A Comparison of Handgun and Tree-Row-Volume Pesticide Applications

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ABSTRACT

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Handgun (HG) pesticide applications resulted in greater, but less variable, deposits of chelated micronutrients on apple foliage than applications made with a speed sprayer calibrated to deliver the micronutrients at tree-row-volume (TRV) or 70% TRV (70TRV) rates. These results were consistent on both small and large trees at two locations. Tree-row-volume applications resulted in greater deposits than the 70TRV applications on small trees. Deposit from 70TRV was significantly less than TRV on large trees at one location. Handgun applications of captan resulted in significantly better sooty blotch and flyspeck control than TRV or 70TRV applications, but TRV and 70TRV applications provided acceptable commercial control. Handgun applications of naphthaleneacetic acid resulted in greater fruit thinning than TRV application in one of two tests. There was no difference in the degree of fruit thinning in the other test, but fruit on trees sprayed with the HG were larger. Both HG and airblast applications should be used to evaluate pesticides or growth regulators for activity in the orchard.

The tree-row-volume (TRV) concept is suggested in many states as a guide for helping to determine the correct rate of a pesticide (growth regulator, fungicide, insecticide, miticide, etc.) to use per hectare. Tree-row-volume is based on the assumption that each row of trees is a wall of foliage and the chemical deposit can be related to the volume of foliage within that wall (2,6,8). A standard apple orchard of 39,907 m^3 (trees 6.1 m wide, 7.0 m tall, set on 10.7 m middles) is the reference base and 1.0 L of dilute chemical suspension is considered to wet 7.48 m^3 of foliage (equivalent to 5,335 L/ha) to runoff. The TRV dilute base, calculated on this basis, is the standard for growth regulator application for such responses as inhibition of vegetative growth and thinning spur Red Delicious (6,8). A dilute pesticide suspension of 3,741 L/ha has been used as the basis for disease and insect control on the standard orchard (4), thus the pesticide TRV gallonage is approximately 70% of the TRV dilute base used for growth regulator application ([3,741 L/ha]/[5,335 L/ha] = 0.7). This is equivalent to 1 L of pesticide suspension per 10.24 m^3 of foliage (0.7 gal/1,000 ft^3).

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Pesticide label rates are usually determined through a series of tests in which various concentrations of the materials are applied with a handgun. These materials are mixed on a per 378.5 L (100 gal) basis and trees are sprayed to drip. The concentration of material that gives the desired response is then selected as the label rate and recommendations are usually expressed as a rate per 378.5 L (100 gal) or per ha (acre). However, today most orchards are sprayed with an airblast sprayer and usually less water is used per hectare than needed to spray the trees to drip.

The relationship between handgun application and applications based on TRV calculations needs to be compared to provide a reliable basis for making pesticide recommendations. Thus, the objectives of this study were to compare the deposit resulting from handgun and TRV applications, and to compare growth regulator response and disease control using these two application methods.

MATERIALS AND METHODS

Location. Tests were conducted in orchard blocks located at the Mountain Horticultural Crops Research Station (MHCRS), Fletcher, NC and the Central Crops Research Station (CCRS), Clayton, NC. The three youngest orchards, at MHCRS (MHCRS1 and MHCRS3) and CCRS (CCRS1), were spur-type Delicious and Golden Delicious pruned to a modified central leader; the two oldest blocks were nonspur Delicious and Golden Delicious (MHCRS2 and CCRS2) pruned to a modified central leader. All trees were moderate to well pruned. Trees in the orchard blocks are described in Table 1.

Treatment application. Handgun applications (HG) were applied with a single-nozzle spray gun at 203 kPa and trees were sprayed to runoff. The amount of water required in the dilute TRV application was determined from a calculation of the dilute TRV base (6,8), and the amount for the TRV rate adjusted for pesticides was determined by multiplying the dilute TRV base by 0.7 (70TRV). The dilute TRV rate calculated for each block is listed in Table 1.

Airblast sprayer applications were made with a Swanson DA500 speed sprayer (Durand-Wayland, Inc., LaGrange, GA) driven at 54.6 m/min (2 mph). Manifold pressure was 192.4 kPa. Combinations of nozzle numbers and core and disc sizes were selected to deliver the appropriate water volume. Two-thirds of the spray volume was directed to the top one-third of the tree, and one-third of the volume to the bottom two-thirds of the tree.

Deposition study. Heavy metal chelated micronutrients were used to determine

Table 1. Description of trees in orchard blocks used in tests at the Mountain Horticultural Crops Research Station (MHCRS) and the Central Crops Research Station (CCRS) during 1985 and 1986

Orchard	Age (yr)	Tree Height (m)	Tree Width (m)	Row spacing (m)	Tree density[x]	TRV[y] (m^3)	Dilute TRV (L/ha[z])
MHCRS1	6	3.81	2.59	7.62	0.8	10,360	1,385
MHCRS2	24	4.88	5.64	10.67	0.8	20,636	2,759
MHCRS3	17	4.27	3.97	6.1	0.8	22,232	2,972
CCRS1	5	3.05	2.59	7.62	0.75	7,775	1,039
CCRS2	25	4.27	5.64	9.14	0.9	23,714	3,170

[x] For description of tree density ratings see references 6 and 8.
[y] Tree-row-volume, m^3 foliage ha.
[z] Liters of water needed per ha to spray trees to runoff. Based on 1 L water per 7.48 m^3 foliage.

deposit levels (7). Sequestrene Zinc (Zn, 14.2%), Sequestrene Manganese (Mn 12.0%), Sequestrene Copper (Cu, 13.0%), and Sequestrene 330 Fe (Fe 10.0%) (Ciba-Geigy Corp., Greensboro, NC) were used in all tests. All treatments were applied to the same four trees in each orchard block. Handgun treatments were applied first and the deposits were allowed to dry. This was followed by the dilute TRV rate, and after these deposits dried the 70TRV rate was applied. The cultivar Delicious was used in each block.

Trees were partitioned into four regions for sample collection. They were divided by a vertical plane in the center of the tree and by a horizontal plane at the midpoint of the tree. Regions 1 and 2 were in the bottom half of each tree and regions 3 and 4 were in the top half. After deposits dried, five three-leaf samples were picked at random from each region. Leaves within 10 cm of one another were selected and picked by their petioles to minimize contact with the leaf surfaces. Each sample was placed in a paper bag and refrigerated at 2 C.

Deposit determination. Deposits from each of the three treatments were determined from each leaf sample by foliar mineral analysis. Leaf samples were dried at 75 C for 48 hr, ground, and dry weights were determined. Dried samples were ashed at 500 C for 12 hr, dissolved in HCl, evaporated, and diluted to volume with distilled water. The weight of heavy metals in micrograms per gram of leaf tissue was determined using an atomic absorption spectrophotometer (7).

Regression equations relating leaf dry weight to surface area were used to convert micrograms of heavy metal per gram of leaf tissue to micrograms of heavy metal per square centimeter of leaf surface. Equations were derived for each block from 50 leaves chosen at random from the test trees. The area of each leaf was measured with an area meter (Li-Cor, model 5000, Lamda Instruments Corp., Lincoln, NE); leaves were dried at 75 C and the dry weight of each leaf was determined.

Fruit thinning studies. Naphthaleneacetic acid (NAA) was applied to Golden Delicious trees for fruit thinning in orchards CCRS1 and MHCRS3 in 1986. At CCRS1, treatments were applied to two five-tree groups of trees. Data were collected from the second and fourth tree within each five-tree group. At the pink stage of bud development, two limbs on each tree were selected and all blossom clusters were counted. Naphthaleneacetic acid, at 15 μg/ml, was applied to the trees on 29 April. The HG rate was approximately 5,612 L/ha (600 gal/acre), the TRV rate was 1,048 L/ha (112 gal/acre), and the 70TRV rate was 655 L/ha (78 gal/acre). Two nonsprayed groups of five trees each served as checks. On 2 June, fruit set was determined by examining fruit spurs on each tagged limb and the number of fruit was recorded.

At MHCRS3, treatments were assigned at random to three to six Golden Delicious trees, each within a row. Two limbs in the lower portion of the canopy were selected on each tree and all blossom clusters were counted before bloom. Two HG treatments (NAA at 7.5 and 15 μg/ml) and one airblast TRV treatment (NAA at 15 μg/ml) were applied on 14 May. Sorbiton monolaurate (Tween 20, ICI Americas, Wilmington, DE) at 1.25 ml/L was included in each treatment. Controls did not receive NAA or sorbiton monolaurate. The TRV rate was 2,972 L/ha (320 gal/acre). Fruit counts were made on 4 June.

At both locations, 25 fruit per replication were selected arbitrarily throughout the tree at harvest. Their diameter, length, and weight were determined.

Sooty blotch and flyspeck control. Captan 50W at 1.198 g a.i./L was applied to Golden Delicious trees in orchards CCRS1 and CCRS2 in 1986 for sooty blotch (*Gloeodes pomigena* (Schw.) Colby) and flyspeck (*Zygophiala jamaicensis* Mason, teleomorph: *Schizothyrium pomi* (Mont. & Fr.) von Arx) control. At CCRS1, eight groups of five trees each were selected and two groups each were sprayed by either HG, TRV, or 70TRV. Two groups of trees served as controls. The HG rate was approximately 5,612 L/ha, the TRV rate was 1,048 L/ha, and the 70TRV rate was 655 L/ha. In CCRS2, individual trees were used as replications for each treatment. In CCRS2 the HG rate was approximately 7,000 L/ha, the TRV rate was 2,656 L/ha, and the 70TRV rate was 1,861 L/ha. Treatment applications were made on 29 April (phenophase first cover), 13 and 27 May, 10 and 24 June, 8 and 22 July, and 5 and 25 August. The second and fourth trees within each five-tree block in CCRS1 were selected for data collection at harvest on 11 September. Fruit were rated on all treated trees in CCRS2. Twenty-five fruit were chosen at random from each tree and were scored for sooty blotch and flyspeck incidence and severity. The percent of surface area affected was estimated on each infected fruit.

Experimental design and data analysis. The deposition experiment was designed as a split-split plot with size being factor A; method, factor B; and region, factor C. The analysis of variance was carried out accordingly. Because interactions were significant in the analysis of variance, interaction means are presented in the tables together with appropriate least significant differences. Analyses of variance were also conducted by method, and coefficients of variation were computed by application method. The coefficients of variation, although somewhat different among the methods, did not differ enough to invalidate the combined analysis of variance described above. Fruit thinning and disease control experiments were conducted in a

Table 2. Means and coefficients of variation (CV) for heavy metal deposits obtained after applications with a handgun and with an airblast sprayer calibrated to deliver applications at dilute TRV and 70% TRV rates at the Mountain Horticultural Crops Research Station (MHCRS) and the Central Crops Research Station (CCRS) in 1985

	MHCRS		CCRS	
Treatment[x]	Deposit[y]	CV[z]	Deposit	CV
Handgun	3.51	30.98	4.23	21.33
TRV	2.21	43.80	2.18	36.50
70TRV	1.54	38.63	1.72	46.84
$LSD_{0.05}$	0.25		0.29	

[x]TRV = Tree-row-volume rate; 70TRV = 70% calculated tree-row-volume rate.
[y]Deposit of heavy metal in $\mu g/cm^2$ leaf tissue.
[z]Coefficient of variation based upon Error (b) which was estimated with 18 degrees of freedom.

Table 3. Mean deposits ($\mu g/cm^2$ leaf tissue) on small and large trees obtained from applications of heavy metal tracers by a handgun or an airblast sprayer calibrated to deliver the TRV dilute rate or 70% TRV at the Mountain Horticultural Crops Research Station (MHCRS) and the Central Crops Research Station (CCRS) in 1985

Application	Small trees		Large trees	
method[y]	MHCRS	CCRS	MHCRS	CCRS
Handgun	3.68[z]	4.74	3.33	3.77
TRV	2.22	2.34	2.18	2.12
70TRV	1.37	1.49	1.70	1.96
$LSD_{0.05}$	0.35	0.41	0.35	0.41

[y]TRV = Tree-row-volume rate; 70TRV = 70% calculated tree-row-volume rate.
[z]Deposit of heavy metals in $\mu g/cm^2$ leaf tissue.

completely random design and means were separated according to the Waller-Duncan *k*-ratio *t* test (5).

RESULTS

Deposition study. Deposits were greater ($P = 0.05$) and the coefficient of variation was less with the HG applications at MHCRS and CCRS than with the TRV and 70TRV applications (Table 2). The TRV applications resulted in greater deposits than the 70TRV applications. Deposits from the 70TRV application were more variable than deposits from the TRV application at CCRS. However, at MHCRS deposits from the TRV application were more variable.

Handgun applications resulted in the greatest deposit on both large (CCRS2 and MHCRS2) and small (CCRS1 and MHCRS1) trees (Table 3). Tree-row-volume applications resulted in greater deposits than 70TRV applications on small trees. On large trees the TRV application resulted in greater deposits at MHCRS1, but there was no difference at CCRS1.

The method of application accounted for the greatest amount of variation in the data as determined in an analysis of variance (Table 4). Tree size was not significant, although this factor interacted with both method and region. Region was significant at MHCRS; deposits were generally less with the TRV and 70TRV applications in the two lower regions of the trees in MHCRS1. The size × method interaction was significant; handgun deposits were proportionally greater in small trees than large ones. The size × region interaction was significant at both locations. At MHCRS, deposits were proportionally greater in the tops of the small trees. At CCRS, deposits in region 2 of the small trees were greater than regions 3 and 4 and greater than in the large trees. Deposits in region 1 were less than in region 3. The method × region interaction was significant at CCRS; there was less deposit in the bottom of trees sprayed with the 70TRV rate than in the tops of the trees and less in regions 2 and 3 than in region 1 with the TRV treatment.

Fruit thinning experiments. Freeze injury on 24 April resulted in a light crop at CCRS1. However, fruit set was significantly less ($P = 0.05$) on trees sprayed with the HG compared with TRV, 70TRV, and the nontreated control (Table 5). There were no significant differences in fruit weight, diameter, or length among the treatments.

At MHCRS3, the fruit set was heavy. There were no differences in fruit set among the three treatments, although the fruit set in all treatments was significantly less than the control (Table 6). Fruit length and weight from HG treatments were greater than the TRV application treatment and the control. Fruit diameter was greater when NAA was applied at 15 μg/ml with HG as opposed to TRV.

Sooty blotch and flyspeck control. The 1986 growing season was characterized by unusually hot, dry weather. Consequently, sooty blotch and flyspeck did not develop until late in the season. Sooty blotch and flyspeck incidences were less with HG applications in both size trees (Table 7). There was no significant difference between TRV and 70TRV applications. Sooty blotch and flyspeck incidences were less with TRV applications at CCRS2 but greater in CCRS1. There was no significant difference among treatments in the percent of surface area covered with sooty blotch or flyspeck.

DISCUSSION

The TRV model is used to calculate the volume of water necessary to wet the foliage in an apple orchard to runoff (8). According to the logic of the model, fungicides, insecticides, and miticides should be applied at 70% of the TRV dilute base. This rate wets foliage only to the drip point and reflects the proportion of the TRV dilute base that has been used historically for recommending pesticides for apple orchard use in the eastern United States. In our study, heavy metal deposit was generally higher with the TRV application than the 70TRV application; the difference was greater on small than on large trees. Although there

Table 4. Mean squares of the deposit of heavy metal ($\mu g/cm^2$/leaf tissue) resulting from the interaction of applications of the materials by three methods on two sizes of trees and within four regions per tree at the Mountain Horticultural Crops Research Station (MHCRS) and the Central Crops Research Station (CCRS) in 1985

Source[y]	Degrees of freedom	Mean squares for spray deposit MHCRS	Mean squares for spray deposit CCRS
Size	1	0.04 ns[z]	6.03 ns
Method	2	160.37***	281.83***
Size × method	2	4.46*	21.62**
Region	3	5.98**	1.77 ns
Size × region	3	4.73**	4.25**
Method × region	6	1.75 ns	3.28**
Size × method × region	6	7.50 ns	0.70 ns

[y] Data analyzed in a split-split plot design.
[z] *** = Significant at $P = >0.01$; ** = significant at $P = 0.01$; * = significant at $P = 0.05$; ns = not significant.

Table 5. Percent of blossoms that set fruit at Central Crops Research Station (CCRS1) following the application of naphthaleneacetic acid at 15 μg/ml on 19 April with fruit count made on 2 June

Application method[y]	Blossoms that set fruit (%)	Fruit Diameter (cm)	Fruit Length (cm)	Fruit Weight (g)
Handgun	2.2 a[z]	7.44	6.50	1.67
TRV	7.3 b	7.44	6.58	1.62
70TRV	7.4 b	7.37	6.50	1.59
Check	11.3 b	...	...	...
		ns	ns	ns

[y] TRV = Airblast sprayer at tree-row-volume rate; 70TRV = 70% tree-row-volume rate.
[z] Means followed by the same letter are not significantly different by a Waller-Duncan *k*-ratio *t* test (*k*-ratio = 100 ~ $P = 0.05$).

Table 6. Percent of blossoms that set fruit at the Mountain Horticultural Crops Research Station (MHCRS3) following the application of naphthaleneacetic acid on 14 May with fruit count made on 4 June

Application method[y]	Blossoms that set fruit (%)	Fruit Diameter (cm)	Fruit Length (cm)	Fruit Weight (g)
HG 7.5	28.2 a[z]	6.76 ab	5.74 a	1.30 a
HG 15	23.6 a	7.01 a	5.94 a	1.46 a
TRV 15	24.7 a	6.45 bc	5.43 b	1.12 b
Check	46.5 b	6.43 c	5.23 b	1.08 b

[y] HG 7.5 = Handgun at 7.5 μg/ml naphthalene acetic acid; HG 15 = handgun at 15 μg/ml naphthalene acetic acid; TRV 15 = airblast sprayer, tree-row-volume at 15 μg/ml naphthalene acetic acid.
[z] Means followed by the same letter are not significantly different by Waller-Duncan's *k*-ratio *t* test (*k*-ratio = 100 ~ $P = 0.05$).

were differences in deposit between TRV and 70TRV applications on small trees, this was not reflected by differences in fruit thinning or in the level of sooty blotch and flyspeck control at CCRS1. However, sooty blotch and flyspeck control was poorer in the larger trees with the 70TRV application. We observed that in the larger trees sooty blotch and flyspeck incidence and severity were greater in the 70TRV application on the inside of the tree than the outside. This may be a reflection of renozzling to deliver the smaller water volume. Renozzling would result in the production of finer water droplets that would be less efficient in penetrating the foliage. The sampling scheme that we used would not have detected differences in deposit in the center of the tree.

Deposits from the HG applications were consistently greater and more uniform than the TRV or 70TRV applications, and HG treatments with captan resulted in significantly better sooty blotch and flyspeck control. Under orchard conditions, deposits from airblast sprayer applications would probably be somewhat greater than in this study due to deposits resulting from blow-through and drift from adjacent sprayed rows. Although we were able to achieve superior sooty blotch and flyspeck control with the HG applications, we applied 2.6–8.5 times as much captan per hectare as the other applications. However, the level of disease control achieved with the TRV applications did not differ very much from those that have been observed in previous studies. Brown and Sutton (1) found that the residual activity of captan against sooty blotch and flyspeck varied from 4 to 30 days depending on the season. In our study, we did not observe any disease development in the sprayed plots until approximately 21 days after the final spray. At that time, approximately 30% of the fruit in the TRV treatment were affected.

Differences in thinning response to HG and TRV applications of NAA were not consistent between locations. At CCRS1, HG application of NAA resulted in greater fruit thinning than the TRV or 70TRV applications. However, this was not reflected by increased fruit size. There was generally a light crop on all trees as a result of frost injury. Consequently, an increase in fruit size was not expected. At MHCRS3, there was no significant difference in thinning between HG or TRV applications of 15 μg/ml of NAA. However, fruit on trees thinned with HG were significantly larger than those thinned with TRV. This may be a result of more uniform thinning with HG. Limbs for fruit counts were selected from the lower half of the tree, while at harvest fruit were picked at random from throughout the tree. Poor thinning in the tops of trees would have resulted in smaller fruit and overall smaller fruit size.

Greater deposits obtained with HG applications at CCRS1 compared with MHCRS1 are probably a result of different application techniques; the treatments were applied by different individuals at each location. Handgun applications are applied until water is dripping from most leaves (referred to as runoff). However, techniques vary from individual to individual and the perception of runoff is equally variable. Hall recognized this problem in a paper addressing the need for innovative research in fruit production (3). In a comparison of applications of azinphos-methyl made by investigators in four states, he found that the liters (gallons) of azinphos-methyl suspension applied per 28.3 m^3 (1,000 ft^3) of foliage varied from 7.34 to 45.90 (1.94 to 12.13 gal). In the same study, the g a.i./28.3 m of foliage ranged from 2.20 to 13.80. Interestingly, there was no difference in the degree of codling moth control.

Differences in deposits and biological activity observed between HG and TRV applications question the continued use of handgun applications to evaluate pesticide efficacy. Variation in rates may not have been critical with older materials such as captan or mancozeb that are applied at 4.48 and 6.95 kg a.i./ha, respectively, but may be extremely important to many of the newer materials such as the demethylation-inhibiting fungicides that are applied at 70 g a.i./ha or less. There is some evidence that this problem may have already occurred. Etaconazole, a triazole fungicide developed by Ciba-Geigy Corp., was observed to cause plant growth regulator effects when applied at high rates; affected fruit were flattened. However, at rates selected for commercial evaluation, plant growth regulator effects were only observed in trials that were applied with a handgun (H. V. Morton, *personal communication*).

Historically, new pesticides have been evaluated in small plots using dilute handgun applications of varying pesticide concentrations. Since most new products are available only in small quantities, initial field screening will have to be conducted in this manner. However, before rates are selected for inclusion on a label, it is imperative that the material be tested in dilute and concentrate applications with airblast sprayers.

Table 7. Effect of application method on control of sooty blotch and flyspeck with captan at Central Crops Research Station in 1986

Orchard	Application method	Fruit affected (%) Sooty blotch	Fruit affected (%) Flyspeck	Surface covered (%)
CCRS2[w]	HG[y]	13.3 a[z]	6.7 a	2.6 a
	TRV	33.3 a	58.7 b	2.3 a
	70TRV	65.3 b	72.0 b	4.4 a
	None (Check)	100.0 c	100.0 c	24.3 b
CCRS1[x]	HG	4.0 a	13.0 a	2.0 a
	TRV	42.0 b	64.0 b	3.0 a
	70TRV	30.0 c	54.0 b	2.4 a
	None (Check)	100.0 d	100.0 c	31.7 b

[w] HG Application approximately 7,000 L/ha; TRV application at 2,656 L/acre; 70TRV at 1,861 L/acre.
[x] HG Application approximately 5,600 L/ha; TRV application 1,048 L/ha; 70TRV at 655 L/ha.
[y] HG = Handgun; TRV = airblast sprayer at tree-row-volume rate; 70TRV = 70% tree-row-volume rate.
[z] Means followed by the same letter are not significantly different by Waller-Duncan's k-ratio t test (k-ratio = 100 ~ $P = 0.05$).

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LITERATURE CITED

1. Brown, E. M., and Sutton, T. B. 1986. Control of sooty blotch and flyspeck of apple with captan, mancozeb, and mancozeb combined with dinocap in dilute and concentrate applications. Plant Dis. 70:281-284.
2. Byers, R. E., Hickey, K. D., and Hill, C. H. 1968. Base gallonage per acre. Va. Fruit 60:19-23.
3. Hall, F. R. 1979. The need for innovative pesticide research in fruit production. Insectic. and Acaric. Tests 4:4-7.
4. Lewis, F. H., and Hickey, K. D. 1972. Fungicide usage on deciduous fruit trees. Annu. Rev. Phytopathol. 10:399-428.
5. Steele, R. G. D., and Torrie, J. H. 1980. Principles and Procedures of Statistics. 2nd ed. McGraw-Hill, New York. 633 pp.
6. Sutton, T. B., and Unrath, C. R. 1984. Evaluation of the tree-row-volume concept with density adjustments in relation to spray deposits in apple orchards. Plant Dis. 68:480-484.
7. Travis, J. W., Sutton, T. B., and Skroch, W. A. 1985. A technique for determining the deposition of heavy metals in pesticides. Phytopathology 75:783-785.
8. Unrath, C. R., Sutton, T. B., Obermiller, J. D., and Williams, K. M. 1986. A tree-row-volume model for determining proper spray rates in apple orchards. N. C. Apple Grow. Assoc. Publ. 001. 8 pp.