III.—CONTRIBUTIONS TO THE STUDY OF SPIKE-DISEASE OF SANDAL (*SANTALUM ALBUM*, LINN.). PART IX.

Chemical composition of tissue fluids from the stem.

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The tissue fluids from healthy and diseased sandal stems after expression in the usual way (*J. Indian Inst. Sci.*, 1928, **11A**, 23) were centrifuged at 3,000 r. p. m. and the respective centrifugates examined for their total nitrogen, total solids, ash, phosphorus and calcium. The results have been tabulated in the three following tables.

TABLE I A.

UTTARAHALLI AREA.

Yield of tissue fluid from stems (Uttarahalli).

Date	Percentage yield on weight of green material	
	Healthy	Spiked
30-4-28	28·9	29·9
7-5-28	33·0	27·5
22-6-28	25·3	24·2
Mean ...	29·1	27·2

TABLE I B.

(RAGIHALLI).

Date	Healthy	Spiked
8-7-27	23·0	13·0
22-7-27	19·8	12·9
29-7-27	15·1	17·0
15-5-28	12·6	16·7
Mean ...	17·6	14·9

TABLE II A.

Grams per 100 c.c. of tissue fluid (Uttarahalli).

Date	Healthy			Spiked		
	Total solids	Ash	Per cent. of ash in solids	Total solids	Ash	Per cent of ash in solids
5—8—27	11·88	0·71	5 99	6·46	1·40	21·60
27–10—27	11·77	1·22	10·38	11·77	1·63	13·83
9—1—28	15·30	1·26	8·23	9 93	1·63	16·41
11—4—28	9·58	1·30	13·56	8·94	1·84	20·58
20—4—28	8·54	1·23	14·39	8·78	1·89	21·57
30—4—28	7·87	1·05	13·31	9·35	2·13	22·74
7—5—28	7·98	1·29	16·15	11·08	2·60	23·47
22—5—28	6·83	0·93	13·64	7·86	1·93	24·56
8—6—28	10·73	1·52	14·12	12·71	3·18	25·04
22—6—28	10·40	1·40	12·47	9·27	2·16	23·34
Mean ...	...	1·19	...	...	2·04	...
Standard deviation ...	...	± 0·22	...	...	± 0·49	...

TABLE II B.

Ragihalli Area.

Grams per 100 c.c. of tissue fluid (Ragihalli).

Date	Healthy			Spiked		
	Total solids	Ash	Per cent. of ash in solids	Total solids	Ash	Per cent. of ash in solids
8—7—27	10·75	0·70	6·51	11·30	0·38	3·37
22—7—27	16·33	0·70	4·31	13·79	0·83	6·02
29—7—27	14·41	1·01	6·98	21·52	0·97	4·51
14–10—27	13·78	1·04	7·57	14·42	0·97	6·70
7–11—27	11·18	1·08	9·69	13·91	0·99	7·17
23–11—27	12·16	2·00	16·44	14·70	1·60	10·88
19–12—27	13·59	1·21	8·90	13·54	1·18	8·71
15—5—28	12·58	0·76	6·08	13·81	1·92	13·86
15—6—28	15·59	0·83	5·33	13·98	1·23	8·81
Mean ...	...	1·04	...	...	1·12	...
Standard deviation ...	...	±0·39	...	...	±0·41	...

TABLE III A.

Milligrams per 100 c.c. of tissue fluid (Uttarahalli).

Date	Healthy			Spiked		
	Total N	P_2O_5	Ca	Total N	P_2O_5	Ca
5- 8-27	...	92·0	136·0	...	99·6	128·0
15- 9-27	145 0	101·8	144·0	258·5	184 0	117·0
27-10-27	171·0	88·0	125·0	481·6	164·0	125·0
9- 1-28	247·8	33·0	163·0	415·6	77·0	129·0
11- 4-28	239·6	130·2	...	365·1	176·7	...
20- 4-28	281·1	168·4	36·0	398·0	194·2	90·0
30- 4-28	378·3	223·6	72·0	467·2	321·2	132·0
7- 5-28	270·1	148·9	62·0	280·2	237·6	116·0
22- 5-28	198·8	92·6	64·0	375·4	150·0	74·0
8- 6-28	262·6	108·1	80·6	591·8	114·9	101·6
22- 6-28	214·5	86·2	82·1	298·6	94·3	126·3
Mean ...	240·8	112·9	96·5	393·2	164·7	113·9
Standard deviation ...	± 61·9	± 50·4	± 40·0	± 96·9	± 67·9	± 18·3

TABLE III B.

Milligrams per 100 c.c. of tissue fluid (Ragihalli).

Date	Healthy			Spiked		
	Total N	P_2O_5	Ca	Total N	P_2O_5	Ca
8- 7-27	72·5	...	...	...	...	...
11- 8-27	...	45·6	103·0	...	68·1	89·0
14-10-27	95·0	41·0	133·0	162·0	66·0	129·0
7-11-27	96·3	109·3	121·0	147·3	153·1	114·0
23-11-27	153·6	68·0	94·0	176·8	35·0	94 0
19-12-27	128·0	7·0 (?)	104·0	214·0	32·0	82·0
15- 5-28	...	90·9	29·0	...	76·9	60·8
15- 6-28	188·2	78·8	77·5	254·7	100·1	64·5
Mean ...	122·3	72·3	94·5	190·9	75·9	90·5
Standard deviation ...	± 39·3	± 24·0	± 31·4	± 38·8	± 38·3	± 22·9

TABLE IV A.

UTTARAHALLI AREA.

Milligrams of calcium per 100 c.c. of tissue fluid
(Uttarahalli: healthy)

Date	Leaf	Stem
15—9—27	165·0	144·0
20—4—28	750·0	36·0
30—4—28	634·0	72·0
7—5—28	668·0	62·0
22—5—28	558·0	64·0
8—6—28	940·2	80·6
22—6—28	540·4	82·1
Mean	615·1	77·2
Standard deviation ...	±219·9	± 30·7

TABLE IV B.

(Uttarahalli: diseased).

Date	Leaf	Stem
15—9—27	107·5	117·0
20—4—28	154·0	90·0
30—4—28	154·0	132·0
7—5—28	118·0	116·0
22—5—28	154·0	74·0
8—6—28	120·0	101·6
22—6—28	96·8	126·3
Mean	129·0	108·1
Standard deviation ...	± 22·6	± 19·1

Discussion of Results.

Tables I A and B give the yield of tissue fluids from stems. It has been observed that the yield is lower in the case of diseased stems and progressively decreases with the onset of the disease. The root ends and the haustorial connections are damaged by the disease, so that the absorption of water and nutrients from the soil solution is affected. The heavy accumulation of starch in the conducting tracts of the stem renders free passage of the sap extremely difficult. This can be experimentally demonstrated by selecting two four-inch lengths of twig having the same diameter, one from the healthy and the other from the diseased sandal and sucking water through them under a known negative pressure. It will be found that, while water can easily be sucked through the healthy twig, the diseased offers very great resistance.

Tables II A and B give the total solids, ash in grams per 100 c.c. of the tissue fluid and also the percentage of ash calculated on the weight of the total solids. In the case of the diseased stem fluid, the ash is distinctly higher for the Uttarahalli area. The corresponding average value in II B also shows a slight increase, but is not significant. It is however clear that the ash is not lower in the diseased condition, as was shown to be the case in the instance of the tissue fluids from diseased leaves.

Tables III A and B give the nitrogen, phosphorus pentoxide and calcium values expressed as milligrams per 100 c.c. of tissue fluid. Nitrogen figures are uniformly higher in the diseased condition, and in the majority of instances the phosphorus values are distinctly higher in the diseased state. The calcium content of the diseased tissue fluid is in many cases higher and in fact the average value of calcium for the Uttarahalli area is about 17 per cent. higher. At any rate, the distinctly lower calcium content which characterises the diseased leaf tissue fluid, is not to be found in the case of the diseased stem tissue.

The study of gradients of concentration of the several nutrient elements from the root to the growing tips will throw light on the nature of the distribution. In the case of the healthy sandal, it will be observed from Table IV A that there is a great difference between the calcium concentrations of the leaf and stem tissue fluids in the healthy state.

The average value for the stem fluid is only one-tenth of the value for the leaf. In the diseased condition, however, the calcium concentration of the leaf tends to fall to that of the stem and in

advanced stages of the disease the concentration may fall far below that level (see Table IV B.)

Some investigators have found that pine trees grown in quartz sand and fed by a synthetic culture solution lacking calcium, exhibited irregularities in the transportation of starch, and a diminution in the size of the several organs (Loew, *U. S. Dept. of Agric. Bureau of Plant Industry*, 1903, Bull. No. 45). The low calcium concentration in the leaf, the main centre of photosynthetic activity, probably stimulates formation of starch, which in turn accumulates in the tissues of the diseased sandal.

SUMMARY.

The tissue fluids of healthy and diseased stems of sandal have been examined for total solids, total nitrogen, ash, phosphorus and calcium.

Nitrogen and phosphorus concentration of the tissue fluids from diseased stems is higher as compared with the values for the healthy stems, but the calcium content in the diseased state is higher.

A high gradient of calcium concentration exists from the stem towards the leaf which tends to flatten as the disease advances. It is suggested that the rapid transport of calcium through the stem is impaired with the incidence of spike; consequently, the leaf does not receive its adequate share of the calcium which, as shown by previous investigators, prevents abnormalities in the translocation of starch.

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