemical composition of the seed.

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Additional key words: Glycine max, perchlorate toxicity, seed composition, yield reduction.

RESUMEN

Aplicaciones de salitre sódico en poroto soya producen un encarrujamiento de la hoja, quemadura del ápice de la hoja y una reducción del crecimiento en los brotes terminales de esta planta. Se determinó que la pequeña fracción de perclorato de potasio que posee el salitre, era la responsable de estas anormalidades.

Los residuos de perclorato de potasio que quedan en el suelo, de las aplicaciones de sanitre efectuadas en cultivos anteriores, pueden causar encarrujamiento de las hojas en siembras comerciales sin fertilización nitrogenada. Sin embargo, se constató que cuando las plantas de poroto soya muestran un ligero daño producido por perclorato, no se ven afectados los rendimientos ni la composición quimica de la semilla.

Soybeans (*Glycine max* [L.] Merr.) were introduced into Chile in 1958, but until 1965 they were grown only in experimental plots across the country. In 1965, small commercial plantings were made in the central valley, and the total acreage of soybeans in Chile has now increased to 1,500 hectares. In 1967, our attention was called to soybean plants with rugose leaves (Fig. 1). Affected plants were sometimes stunted because of reduced terminal growth; their leaves were strongly crumpled, had burned tips, and were one-half to one-third the size of normal leaves. Generally, affected plants were evenly distributed in commercial soybean plantings. However, in field experiments where different nitrogen (N) fertilizers were being tested, we observed a considerably higher incidence of affected plants in plots which had received Chilean sodium nitrate ($NaNO_3$) than in plots fertilized with other N sources. This observation suggested that Chilean $NaNO_3$ might be the cause of the deformation.

Initially, N fertilizers, particularly Chilean $NaNO_3$, were applied to soybeans because available strains of *Rhizobium japonicum* (Kirchner) Buchanan would usually not produce nodulation in either experimental plots or commercial plantings. New strains of *R. japonicum*, producing good nodulation, became available in 1968, and consequently the use of nitrogen fertilizers in soybeans diminished substantially. Yet rugose leaves and stunted plants could still be observed in inoculated plantings, although in smaller numbers. The purpose of this investigation was to determine the cause of rugosity and stunting, and their effect on yield.

Role of Chilean $NaNO_3$.–To test our previous observation that Chilean $NaNO_3$ was involved, a fertilizer experiment was carried out in a field which had not been fertilized with Chilean $NaNO_3$ in the previous 6 years. We used a randomized complete block design with four replications, and treatments consisted of application of Chilean $NaNO_3$ (Old Style) at rates per hectare of 0, 300 kg (48.7 kg N); 600 kg (97.4 kg N); and 900 kg (146.1 kg N), respectively. Differences in the amount of nitrogen applied to the respective treatments were compensated with additional applications of ammonium nitrate. All treatments received an infurrow application of superphosphate at the rate per hectare of 436 kg (200 kg P_2O_5), and were sown with soybean cultivar Amsoy at a rate of 90 kg/hectare. Each plot consisted of four rows of 5-m each with a row spacing of 50 cm.

Visual estimations on the degree of rugosity of soybean plants showed that rugosity increased from a few leaves in plots with 300 kg Chilean $NaNO_3$/hectare to general rugosity in most plants in plots fertilized at a rate/hectare of 900 kg Chilean $NaNO_3$, whereas no symptoms could be detected in the treatment without Chilean $NaNO_3$. However, treatment yields were not significantly different.

Role of individual components of Chilean $NaNO_3$.–The principal components of Chilean sodium nitrate (Champion Brand), as listed by Collings (1), were applied individually and in combination to pots with noncontaminated field soil at a rate equivalent to their respective concentration in a soil with an application per hectare of 3,000 kg Chilean $NaNO_3$ (1 hectare = 3×10^6 kg soil). Subsequently, the pots were sown with soybean cultivar Amsoy and placed in the greenhouse.

Only plants in pots containing $KClO_4$ developed rugosity, and these symptoms were identical to those obtained with Chilean $NaNO_3$. Since Weaver (3) induced this leaf rugosity in soybean plants by adding $KClO_4$ to a complete nutrient solution in which these plants were growing, we conclude that $KClO_4$ in Chilean $NaNO_3$ produces the rugosity in commercial soybean plantings.

Recent data from the producer of Chilean nitrate, Sociedad Quimica y Minera de Chile S.A. (L. S. Carvajal, *personal communication*), indicate that the sodium and potassium types of Chilean nitrate contain 0.15-0.26% and 0.12-0.25% $KClO_4$, respectively.

Effect of $KClO_4$.–Another experiment, similar to the first field test, was carried out in a field not

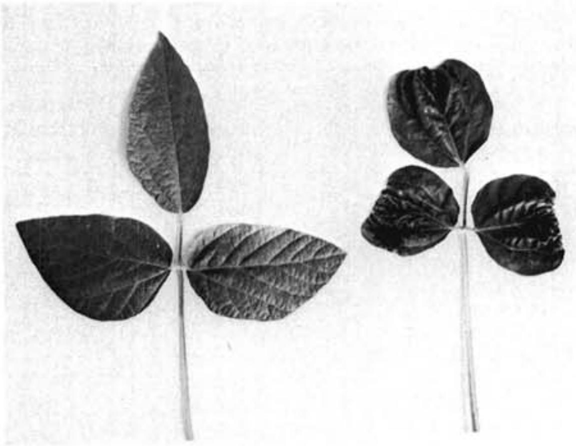

Fig. 1. A trifoliate soybean leaf with rugosity induced by Chilean nitrate fertilization (right) compared with a normal trifoliate leaf from a soybean plant inoculated with *Rhizobium japonicum* (left).

contaminated with $KClO_4$ to study the effect of perchlorate on soybean yield and seed composition. Treatments consisted of applications per hectare of (i) 379 kg urea (146 kg N); (ii) 379 kg urea + 1.8 kg $KClO_4$; (iii) 379 kg urea + 3.6 kg $KClO_4$; (iv) 900 kg Chilean $NaNO_3$ (146.1 kg N); (v) inoculation with *R. japonicum*; (vi) inoculation with *R. japonicum* + 1.8 kg $KClO_4$; and (vii) inoculation with *R. japonicum* + 3.6 kg $KClO_4$, respectively. These treatments were sown with seed of soybean cultivar Amsoy, originating from plots inoculated with *R. japonicum*, at a rate per hectare of 114.4 kg (weight per 100 seed = 17.16 g). Potassium perchlorate dissolved in water was sprayed with a hand gun sprayer on the soil surface after sowing. Two additional treatments: (viii) application per hectare of 900 kg Chilean $NaNO_3$ (146.1 kg N); and (ix) inoculation with *R. japonicum*; were sown with Amsoy seed, originating from plots fertilized with Chilean $NaNO_3$, at a rate per hectare of 91.9 kg (wt/100 seed = 13.78 g). All treatments received an infurrow application of superphosphate at a rate per hectare of 240 kg (110 kg P_2O_5).

Application of $KClO_4$ at a rate of 1.8 kg/hectare produced a degree of rugosity in soybean plants which was only slightly higher than in plots with 900 kg Chilean $NaNO_3$/hectare. At the higher rate of $KClO_4$, 3.6 kg/hectare, leaves of the seedlings were completely deformed, and shoots developed in the axils of cotyledons and leaves. These symptoms corresponded with the detailed description and illustrations of perchlorate injury in soybean plants given by Weaver (3). Severity of the perchlorate injury diminished as the growing season advanced, but reduced growth rate persisted. Consequently, these plants never attained maturity and were finally killed by frost. Thus, application of 3.6 kg $KClO_4$/hectare provoked a considerable yield reduction, whereas no significant difference in yield

TABLE 1. Effect of seed origin, nitrogen source and soil application of potassium perchlorate on yield, weight of 100 seeds, and protein and oil content of soybean seed

Seed sown (Nitrogen source of mother plant)	Nitrogen source	Potassium perchlorate added	Seed harvested			
			Yield[a]	Weight of[a] 100 seeds	Protein[b]	Oil[b]
		kg/hectare	*kg/hectare*	*g*	%	%
Chilean nitrate	Chilean nitrate	0	2,943 b	14.49 ab	29.82	15.43
Rhizobium japonicum	Chilean nitrate	0	3,062 b	14.73 ab	29.56	16.70
R. japonicum	Urea	0	3,283 b	13.66 ab	29.51	15.09
R. japonicum	Urea	1.8	3,431 b	13.28 ab	33.82	16.66
R. japonicum	Urea	3.6	1,305 a	11.99 a	28.64	16.80
Chilean nitrate	*R. japonicum*	0	5,263 c	20.18 c	39.55	14.13
R. japonicum	*R. japonicum*	0	5,836 c	20.97 c	38.42	13.97
R. japonicum	*R. japonicum*	1.8	5,424 c	20.47 c	40.11	14.87
R. japonicum	*R. japonicum*	3.6	1,523 a	17.65 bc	38.42	14.47

[a] Duncan's multiple range test. Treatments with code letters in common do not differ significantly at 1% level.
[b] On moisture-free basis.

could be observed between treatments with 1.8 kg $KClO_4$/hectare and the check plots (Table 1).

Factors affecting seed composition and yield.—In a previous field experiment, soybean seed from plots fertilized with Chilean $NaNO_3$ showed a reduction in weight per 100 seed from 17.16 to 13.78 g and in protein content from 38.4 to 28.9%, and an increase in oil from 20.6 to 24.1% when compared with seed from plots inoculated with *R. japonicum* (H. Tollenaar, *unpublished data*). It was not clear whether this difference could be attributed to the presence of $KClO_4$ or to the absence of *R. japonicum*. This question is of some practical significance, because commercial soybean plantings inoculated with *R. japonicum* and without application of Chilean nitrate also suffer from rugosity. These fields received Chilean nitrate previously while planted with other crops, and apparently subsequent rains and irrigation water failed to leach all perchlorate from the topsoil.

Our results (Table 1) demonstrate that neither application of $KClO_4$ nor chemical composition of the seed used for sowing affect chemical composition of soybean seed. Differences in yield, chemical composition of the seed, and weight per 100 seed between treatments are attributed mainly to the presence or absence of *R. japonicum*. Seed composition also appears to change with growing seasons, independent of the presence or absence of *R. japonicum*. For example, in our experiment the harvested seed as compared with seed used for sowing has a higher weight per 100 seed and a lower oil content. Soil type, seedbed preparation, and irrigation practices were identical in both growing season, and neither planting was affected by disease. However, below-average summer temperatures were observed (2) which prolonged the growth period of the soybean plants 1 month beyond the regular harvest date, thus perhaps influencing a change in seed composition.

LITERATURE CITED

1. COLLINGS, G. H. 1955. Commercial fertilizers. McGraw-Hill Book Co., Inc. New York [5th ed.]. 617 p.
2. ESCUELA DE AGRONOMIA. 1971. Boletin Agrometeorológico 79-83. Universidad de Concepción, Chillán, Chile.
3. WEAVER, R. J. 1942. Some responses of the bean plant to chlorate and perchlorate ions. Plant Physiol. 17:123-128.