

TAXONOMY AND ECOLOGY OF ECTOMYCORRHIZAL MACRO-
FUNGI OF GRAND TETON NATIONAL PARK

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Introduction

This installment is one of a series of reports (McKnight, et al 1981, 1982, 1983, 1984) on an extended project studying taxonomy and ecology of ectomycorrhizal macrofungi in and around the Grand Teton and Yellowstone National Parks. It reports the work done on the project during the last year by scientists with specialties as follows: L. R. Batra, Mycology-Plant Pathology; K. T. Harper, Ecology; K. H. McKnight, and M. Moser, Mycology-Taxonomy; K. B. McKnight, Mycology-Biometry. The significance of this program lies in obtaining fundamental information on symbiotic fungi as indispensable intermediates in the uptake of minerals by Tracheophyta. The latter are a major force in building soil, regulating stream flow, and in erosion control.

This continuing study adds to the inventory of Park fungi (McKnight, 1982) and the supporting documentation of annotations, descriptions, and illustrations. Very little field work was undertaken during the 1984 collecting season, the major emphasis being on analysis of soil and vegetation samples obtained previously.

Methods

Standard methods were used for collecting, annotating and curating specimens and analysis of soil and vegetation samples. Specimens collected are deposited at the National Fungus Collections (BPD). An additional 100 collections of duplicate specimens have been prepared from this and previous years' collections in Yellowstone and Grand Teton Parks and vicinity for deposit in the herbarium (YELLO) at Mammoth.

Localities studied in and around the Parks were described in the Research Center 5th Annual Report, 1982 (See McKnight, Harper, & McKnight, 1984). Names of these localities are abbreviated as follows: CAB=Cattle Bridge, NEE=Northeast Entrance, NEZ=Nez Perce Creek, PAC=Pacific Creek, PET=Petrified Tree, PIL=Pilgrim Creek, REM=Reid Mtn., SIG=Signal Mountain, SNA=Snake River Picnic Ground, TUP=Turpin Meadow, WES=West Side Teton Pass.

Soil samples were collected at three locations from each of the eleven study sites. Samples were taken from the top 1.5 dm of the "A" horizon. All samples were dried and stored in air-tight plastic bags until the laboratory analyses could be made. Analyses were done by the University of Maryland Cooperative Extension Service. Soil pH was determined as a 1:1 soil-to-water, wet paste. Available Mg, P₂O₅, K₂O, Ca, Cu, Mn, and Zn were extracted with a weak double acid (Mehlich D). Magnesium blue and molybdate-vanadate reagents were used to detect color changes for Mg. (630 nm) and P₂O₅ (420 nm), respectively. Emission at 768 nm (for K₂O) and 623 nm (for Ca) was detected with a flame photometer. Levels of Cu, Mn, and Zn were detected with an atomic absorption spectrophotometer at 324.7, 403, and 213.8 nm, respectively. Cation exchange capacity (CEC) summed the available cations as determined above (Mg, K₂O, and Ca) as well as the exchangeable acidity as determined by a buffer pH method developed by the North Carolina Department of Agriculture using sodium glycerophosphate. Nitrate-nitrogen was determined by the sodium acetate-brucine sulfate method with spectrophotometer readings taken at 450 nm. The colorimetric determinations (650 nm) of organic matter used a modification of the Walkley-Black, wet-oxidation procedure using sodium dichromate. Soil texture determinations were made by hand.

Data and Analysis

Collection of Fungi

The very brief field studies in Yellowstone Park during the summer of 1984 concentrated on collections in the alpine zone of Mt. Washburn and in additional paintings and photographs of park fungi. Forty-one collections were made in the park on Mt. Washburn and in the vicinity of Lewis Lake.

In collaboration with Dr. Meinhard Moser, University of Innsbruck, Austria, a first series of observations on the fungus flora of the alpine zone in mountains of Wyoming and Montana was presented at the Second International Symposium on Arctic and Alpine Mycology at Fetan, Switzerland, and the written report has been accepted for publication in the Conference Proceedings now being compiled. This was based on research in Yellowstone and Grand Teton National Parks and in the Beartooth Mts. adjacent to Yellowstone National Park. In this study special attention is given to species of the genus Cortinarius. Thirteen species of Cortinarius are discussed or described. Five of them, all from the Beartooths and Mt. Washburn are new: Cortinarius absarokensis Moser & McKnight, C. fuscoflexipes Moser & McKnight, C. mucronatus Moser & McKnight, C. rufoanuliferus Moser & McKnight, and C. vulpicolor Moser & McKnight. In addition, several species in Cortinarius and other genera treated

in that report are new for North America, including Lactarius nanus Favre.

For studies on plant pathogenic fungi directed by Dr. L. R. Batra, ARS, Beltsville, MD., overwintering fruit bodies (sclerotia) of Monilinia (Cup-fungi) were collected from 9 sites in the Park. All were subsequently obtained in pure culture in the laboratory. These fungi are obligate parasites of Vaccinium and cause a complex of diseases called Mummy Berry Disease. The material collected belongs to M. baccarum, but also include an undescribed species. We must now find the sexual stages which are produced in springtime to definitively identify the fungi to species.

Soil Analyses

The average and standard deviation of the amount of P_2O_5 , K_2O , Mn, and O.M. for the 11 study sites were significantly correlated ($P < .05$). The average and standard deviation of the amount of Ca, Mg, Zn, NO_3 , and pH for the 11 study sites likewise were correlated, although not significantly ($P < .10$). Cation exchange capacity (CEC) and Cu showed no relationship between the average and standard deviation. The general agreement between the average and the standard deviation for most soil parameters permitted us to restrict subsequent analysis and discussion to the average values. Analysis of soil texture was not reported to us quantitatively and consequently does not appear in most of our analyses.

The 11 soil parameters appeared to fall into two groups (Table 2): the first group consists of P_2O_5 , K_2O , Mn, and Zn. Amounts of these elements were not correlated with amounts of any other soil parameters measured. The second group consisted of the remaining parameters. In these, CEC was negatively correlated with Cu and positively correlated with Mg, Ca, NO_3 , and O.M. (Table 2). Calcium was positively correlated with pH, Mg, CEC, and O.M. and negatively correlated with Cu. The two groups are further distinguished by the eigen values of the principal components analysis (Table 3). The axis of the first component clearly lies closest to Mg, Ca, CEC, and Cu. The axes of the second and third components are largely determined by P_2O_5 , K_2O , Mn, and Zn. The fourth component is mostly directed by the remaining variation in pH.

The 6 sites having fine-textured soil (PAC, REM, SIG, SNA, TUP, WES) had among them the maximum values for almost all of the parameters measured and minimum values for almost none of these parameters (Table 1). The 4 sites (CAB, NEZ, NEE, PET), having more coarse-textured soils generally showed the reverse relationship. With minimum values for Mg, P_2O_5 , Ca, CEC, and pH, NEZ appears to have the most impoverished soil.

Relationships between the 11 sites can perhaps be seen most clearly from the principal components analysis. The 11 sites can be divided into 5 groups (Figure 1). The more impoverished soils, having comparatively large amounts of only Mn are at NEZ and SIG. With particularly high values for O.M., CEC, and Ca, the richest soils seem to be at TUP, PET, and WES. The four alluvial sites (PAC, CAB, PIL, SNA) have intermediate values for almost all parameters. Northeast Entrance (NEE) can be distinguished from the four alluvial sites mostly by its high P_2O_5 and low Mn, O.M. and pH. Reid Mtn. Ridge (REM) can be

Table 1. Soil pH, CEC, organic matter and nutrients at the 11 study sites. Means and standard deviations were based on three samples from each site.

Loc	pH		Mg (Lb/A)		P ₂ O ₅ (Lb/A)		K ₂ O (Lb/A)		Ca (Lb/A)		CEC (meq)		Cu (Lb/A)		Mn (Lb/A)		NO ₃ (Lb/A)		O.M. (%)		Zn (Lb/A)		Txt
	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s	
CAB	6.3	.3	313	19	253	53	308	103	2800	605	11.1	2.3	4.1	0.7	140	47	13	2	3.0	1.1	6.8	3.9	SL
NEZ	5.1	.4	180	46	22	9	231	38	973	423	7.0	0.9	3.5	1.7	203	36	11	2	5.3	1.4	7.9	2.0	SL
NEE	5.4	.5	309	53	274	67	236	32	2807	730	13.3	2.3	4.3	0.4	65	24	37	6	4.3	1.4	3.6	1.5	SL
PAC	5.7	.2	322	12	191	29	249	53	3473	671	14.3	1.8	2.6	0.6	124	17	16	2	7.2	1.0	16.3	3.4	SIL
PET	5.5	.3	312	56	125	60	404	74	4427	2175	17.5	6.1	1.4	0.7	104	7	25	24	13.1	7.3	9.0	1.9	SL
PIL	5.6	.2	333	19	204	42	339	38	3733	344	15.2	0.9	3.6	0.7	150	9	40	5	6.3	2.2	9.8	2.0	L
REM	6.1	.3	370	26	132	34	483	150	4240	139	16.2	0.1	2.9	2.0	96	32	29	15	8.7	1.2	19.5	5.5	SIL
SIG	5.2	.2	188	54	142	60	295	155	1113	528	7.8	2.0	4.8	1.4	287	147	17	5	5.9	2.1	10.5	6.1	SIL
SNA	7.0	.6	351	9	231	46	433	123	3747	1204	13.2	2.8	1.8	0.8	99	31	29	19	5.1	2.4	7.9	3.2	SIL
TUP	6.5	.9	352	32	45	17	189	45	5447	1218	18.6	2.2	2.4	1.9	150	79	35	15	11.2	2.5	3.1	1.9	SIL
WES	6.3	.7	346	31	157	28	260	11	3640	726	14.1	2.7	2.4	0.8	284	204	20	7	8.4	4.4	13.4	12.2	SIL

L= loam

SL= sandy loam

SIL= silty loam

Table 2. Correlation matrix of 11 soil parameters for the 11 study sites.

**= P<.01 *= P<.05

pH	1.000																						
Mg	.724*	1.000																					
P ₂ O ₅	.209	.351	1.000																				
K ₂ O	.273	.350	.221	1.000																			
Ca	.613*	.888**	.000	.241	1.000																		
CEC	.436	.846	**	.010	.228	.975**	1.000																
Cu	-.504	-.548	.239	-.335	-.695*	-.646*	1.000																
Mn	-.199	-.514	-.374	-.362	-.464	-.494	.273	1.000															
NO ₃	.207	.565	.217	.168	.597	.650*	-.133	-.481	1.000														
O.M.	.054	.312	-.553	.134	.656*	.709*	-.689*	-.032	.233	1.000													
Zn	-.026	.184	-.038	.472	.041	.074	-.171	.128	-.258	.163	1.000												
pH																							
				</																			

Table 3. Principal components analysis of the 11 soil parameters for the 11 study sites.

	Component			
	1	2	3	4
% Variance	44.5	63.1	76.9	85.8
Soil Parameter	Eigen Values			
pH	.28494	.14259	.10988	-.70051
Mg	.41366	.17030	.07372	-.17154
P ₂ O ₅	.04552	.61886	.15517	-.03272
K ₂ O	.19253	.10273	.56554	.29526
Ca	.43822	-.06616	-.11789	-.07500
CEC	.42839	-.07842	-.14296	.11647
Cu	.33601	.29382	-.11219	.18415
Mn	-.25679	-.33584	.05392	-.37852
NO ₃	.28052	.22726	-.34455	.34978
O.M.	.26968	-.51204	-.10225	.20614
Zn	.05240	-.18342	.67792	.17433

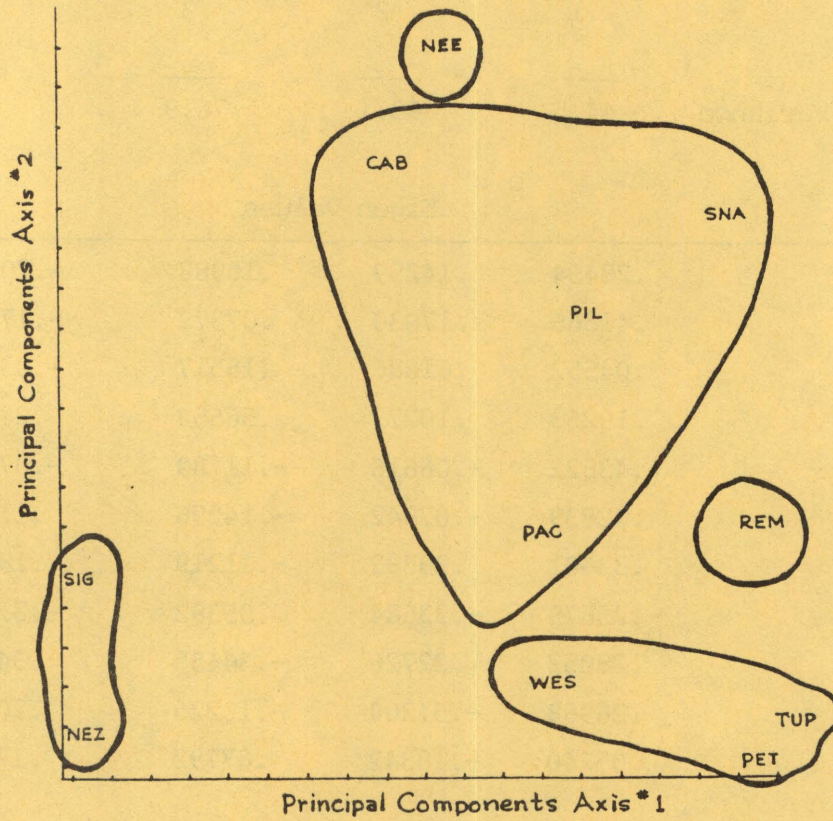


Figure 1. The relationship of the 11 study sites plotted by their first two principal components axis scores.

distinguished from the four alluvial sites mostly by its higher values of Mg, K_2O , Zn, CED, Ca and O.M. Also, REM can be distinguished from TUP, PET, and WES mostly by its lower Mn and higher Mg, K_2O , and Zn. Future reports will correlate the soil and other site analysis data with information on the plant community composition in the 1983 report and the macrofungi.

Mineral Uptake by Fungi

Although foresters have long recognized that ectomycorrhizal associations of fungi and tree roots greatly enhance the ability of trees to obtain potassium, phosphorus and nitrogen from soil (Bowen 1973), few studies report mineral content of the tissue of fungal participants in the associations (Vogt and Edmonds 1980). Such data for fungal participants in mycorrhizal associations may help explain the mechanisms by which the fungi enhance the mineral uptake of associated trees. If the effect is related to variable abilities of the fungal participants in mycorrhizal association to take up certain elements, it may be possible to improve the ability of specific tree species to acquire particular nutrient elements by substitution one fungal associate for another.

The elemental content of sporocarps of 18 fungi of western American forests is reported in Table 4. All of the species except *Auricularia auricula* are suspected participants in mycorrhizal associations with one or more western American trees. Our mean values probably do not differ significantly from those reported by Vogt and Edmonds (1980) for nitrogen, phosphorus, calcium or magnesium. On the average, our samples do seem to have more potassium and less sodium than those from western Washington (Vogt and Edmonds 1980). Without more information about soil in the two areas, we cannot offer an explanation for the apparent differences.

In an effort to understand the significance of fungal species differing among themselves in respect to tissue content of various elements, we have obtained cation exchange capacity (CEC) of the lower stipe portions of the sporocarps (Table 4). Some vascular plant physiologists have long held that CEC of root surfaces exerts a significant and predictable impact on the ratio of monovalent and divalent cations in plant tissue (Haynes 1980, Drake 1964). In Figure 2, we show that potassium content of tissue declined significantly as CEC increased in our samples. That pattern is also commonly observed among vascular plants (Haynes 1980). In contrast, tissue content of the divalent cations, calcium and magnesium, increased significantly with increasing CEC in our samples (Figure 2). That response is also observable among vascular plants (Haynes 1980).

Prior to our work, CEC values had not previously been reported for any fungal species. In comparison with CEC values for vascular plants from Utah, the fungi appear to have lower values on the average than dicotyledonous species (33.0 miliequivalents/100 g of root tissue, N=24) and somewhat higher values than root tissue of monocotyledonous species (14.8 m.e./100 g, N=9). The vascular plant values are from Woodward et al. (1984). On the basis of a small sample of 8 local tree species, fungal tissue CEC averages are somewhat lower than either coniferous or angiosperm trees (23.2 vs 31.3 and 30.2 respectively, Tables 4 and 5). Feeder roots of nine California conifer species sampled by us give an average CEC value of 37.8 m.e./100 g. To our knowledge, ours are the

Table 4. Some chemical characteristics of the sporocarps of 18 fleshy fungi of western American Mountains. All but *Auricularia auricula* are probable ectomyorrhizal associates with forest trees of the region.

FUNGAL SPECIES	CONCENTRATIONS OF ELEMENTS IN TISSUES ¹										CEC ²	LOC
	N	P	K	Na	Ca	Mg	ASH					
<i>Amanita muscaria</i>	3.68	0.75	3.81	0.017	0.05	0.12	NA ⁵	18.9	NEE			
A. pantherina	T ⁴	0.76	5.39	0.008	0.03	0.11	NA	15.6	NEE			
<i>Auricularia auricula</i>	T	0.23	1.09	0.042	0.12	0.16	NA	51.4	PIL			
<i>Clitocybe albirhiza</i>	4.78	0.66	2.37	0.005	0.11	0.08	NA	16.7	PAC			
<i>Cortinarius absii</i>	2.34	0.44	5.62	0.017	0.07	0.13	NA	25.3	SIG			
C. glaucopus	3.68	0.43	5.40	0.003	0.08	0.14	NA	16.8	TUP			
<i>Gyromitra gigas</i>	4.88	1.30	3.26	0.016	0.08	0.10	9.1	16.5	WES			
<i>Hygrophorus pudorinus</i>	2.05	0.63	4.72	0.002	0.03	0.11	10.9	21.3	PET			
<i>Inonotus tomentosus</i>	2.85	0.53	2.02	0.004	0.16	0.17	10.3	38.3	PAC			
<i>Lactarius deliciosus</i>	2.43	0.36	2.10	0.001	0.03	0.09	4.3	28.3	CAB			
<i>Lycoperdon pyriforme</i>	T	1.18	2.23	0.010	0.15	0.17	NA	40.0	PET ³			
<i>Morchella atrotomentosa</i>	5.35	1.50	3.38	0.010	0.15	0.12	9.8	14.8	SPA ³			
<i>Ramaria largentii</i>	3.65	0.42	2.87	0.003	0.07	0.17	7.0	23.8	TUP			
<i>Russula brevipes</i>	3.10	0.41	3.08	0.001	0.02	0.07	6.3	9.2	PAC			
R. xerampelina	3.33	0.45	3.76	0.001	0.03	0.09	7.5	17.8	PIL			
<i>Sarcodon imbricatum</i>	4.13	0.58	3.65	0.004	0.04	0.11	9.6	24.6	PET			
<i>Suillus tomentosus</i>	3.20	0.45	2.11	0.008	0.25	0.08	6.3	20.8	CAB			
<i>Tricholoma saponaceum</i>	3.85	0.77	5.05	0.002	0.03	0.12	13.3	17.7	SNA			

¹ = % by weight ² = cation exchange capacity of lower stipe tissues in milliequivalents/100 g

³SPA= Spalding Bay ⁴T= trace ⁵NA= not available

Table 5. Cation exchange capacity of feeder roots of some common tree species of Grand Teton and Yellowstone National Parks.

SPECIES	PLANT DIVISION	ROOT CEC ¹
<i>Abies lasiocarpa</i>	Coniferophyta	40.9
<i>Picea engelmannii</i>	Coniferophyta	34.9
<i>P. pungens</i>	Coniferophyta	30.9
<i>Pinus contorta</i>	Coniferophyta	24.4
<i>Pseudotsuga menziesii</i>	Coniferophyta	25.4
<i>Populus angustifolia</i>	Anthophyta	32.2
<i>P. sargentii</i>	Anthophyta	25.4
<i>P. tremuloides</i>	Anthophyta	33.0
	average	30.0
conifer ave.= 31.3		angiosperm ave.= 30.2

¹ = milliequivalents/100 g

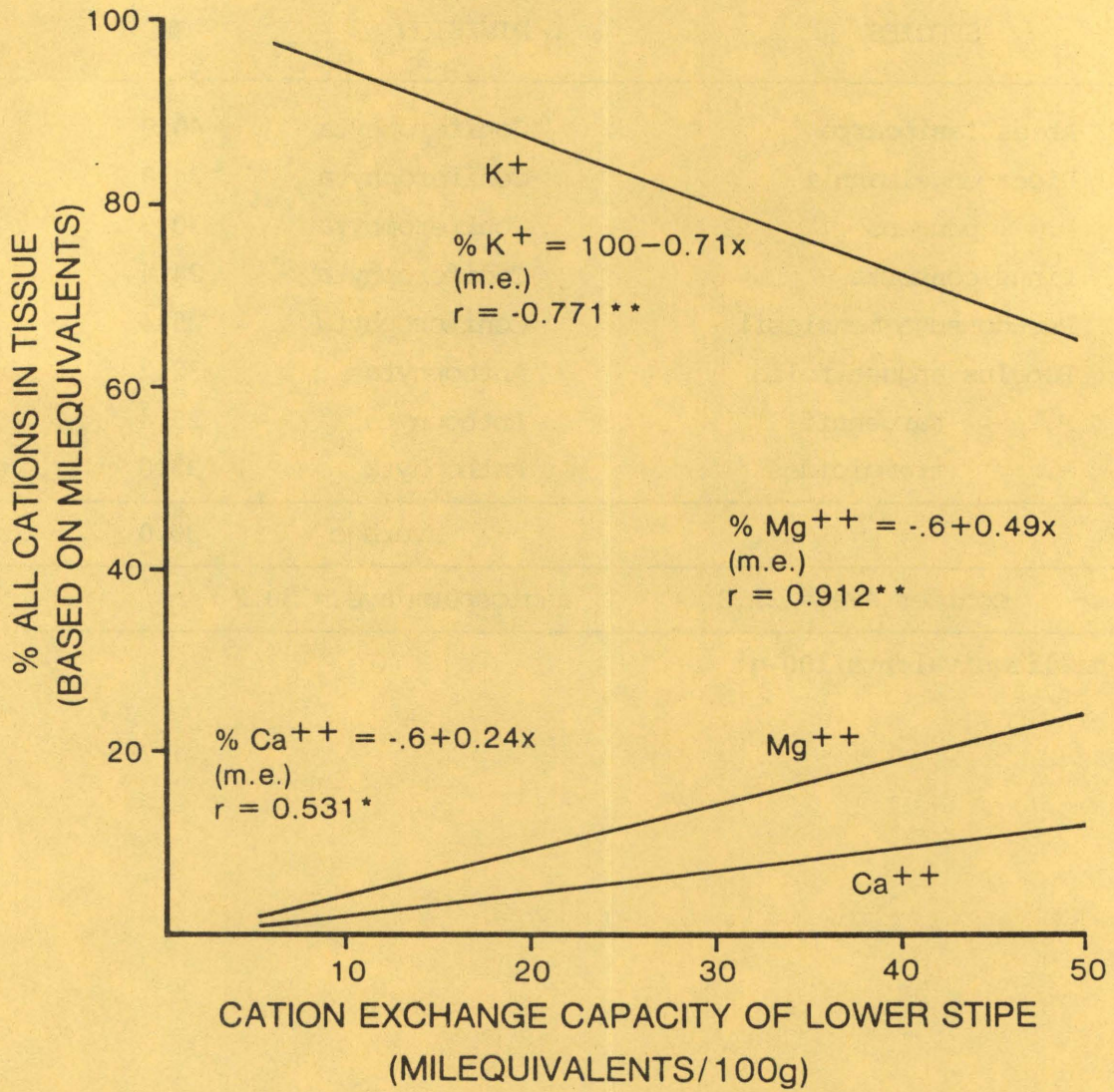


Figure 2. Regression lines relating fungal tissue cation exchange capacity to the relative amounts of monovalent and divalent cations present.

only root CEC values available for conifers.

Our preliminary results suggest that mycorrhizal fungi may take up monovalent and divalent cations in different proportions than their tree hosts because of basic differences in cell wall CEC. As a result, it seems possible that the fungi permit associated trees to acquire a more balanced ration of mono- and divalent cations than would otherwise be possible.

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