New Dosage Tables
Fumigation Studies no.7

By
C.W. Woodworth

UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

NEW DOSAGE TABLES

FUMIGATION STUDIES, No. 7

BY
C. W. WOODWORTH

BULLETIN No. 257
Berkeley, Cal., July, 1915

UNIVERSITY OF CALIFORNIA PRESS
BERKELEY
1915

Benjamin Ide Wheeler, President of the University.

EXPERIMENT STATION STAFF

HEADS OF DIVISIONS

Thomas Forsyth Hunt, Director.
Eugene W. Hilgard, Agricultural Chemistry (Emeritus).
Edward J. Wickson, Horticulture (Emeritus).
Herbert J. Webber, Director Citrus Experiment Station; Plant Breeding.
Hubert E. Van Norman, Vice-Director; Dairy Management.
William A. Setchell, Botany.
Meyer E. Jaffa, Nutrition.
Robert H. Loughridge, Soil Chemistry and Physics (Emeritus).
Charles W. Woodworth, Entomology.
Ralph E. Smith, Plant Pathology.
J. Eliot Coit, Citriculture.
John W. Gilmore, Agronomy.
Charles F. Shaw, Soil Technology.
John W. Gregg, Landscape Gardening and Floriculture.
Frederic T. Bioletti, Viticulture and Enology.
Warren T. Clarke Agricultural Extension.
John S. Burd, Agricultural Chemistry.
Charles B. Lipman, Soil Chemistry and Bacteriology.
Clarence M. Haring, Veterinary Science and Bacteriology.
Ernest B. Babcock, Genetics.
Gordon H. True, Animal Husbandry.
James T. Barrett, Plant Pathology.
Fritz W. Woll, Animal Nutrition.
A. V. Stubenrauch, Pomology.
Walter Mulford, Forestry.
W. P. Kelley, Agricultural Chemistry.
H. J. Quayle, Entomology.
D. T. Mason, Forestry.
J. B. Davidson, Rural Engineering.
Elwood Mead, Rural Institutions.
William G. Hummel, Agricultural Education.
Leon M. Davis, Dairy Industry.
John E. Dougherty, Poultry Husbandry.
Frank Adams, Irrigation Practice.
David N. Morgan, Assistant to the Director.
Mrs. D. L. Bunnell, Librarian.

DIVISION OF ENTOMOLOGY

C. W. Woodworth
W. B. Herms
E. C. Van Dyke
Geo. A. Coleman
Geo. P. Gray
L. J. Nickels
E. O. Essig
S. B. Freeborn
E. P. Van Duzee
M. R. Miller

NEW DOSAGE TABLES

By C. W. WOODWORTH

A new principle applicable to the construction of dosage tables was discovered while making a careful comparison of the rate of charge in the dose necessary to compensate for the differences in leakage.

Since large tents contain a greater volume of gas in proportion to the surface than smaller tents the leakage is correspondingly less important and it is possible to arrange a series of sizes of tents which will correspond with the various degrees of leakage in such a manner that they should require identical doses.

Such a series, omitting the fraction, is as follows:

37	35	32	30	28	26	24 ft.
.10	.15	.20	.25	.30	.35	.40 %

A further inspection brought out the fact that while these numbers do not form a regular simple series the doses that are assigned to these sizes under the same tent do form a regular geometrical progression decreasing at such a rate that after five intervals the number is reduced by one half.

The principle is then that *an arithmetical series of leakages is related to a geometrical series of dosages and both correspond to the same complex series of sizes of tents.*

The application of this principle to the construction of dosage tables resulted in the production of the remarkably simple and practical form presented below. It is necessary to point out again that there is urgent need of a series of new and acceptable tables.

One of the causes of the continued dissatisfaction with the process of fumigating citrus trees is the common use of dosage tables that are grossly inaccurate. It is difficult to understand why these should be so persistently advocated unless it be that their inaccuracy has not been sufficiently emphasized.

The tables most in use are incorrect in the three following particulars.

I. SHAPE

The range of shape found in the extensive series of measurements made by this station varied between tents in which the distance over equaled that around the tent in the case of high seedling orange trees to the low broad lemons which had a circumference twice that of the distance over the top.

A very prevalent form of table determines the relative doses in proportion of the product of the two dimensions. Thus a tree 30 × 30 ft. would have the same dose as one 21 × 42 ft. This is evidently only a mathematical blunder and is about equivalent to insisting that a man six feet high and three feet waist measure weighed the same as another man four feet around and four and one-half feet high, since the product in each case is 18.

The inaccuracy of this method of calculating is perhaps better shown by the accompanying diagram (Fig. 1), in which the difference in size is very evident to the eye.

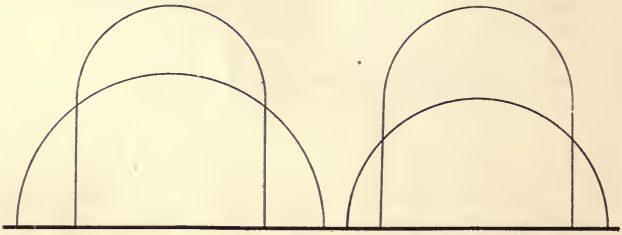

Fig. 1.—Extreme shapes of trees. Those at the left are of equal size and should receive equal doses. Those at the right receive the same dose by the common tables but one is a third larger than the other.

The distance over the top is the most significant dimension since it varies with changes either in height or width. Every foot of decrease of this dimension requires approximately four feet of increase in circumference to maintain the tree of the same size. This is true whether the calculations are made on the basis of cubic contents or of tent area.

The dimensions corresponding with each foot change in distance over are as follows:

30 × 30, 29 × 34, 28 × 38, 27 × 42, 26 × 46, 25 × 50.

This is very different from the common figures:

30 × 30, 29 × 31, 28 × 32, 27 × 33, 26 × 35, 25 × 36, 24 × 37, 23 × 39, and 22 × 41,

which are in no way defensible and should be discarded.

II. SIZE

The writer acknowledges the responsibility of having first suggested the method of size calculation now in vogue, though it had previously been used unconsciously by the late Alexander Craw and some who

have adopted it subsequently were not aware of the identity of their method of calculation. The prevailing plan is to vary the dose at the same rate as the tent area varies. That is, a ten-foot tree receives four times as much as a five-foot tree and has four times as much tent area. Each square foot of tent area by this plan may allow the same amount of gas to escape before the tent is empty, no matter what the size of the tree.

How completely incorrect this plan is can be appreciated by extending the table to trees of very large size. The amount per cubic foot is half as large in a ten-foot tree as in a five-foot tree and a quarter

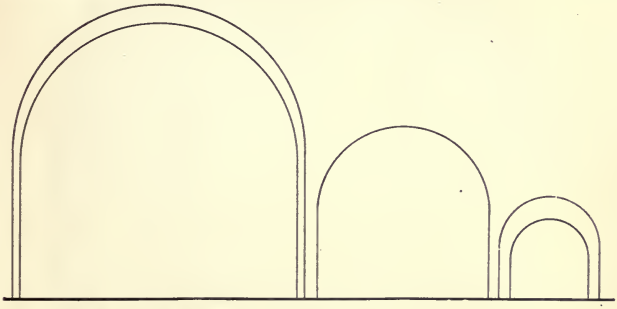

Fig. 2.—Sizes of trees that receive 20, 7 and 2 oz. respectively. The medium size tree has the same dose in all tables. At both extremes the correct size is smaller than those given in the common tables, therefore the doses in the common tables are much too weak.

as dense in a twenty-foot, an eight in a forty-foot, etc. Evidently the initial density will soon come to be so low as to be completely inefficient.

The calculation of the dose by this method is not far wrong for trees of medium size and the plan served a useful purpose as long as there was nothing better, but it is now clearly time to discard what was from the first given as a tentative makeshift to be used until a better method was worked out.

The method gives in fact doses that are too weak at both ends of the table and most of the tables have been arbitrarily increased at the lower end to accord with the experience of fumigators which has abundantly shown the weakness of the calculated tables.

The tables which follow give a much more accurate determination of the doses and these are conspicuously different both for large and for small trees as shown in Figure 2.

III. LEAKAGE

A fundamental defect of the area calculations is that they only provide approximately correct doses for a rather small range of sizes and of degrees of leakage. Every one will appreciate that since a

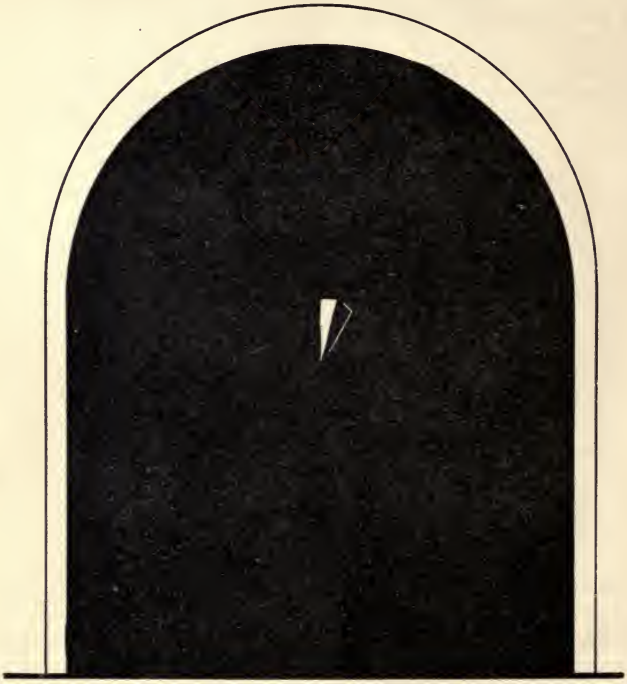

Fig. 3.—The size of a rent, more than a foot long in an average tree, that requires a 15% increase in dose, the same would be given for the larger tent shown in outline. One degree (.05%) on the leakage meter is equivalent to a rent of this size.

comparatively tight tent will require doses on a volume basis and tents with average size and leakage on an area basis that other degrees of leakage will not be properly provided for by either of the systems. If a tent is tighter than the average it is not correct to simply reduce all doses proportionately, as given on the ordinary table, since such a process preserves the same system. For instance, if a five and a

ten-foot tree received respectively four and sixteen ounces, a reduction of 25% would give 3 and 12, which have the same relation, that is, one is four times the other. 2 and 12 might be nearer correct, which would be in proportion of 1 to 6, intermediate between the 1 to 4 area basis and the volume basis of 1 to 8. Likewise for a more leaky tent a 25% increase, making 5 and 20 ounces, should more likely read 10 and 20. However, if the tables were constructed according to the right system as regards the relation of size to dose a percentage increase or decrease would result in the correct adjustment for different leakages. The error in the calculation of the table is exactly of the same character as that regarding size and leakage.

Since the invention of the leakage meter we have a ready means of learning just what the natural leakage of a tent is, and should regulate our dose accordingly. Standing on the inside of the tent one can see, between the interlacing of the fibres of the weave of the cloth, hundreds of thousands of openings; though small enough to prevent the passage of drops of water, they are very large compared with the size of the gas particles which escape through these holes without any hindrance. In dry weather the fibres shrink, leaving larger openings which the meter will detect and measure, but to compensate for which the dose should be larger.

The diagram (Fig. 3) will show graphically the significance of leakage. The average tent is equivalent to a tight tent with five rents as large as the one here figured and many tents are operating with a leakage as great as eight such openings and others as small as two. One will make a fuss, and rightly so, if a fumigator uses a tent with a number of acid burns big enough to put his fist through, but will very complacently permit the use of a tent with a natural leakage ten times as great. Natural leakage cannot be wholly prevented but should be measured and compensated for by increased dosage and when this is done tables properly calculated for dosage should, by all means, be used.

Where the Common Tables Are Right

While the common tables are calculated on wrong principles it should be remembered that the doses for average-sized trees of average shape and for tents with average leakage, are correct and that serious inaccuracies only occur when these average conditions are departed from, and, furthermore, it may frequently happen that errors compensate each other, where, as in this case, there are three different kinds of errors varying independently of each other. The satisfactory

results usually obtained by the use of the common tables have tended to blind the users to this cause of occasional bad results. The use of a better calculated table will in no way improve the results under these normal conditions.

Construction of the New Tables

The following method was employed in the construction of the tables given below. The dose column was made by using the numbers 5, 6, 7, 8, 9, and 10 oz, and halving and doubling the same so as to maintain the same ratios through the whole length of the column. The average difference is almost exactly 14% increase or 15% decrease.

The next column gives the dimensions in feet for tents in which the distance around equals the distance over the top and is so calculated that there should be a difference of 14% in the doses the adjacent sizes should receive. The calculation of this column is the most important element of the whole table.

Three methods of calculation have been proposed, viz., volumne, area and leakage.

The *volumne* method was used in all the older tables and would require a little less than 5% increase in size for each line on the table.

The *area* method, requiring a little over 7% per line is that now almost universally employed and is somewhat justified on the ground that it approximately allows for the average leakage of fumigation tent material.

The *leakage* method used in this table allows accurately for leakage. The average increase in size between 22 and 44 feet is precisely the same as by the area method, but the upper end of the table approaches nearer the 5% and the lower toward the 14%. This method conforms with the actual practice of fumigators who find it necessary to arbitrarily modify the two ends of the common table.

The remainder of the table gives the dimensions of trees of different shapes but approximately the same sizes and which should therefore receive the same doses. The distance over the top of the tent is given in black type, the numbers simply being arranged consecutively and beneath each the corresponding circumferences are written. These differ by fours.

Accuracy of the Tables

All fractional parts have been omitted in these tables. The dose series is actually 5, 5.7, 6.5, 7.5, 8.7, and 10 oz. A slightly more accurate continuation would be 11, 13, 15, 18, 20, 22, 26, 30, 35, and

40, but it seemed best to adhere strictly to the round numbers since it introduced no large error. In the size column, 35 and 40 are about 0.4 too high, and 16 and 44, 0.3 or 0.4 too low, but all the other numbers are within 0.2 of the theoretical value.

Use of the Tables

These tables are printed in large type so as to be easily read at night.

All combinations receiving the same dose are on the same line and cannot therefore be confused.

The important dimension (the distance over the top), is given foot by foot, making it possible to read the dose accurately and rapidly. After a little practice one can read the dose from the large figures only and will be inclined to disregard the smaller type. The rule is as follows where the two dimensions differ: For adjacent dimensions the dose is opposite the lower number, otherwise it is opposite the one just above, unless the difference is six or more lines, that is, where the dose opposite the upper number is more than twice that of the lower in which case look on the second line above lower size.

The tables can be designated by the upper numbers, thus a 50-20 table means that a tree 50×50 receives a 20 oz. dose.

If the tents show .25% leakage and it is decided to use the 50-18 table the tent may become tighter after the dew falls and read .20% leakage when it will be safe to use 50-16 table, but on the other hand if a dry wind increases the leakage to .30% by all means change to the 50-20 table, or if it becomes .35% take the 50-24 table.

It will be observed that all these new tables are identical except the shifting of the dose column.

Relation to Other Tables

Because of the errors in calculation in the common tables, pointed out in the first part of this bulletin, they are not strictly comparable with these here presented. In the majority of the doses the table called 110% in Circular 129 corresponds closely with a 50-32 table, the 100% with 50-28, 90% with 50-24 and the 75% with 50-20; the last, however, gives some doses as low as in the 50-16 table and equally large errors occur in all.

Fumigation Table—Sodium Cyanid

SIZES OF TENTS							Feet	Dose oz.
43	**44**	**45**	**46**	**47**	**48**	**49**	50	32
78	74	70	66	62	58	54		
40	**41**	**42**	**43**	**44**	**45**	**46**	47	28
75	71	67	63	59	55	51		
37	**38**	**39**	**40**	**41**	**42**	**43**	44	24
72	68	64	60	56	52	48		
	36	**37**	**38**	**39**	**40**	**41**	42	20
	66	62	58	54	50	46		
	34	**35**	**36**	**37**	**38**	**39**	40	18
	64	60	56	52	48	44		
	31	**32**	**33**	**34**	**35**	**36**	37	16
	61	57	53	49	45	41		
		30	**31**	**32**	**33**	**34**	35	14
		55	51	47	43	39		
		27	**28**	**29**	**30**	**31**	32	12
		52	48	44	40	36		
		25	**26**	**27**	**28**	**29**	30	10
		50	46	42	38	34		
			24	**25**	**26**	**27**	28	9
			44	40	36	32		
			22	**23**	**24**	**25**	26	8
			42	38	34	30		
			20	**21**	**22**	**23**	24	7
			40	36	32	28		
				19	**20**	**21**	22	6
				34	30	26		
				17	**18**	**19**	20	5
				32	28	24		
				15	**16**	**17**	18	
				30	26	22		
					14	**15**	16	4
					24	20		
					13	**14**	15	
					23	19		
					11	**12**	13	3
					21	17		

Fumigation Table—Sodium Cyanid

SIZES OF TENTS							Feet	Dose oz.
43 78	**44** 74	**45** 70	**46** 66	**47** 62	**48** 58	**49** 54	50	28
40 75	**41** 71	**42** 67	**43** 63	**44** 59	**45** 55	**46** 51	47	24
37 72	**38** 68	**39** 64	**40** 60	**41** 56	**42** 52	**43** 48	44	20
	36 66	**37** 62	**38** 58	**39** 54	**40** 50	**41** 46	42	18
	34 64	**35** 60	**36** 56	**37** 52	**38** 48	**39** 44	40	16
	31 61	**32** 57	**33** 53	**34** 49	**35** 45	**36** 41	37	14
		30 55	**31** 51	**32** 47	**33** 43	**34** 39	35	12
		27 52	**28** 48	**29** 44	**30** 40	**31** 36	32	10
		25 50	**26** 46	**27** 42	**28** 38	**29** 34	30	9
			24 44	**25** 40	**26** 36	**27** 32	28	8
			22 42	**23** 38	**24** 34	**25** 30	26	7
			20 40	**21** 36	**22** 32	**23** 28	24	6
				19 34	**20** 30	**21** 26	22	5
				17 32	**18** 28	**19** 24	20	
				15 30	**16** 26	**17** 22	18	4
					14 24	**15** 20	16	
					13 23	**14** 19	15	3
					11 21	**12** 17	13	

Fumigation Table—Sodium Cyanid

SIZES OF TENTS							Feet	Dose oz.
43 78	**44** 74	**45** 70	**46** 66	**47** 62	**48** 58	**49** 54	50	24
40 75	**41** 71	**42** 67	**43** 63	**44** 59	**45** 55	**46** 51	47	20
37 72	**38** 68	**39** 64	**40** 60	**41** 56	**42** 52	**43** 48	44	18
	36 66	**37** 62	**38** 58	**39** 54	**40** 50	**41** 46	42	16
	34 64	**35** 60	**36** 56	**37** 52	**38** 48	**39** 44	40	14
	31 61	**32** 57	**33** 53	**34** 49	**35** 45	**36** 41	37	12
		30 55	**31** 51	**32** 47	**33** 43	**34** 39	35	10
		27 52	**28** 48	**29** 44	**30** 40	**31** 36	32	9
		25 50	**26** 46	**27** 42	**28** 38	**29** 34	30	8
			24 44	**25** 40	**26** 36	**27** 32	28	7
			22 42	**23** 38	**24** 34	**25** 30	26	6
			20 40	**21** 36	**22** 32	**23** 28	24	5
				19 34	**20** 30	**21** 26	22	
				17 32	**18** 28	**19** 24	20	4
				15 30	**16** 26	**17** 22	18	
					14 24	**15** 20	16	3
					13 23	**14** 19	15	
					11 21	**12** 17	13	

Fumigation Table—Sodium Cyanid

SIZES OF TENTS							Feet	Dose oz.
43	**44**	**45**	**46**	**47**	**48**	**49**	50	20
78	74	70	66	62	58	54		
40	**41**	**42**	**43**	**44**	**45**	**46**	47	18
75	71	67	63	59	55	51		
37	**38**	**39**	**40**	**41**	**42**	**43**	44	16
72	68	64	60	56	52	48		
	36	**37**	**38**	**39**	**40**	**41**	42	14
	66	62	58	54	50	46		
	34	**35**	**36**	**37**	**38**	**39**	40	12
	64	60	56	52	48	44		
	31	**32**	**33**	**34**	**35**	**36**	37	10
	61	57	53	49	45	41		
		30	**31**	**32**	**33**	**34**	35	9
		55	51	47	43	39		
		27	**28**	**29**	**30**	**31**	32	8
		52	48	44	40	36		
		25	**26**	**27**	**28**	**29**	30	7
		50	46	42	38	34		
			24	**25**	**26**	**27**	28	6
			44	40	36	32		
			22	**23**	**24**	**25**	26	5
			42	38	34	30		
			20	**21**	**22**	**23**	24	
			40	36	32	28		
				19	**20**	**21**	22	4
				34	30	26		
				17	**18**	**19**	20	
				32	28	24		
				15	**16**	**17**	18	3
				30	26	22		
					14	**15**	16	
					24	20		
					13	**14**	15	
					23	19		
					11	**12**	13	2
					21	17		

Fumigation Table—Sodium Cyanid

SIZES OF TENTS							Feet	Dose oz.
43	**44**	**45**	**46**	**47**	**48**	**49**	50	18
78	74	70	66	62	58	54		
40	**41**	**42**	**43**	**44**	**45**	**46**	47	16
75	71	67	63	59	55	51		
37	**38**	**39**	**40**	**41**	**42**	**43**	44	14
72	68	64	60	56	52	48		
	36	**37**	**38**	**39**	**40**	**41**	42	12
	66	62	58	54	50	46		
	34	**35**	**36**	**37**	**38**	**39**	40	10
	64	60	56	52	48	44		
	31	**32**	**33**	**34**	**35**	**36**	37	9
	61	57	53	49	45	41		
		30	**31**	**32**	**33**	**34**	35	8
		55	51	47	43	39		
		27	**28**	**29**	**30**	**31**	32	7
		52	48	44	40	36		
		25	**26**	**27**	**28**	**29**	30	6
		50	46	42	38	34		
			24	**25**	**26**	**27**	28	5
			44	40	36	32		
			22	**23**	**24**	**25**	26	
			42	38	34	30		
			20	**21**	**22**	**23**	24	4
			40	36	32	28		
				19	**20**	**21**	22	
				34	30	26		
				17	**18**	**19**	20	3
				32	28	24		
				15	**16**	**17**	18	
				30	26	22		
					14	**15**	16	
					24	20		
					13	**14**	15	2
					23	19		
					11	**12**	13	
					21	17		

Fumigation Table—Sodium Cyanid

SIZES OF TENTS							Feet	Dose oz.
43 78	**44** 74	**45** 70	**46** 66	**47** 62	**48** 58	**49** 54	50	16
40 75	**41** 71	**42** 67	**43** 63	**44** 59	**45** 55	**46** 51	47	14
37 72	**38** 68	**39** 64	**40** 60	**41** 56	**42** 52	**43** 48	44	12
	36 66	**37** 62	**38** 58	**39** 54	**40** 50	**41** 46	42	10
	34 64	**35** 60	**36** 56	**37** 52	**38** 48	**39** 44	40	9
	31 61	**32** 57	**33** 53	**34** 49	**35** 45	**36** 41	37	8
		30 55	**31** 51	**32** 47	**33** 43	**34** 39	35	7
		27 52	**28** 48	**29** 44	**30** 40	**31** 36	32	6
		25 50	**26** 46	**27** 42	**28** 38	**29** 34	30	5
			24 44	**25** 40	**26** 36	**27** 32	28	
			22 42	**23** 38	**24** 34	**25** 30	26	4
			20 40	**21** 36	**22** 32	**23** 28	24	
				19 34	**20** 30	**21** 26	22	3
				17 32	**18** 28	**19** 24	20	
				15 30	**16** 26	**17** 22	18	
					14 24	**15** 20	16	2
					13 23	**14** 19	15	
					11 21	**12** 17	13	

Resumé

A new principle in dosage relationships produces a simpler form of dosage tables than any hitherto known.

The common tables are grossly inaccurate in their method of computation.

Extremes in shape show inconsistencies as high as 33%.

Both high and low trees are given relatively much weaker doses than trees of medium size.

Percentage adjustments for varying degrees of leakage exhibit the same faults in the common tables as shown regarding sizes of trees.

The most important improvement to come in fumigation practice is the general adoption of correct allowance for tent leakage.

All three sources of error may contribute to the production of a very faulty estimate of dose or may compensate each other and all tables are practically sound for medium conditions.

The construction of the new tables involves no mathematical difficulties except for the calculation of the series of 18 sizes.

The tables are exceptionally simple, legible, not liable to confusion and allow for all needed variations of strength of dose.