Gro-Mate Soil Amendment Improves Growth of Greenhouse-grown ‘Chardonnay’ Grapevines

Andrew G. Reynolds¹, Douglas A. Wardle², Brian Drought³, and Robert Cantwell⁴

Agriculture and Agri-Food Canada, Research Center, Summerland, B.C. V0H 1Z0, Canada

Additional index words. *Vitis vinifera*, humate, organic matter, pot culture

Abstract. Own-rooted, glasshouse-grown ‘Chardonnay’ vines (*Vitis vinifera* L.) were planted in a sand medium to which was added one of five levels of granular Gro-Mate (GM), a commercial humate (0, 8, 16, 32, 64 g/pot; 0 to 35 g a.i./pot). Two other treatments consisted of weekly (1× W) or twice-weekly (2× W) applications of liquid GM, whose cumulative addition over the 28 weeks of the experiment totaled 6.7 and 13.4 g a.i., respectively. Shoot length responded to increasing level of GM in a predominantly cubic fashion, with 32 g/pot resulting in the longest shoots. Fresh and dry weights of leaves, shoots, and roots, as well as leaf count and area, exhibited increasing linear or quadratic trends in response to increased level of granular GM. GM increased soil organic matter, K, Ca, Mg, Fe, Mn, Cu, Na, and S and also increased petiole Fe and lamina P, K, and Fe. Liquid treatment resulted in lower soil pH, organic matter, bulk density, and Fe and higher soil conductivity, NO₃, P, K, Mg, Cu, Zn, Na, and S than the granular treatments, as well as higher petiole and lamina N and K, lower petiole and lamina P, and lower petiole Zn. Compared to the 1× W treatment, the 2× W produced lower soil bulk density and higher P, lower lamina K, Mn, and Fe; lower petiole Mn; and higher petiole Cu. Plant tissues contained extremely high levels of Mn irrespective of treatment, whereas liquid treatments resulted in high soil NO₃ levels. Although liquid GM cannot be recommended for young grapevines under an application regime such as described here, preplant applications of granular GM may have potential for improving growth of young vines in coarse-textured soils. High granular or excessive liquid applications may result in leaf necrosis and retarded growth.

Commercial humates have been tested on a multitude of horticultural crops (Bryan, 1976; Burdick, 1965; Linderman, 1989; Rauthan and Schnitzer, 1981; Schnitzer and Poapst, 1967; Senn and Kingman, 1973; Tan and Nopamornbodi, 1979) for their ability to promote plant growth through increases in soil water-holding capacity and cation exchange capacity (CEC). Gro-Mate (GM) (Humate Canada, Calgary, Alberta) is an example of such an organic soil amendment, containing humic acid, one of the active ingredients in soil organic matter. In the coarse-textured soils of the Okanagan and Similkameen valleys of British Columbia, commercial humates may prove valuable by adding sufficient humic acid to increase the CEC and water-holding capacity of the soil. Products such as GM

thus may aid the establishment of young vineyards, as well as improve the growth of vines in nurseries. The purpose of this experiment was to evaluate the efficacy of GM as a growth-promoting substance on potted ‘Chardonnay’ vines grown in a greenhouse.

Materials and Methods

Own-rooted ‘Chardonnay’ vines were planted in Dec. 1991 into 5-liter plastic pots containing coarse sand (hereinafter referred to as “soil”). The vines were divided equally into seven groups (treatments) of 18 vines each, and one of five levels of granular GM (active ingredients 55% humic acid + fulvic acid + humin; 0, 8, 16, 32, and 64 g material/pot) was incorporated into the sand in five of the seven treatment groups. Active ingredients of granular GM were 0, 4.4, 8.8, 17.6, and 35.2 g a.i./pot. The two remaining treatments received a 400-ml weekly (1× W) and twice-weekly (2× W) application, respectively, of 4 ml liquid GM (15 % humic acid + fulvic acid + humin) per liter of water (600 mg a.i./liter). The liquid GM treatments constituted 6.7 and 13.4 g a.i./pot, with the initial assumption that 1) the experiment’s duration would be 28 weeks from the point of the initial liquid application on 2 Mar. 1992 (28 1× W and 56 2× W applications, respectively), and 2) the liquid treatments would be applied as 400-ml aliquots. The seven treatments were arranged as a ran-

domized complete-block experiment with six blocks and three-vine treatment replications. Vines were trained to single shoots and all crop was removed. The greenhouse was at 26C day/20C night. Supplementary lighting was supplied for 6 h/day (0600–0900 HR and 1600–1900 HR) by high-intensity sodium lamps. Vines were watered twice weekly with 400 ml water containing 0.5 mg 20N–20P–20K soluble fertilizer/liter with trace elements (Plant Products Co., Brampton, Ont.); solutions for the 1× W and 2× W treatments were also made from this water–fertilizer mixture. Trace element concentrations in the soluble fertilizer were (mg·kg⁻¹): 1000 Fe, 500 for Mn, Cu, and Zn, and 200 B; or 0.005, 0.0025, and 0.001 mg·kg⁻¹ irrigation water, respectively.

Cumulative shoot length was measured at ≈6-week intervals beginning on 9 Apr. 1992. Fresh and dry weight of leaves, petioles, shoots, and roots were collected from each vine at the conclusion of the experiment in Nov. 1992. Leaf count and area of main leaves and lateral shoot leaves also were measured at that time. Elemental analysis was performed on three 50-g GM samples; three-vine composite (i.e., each treatment replication), 50-g, air-dried soil samples; and oven-dried lamina and petiole samples, using previously described methods (Neilsen et al., 1987).

All data were analyzed using the SAS statistical package (SAS Inst., Cary, N.C.). Analysis of variance was accomplished using the GLM procedure. Relationships within the five granular GM levels, between the granular and liquid treatments, and within the two liquid treatments were ascertained through the use of single-degree-of-freedom contrasts.

Results and Discussion

Vegetative growth. Shoot length was highest with 32 and 64 g GM/pot at the first measurement date, but subsequently only the 32-g application showed appreciable advantage over the control and other treatments (Fig. 1). The trend in the data was linear with increasing level of GM for the first measurement date, but predominantly cubic thereafter. Little, if any, shoot growth enhancement occurred between 0 and 16 g GM/pot, and shoot growth was suppressed at 64 g GM. The 1× W and 2× W treatments initially had no apparent effect on shoot growth, but led to obvious growth inhibition throughout the remainder of the trial (Fig. 1). These two liquid GM treatments and 64 g GM of granular material also caused significant adult leaf chlorosis and marginal necrosis and cupping of young leaves. The conductivity induced by 64 g GM and by the liquid treatments may have been high enough at application to harm the roots and cause a salt effect consistent with these foliar symptoms.

Increasing levels of granular GM increased leaf count per vine, leaf area per vine, fresh and dry weight of leaves, and dry weight of petioles (Table 1). Fresh and dry weight of stems followed cubic trends in which 32 g/pot was superior to the other concentrations. Fresh and dry weights of roots followed quadratic (para-

Received for publication 16 June 1994. Accepted for publication 19 Dec. 1994. Summerland Research Center contribution no. 892. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

¹Research Scientist, Horticulture and Basic Studies.

²Research Assistant, Horticulture and Basic Studies.

³Research Assistant, Environmental Studies.

⁴Humate Canada, Calgary, Alberta T3C 3W2, Canada.

Fig. 1. Cumulative shoot length of potted 'Chardonnay' vines subjected to five concentrations (grams/pot) of granular Gro-Mate (GM) and two application frequencies [once weekly (1×W) and twice weekly (2×W)] of liquid GM, from 9 Apr. to 19 Nov. 1992. The upper row of asterisks refers to the trends in the data from the five granular levels, while the lower row refers to differences between the granular and liquid treatments. NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively; L, Q, C: linear, quadratic, or cubic trends, respectively.

bolic) trends, wherein plants with 16 and 32 g/pot exceeded the rest. All aspects of leaf area, fresh weight, and dry weight per vine were reduced relative to the granular form and mostly relative to the control by the liquid treatments (Table 1). The 2×W treatment also reduced leaf count, leaf area per vine, and dry weight of leaves relative to the 1×W treatment. These results suggest that, although 16 g GM/pot failed to increase shoot length, there was nonetheless some effect in increased biomass of roots. Also, despite a lack of shoot growth increase in the 64-g GM vines, leaf count, total leaf area, and fresh and dry weight of leaves were increased.

These data confirm those of Bryan (1976), Schnitzer and Poapst (1967), and Rauthan and Schnitzer (1981), who, respectively, found increases in tomato (*Lycopersicon esculentum* L.) seedling growth, bean (*Phaseolus vulgaris* L.) seedling root growth, and cucumber (*Cucumis sativus* L.) root and shoot growth in response to commercial humate additions. In

most cases, these researchers found responses similar to those in this study; however, high rates of humates also tended to restrict height and cotyledon area of tomato seedlings (Bryan, 1976); root initiation of bean seedlings (Schnitzer and Poapst, 1967); and cucumber plant height, root length, leaf and flower number, and dry weight of roots and shoots (Rauthan and Schnitzer, 1981).

Nutrient concentrations in plants. Nutrient concentrations in the petioles were within normal ranges for K, Ca, Mg, and Cu; high for P; very high for Mn and Zn; and low for Fe, based on recommended concentration ranges for local vineyards [British Columbia Ministry of Agriculture, Fisheries, and Food (BCMAFF), 1993]. Increasing level of granular GM increased petiole Fe, but had no effect on other elements (Table 2). Use of liquid GM increased petiole N and K, but decreased P and Zn (Table 2). Twice-weekly liquid applications of this product decreased petiole Mn, but increased petiole Cu (Table 2). Elemental con-

centrations in the lamina were normal for P, K, Ca, Mg, Fe, Cu, and Zn, but were high for N and extremely high for Mn. In the lamina, increasing the amount of granular GM decreased K but increased Fe (Table 2). A quadratic trend showed that lamina P increased with increasing granular GM up to 32 g/pot, then decreased (Table 2). Use of the liquid formulation increased lamina N and K, but decreased P; twice-weekly application decreased lamina K, Mn, and Fe over those observed in the 1×W vines (Table 2).

The most striking feature of these data are the extremely high petiole and lamina Mn concentrations, which are 6 to 8 times higher than the upper normal limit (150 mg·kg⁻¹) for *Vitis vinifera* in this region (BCMAFF, 1993). However, Stevenson (unpublished data, 1971) found Mn concentrations >500 mg·kg⁻¹ in 'Diamond' (*V. labruscana* Bailey) petioles sampled from healthy vines growing in permanent sod cover crop and provided with medium irrigation frequency (Stevenson, 1975). Petiole Fe levels were extremely low. Also notable are the increased K and reduced P levels in the tissues following use of the liquid formulations. This combination of phenomena were the only significant trends in the plant tissue data that could account for the substantially reduced growth rate and the cupped, chlorotic, necrotic leaves in the liquid treatments. The relatively low levels of N, P, and K in the granular GM (Table 2) likely had no direct effect on concentrations of these elements in tissue, but the high Fe may have been actively absorbed and translocated; however, all tissue Fe levels were low (<40 mg·kg⁻¹) to normal (40 to 300 mg·kg⁻¹). Despite low tissue Fe, the mostly linear trends in vegetative growth in response to increased granular GM application could not be clearly linked to increases in any element other than tissue Fe. Rauthan and Schnitzer (1981) hypothesized that high concentrations of humates may provide adsorption surfaces for metal ions (primarily Fe, Mn, and Zn), which would render these elements partially unavailable.

Our data suggested a preferential uptake of Mn and Zn over that of Fe, and imply that although the GM may have been acting as a reservoir for these micronutrients, Fe was ren-

Table 1. Effect of five concentrations (grams/pot) of granular Gro-Mate (GM) and two application frequencies of liquid GM on leaf count, leaf area, fresh weight, and dry weight of greenhouse-grown 'Chardonnay' vines.

Amount/pot (g)	Leaf area (cm ²)			Fresh wt (g)/vine			Dry wt (g)/vine				
	Leaf count/ vine	Per vine	Per leaf	Leaves	Stems	Roots	Leaves	Petioles	Stems	Roots	Total
0	28	1264	47.1	24.0	47.2	72.3	4.79	0.57	21.1	31.6	73.5
8	21	1118	51.8	19.3	38.5	70.5	3.67	0.43	17.0	32.8	72.4
16	26	1335	79.5	20.2	41.4	83.5	4.34	0.49	17.6	34.8	75.7
32	31	1668	56.1	29.1	60.8	87.3	5.65	0.74	26.9	40.2	95.0
64	35	1707	50.9	29.2	43.8	69.7	5.70	0.70	18.9	34.5	78.1
Weekly (1×W)	33	1323	39.5	20.9	22.0	45.5	4.04	0.47	8.2	25.2	57.6
Twice-weekly (2×W)	23	962	42.7	15.2	26.7	54.0	2.87	0.33	10.4	28.9	60.5
Significance (granular)	L**	L**	NS	L**	C**	Q*	L**	L**	C**	Q*	L, Q*
Liquid vs. granular	NS	*	*	**	***	***	***	**	***	***	***
1×W vs. 2×W	**	*	NS	NS	NS	NS	*	NS	NS	NS	NS

NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively; L, Q, C: linear, quadratic, or cubic trends, respectively.

Table 2. Chemical analysis of Gro-Mate (GM), plus effects of five concentrations of granular GM (grams/pot) and two application frequencies of liquid GM on lamina and petiole elemental analysis of greenhouse-grown 'Chardonnay' vines.

Amount/pot (g)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (mg·kg ⁻¹)	Fe (mg·kg ⁻¹)	Cu (mg·kg ⁻¹)	Zn (mg·kg ⁻¹)
<i>Gro-Mate^z</i>									
	0.83	0.11	0.10	0.32	0.07	63.4	4206	43.7	28.3
<i>Petioles</i>									
0	1.22	0.82	4.65	1.23	0.27	640	14.7	8.5	94.1
8	1.10	0.86	5.31	1.23	0.23	672	17.9	14.0	99.8
16	1.19	0.86	4.98	1.28	0.23	605	18.6	11.5	100
32	1.33	0.85	4.85	1.20	0.25	583	17.0	11.7	96.1
64	1.20	0.72	5.67	1.44	0.28	783	21.4	12.0	108
Weekly (1× W)	1.85	0.67	6.42	1.48	0.25	840	18.7	10.2	86.4
Twice weekly (2× W)	1.79	0.54	6.41	1.36	0.34	644	17.5	16.2	70.2
Significance (granular)	NS	NS	NS	NS	NS	NS	L*	NS	NS
Liquid vs. granular	***	***	***	NS	NS	NS	NS	NS	*
1× W vs. 2× W	NS	NS	NS	NS	NS	*	NS	*	NS
<i>Lamina</i>									
0	2.81	0.95	3.16	1.32	0.24	466	94.6	14.0	20.5
8	2.91	1.03	3.06	1.31	0.23	469	97.1	13.8	22.1
16	2.64	1.01	3.00	1.48	0.23	527	106	12.8	21.9
32	3.07	1.05	2.87	1.35	0.24	450	101	16.0	22.7
64	2.81	0.82	2.67	1.45	0.25	503	121	13.6	21.1
1× W	3.55	0.82	4.35	1.48	0.23	624	107	14.8	23.5
2× W	3.70	0.73	3.83	1.21	0.25	440	89.2	16.4	21.4
Significance (granular)	NS	Q*	L*	NS	NS	NS	L**	NS	NS
Liquid vs. granular	***	***	***	NS	NS	NS	NS	NS	NS
1× W vs. 2× W	NS	NS	*	NS	NS	*	*	NS	NS

^zGM also contained (mg·kg⁻¹): 25,000 Al; 9,000 Ti; 500 Na; and 0.95% S.

NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively; L = linear, Q = quadratic.

Table 3. Effects of five concentrations of granular Gro-Mate (GM) (grams/pot) and two application frequencies of liquid GM on soil physical and extractable elemental analysis.

Amount/pot (g)	Physical analysis				Extractable elemental analysis (mg·kg ⁻¹ soil)											
	pH	BD ^y	COND ^x	OM ^z (%)	NO ₃	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B	Na	S
0	7.67	1.65	0.27	0.28	8.3	73	106	338	24.7	10.9	8.5	1.10	0.70	0.14	50	11.5
8	7.62	1.62	0.24	0.70	6.3	88	113	364	26.8	11.2	9.3	1.23	0.77	0.15	50	12.3
16	7.60	1.62	0.23	0.37	6.2	93	135	374	26.3	11.0	9.7	1.22	0.68	0.19	57	13.8
32	7.53	1.62	0.27	0.68	6.3	105	127	420	27.7	10.8	10.3	1.76	0.77	0.12	61	14.7
64	7.58	1.62	0.27	0.72	8.0	93	112	487	32.3	9.9	8.6	1.97	0.72	0.19	60	16.2
Weekly (1× W)	7.38	1.63	0.72	0.25	43.7	129	249	410	34.7	8.0	8.7	1.88	0.92	0.23	77	19.2
Twice weekly (2× W)	7.40	1.59	0.75	0.28	42.8	133	276	427	35.5	8.2	9.2	2.22	0.87	0.16	75	19.2
Significance (granular)	NS	NS	NS	L*	NS	NS	Q*	L***	L**	L*	L*	L***	NS	NS	L**	L***
Liquid vs. granular	**	*	***	**	***	***	***	NS	***	***	NS	***	**	NS	***	***
1× W vs. 2× W	NS	*	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS

^zOM = organic matter.

^yBD = bulk density (g·ml⁻¹).

^xCOND = conductance (dS·m⁻¹).

NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively; L = linear, Q = quadratic.

dered partially unavailable. Manganese, however, accumulated in the leaf tissues at potentially toxic levels, although we are not aware of any study that has established a tissue concentration range for Mn toxicity in grapes. Since high Mn also was found in the control, the source of the Mn was probably the soluble fertilizer in the irrigation water. The high Mn could thus not have fully explained the chlorotic condition of the adult leaves from the 64-g GM treatment, as well as from both liquid treatments in our experiment. Whether the high concentrations of Al and Ti in the granular GM were in any way toxic is unknown; however, Le Roux et al. (1988) reported Al toxicities in South African potted grapevines when Al was added to liquid nutrient medium at 10 mg·kg⁻¹. Theoretical Al concentrations in our granular GM-augmented soils ranged from

40 to 320 mg·kg⁻¹, since GM contained 25,000 mg Al/kg.

Nutrient concentrations in soil. As expected, increasing granular GM applications led to linear increases in soil organic matter, along with increases in Ca, Mg, Fe, Mn, Cu, Na, and S (Table 3). However, actual organic matter increases over the control were very small and ranged from an additional 0.42% to 0.44% for 8 to 64 g GM; theoretical increases based on measured bulk density were 0.05% to 0.39% and were not well-correlated with the actual values. The high Fe in the granular GM may have had a direct effect on soil Fe. However, 64 g GM did not lead to noticeable increases in soil Fe and Mn, and the relationship between soil K and granular GM level was quadratic. The liquid formulation decreased soil pH, bulk density, organic matter,

and Fe, and increased soil conductivity, NO₃, P, K, Mg, Cu, Zn, Na, and S compared to the granular applications (Table 3). Use of twice-weekly liquid feedings slightly decreased bulk density compared to weekly applications, but increased soil K (Table 3). Bulk density increases are attributed in this case to added organic matter rather than compaction, since all treatments received equal volumes of water. Based on analyses of local virgin soil (Skaha gravelly sandy loam), physical characteristics of the soil in this experiment were considered within normal ranges, other than slightly lower organic matter (E.J. Hogue, personal communication). Among the elemental analyses, NO₃, K, Ca, Mg, and S levels were lower than normal. Phosphorus and Na concentrations were higher than normal, especially with the liquid GM. Soil NO₃ following

application of the liquid formulations was 3 times the normal level found in local coarse-textured soils, and is likely a result of nitrate mineralization following these applications. The exceptionally high concentrations of soil NO_3 , P, and Na due to these liquid treatments, in conjunction with low organic matter, Ca, and Mg in general, were likely contributing factors to the poor growth and presence of chlorosis in the leaves of these treatments.

Few studies with humates have focused on woody plant nutrition. Similar to the results of our study, Fardossi et al. (1990) found only a slight increase in petiole K, Ca, and Fe in potted 'Grüner Veltliner' vines growing in P-deficient soils treated with manures. These workers also showed that although Cu and Zn uptake was enhanced, these elements appeared to remain in the roots. This phenomenon also may explain why high levels of granular GM in our study stimulated root formation, but failed to promote shoot growth, and led to leaf chlorosis. Our results nonetheless indicate that

commercial humates may be used at moderate levels in conjunction with a complete fertilizer to stimulate growth of grapevines in coarse-textured soils.

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