were superior; this again may be due to uniformity of grind, plus good drainage. But it was better. This is about the only reason for us doing that; we felt we want a medium that would not break down fast, because when it breaks down you have more drainage problems. And with cedar, like redwood in California, breakdown is slow. So we are getting to a product that remains more stable, especially when it is to be used for a long, long period of time.

MODERATOR WOOD: Our next speaker took his undergraduate work at Utah State, then to Michigan State for his Ph.D., then to Washington State at Pullman about 14 years ago, where he has been working in Pomology. Fenton Larson:

SUCCESSFUL DEFOLIATION OF NURSERY STOCK WITH CHEMICALS[1]

FENTON E. LARSEN[2]

Washington State University
Pullman, Washington 99163

Work on chemical stimulation of leaf abscission of nursery stock started at Washington State University in 1962. Some work had been done elsewhere in the United States prior to that time (1,2,12,13,14). Since 1962, sporadic attention has been given to this problem by others in the United States and Western Europe. Apparently somewhat more consistent attention has been given in Eastern Europe. Much work in Europe, however, has been with materials which are more desiccants than defoliants.

In 1967, a report to the International Plant Propagator's Society (IPPS) covered the findings of the early work in Washington (4). Since 1967, several additional reports have been published concerning the most successful treatments (5,6,7,8,9,10) under central Washington conditions. Other materials have been tried which might be useful elsewhere. It is the purpose of this report to briefly present information gathered since the above mentioned report to IPPS (4) and to describe the currently most successful approaches to nursery stock defoliation in Washington.

---

[1]Received for publication August 11, 1973. Scientific Paper No. 4112. College of Agriculture Research Center. Washington State University. Work was conducted under project 1690. The contributions and assistance of the following nurseries are gratefully acknowledged: C and O, Chervenka, Columbia Basin, Heath, Hilltop, May, Milton, Pacific Coast, Van Well, Willow Drive. Contributions of chemicals from various companies is also appreciated.

[2]Professor, Department of Horticulture.

MATERIALS AND METHODS

Defoliate sprays were applied at commercial nurseries and experiment station plots using trombone-type hand sprayers. Replicated plots of 3 or more plants each for budded stock or plots of about 1 meter in length for seedlings and rootstock stoolbeds were used. Single, double, and triple applications were tried, using apple, pear, cherry, plum, and peach. Sprays were usually begun the first half of October, but late September sprays have been used. Plots were examined weekly and visually rated for defoliation until the time of digging. After storage, treated plants were replanted and observed the first season for after-effects of sprays.

Chemicals used were: 1967 — KI (potassium iodide), DEF (S, S, S-tributyl phosphorotrithioate), Nacconol NR (an alkylaryl-sulfonate), Bromodine (a bromine-iodine complex), DEF + KI, Bromodine + KI, iodoacetic acid, chloroacetic acid, bromoacetic acid, ethephon [(2-chloroethyl) phosphonic acid]; 1968 — ethephon, Bromodine, abscisic acid (ABA), ethephon + napthalene acetic acid, ethephon + urea; 1969 — Bromodine, ethephon, Bromodine + ethephon 1970 — KI, D-WK (Dupont-WK surfactant, the dodecyl ether of polyethylene glycol), ethephon, Bromodine, sodium iodide, iodide, ioxynil (4-hydroyy-3, 5 diiodobenzonitrile), KI + ethephon, D-WK + ethephon, Bromidine + D-WK; 1971 - D-WK, Bromidine, ethephon, D-WK + ethephon; 1972 - D-WK, ethephon, D-WK + ethephon, Fisons 9565, Dupont 1840, Mobil-leaf (an anti-transpirent) + ethephon, Amchem 72-29 (an ethephon + KI formulation), KA (potassium azide), and cycloheximide.

RESULTS

Specific data for only 1967 (Table 1), 1970 (Table 2), and 1972 (Table 3) are presented here since the major findings for 1968, 1969, and 1971 have been published elsewhere (5, 6, 7, 8, 9, 10).

DISCUSSION

Experimental Results.

The 1967 tests included the most successful chemicals from the previous 5 years' tests plus some previously untested chemicals. From the 1967 tests, Bromodine was judged to have the most potential for further testing.

While several chemicals produced significant amounts of leaf abscission in the tests of 1967 through 1972, those that gave the most favorable results under central Washington conditions were Bromodine, D-WK, ABA, and D-WK + ethephon. These materials were considered most useful because of the degree and speed of

Table 1. Percent[1] defoliation induced in the nursery at digging time by chemicals applied to several tree fruit cultivars (1967)

Chemical	Conc (ppm)	PLANT						
		d Anjou pear	Oregon Spur Delicious apple	Golden Delicious apple	Rome Beauty apple	Elberta peach	Bing cherry	Italian prune
		Observation Date						
		11/9	11/9	11/9	11/9	10/26	11/2	11/2
Potassium iodide (KI)	1000[2]	11	5	19	7	82	94	99
	2000	49	13	29	10	86	91	99
DEF	2500[2]	38	2	21	10	88	97	92
	5000	79[4]	11	21 _	13	89	66	91
Nacconol NR	5000[2]	27	0	9	0	90	69	84
	10,000	15	0	11	6	91	62	87
Bromodine	10 000[2]	91[4]	27	71	57	95	95	100
	15,000[3]	99[4]	54[4]	92	98[4]	97	93	100
DEF + KI	2500 + 1000[2]	92[4]	16	61	36	90	99	100
	5000 + 2000	87[4]	36	56	43	92	100	100
Nacconol NR + KI	5000 + 1000[2]	59	6	42	7	93	98	100
	10,000 + 2000[3]	89	19	62	26	95	95	100
Bromodine + KI	10,000 + 1000[2]	95	35	84	65	97	98	100
	15,000 + 2000[3]	97	50[4]	91	96[4]	98	96	100
Iodoacetic acid	500[2]	85	15	65	45	95	95	95
	2000[2]	100[4]	95	95[4]	85[4]	100[5]	95[5]	95[5]
Bromoacetic acid	500[2]	25	0	45	5	95	85	95
	2000[2]	95[4]	15	65	45	100	95	95
Chloroacetic acid	500[2]	95[4]	15	55	15	85	85	95
	2000[2]	95[5]	85	85	95[4]	95[5]	65[5]	95[5]
Control		5	0	0	5	80	45	50

[1]Figures represent means of 10 plots of at least 3 plants each.

[2]Application on 10/11

[3]Application on 10/19.

[4]Damaged bark and buds on 2 to 5 cm of the tips of some shoots at digging time.

[5]Similar to 4 but also with desiccated leaves attached to some terminals

Table 2. Percent[1] defoliation induced in the nursery by 10/29/70 by chemicals applied to several tree fruit cultivars.

Chemical	Conc (ppm)	PLANT						
		Ottawa 292 apple	MM 106 apple stoolbed	M 7A apple stoolbed	Goldspur apple	Earlistripe Delicious apple	Winesap apple	Old Home pear
Potassium iodide (KI)	1000	15,20,25	12,22,25	5,15,60	25,30,42	18,20,25	10,15,22	55,72,97
	1500	15,20,25	22,27,32	25,25,25	80,87,90	37,47,60	37,40,55	89,94,94
Dupont-WK (D-WK)	10,000	65 88,95	32,67,77	40,60,60	85,85,96	25,27,32	20,40,60	69,86,96
	20,000	99,99,99	60,92,99	90,98,98	90,98,100	80,82,90	70,79,80	99,100,100
Bromodine	2500	10,10,10	12,18,25	5,10,10	15,17,22	12,22,25	17,20,25	37,40,62
	5000	10,15,15	30,35,40	10,15,20	32,50,82	20,25,30	20,20,25	57,70,86
Ethephon	500	30,48,60	15,17,28	20,25,30	70,90,94	42,50,52	5, 5, 7	20,25,40
	750	45,55,70	20,38,48	20,30,40	92,98,98	47,57,67	10,10,10	75,75,75
Bromodine + D-WK	2500 + 10,000	60,79,89	38,47,57	50,75,85	90,95,96	45,47,70	52,57,72	87,87,96
	2500 + 20,000	98,98,99	50,94,98	90,95,95[3]	98,99,99	90,94,96	55,90,95	100,100,100
D-WK + ethephon	20,000 + 500	99,100,100	99,100,100	90,100,100	99,100 100	95,99,100	55,99,99	100,100,100
	20,000 + 750	100,100,100	100,100[2],100[2]	100,100,100	100,100,100	99,100,100	80,100,100	100,100,100
KI + ethephon	1000 + 500	17,25,30	40,55,60	35,50,50	87,94,97	45,50,50	25,30,37	67,75,60
	1000 + 750	30,62,65	45,62,62	35,50,60	96,98,98	47,60,72	32,40,45	92,96,94
Sodium Iodide	1000	17,17,17	27,35,42	10,20,25	85,90,95	47,50,50	45,62,75	95,99,99
	1500	15,15,17	38,38,43	30,30,30	87,92,96	75,82,85	75,85,92	100,100,100
Ioxynil	600	27,32,32	17,30,47[3]	15,20,30[3]	22,25,35[3]	12,15,15	25,25,25	30,40 50
	1200	37,37,32	47[3],60[3],65[3]	60[3],75[3],95[3]	52 55[3],62[3]	15,17,17	25,25,27	60,70,70
Control		7	7	10	10	10	5	25

1 Figures represent means of duplicate plots of at least 3 plants (about 1 m for stool beds) each The means in each series of 3 figures represent the results of single, double, and triple applications made on 10/8, 10/8 and 10/15, 10/8, 10/15 and 10/22 respectively

2 Damaged bark on 2 to 5 cm of the tips of some shoots at digging time

3 Similar to 2 but also with desiccated leaves attached to some terminals.

Table 3 Percent[1] defoliation induced in the nursery by 10/26/72 by chemicals applied to tree fruit nursery stock

Chemical	Conc (ppm)	PLANT						
		Golden Delicious apple	Wellspur Delicious apple	domestic apple seedling	Prunus mahaleb seedling	Hi Early Delicious apple	Ottawa 292 apple	Bartlett pear
Dupont-Wk (D-Wk)	10,000	30 38 55	20,20,60	17,85 90	48,55 65	23,75,99	83,100,100	28,30,48
	15 000	35,60,99	25,89,99	33,78,98	65,80[3]95[3]	30,100,100	89,100,100	28,35,63
Ethephon	100	20 20 20	8,10,10	5, 8, 8	13,13,18	5, 5,20	24,32,32	25,33,33
	200	20,20,20	8,13,15	5, 8,15	13,15,25	5,25,35	28,32,40	25,43,63
D Wk + ethephon	10 000 + 100	28,48 78	15 35 99	25 80[2],97[2]	30 55 78	45 100,100	59,90,100	53 75,98
	10,000 + 200	38 55 50	30,38,99	90[2],97[2],99[2]	30 63,73	92,100,100	89,99 100	53,74,95
	15 000 + 100	50,90,100	87,99,100	63[2],93[2],100[2]	30,78,95	58,100,100	65,100,100	70,70,100
	15,000 + 200	43,95,100	55,90,100	92[2],100[2],100[2]	65,95[3],98[3]	80,100,100	87,100,100	63,73,99
Dupont-1840	100	20,20	30, 0	10, 5	15,10	—	—	—
	1000	20,20	15,25	15, 5	25,15	—	—	—
Mobil-leaf + ethephon	30,000 + 200	25,20	13,18	3,18	20,15	—	—	—
	80,000 + 200	20,28	8,25	8,13	20,40	—	—	—
Potassium azide	100	15,18	10,10	0, 0	13,13	—	—	—
	400	20,20	13,10	0, 0	13,10	—	—	—
Fisons 9665	500	20,20	65,40	50,15	5,15	—	—	—
	2000	20,20	65,30	50,30	25,35	—	—	—
Amchem 72-29	400	33 30	13,10	25, 8	55,13	—	—	—
	600	30,25	15,15	38[2],63	60,50	—	—	—
Cycloheximide	25	70,75	98,99	75[3],35	80,75	—	—	—
	50	95,98	100,100	95[1],30[1]	85,65	—	—	—
Control		20	18	8	70	5	30	35

[1] Figures represent means of 2 to 4 plots of at least 3 plants (about 1 m for seedling) each The means in each series of 3 figures represent the results of single, double, and triple applications made on 9/28; 9/28 and 10/5, and 9/28, 10/5 and 10/12 respectively Means in each group of two figures represent the results of single applications applied on 9/28 or 10/12 respectively

[2] Damaged bark and buds on 2 to 5 cm of the tips of some shoots at digging time.

[3] Not more than 2 cm of some shoot tips desiccated

leaf abscission produced and the absence of or low degree of injury evident prior to and after storage. ABA has not been commercially tested because of its high cost but it appears to have considerable potential. Bromodine has been used commercially for about 4 years.

As experimental work has proceeded, commercial tests of D-WK and D-WK + ethephon have been very favorable and commercial use of these materials is now occurring. Experimental and commercial tests indicate that these chemicals are usually superior to Bromodine.

Another chemical, cycloheximide, deserves further experimental trial as demonstrated by the 1972 tests. This material produced a high level of abscission in 2 to 4 weeks with little or no injury from single applications of 25 or 50 ppm. Sprays of 100 ppm did not produce significantly better abscission but injury to shoot tips was significant at this higher rate.

While some chemicals have not been considered sufficiently satisfactory for Washington use on tree fruit nursery stock, testing in other areas and on other stock might be worthwhile. For example, KI was first tested in Washington on nursery stock and found to be useful (3). Later tests revealed better materials. As a result, KI has not been used commercially in Washington, but it has been commercially successful in Oregon on roses (personal communication with Fred Edmunds). Other chemicals which might be useful elsewhere include Bromodine + ethephon, ethephon + KI, NaI, Nacconol NR, DEF, and iodacetic acid.

Commercial Procedure

Commercial procedures with Bromodine in Washington have included 1 to 3 applications of 200 to 300 gal/A at 2500 ppm (of the formulation) at 3 to 5 day intervals for tender or more easily defoliated types (apricot, peach, pear, cherry). For more difficult types, such as apple and some plums, 2 to 3 applications of 5000 ppm have been used. Where tissues are not excessively succulent, or late in the season, higher rates up to 10,000 ppm have been used without damage on some apple cultivars. Apricot, peach, *P. mahaleb* seedlings, Rome apple, and M26 apple rootstocks are rather sensitive to damage with defoliants and are likewise sensitive to Bromodine. Consequently, application of defoliants to these types of stock should be conservative. Pruning wounds should be healed prior to Bromodine application since fresh wounds apparently absorb excessive Bromodine resulting in hypertrophied tissue around the wound.

Experimental and commercial trials show that 1 to 2 applications of 10,000 to 15,000 ppm (of the formulation) D-WK + 100 to 200 ppm (active ingredient) ethephon produce high degrees

of leaf abscission in 3 to 4 weeks with little or no damage if applications are modified according to the above mentioned sensitivities of plants. These treatments have been tested in experimental plots on a number of apple cultivars, on *P. mahaleb* cherry seedlings, sweet cherry, pear, Early Red Haven peach and Early Italian prune. Commercial tests have been more extensive, particularly with apples. On the following sensitive plants, combination rates higher than those indicated should not be used. Rome apple and *P. mahaleb* seedlings - 10,000 ppm D-WK + *200 ppm ethephon; Early Italian prune - 10,000 ppm D-WK* + 100 ppm ethephon. D-WK *alone* at 10,000 ppm is excessive for peach.

D-WK can be used quite successfully alone at 10,000 to 20,000 ppm (except as noted) but defoliation is somewhat slower than when it is combined with ethephon. D-WK alone, however, is much safer for the plant, and for this reason some nurserymen favor it over the combination treatment with ethephon.

Influencing Factors.

While insufficient work has been done on conditions which influence the reactions to defoliants, evidence indicates that at least the following are important: temperature, humidity, precipitation, soil moisture, nutrition, species, cultivar, plant age, vigor and maturity, timing, chemical concentration, and adjuvants (11). At present, the prime considerations for the nurseryman *seem* to be:

1. weather—spray absorption is greater with high humidity. Defoliants work best if preceeded by one or more light frosts and if day temperatures at the time of application are 18°C (64°F) or higher. Rain should not immediately follow an application.

2. plant factors — applications should be adjusted appropriately for differences in species and cultivar sensitivity. Some damage may be expected if terminal buds have not been formed prior to treatment. Nursery stock that has grown vigorously is more difficult to defoliate than low vigor stock or an older, established tree.

3. application considerations— timing, concentration, and adjuants must be adjusted to give desirable results and avoid undesirable side effects. Timing should be regulated by weather and plant development. Concentration will vary with species, cultivar, and timing. Multiple applications probably should not be closer than 3 days in order to allow sufficient reaction time and to avoid the possibility of damage.

Of prime importance is the judgment and care of the applicator. The mixing and application should be at least as care-

fully done as with a herbicide or chemical fruit thinning spray. Ineffective treatments, plant damage and unnecessary costs are the inevitable result of careless, poorly timed application. On the other hand, very good results are obtained by nurserymen who carefully time and control their applications.

LITERATURE CITED

1. Chadwick, L. C. 1947. Prestorage defoliation of some shrubs and trees. *Ohio State Nursery Notes.* 16(8):1-5.
2. _____. and R. Houston. 1948. Apreliminary report on the prestorage defoliation of some trees and shrubs. *Proc. Amer. Soc. Hort. Sci.* 51:659-667.
3. Larsen, F. E. 1966. Potassium iodide induced leaf abscission of several deciduous woody plants. *Proc. Amer Soc. Hort. Sci.* 88:690-697.
4. _____. 1967. Five-year's results with prestorage chemical defoliation of deciduous nursery stock. *Proc. Inter. Plant Prop. Soc.* 17:157-172.
5. _____.1969. Promotion of leaf abscission of deciduous tree fruit nursery stock with abscisic acid. *HortScience.* 4(3):216-218.
6. _____. 1970. Prestorage promotion of leaf abscission of nursery stock with Bromodine. *J. Amer. Soc. Hort. Sci.* 95(2):231-233.
7. _____. 1970. Promotion of leaf abscission of deciduous nursery stock with (2-chloroethyl) phosphonic acid. *J. Amer Soc. Hort. Sci.* 9(6):135-137.
8. _____. 1971. Prestorage promotion of leaf abscission of deciduous nursery stock with Bromodine-ethephon mixtures. *HortScience.* 6(2):135-137.
9. _____. 1972. Surfactant stimulates leaf abscission of nursery stock. *HortScience.* 7(6):563-564.
10. _____. 1973. Stimulation of leaf abscission of tree fruit nursery stock with ethephon-surfactant mixtures. *J. Amer. Soc. Hort. Sci.* 98(1): 34-36.
11. _____. 1973. Promotion of leaf abscission in fruit nursery stock. *Acta Horticulturae.* 34(1):129:133.
12. Milbrath, J. A., A. E. Hansen, and H. Hartmann. 1940. The removal of leaves from rose plants at time of digging. *Ore. Agric Exp. Sta. Bul.* 383.
13. Pridham, A. M. S. 1952. Preliminary report on defoliation of

nursery stock by chemical means. *Proc. Amer. Soc. Hort. Sci.* 59:475-478.

14. Roberts, A. N. 1950. Prestorage defoliation of field grown roses with certain sprays and dusts. *Proc. Amer. Soc. Hort.*

SUNDAY MORNING SESSION
August 12, 1973

VICE-PRESIDENT OKI: Our session this morning will be chaired by our able program committee member from Hawaii, Bob Warner. Bob, will you take over now?

MODERATOR WARNER: Our first speaker this morning is Donald Watson. He is Professor of Horticulture at the University of Hawaii and is working in Urban Horticulture. He has been doing a lot to bring the beauty and freshness of living plants to the city dwellers. He has had a local newspaper column for over a year and has a television program every other week. His topic is "Plants are for People." He has written a book with this title that was published just a couple of months ago. It is a great deal of pleasure to introduce my associate, Don Watson:

PLANTS ARE FOR PEOPLE[1]

DONALD P. WATSON

University of Hawaii
Honolulu, Hawaii 96822

About a thousand years ago when the Polynesians first settled in Hawaii they were greeted with a forbidding shoreline, a blue ocean, and attractive beaches, but absolutely no plants. There was just no vegetation whatsoever. Anything that is growing on these islands has been brought in since. When they arrived in their outrigger canoes they gradually climbed into the areas where they might be able to grow things and they brought with them quite a number of the plants to which they were accustomed. In some areas there was so little rainfall that it was practically impossible to grow anything and in other areas there was so much rainfall that it was an absolute paradise that would later grow into a jungle.

Now the most common and perhaps the most necessary plant as far as the Polynesians were concerned was the taro [*Colocasia*

[1] Ed Note This paper was given extemporaneously and transcribed on tape and supplemented with 160 Kodachrome slides