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Copper Nutrition of Millets (Part II)

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Effect of copper on foliar symptoms in Cumbu: At a higher concentration of copper about 20 ppm, chlorotic striations in the leaves were developed to a marked degree when the experiment was conducted in sand cultures. Similar striations were noted at 5 ppm. concentration in solution cultures. This chlorotic pattern, resembling iron deficiency was characteristic which was studied by Chapman et al (1939) elsewhere while studying antagonism between iron and copper. The observations fall in line with those of Willis and Pilland (1934) on corn.

In view of the striations and chlorosis, chlorophyll estimation of leaf samples obtained from plants growing in sand cultures having 20 ppm and 50 ppm concentration was done and the mean data expressed as a ratio over control were as follows.

Control = 1.	Cholam Co. 12.	Ragi Co. 1.	Cumbu Co. 4.
20 ppm Cu	0·63	1·38	0·91
50 ppm Cu	0·72	0·94	0·74

With increasing concentrations of copper, 20 ppm and above, chlorophyll content is decreased in Cholam and Cumbu. In Ragi too 50 ppm. effected a decrease. Copper in very low concentrations is considered to increase the chlorophyll content. In chemical studies magnesium content of the leaves under copper treatment was found to be lower than control. Since the inter veinal chloratic symptoms appear to be closely similar to those induced by Magnesium deficiency. It is not unlikely that an inter-relation might exist between copper and magnesium an excess of one leading to deficiency levels in another. Observations of Okuntsov (1946) and Chuard and Porchet (1900) were that addition of copper increased chlorophyll content. The observations in this study are not in line with those above but it is possible that the apparent difference is due to higher concentrations of copper employed in the study.

Chemical Studies: The data on chemical analysis are presented in the appendix. Chemical analysis of the leaves of plant samples indicate that in the same group of plants, viz., millets, the plants do not respond in the same way with regard to intake of macro-nutrients at different levels of copper nutrition.

Low concentrations of copper at 10 and 20 ppm results in a higher percentage of Nitrogen in the leaves in all the three crops. This increase persists till the flowering stage, whereafter the difference is not perceptible. Findings are similar to Lipman and Burgess who found the stimulating effect of copper on nitrifying flora and doubling the nitrate yield. Various other works lend support to this observation — Suisen Dyo (1938) — on Nitrogen nutrition of Paddy, Trumble (1950) — on copper on increased production of plant protein, Kwiscinski (1930) — on mobilisation of ammonia and role of Tyrosinase and Ascorbic acid oxidase in plant body, Girst, (1953)/on the effect of copper on growth, maturation and yield and also increased Nitrogen intake. At higher levels of copper, Jensen (1926) found a reduction in the amounts of nitrate due to the destruction of nitrifying organism.

As for Phosphoric acid similar trend is seen in Cholam and Cumbu but not Ragi within the same range.

A slight increase of Potash intake between 10 and 50 parts per million copper levels is noted in all the three crops till about the flowering stage. Thereafter Potash content goes down.

In the case of lime there is very little variation till about the flowering stage. Only at higher concentrations of fifty and hundred parts per million of copper, the lime content was reduced in Cholam.

The effect of added copper to the intake of Magnesium seems to be inversely related, the magnesium content decreasing as the concentration of copper increased in the growing medium. This effect is noticeable in all the three crops studied.

Observations on variations in the chemical constituents in the earhead show that Nitrogen content is not increased in Cholam and Cumbu as a result of adding copper in the growing medium. In Ragi earheads, there is a small increase. Phosphoric acid and lime content decrease to a small extent due to added copper. Magnesium intake was increased in Ragi and Cumbu due to copper but not in Cholam. Little variation is noticed in potassium intake in all the three crops due to added copper.

Copper, Iron, and Magnesium are said to produce a series of inter-dependent catalytic reactions in the development of photosynthetic system of the green leaf. Hill (1949) has pointed out similarities of the structure of chlorophyll and iron porphyrin of haemoglobin. Considerable studies on structural similarities are in progress which would through enough information as to the possibility of copper replacing Magnesium in the porphyrin structure of the chlorophyll molecule.

Effect of Copper on the intake of iron: In all the three millets, Copper was found to increase in the leaves, stems, and earheads according to increasing concentrations in the growing medium. Apart from the visual symptoms of chlorotic striations increasing with higher levels of copper, the data of chemical analysis show that there appears to exist an inverse relationship between iron and copper in the leaves. The observations on antagonism are in line with those of Willis and Pilland (1934). Iron assimilation was found to be depressed by copper suggesting the possibility of copper replacing iron in chlorophyll formation (Densch and Hunnius) (1924). The findings of Mader and Mary Mader (1937) that the cooking quality of Potato tubers that had received a spray of copper sulphate was superior to tubers from unsprayed controls and that the former contained less iron than the latter lend to support to this view. Jorma Erkama's (1947) study on the effect of copper and manganese on iron status and Delf's (1946) studies on the channels of translocation of copper within the plant body go to show the ready action of copper in oxidising ferrous into ferric state. Kliman (1937) is of the view that iron is taken in within the plant in the ferrous state. The oxidation of iron within the plant results in its precipitation, as evidenced by the increased concentration at the root zone.

Effect of copper on the content of reducing sugars:

Reducing sugars (mg/gm in fresh leaves)

Crop	Control	10 ppm.	20 ppm.	50 ppm.	100 ppm.
Cholam Co. 12	3·25	3·60	4·10	1·20	0·30
Ragi Co. 1	3·08	3·40	4·18	3·82	2·86
Cumbu Co. 4	4·36	4·51	4·63	4·25	3·15

In the three crop plants a slight increase in reducing sugars at lower concentrations of copper is noticed and at higher concentrations it was reduced. Chuard and Porchet's (1900) observations on the slight increase in sugar in fruit of grapes and gooseberries consequent to Bordeaux Mixture application lend support to this response. The increased catalase activity in the leaves rather than roots produced by boron in rice seedlings, is an instant in point (Pattanaik) (1950) and as Copper along with Manganese, Zinc and Boron froms a group having similar physiological functions (Thatcher) (1934), it may be considered to play a similar role in effecting increased sugar content within an optimum range.

Summary and conclusion: Studies on copper nutrition of millets formed part of the study in this article. The effect of copper on different plant attributes like height, leaf area, flowering, dry matter production and yield were studied in detail. Chemical analysis of leaves were carried out to have an idea of any inter-relationship between added copper and other nutrients. Its effect on germination, chlorophyll content and reducing sugars was observed. Copper in low concentrations stimulates growth in millets and eventhough it modifies growth rate at about the post-vegetative stage, improves dry matter productions and also increases the final yield. Nitrogen intake is improved at low concentrations of copper but there is an inverse correlation between Copper and Magnesium intake. A similar antagonism is also apparant between Copper and Iron.

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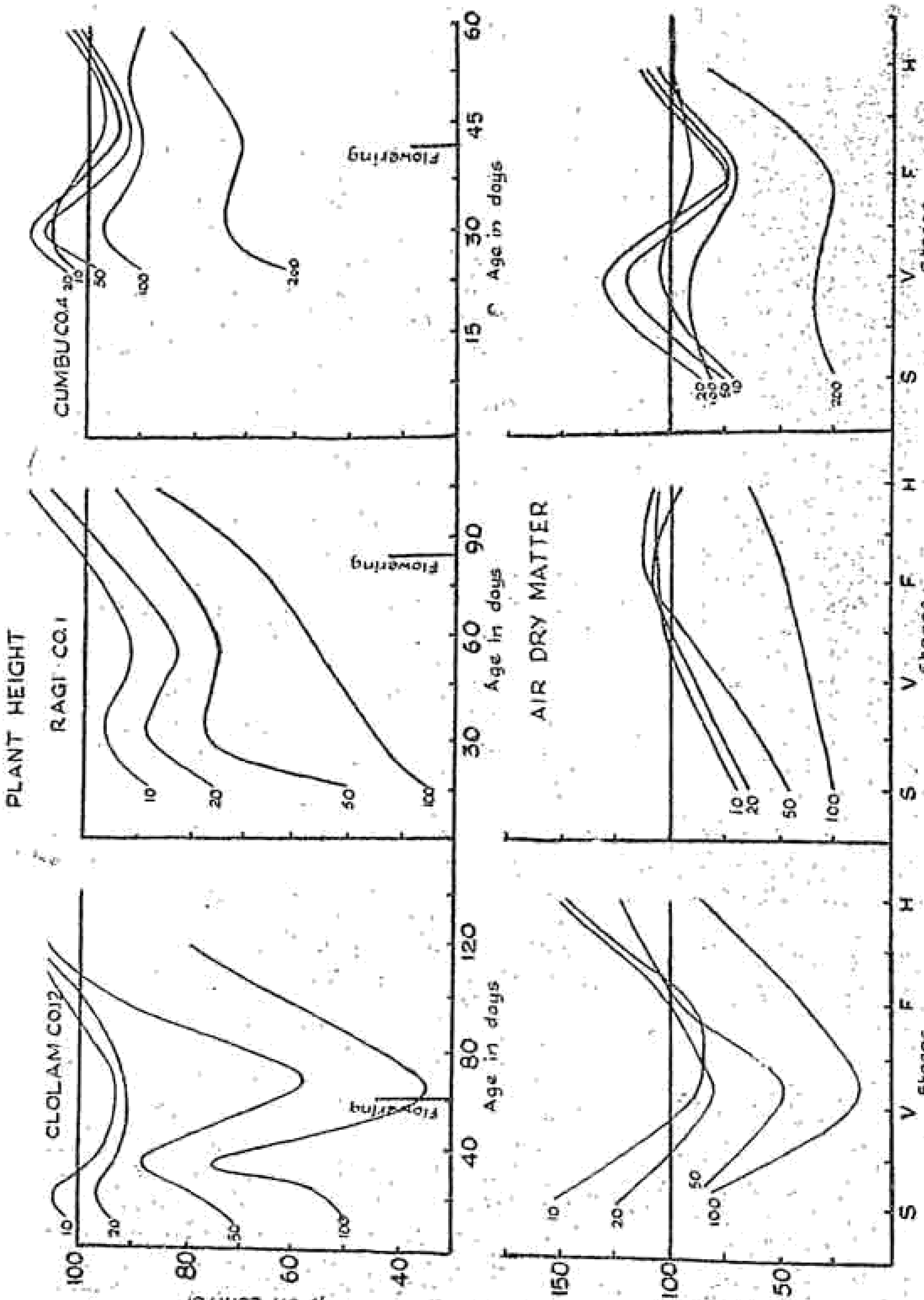
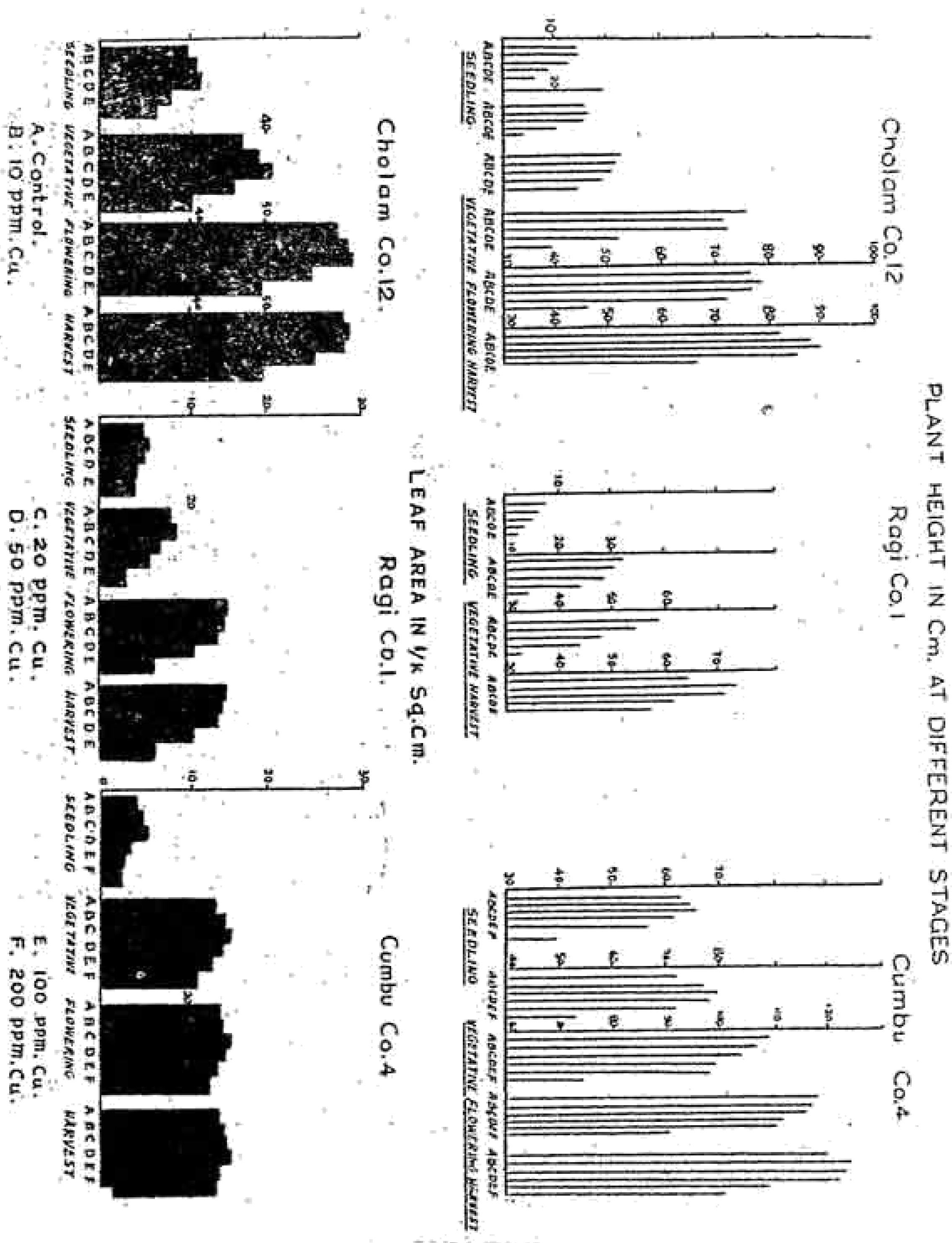

PLANT HEIGHT
CLOLAM CO12
RAGI CO.1
CUMBU CO.4
Plant height expressed as % on control
Age in days
Flowering
AIR DRY MATTER
Air dry matter expressed as % on control
Stages
S - Seedling
V - Vegetative
F - Flowering
H - Harvest


PLANT HEIGHT IN Cm. AT DIFFERENT STAGES
Cholam Co.12
Ragi Co.1
Cumbu Co.4
SEEDLING
VEGETATIVE
FLOWERING
HARVEST
LEAF AREA IN 1/k Sq.Cm.
Cholam Co.12.
Ragi Co.1.
Cumbu Co.4
A. Control.
B. 10 PPM. Cu.
C. 20 PPM. Cu.
D. 50 PPM. Cu.
E. 100 PPM. Cu.
F. 200 PPM. Cu.

APPENDIX

Effect of Copper on the intake of Macro-nutrients.
Cholam Co. 12.
Leaves (at various stages)

	Seedling	Vegetative	Flowering	Harvest	Earhead
		Moisture %			
Control	8·73	8·66	8·58	8·50	8·88
10 ppm. Cu	8·68	8·64	8·56	8·54	9·10
20 ppm. Cu	8·74	8·66	8·60	8·48	9·06
50 ppm. Cu	8·70	8·60	8·56	8·50	8·98
100 ppm. Cu	8·66	8·62	8·58	8·54	9·06
		Nitrogen % (moisture-free)			
Control	2·792	1·288	1·119	0·933	1·290
10 ppm. Cu	2·944	1.379	1·225	0·918	1·263
20 ppm. Cu	2·976	1.410	1·256	0·918	1·262
50 ppm. Cu	2·760	1.256	1·072	0·826	1·200
100 ppm. Cu	2·500	1.073	1·041	0·765	1·078
		Phosphoric acid P_2O_5% (moisture-free)			
Control	0·590	0·449	0·328	0·284	0·615
10 ppm. Cu	0·613	0·471	0·339	0·273	0·605
20 ppm. Cu	0·603	0·460	0·339	0·273	0·605
50 ppm. Cu	0·482	0·372	0·279	0·251	0·511
100 ppm. Cu	0·438	0·334	0·252	0·219	0·484
		Lime (Ca O) % (moisture-free)			
Control	0·368	0·553	0·613	0·765	0·123
10 ppm. Cu	0·399	0·490	0·612	0·735	0·123
20 ppm. Cu	0·339	0·491	0·613	0·734	0·123
50 ppm. Cu	0·276	0·337	0·459	0·551	0·092
100 ppm. Cu	0·270	0·245	0·276	0·467	0·062
		Magnesia (Mg O)% (moisture-free)			
Control	0·656	0·762	0·881	0·979	0·329
10 ppm. Cu	0·635	0·705	0·773	0·833	0·310
20 ppm. Cu	0·621	0·677	0·726	0·838	0·304
50 ppm. Cu	0·621	0·564	0·599	0·669	0·283
100 ppm. Cu	0·529	0·564	0·571	0·599	0·283

	Seedling	Vegetative	Flowering	Harvest	Earhead
	Potash (K_2O)% (moisture-free)				
Control	2·612	2·100	1·344	1·241	1·093
10 ppm. Cu	2·725	2·226	1·356	1·216	1·066
20 ppm. Cu	2·709	2·122	1·349	1·215	0·823
50 ppm. Cu	2·615	2·095	1·314	1·144	1·014
100 ppm. Cu	2·601	1·709	1·238	1·059	0·955

Effect of Copper on the intake of Macro-nutrients.

Ragi Co. 1.

Leaves (at various stages)

	Seedling	Vegetative	Flowering	Harvest	Earhead
	Moisture %				
Control	7·65	7·70	7·43	7·21	7·84
10 ppm. Cu	7·69	7·84	7·54	7·33	7·92
20 ppm. Cu	7·70	7·69	7·58	7 39	7·78
50 ppm. Cu	7·68	7·65	7·44	7·29	7·86
100 ppm. Cu	7·80	7·84	7·54	7·35	7·74
	Nitrogen % (moisture-free)				
Control	1·774	1·774	1·694	1·509	1·458
10 ppm. Cu	1·896	1·762	1·620	1·481	1·688
20 ppm. Cu	3·049	1·790	1·379	1·300	1·518
50 ppm. Cu	2·917	1·668	1·225	1·178	1·504
100 ppm. Cu	2·032	1·519	1·090	0·907	1·426
	Phosphoric acid (P_2O_5)% (moisture-free)				
Control	1·722	1·273	1·186	1·067	0·825
10 ppm. Cu	1·300	0·949	0·860	0·853	0·792
20 ppm. Cu	1·278	0·922	0·849	0·826	0·786
50 ppm. Cu	1·106	0·888	0·832	0·798	0·760
100 ppm. Cu	0·981	0·828	0·800	0·783	0·737

	Seedling	Vegetative	Flowering	Harvest	Earhead
		Lime (Ca O) % (moisture-free)			
Control	...	...	...	...	0·638
10 ppm. Cu	...	...	...	...	0·305
20 ppm. Cu	...	...	...	...	0·304
50 ppm. Cu	...	...	...	...	0·304
100 ppm. Cu	...	...	...	...	0·229
		Magnesia (Mg O) % (moisture-free)			
Control	0·882	1·054	1·176	1·222	0·329
10 ppm. Cu	0·844	0·999	1·052	1·203	0·336
20 ppm. Cu	0·838	0·977	1·059	1·183	0·321
50 ppm. Cu	0·578	0·712	0·880	1·049	0·289
100 ppm. Cu	0·392	0·572	0·732	0·918	0·255
		Potash (K_2O) % (moisture-free)			
Control	4·701	4·359	4·110	3·826	2·120
10 ppm. Cu	4·870	4·580	4·280	3·910	2·126
20 ppm. Cu	5·115	4·535	4·211	3·814	2·187
50 ppm. Cu	4·778	4·478	4·194	3·830	2·074
100 ppm. Cu	4·633	4·479	4·158	3·782	2·025

Effect of Copper on the intake of Macro-nutrients.
Cumbu Co. 4
Leaves (at various stages).

	Seedling	Vegetative	Flowering	Harvest	Earhead
		Moisture %			
Control	8·85	8·58	8·73	8·32	9·03
10 ppm. Cu	8·78	8·62	8·80	8·40	8·98
20 ppm. Cu	8·75	8·64	8·78	8·36	9·02
50 ppm. Cu	8·80	8·50	8·65	8·44	9·02
100 ppm. Cu	8·82	8·50	8·72	8·36	8·96
200 ppm. Cu	8·90	8·54	8·81	8·40	9·06

	Seedling	Vegetative	Flowering	Harvest	Earhead
		Nitrogen % (moisture-free)			
Control	..	2·262	1·948	1·558	3·755
10 ppm. Cu	...	2·664	2·522	1·452	3·692
20 ppm. Cu	...	2·651	2·466	1·406	2·493
50 ppm. Cu	...	2·569	2·253	1·376	2·370
100 ppm. Cu	...	2·540	2·255	1·258	2·307
200 ppm. Cu	...	2·394	2·182	1·070	2·125
		Phosphoric acid (P_2O_5) % (moisture-free)			
Control	1·103	0·874	0·762	0·529	0·995
10 ppm. Cu	1·132	0·908	0·822	0·459	0·945
20 ppm. Cu	1·205	0·799	0·778	0·437	0·939
50 ppm. Cu	1·151	0·654	0·640	0·409	0·890
100 ppm. Cu	1·051	0·601	0·592	0·398	0·818
200 ppm. Cu	...	0·481	0·417	0·327	0·786
		Lime (Ca O) % (moisture-free)			
Control	1·091	0·780	0·828	1·771	0·154
10 ppm. Cu	0·989	0·858	1·013	1·865	0·215
20 ppm. Cu	1·074	0·858	1·166	1·925	0·185
50 ppm. Cu	1·176	0·826	1·379	1·701	0·185
100 ppm. Cu	1·177	0·826	1·166	2·230	0·185
200 ppm. Cu	...	0·765	1·075	2·598	0·185
		Magnesia (Mg O) % (moisture-free)			
Control	1·138	1·211	1·511	1·609	0·361
10 ppm. Cu	1·031	0·987	1·183	1·505	0·563
20 ppm. Cu	0·984	0·836	0·876	1·487	0·336
50 ppm. Cu	0·853	0·855	0·864	1·460	0·188
100 ppm. Cu	0·283	0·774	0·801	1·086	0·170
200 ppm. Cu	...	0·539	0·738	3·774	0·149
		Potash (K_2O) % (moisture-free)			
Control	6·046	4·783	4·306	3·887	2·215
10 ppm. Cu	6·267	4·778	4·718	4·210	2·223
20 ppm. Cu	7·097	5·054	4·924	4·219	2·223
50 ppm. Cu	9·277	4·982	4·709	4·008	2·210
100 ppm. Cu	8·267	4·490	4·306	3·878	2·219
200 ppm. Cu	...	4·229	4·080	3·787	2·208

COPPER - IRON RELATIONSHIP

Cholam Co. 12.

	Seedling			Vegetative			Flowering			Harvest			
	L	S	R	L	S	R	L	S	R	L	S	R	E
	Copper (Expressed in Parts Per Million)												
Control ...	0·18	0·06	0·20	0·47	0·08	0·24	0·31	0·05	0·30	0·27	0·04	0·30	0·94
10 ppm. Cu ...	0·30	0·14	0·84	0·70	0·16	1·02	0·55	0·20	1·63	0·50	0·20	2·60	2·07
20 ppm. Cu ...	0·73	0·24	1·00	1·32	0·30	1·28	1·04	0·22	1·81	1·00	0·20	3·00	2·62
50 ppm. Cu ...	1·23	1·43	2·83	2·90	0·50	5·66	1·27	0·48	2·06	1·20	0·44	3·40	3·78
100 ppm. Cu ...	2·12	0·58	4·44	4·75	0·78	8·28	2·62	0·70	3·63	2·58	0·66	4·20	5·84
	Iron (Expressed in Parts Per Million)												
Control ...	130	19	393	126	17	382	108	13	314	106	12	302	47
10 ppm. ...	124	21	395	116	18	386	105	15	342	105	15	314	42
20 ppm. ...	101	23	410	103	21	392	86	16	351	77	15	347	40
50 ppm. ...	67	29	473	61	25	448	57	20	401	52	19	367	33
100 ppm. ...	57	36	505	56	33	464	43	29	425	44	29	410	27

L — Leaf; S — Stem; R — Root; E — Earhead.

COPPER - IRON RELATIONSHIP

Ragi Co. 1.

	Seedling			Vegetative			Flowering			Harvest			
	L	S	R	L	S	R	L	S	R	L	S	R	E
Copper (Expressed in Parts Per Million)													
Control ...	0·18	0·05	0·18	0·33	0·06	0·20	0·24	0·04	0·20	0·20	0·04	0·18	1·90
10 ppm. Cu ...	0·28	0·08	0·38	0·42	0·14	0·42	0·35	0·14	0·40	0·30	0·12	0·38	2·14
20 ppm. Cu ...	0·37	0·18	0·54	0·68	0·22	0·50	0·48	0·18	0·52	0·38	0·20	0·66	2·52
50 ppm. Cu ...	0·82	0·20	1·00	0·96	0·34	1·25	0·63	0·30	1·06	0·44	0·26	1·14	3·85
100 ppm. Cu ...	0·72	0·24	1·80	1·24	0·40	2·14	0·84	0·36	1·80	0·73	0·33	1·86	5·12
Iron (Expressed in Parts Per Million)													
Control ...	126	18	382	117	17	377	99	14	303	92	13	294	58
10 ppm. Cu ...	120	21	390	112	19	382	89	16	320	88	15	313	51
20 ppm. Cu ...	116	22	405	111	22	405	81	17	429	77	16	325	49
50 ppm. Cu ...	86	57	433	81	24	422	72	23	380	64	21	363	48
100 ppm. Cu ...	69	32	492	63	30	448	41	27	449	35	25	430	43

L — Leaf; S — Stem; R — Root; E — Earhead.

COPPER - IRON RELATIONSHIP

Cumbu Co. 4.

	Seedling L	Seedling S	Seedling R	Vegetative L	Vegetative S	Vegetative R	Flowering L	Flowering S	Flowering R	Harvest L	Harvest S	Harvest R	Harvest E
Copper (Expressed in Parts Per Million)													
Control ...	0·44	0·08	0·26	1·14	0·12	0·38	0·74	0·12	0·38	0·58	0·10	0·30	1·04
10 ppm. Cu ...	0·52	0·18	0·48	1·38	0·38	0·58	1·06	0·32	1·86	0·92	0·24	1·84	2·02
20 ppm. Cu ...	1·10	0·22	1·20	2·84	0·55	1·63	1·42	0·54	2·14	1·30	0·38	2·00	2·86
50 ppm. Cu ...	1·66	0·46	2·82	3·97	0·64	3·74	1·88	0·66	4·27	1·68	0·60	4·20	4·22
100 ppm. Cu ...	2·50	0·63	5·30	5·40	1·18	5·88	3·46	1·24	6·10	3·14	1·18	5·93	6·24
200 ppm. Cu ...	3·46	0·88	6·52	6·82	1·42	8·43	5·02	1·46	7·14	4·55	1·24	6·86	8·14
Iron (Expressed in Parts Per Million)													
Control ...	165	23	430	142	18	426	112	15	342	97	14	368	60
10 ppm. Cu ...	114	23	440	105	19	430	96	17	347	85	15	312	57
20 ppm. Cu ...	89	24	493	96	23	460	71	21	349	68	22	329	54
50 ppm. Cu ...	62	32	550	56	29	480	44	28	380	41	25	362	49
100 ppm. Cu ...	41	38	553	38	33	510	55	30	422	34	27	403	37
200 ppm. Cu ...	25	44	650	25	37	643	22	30	525	21	28	510	[illegible]

L — Leaf; S — Stem; R → Rooting; E — Earhead.