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RESPONSE OF SEEDED ANNUAL GRASSES AND CLOVERS TO FERTILIZATION ON A SERPENTINE SITE

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The establishment of herbaceous vegetation on soil derived from parent material of peridotite-serpentine rock is important to reduce erosion on sites cleared for roads, mining, drilling, or for increased forage production. The natural vegetation includes shrubs and stunted trees with little or no herbaceous ground cover. The soils are characteristically deficient in N, P, K, Ca, and Mo, as well as being gravelly and shallow to parent material (Rai, et al. 1970). Other problems include a high Mg content and possible toxicities of Ni and Cr (Walker 1954, Walker and Ashworth 1955). Jones, et al. (1977) reported that subclover grown on potted serpentine soils taken from 23 sites in Lake and Napa Counties responded to P and S applications on all of the soils. There were also 17 yield responses to Ca, 10 to K, and 14 to Mo.

This study was done to determine the field response of seeded grasses and clovers to fertilization with macro- and micronutrients at one of the 23 serpentine soil sites.

MATERIALS AND METHODS

A 27 by 58 m field plot was established October 13, 1970 on a Henneke soil, a lithic argixeroll, in Lake County, California at an elevation of 700 m. The site had about a five percent slope. It had been cleared of brush with a bulldozer the preceeding month. Brush snags were removed by hand ax. Rose clover (Trifolium hirtum var. Hykon) and subclover T. subterraneum L. var. Geraldton) were each seeded at 6 kg/ha, soft chess (Bromus mollus L.) and annual ryegrass (Lolium multiflorum) at 4 kg/ha each, Hardinggrass (Phalaris tuberosa L.) at 2 kg/ha and smilo (Oryzopsis miliacea) at 1 kg/ha. After the seed was broadcast the area was dragged with a chain to cover the seed and fenced to exclude deer and rabbits. The 17 fertilizer treatments

were broadcast on 3 by 6 m plots in a randomized block design with four replications (Table 2). The complete treatment consisted of 112 kg N/ha as urea; 112 kg P/ha, 145 kg S/ha, and 73 kg Ca/ha as treblesuperphosphate in a homogenized blend with 20 percent elemental S; and 112 kg K/ha as KCl. The following micronutrients were each applied at 6 kg/ha, B as $NaBO_3$, Cu as $CuSO_4$, and Zn as $ZnSO_4$. The rate of Mo as $(NH_4)_6Mo_7O_{24}$ $(4H_2O)$ was 0.28 kg/ha. On the minus P treatments, elemental S and gypsum supplied S and Ca, and on minus S and Ca treatments, Na_3PO_4 was used to supply P. On the minus S treatments $CaCO_3$ supplied the Ca. N, P, and S were reapplied in October 1972 on treatments 10 through 16 at the same rate as in 1970 (Table 2).

Yields were estimated in April each year by hand clipping herbage to ground level in three random quadrate 30 cm square from each treatment. Random grab samples of rose clover were taken for chemical analysis in April 1971. The percent seeded clover was estimated by the step-point method in 1971 and 1972, and by visual estimates from 1973 to 1977. Dry forage was removed with a mower each summer except 1973 when the plots were burned. The burn not only removed dry forage, but also burned off brush that had sprouted since clearing in 1970.

Total forage and clover samples were oven dried at 60 C, weighed and ground for chemical analysis. Nitrogen was determined by the Kjeldahl procedure. After nitric-perchloric acid digestion P was determined by the method of Bridger, et al. (1953), S by the Johnson and Nishita (1952) method, and K, Ca, and Mg by atomic absorption.

Phosphorus was extracted from the soil with 0.5M $NaHCO_3$ at pH 8.5. Soil pH was determined in a saturated paste. Exchangeable Na, K, Ca and Mg were extracted from soil with neutral, normal ammonium acetate solution and determined by atomic absorption spectrophotometry. The cation-exchange capacity was determined by displacement of NH4+ after leaching with neutral normal ammonium.

RESULTS AND DISCUSSION

Forage Production (Table 2) and Percent Seeded Clover (Table 3). The 1970-1971 growing season had adequate rain for herbage growth (Table 1). The yield data for 1971 indicated a large response to N and P and smaller but significant responses to K and S where N and P were applied. The yield of 4470 kg/ha from treatment #1 (complete) indicates a relatively high potential productive capacity for this Henneke soil site.

When treatments #1 and #8 through #16, which received no N, were broken out and analyzed separately, the LSD (0.05) was 141 kg/ha. Clover was a major component of the forage on the no-N teatments that were fertilized with P. Three of those treatments produced significantly more herbage than treatment #3 (complete minus N), #10 with no S, #13 with no Cu, and #17 with 224 kg/ha K. The other compounds used to supply P and Ca could be the reason for higher yields in treatment #10 (Na_3O_4) is more soluble than treble superphosphate and $CaCO_3$ would have a greater effect on soil pH). A possible Cu toxicity may explain the increased yield in treatment #13 and a response to K likely occurred in treatment #17.

In 1971-1972 rainfall was inadequate from October through March and all yields were low. The yields reflected no N carryover. The check and no-P treatments were significantly lower than the complete treatment, which further reflects the large P response seen in the first year.

In 1972-1973 germinating rains fell in October with heavy rains in November and March. Yields of about 2000 kg/ha were measured on treatments fertilized with P in 1970, while treatments with no applied P produced about 800 kg/ha. Repeat applications of P in October 1972 did not increase yields, which suggests that the initial P rates were adequate for maximum production. However, fresh N increased yields to about 5000 kg/ha. There was less clover on residual and fresh N treatments than where P had been applied without N.

In 1973-1974 rains appeared adequate, but highest yields were about 900 kg/ha. The residual value of P was evident by the low production from no P treatments. The 1972 N treatments produced less forage than those without N. This may have resulted from the burning of the plots in the summer of 1973. The plus-N treatments had the hottest fire because they had the heaviest forage. This may have reduced the seed available for the following year. Lower clover percentages on plus-N treatments also contributed to low yields.

The main differences in treatment yields in 1975, 1976, and 1977 were due to P treatments applied in 1970. This indicates the long-term residual value of P fertilizer on this soil. The effects of N on yields and percent clover were not significant during these last three years. However, the poorest clover stands were on the three no-P treatments.

Percent N and N Uptake (Table 4). The application of N in October 1970 and 1972 depressed the percent N values in forage the following spring where P was also applied. Two factors contribute to this decrease: the decrease in clover and N dilution due to rank growth of the grass. There were no significant differences in forage-N levels between any of the no-N treatments.

In 1971 N uptake was greatest on treatment #2 (all nutrients applied) and decreased progressively as the following nutrients were individually withheld: K, Ca, S, and P. All uptake values from no-N treatments were low and were not significantly different from each other.

In 1972 the three highest N concentrations were from those plots not fertilized with P. These three treatments also had the lowest yield, and, thus, there was less dilution of available N. There was no difference in N uptake between any of the treatments.

In 1973 N uptake was directly related to the percentage of clover in each treatment ($r=0.87$ when treatments #11, #14, #15, and #17, which received N in October 1972, were removed). The minus N (treatment #3) and minus N and S (#10) were the only two treatments significantly different than the complete (#2). Where N alone or in combination with P and S were reapplied in October 1972, forage N percentages were about one percent on all plus N treatments. Clover was practically eliminated, and the grass grew so rank

that N became very diluted. Forage N in the minus-N treatments was about two percent. Among the 1970 treatments, nitrogen uptake was greatest from treatment #3, which was significantly greater than #2, indicating that the depressing effect of applied N carried into the third year. The no P treatments were lowest in N uptake. There was no difference in uptake among treatments applied in the autumn of 1972.

In 1974 the minus-S (#6) and minus-Ca (#7) treatments were the only ones significantly higher in percent N than the complete (#2). The minus-P treatments (#4 and #8) were the lowest in uptake. Reapplication in 1972 produced the lowest uptakes where N was applied.

There were no significant differences in forage percent N in 1975, and the lowest N uptake occurred where no P was applied.

Percent P and P Uptake (Table 5). The application of P was the major element affecting percent P in the forage. This effect lasted through the first four years after application. Reapplication in 1972 increased P percentages in 1973 above the residual effects of the 1970 application, but did not significantly increase production. In 1974 and 1975 highest P percentages were on the treatments of reapplied N, probably due to the reduced yields.

Uptake of P was increased significantly by N and P in the first year after application, but mainly by P only in the remaining years.

Nutrient Concentrations in Rose Clover (Table 6). The percent N in rose clover was significantly less in treatments #11 (no micronutrients) and #14 (no Mo) than in #3 (minus N), indicating a Mo response. Treatment #10 was greater than #3, suggesting that the rate of S may have been too high, and a response occurred when it was withdrawn. Treatment #10 (minus S) received about 6 kg S/ha in the micronutrient compounds applied, which helped fulfill the S requirement of the crop.

The lowest P value was from treatment #4 (minus P). There were no other values significantly different from treatment #3. The lowest S value was from treatment #6 (minus S), with no other significant differences. Low values for K were from treatments #5 (minus K), #7 (minus Ca), and #9 (minus N and K), with no other significant differences. Low Ca values were found in treatments #1, #4, #5, #7, #8, and #10, with other values not being significantly different from #3. The Mg values that were significantly lower than treatment #3 were from treatments #1, #4, and #16.

CONCLUSIONS

This Henneke soil was extemely deficient in N and P, and somewhat deficient in K and S. The N concentration in the clover indicated a significant response to Mo. Residual yield responses to N were negative. This was related to the reduction in clover where N was applied which reduced N fixation and, thus, yields in subsequent years. When N, P, K, and S were applied, forage yields ranged from 4500 to 5500 kg/ha. Without applied N, highest forage production ws 2500 kg/ha after the clover was well established and contributing N to the soil. A single application of 112 kg P/ha had the effect of doubling yields through the seventh year after application when the study was discontinued.

REFERENCES

Bridger, G.L., D.R. Boyland, and J. W. Markey. 1953. Colorimetric determination of phosphorus pentoxide in fertilizers using a standard calibration plot. Anal. Chem. 25:336-338.

Johnson, C.M. and H. Nishita. 1952. Micro-estimation of sulfur in plant materials, soil, and irrigation waters. Anal. Chem. 24:736-742.

Jones, M.B., W.A. Williams, and J.E. Ruckman. 1977. Fertilization of Trifolium subterraneum L. growing on serpentine soils. Soil Sci. Soc. Am. J. 41:87-89.

Rai, D., G.H. Simonson and Chester T. Youngberg. 1970. Serpentine derived soils in watershed and forest management. Report to BLM from the Dept. of Soils, Oregon State University, Corvallis, Oregon.

Walker, R.B. 1954. The ecology of serpentine soils. II. Factors affecting plant growth on serpentine soils. Ecology 35:259-266.

Walker, R.B., H.M. Walker, and P.R. Ashworth. 1955. Calcium-magnesium nutrition with special reference to serpentine soils. Plant Physiol. 30:214-221.

Table 1. Monthly Rainfall at Clear Lake, California

YEARS	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOT
	mm rainfall*												
1970-71	0	0	0	18	196	174	85	1	70	12	28	0	586
1971-72	0	0	2	5	44	167	35	51	10	35	13	2	363
1972-73	0	0	23	76	143	64	296	227	67	4	1	0	900
1973-74	1	1	13	70	211	144	146	46	161	35	0	0	827
1974-75	18	4	0	31	19	115	33	225	194	29	0	1	667
1975-76	5	5	0	56	18	13	7	22	24	64	0	1	214
1976-77	1	16	7	13	33	20	41	39	71	3	49	9	303
MEAN	3	3	6	39	85	116	118	85	80	23	11	3	572

*25mm = 1 inch

Table 2. Effect of fertilizing a Henneke soil on the yield of annual clovers and grasses.

	Fertilizer Treatments October		Yields April						
	1970	1972	1971	1972	1973	1974	1975	1976	1977
			kg/ha**						
1	CK		110	190	810	440	390	550	380
2	Complete		4470	470	2060	760	950	1100	970
3	-N		180	370	2580	560	860	1180	960
4	-P		310	250	840	390	410	610	400
5	-K		3600	470	2490	570	1390	1370	1190
6	-S		2850	580	2260	910	1270	1150	750
7	-CA		3970	360	1880	820	1200	1140	1140
8	-NP		120	240	560	414	490	690	560
9	-NK		270	310	2360	690	900	1140	850
10	-NS	**CK**	550	403	**2030**	**740**	**780**	**1430**	**1080**
11	-NMICRO	**+N**	280	360	**5000**	**410**	**610**	**840**	**920**
12	-NB	**+P**	250	520	**3040**	**760**	**900**	**1270**	**1080**
13	-NCu	**+S**	430	390	**2260**	**710**	**950**	**1420**	**1000**
14	-NMo	**+NP**	190	300	**5310**	**380**	**640**	**820**	**1060**
15	-NZn	**+NS**	180	460	**5200**	**400**	**680**	**900**	**1180**
16	-N+10Ca*	**+PS**	240	290	**2200**	**730**	**851**	**1640**	**920**
17	-N+2K*	**+NPS**	370	350	**5530**	**250**	**630**	**870**	**1150**
LSD (0.05) 1970 FERT.			810	220	1030	200	440	310	490
LSD (0.05) 1972 FERT.					**1360**	**196**	**340**	**447**	**490**

*Ten times the amount of Ca and two times the K applied on #16 and #17 respectively as on other Ca and K treatments.

Statistical analyses were run separately on normal and bold data each year (1973-1977).

**kg/ha X 0.89 = lb/a

Table 3. Effect of fertilizing Henneke soil on the percent of seeded clover in the stand.

Fertilizer treatments - October		Clover April						
1970	1972	1971	1972	1973	1974	1975	1976	1977
					%			
1 CK		18	1	6	7	4	5	6
2 Complete		8	4	18	25	12	24	16
3 -N		53	14	53	26	14	29	36
4 -P		8	1	3	4	1	2	10
5 -K		9	11	10	24	14	23	20
6 -S		18	14	23	40	16	23	40
7 -Ca		11	9	30	38	19	18	16
8 -NP		13	3	3	2	1	4	6
9 -NK		53	15	30	25	14	29	16
10 -NS	+CK	65	18	**60**	**35**	**15**	**35**	**30**
11 -NMICRO	+N	45	11	**1**	**11**	**6**	**15**	**26**
12 -NB	+P	60	13	**50**	**26**	**19**	**38**	**40**
13 -NCU	+S	68	18	**73**	**35**	**19**	**28**	**30**
14 -NMo	+NP	35	7	**1**	**10**	**5**	**15**	**20**
15 -NZn	+NS	48	8	**2**	**14**	**6**	**19**	**26**
16 -N+10Ca*	+PS	55	14	**58**	**25**	**11**	**40**	**56**
17 -N+2K*	+NPS	48	10	**1**	**10**	**6**	**20**	**30**
LSD (0.05) 1970 FERT.		24	10	17	16	9	16	29
LSD (0.05) 1972 FERT.				**17**	**16**	**10**	**17**	**n.s.**

*Ten times the amount of Ca and two times the K applied on #16 and #17 respectively as on other Ca and K treatments.

See note on Table 2.

Table 4 Effect of fertilization on percent N and N uptake in annual forage on a Henneke soil.

Fertilizer treatments - October		N in total forage April					N uptake in forage April				
1970	1972	1971	1972	1973	1974	1975	1971	1972	1973	1974	1975
		%					kg/ha				
1 CK		2.12	1.69	1.25	1.76	1.65	2	3	10	8	6
2 Complete		1.18	1.21	1.28	1.72	1.71	53	6	26	13	16
3 -N		2.20	1.49	1.91	1.80	1.78	4	6	49	10	15
4 -P		2.49	1.92	1.30	1.74	1.63	8	5	11	7	7
5 -K		1.12	1.17	1.17	1.80	1.91	40	6	29	10	27
6 -S		1.06	1.27	1.31	2.27	1.87	30	7	30	21	24
7 -Ca		0.94	1.29	1.57	2.16	1.83	37	5	30	18	22
8 -NP		1.76	1.69	1.36	1.72	1.62	2	4	8	7	8
9 -NK		1.96	1.51	1.48	1.92	1.62	5	5	35	13	15
10 -NS	**CK**	2.51	1.39	**2.06**	**1.61**	**1.80**	14	6	**43**	**12**	**14**
11 -NMicro	**+N**	1.96	1.46	**0.99**	**1.90**	**1.78**	5	5	**49**	**8**	**11**
12 -NB	**+P**	2.57	1.40	**2.23**	**1.88**	**1.96**	6	7	**68**	**14**	**18**
13 -NCu	**+S**	2.10	1.62	**2.36**	**2.00**	**2.14**	9	6	**53**	**14**	**20**
14 -NMo	**+NP**	1.74	1.60	**0.99**	**1.82**	**1.78**	3	5	**53**	**7**	**11**
15 -NZn	**+NS**	2.17	1.43	**0.98**	**1.99**	**1.58**	4	7	**51**	**8**	**11**
16 -N+10Ca*	**+PS**	2.06	1.61	**1.95**	**1.78**	**2.12**	5	5	**43**	**13**	**18**
17 -N+2K*	**+NPS**	1.80	1.46	**0.94**	**1.90**	**1.49**	7	5	**52**	**5**	**9**
LSD (0.05) 1970 FERT.		0.56	0.30	0.46	0.40	n.s.	11	n.s.	14	5	11
LSD (0.05) 1972 FERT.				**0.26**	**n.s.**	**n.s.**			**n.s.**	**9**	**n.s.**

Ten times the amount of Ca and two times the K applied on #16 and #17 respectively as on other Ca and K treatments.

See note Table 2.

Table 5. Effect of fertilization of a Henneke soil on percent P and P uptake in annual grassland forage.

Fertilizer treatments - October		P in total forage April					P uptake in forage April				
1970	1972	1971	1972	1973	1974	1975	1971	1972	1973	1974	1975
		-----%					-----		kg/ha		
1 CK		0.18	0.14	0.16	0.21	0.24	0.20	0.27	1.3	0.9	0.9
2 Complete		0.22	0.27	0.21	0.28	0.23	9.83	1.27	4.3	2.1	2.2
3 -N		0.24	0.28	0.20	0.25	0.22	0.43	1.03	5.2	1.4	1.9
4 -P		0.12	0.13	0.17	0.20	0.19	0.38	0.32	1.4	0.8	0.8
5 -K		0.21	0.22	0.24	0.29	0.22	7.55	1.03	6.0	1.7	3.1
6 -S		0.20	0.21	0.21	0.25	0.23	5.69	1.22	4.8	2.3	2.9
7 -Ca		0.18	0.27	0.20	0.25	0.23	7.14	0.97	3.8	2.0	2.8
8 -NP		0.14	0.12	0.15	0.23	0.21	0.17	0.28	0.8	1.0	1.0
9 -NK		0.21	0.23	0.20	0.26	0.24	0.56	0.72	4.7	1.8	2.2
10 -NS	**CK**	0.18	0.25	**0.19**	**0.27**	**0.23**	0.99	1.01	**3.9**	**2.0**	**1.8**
11 -NMicro	**+N**	0.20	0.21	**0.20**	**0.32**	**0.25**	0.56	0.75	**10.0**	**1.3**	**1.5**
12 -NB	**+P**	0.17	0.23	**0.26**	**0.27**	**0.25**	0.42	1.18	**7.9**	**2.1**	**2.2**
13 -NCu	**+S**	0.16	0.22	**0.18**	**0.24**	**0.21**	0.68	0.86	**4.1**	**1.7**	**2.0**
14 -NMo	**+NP**	0.17	0.22	**0.24**	**0.33**	**0.27**	0.32	0.67	**12.7**	**1.3**	**1.7**
15 -NZn	**+NS**	0.17	0.22	**0.19**	**0.29**	**0.25**	0.30	1.01	**9.9**	**1.2**	**1.7**
16 -N+10Ca*	**+PS**	0.16	0.22	**0.22**	**0.26**	**0.26**	0.38	0.64	**4.8**	**1.9**	**2.2**
17 -N+2K*	**+NPS**	0.20	0.21	**0.23**	**0.33**	**0.27**	0.74	0.73	**12.7**	**0.8**	**1.7**
LSD (0.05) 1970 FERT.		0.03	0.04	0.02	0.04	n.s.	1.78	0.42	2.3	0.5	0.8
LSD (0.05) 1972 FERT.				**0.02**	**0.05**	**0.03**			**3.1**	**n.s.**	**n.s.**

*Ten times the amount of Ca and two times the K applied on #16 and #17 respectively as on other Ca and K treatments.

See note Table 2.

Table 6. Effect of fertilization of a Henneke soil on percent of five elements in rose clover in April 1971.

Fertilizer Treatments October 1970	Elements					
	N	P	S	K	Ca	Mg
	%					
1 CK	2.42	0.14	0.15	1.46	1.03	0.60
2 Complete	2.33	0.14	0.11	1.20	1.12	0.75
3 -N	2.45	0.17	0.12	1.52	1.22	0.82
4 -P	2.34	0.12	0.14	1.43	0.96	0.65
5 -K	2.37	0.14	0.10	0.84	0.97	0.85
6 -S	2.34	0.15	0.08	1.24	1.08	0.76
7 -Ca	2.38	0.13	0.11	0.89	1.05	0.90
8 -NP	2.41	0.14	0.15	1.66	1.04	0.68
9 -NK	2.50	0.16	0.14	1.01	1.11	0.87
10 -NS	2.66	0.16	0.11	1.35	1.05	0.77
11 -NMicro	2.17	0.19	0.14	1.65	1.15	0.83
12 -NB	2.60	0.17	0.13	1.44	1.15	0.82
13 -NCu	2.51	0.15	0.13	1.48	1.12	0.69
14 -NMo	2.08	0.18	0.16	1.66	1.07	0.76
15 -NZn	2.56	0.17	0.16	1.51	1.18	0.84
16 -N+10Ca*	2.47	0.15	0.14	1.35	1.40	0.64
17 -N+2K*	2.49	0.15	0.14	1.60	1.10	0.73
LSD (0.05)	0.19	0.03	0.04	0.30	0.17	0.12

*Ten times the amount of Ca and two times the K applied on #16 and #17 respectively as on other Ca and K treatments.