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As summarized by LaVoie and Tietjen (1978), many aspects of vole control using rodenticides including the costs/benefits of rodenticide use, applicator limitations in commercial orchards, and vole biology have not received proper attention. Data relating vole population levels to damage severity have not been generated and thus the exact benefits of control measures are difficult to analyze.

Several aspects of vole biology have only recently been considered in rodenticide application procedures. Problems such as bait acceptance and percentage population control have created disparity in several rodenticide experiments (Richmond et al., 1978). A knowledge of vole use of vegetative cover and food habits is critical to the timing and effectiveness of population control via rodenticide. Several of these points were developed into the objectives for the projects completed in the Fall 1981 and 1982.

Objectives

The objectives of these projects were as follows:

1. To evaluate the effectiveness of several broadcast pelletized rodenticides in reducing pine and meadow vole populations on both grower-treated blocks and comparative test plots.

2. To develop the costs per acre of each of the methods of rodenticide application as well as the actual cost incurred by a grower when applying various rodenticides.

3. To evaluate the impact of several vegetation parameters on rodenticide effectiveness.

4. To evaluate several methods of indexing vole populations for accuracy in depicting vole infestations, ease of grower use, and cost per tree in man-hours expended.

Materials and Methods - Fall 1981

All trials were conducted in the central Ulster County region of the Hudson Valley, New York. Fourteen sites on 6 different fruit farms were selected for the general application trials. These sites were predominantly pine vole infested and were representative of the range of fruit blocks in which control measures have been invoked. Tree densities, ages, and varieties, ground vegetation species composition and structural complexity, and general orchard management programs varied between blocks.

The apple index of Byers (1977) was used to assess pre- and post-treatment effects of rodenticides. The pre-treatment index was conducted 7 to 14 days after baiting during a period of relatively mild weather conditions.

Application methods included hand-placement under bait stations, hand-placement in holes, manual broadcast, machine broadcast, and high-pressure spraying. All pelletized rodenticides were broadcast at 10 lbs per tree row acre. This included the area from alley to alley along the entire row length. Ground spray was applied at 100 gals per orchard acre. Growers provided data on the amount of rodenticide used and the time required in labor and equipment to complete the application. These data were used to compute the application costs per acre for the various methods employed.

Rodenticides were hand-placed only at trees where activity was recorded during the pre-treatment index. In blocks where rodenticides were broadcast or sprayed, approximately 40 percent of the trees were indexed for activity before and after treatment.

Plots of the comparative rodenticide trials ranged from .8 to 1.4 acres in size. Treatments were assigned to 2 or 3 rows of 15 to 20 trees. Due to limitations in block size and a desire to minimize plot heterogeneity, the treatments were applied to consecutive rows. Precautions were taken to ensure rodenticides were not used beyond each treatment plot boundary. All rodenticides were broadcast at 10 lbs per acre.

Vole populations were assessed using a single live trap (5 x 5 x 18 cm) at each tree. Traps were baited with fresh apple slices and checked every 3 to 4 hours between 8:00 a.m. and 5:00 p.m. Each trapping session consisted of 3 trap checks. Captured voles were identified to species, sexed, aged, marked (by toe clipping), and released. Pre-treatment trapping sessions were completed 1 day before the rodenticide application and post-treatment sessions were conducted 10 days after the rodenticide application. On plots 4 and 5, post-treatment trapping could not be completed on schedule due to snow cover. Unfortunately, these plots were not trapped until March 29 to April 2, 1982. Data on post-treatment populations thus includes rodenticide mortality and natural mortality that occurred over the winter months. The population reduction estimated for plots 4 and 5 should be considered residual due to the above circumstances.

Population data were derived using enumeration as adjusted by the relative trapping effort in each block. This adjustment permitted plot-to-plot comparisons by accounting for differential numbers of traps used to capture voles. The population estimation procedures established by Stockrahm, McAninch and Harder (1981) could not be used, due to low to moderate population numbers.

All existing vegetation within the sample loop at every fifth tree was clipped at the soil surface, weighed and recorded as fresh weight biomass. All clipped samples for each treatment plot were mixed in the field and immediately returned to the laboratory for moisture content analysis. Each collective field sample was subsampled 10 times in 5 gm amounts. Each 5 gm sample was dried at 100° C for 24 hrs. Percent moisture content was calculated by dividing the weight loss (in grams) after drying by the initial sample weight and multiplying by 100.

Fall 1982

Most methods followed those of the Fall 1981 study. Sixteen grower-treated blocks located on five different farms were used to determine the efficacy and cost of rodenticide applications. The apple slice index of Byers (1977) was used to assess pre- and post-treatment effects of rodenticides. The pre-treatment index was completed within 24 hours of the initial baiting. Every third tree on each block was used as a sampling unit. The post-treatment was conducted 10 to 14 days after baiting. A second treatment of bait was then applied if the grower felt it justified and another post-treatment index was completed 7 to 10 days later.

Four separate orchard blocks were chosen for the index comparison study. The plots varied in vegetation structure and vole population composition and ranged in size from 2 to 8 acres. Four census methods were compared: sign of vole activity, apple slice index, live trap estimation, and snap trap removal. Each of the census methods was conducted on each block using every third tree as sampling points on 3 blocks and every tree on the fourth block.

On day 1, for each block, fresh sign of vole activity was noted wherever present. Fresh sign included tunnels or runways and any associated fresh digging or dirt piles, grass clippings, and freshly chewed apple drops. Percent activity was calculated as the number of trees with fresh vole sign divided by the total number of trees that were checked in the orchard block and multiplying by 100.

At the completion of the vole activity index, an apple slice index was conducted. Apple slices were placed in a runway or tunnel or, if neither was present, in an area of cover so that any passing animals might find it. The location was then marked with a stake and flag. Percent activity was calculated as the number of trees at which apple slices were chewed or missing, divided by the total number of trees checked and multiplying by 100.

Live traps were then placed at tunnels or runways at every third tree and baited with apple slices. Three trap checks were conducted over 2 days. Traps were checked every 2 1/2 to 3 hours between 0700 and 1600. Species, location, runway use, and age were recorded and all animals marked by toe clip, then released. On the day after the live trap index was completed, snap traps were set at the same locations as the live traps. They were checked once, 24 hours after placement.

The average time spent at each tree plus time spent moving between trees was recorded for each census method and used to calculate the manpower cost of each index.

Results

Fall 1981

The results of rodenticide application of the 14 general trials were inconsistent (Table 1; all tables included at back of text). Almost all applications were in early November, a period in which few rodenticides were effective in the intensive trials. Inconsistent results could also have been due to poor bait distribution by machine or field laborers and/or variation in the precision of the apple index method in detecting population fluctuations. The unequal use of rodenticides was due, in part, to grower preference for certain products.

The blocks that were handbaited were not indexed prior to rodenticide application. Active trees were determined by inspections conducted by field laborers. Variability in the ability of the laborers to recognize active vole tunnel systems from inactive systems likely contributed to the greater apparent reductions in activity on these blocks.

The costs for each method of application were generated from data returned by each grower (Table 2). Hand-placement was the most expensive method, while manual broadcast cost the least. Costs for rodenticides were omitted for easy comparison of application methods.

The results of the comparative rodenticide trials showed substantial variability in the effectiveness of each rodenticide. All rodenticides were broadcast manually except on plot 1. The initial application made with a machine spreader was discontinued when several rodenticides were being pulverized and were not distributed uniformly by the spreader.

Vole numbers were generally adequate on each plot to warrant the comparisons that were generated. In many instances meadow vole numbers were low and therefore population changes were variable and somewhat less meaningful than changes in pine vole numbers.

The results for pine voles from the 5 trials were summarized (Table 3) and evaluated by analysis of variance (Table 4). The ANOVA indicated significant differences ($p < .05$) existed between the treatment means. The Newman, Keuls test was used to make comparisons between treatment means. Each of the rodenticide treatment means was significantly different ($p < .05$) than the mean for the controls. In addition, Rozol, the largest treatment mean, was significantly different ($p < .05$) than the mean for Ramik. The differences between the Rozol and the Volid and ZPAG treatment means were not statistically significant ($p < .10$) but were noteworthy.

For all the above data analysis, plots 4 and 5 were evaluated despite the fact that post-treatment data were taken nearly 4 months after treatment. Since all treatments were applied on neighboring rows within relatively small plots, differential mortality was not likely within each plot. The population differences that existed after rodenticide treatments should be proportional to the population levels observed after winter. Thus, for comparative purposes, plots 4 and 5 were used in the analysis.

The vegetation data generated on each plot for each treatment established the heterogeneity that existed within the blocks. Regression analysis between the estimated proportion of pine vole population reduction and the vegetation variables indicated no significant relationships existed. Partial regression analysis of the change in vegetation moisture content against the estimated proportion of pine vole population reduction from plots 1, 2, and 3 indicated highly significant relationships existed (Table 5). This trend, although plots 4 and 5 could not be used in the analysis, demonstrated that as vegetation dieback occurred, rodenticide effectiveness increased.

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The results of the rodenticide applications on the 16 grower-treated blocks were generally inconsistent in both cost and effectiveness (Tables 6 & 7). The variability in the results could be due in large part to poor bait distribution by machine or field laborers. Only 4 out of 16 of the bait applications were made at the recommended application rates (Table 8). However, a decrease in activity was obtained in every case.

An analysis of variance showed no significant differences in effectiveness among the rodenticides on the grower-treated blocks (Table 9, $p > .25$). However, when the various baits were pooled and analyzed for differences in effectiveness on blocks with high ($>50\%$ activity), moderate (25-50% activity), and low ($<25\%$ activity) populations, a statistically significant result was obtained (Table 10, $p < .01$). The Newman-Keuls test was used to make comparisons between treatment means. While the treatment means for moderate and high populations were not significantly different, each was found to be significantly different from the low population treatment mean ($p < .05$). The baits appeared to be equally effective on high and moderate populations but were less effective on low ones.

Single and multiple bait applications were analyzed by means of a t-test, with all rodenticides combined. When the percent reduction for the single and multiple baited blocks were compared, no significant differences were found ($p > .20$). The percent activity remaining on the blocks after one and two baitings were also compared and the results showed that significantly less activity remained on the blocks receiving two bait applications (Table 11, $p < .05$).

If differences in rodenticide effectiveness do not exist, then choice of baits could be based on cost effectiveness. However, an evaluation by means of analysis of variance showed no difference among the rodenticides in cost effectiveness as well (Table 12, $p > .25$). No statistical differences existed among the baits on the basis of cost per percent reduction, cost per acre, or cost per tree (Table 5).

Differences were found when initial population size (high, medium, and low) was analyzed by means of ANOVA for differences in cost per percent reduction (Table 13, $p < .05$). The Newman-Keuls test showed high and moderate populations to cost about the same per percent reduction, but the cost to reduce vole numbers significantly increases with lower populations ($p < .05$). However, when the 3 population classes were similarly analyzed for cost differences on a per tree and per acre basis, none were found (Table 13, $p > .25$).

The results of the comparative rodenticide trials showed substantial variability in the effectiveness of each bait (Table 14). The pretreatment apple slice index indicated moderate to high populations on both test sites. Replications 1 and 2 were run consecutively on the same orchard block. Although meadow voles were present in replication 3, as indicated by preliminary trapping data, their numbers were insignificant.

The results of the three trials were evaluated by analysis of variance. The ANOVA indicated that no significant differences existed among the treatment means ($p > .10$). A new formulation of Ramik-Brown (200 ppm diaphacinone) was not included in the analysis due to a lack of replication, but its performance is noteworthy.

On the 4 index comparison plots both live and snap trap results were poor, therefore a population estimate could not be established. All 4 trials were completed in mid-October at the peak of the apple harvest. It was felt the combined effects of constant equipment and human activity, periods of inclement weather, and the availability of apple drops disrupted trapping success. The apple slice and vole sign indexes did not appear to be as severely affected.

Labor costs were calculated on a per tree basis for both the apple slice and vole sign indexes. The vole sign index was the cheapest (5 to 8 cents per tree) and quickest (1/2 to 3/4 minute per tree) method, requiring only a single pass through an orchard. The apple slice index required two passes, one to put out the apples and another to check them This raised the total cost ($\approx$ 20 cents per tree) and total time ($\approx$ 2 minutes per tree) spent in monitoring an orchard. It should be noted that extra costs would be incurred if a shingle or flag were used to mark the apple slice.

A major drawback of the vole sign index was the fact that it was useful for only a single check, not a pre- and post-poisoning index, the reason being that vacant runways still looked fresh over the entire trial period. For this reason, activity could easily be overestimated. The apple slice index, however, is amenable to a pre- and post-baiting check and does not require any added expertise in recognizing vole sign.

Table 15 is a summary of costs incurred if an overall baiting and monitoring program is carried out. The costs reflect the average cost per acre of all rodenticides combined for orchard blocks having initial populations at high, moderate, and low levels. Four hypothetical cases are proposed in which populations can be reduced from one level to another. Costs for two bait applications and two monitoring periods were calculated. Costs for a baiting program using a monitoring system are nearly double that of a program without it. However, the increased bait effectiveness could well be worth the effort.

Conclusions

1) Growers need to be strongly encouraged to index vole populations. Indexing was shown to be inexpensive and, if done properly, would likely result in more second and, if necessary, third applications.

2) Growers either need tables or reference information to accurately convert the recommended application rate into the proper amount of rodenticide on the ground. Many problems continue to exist in this area.

3) This study and the work from 1981 indicate the rate and degree of vegetation dieback has a stong influence on the effectiveness of rodenticides. Effectiveness in all baits was poor until late November in 1981. In the present study unseasonably mild weather continued into mid-December and thus was felt to contribute to poor rodenticide acceptance.

4) Grower costs in applying rodenticides occurred within a wide range. Surprising but significant variation exists in actual application rates, in the quality of rodenticide applications, and in grower efforts to evaluate infestation levels. These factors indicate a greater need to work with growers to increase their awareness of the need for indexing vole population levels and making quality rodenticide applications at label rates. In addition, rodenticide effectiveness must improve if growers are to attain the confidence that their manpower and money to control voles are well spent.

5) Although data do not exist on acceptable vole population levels per acre, the levels observed after a single rodenticide treatment were considered high. Multiple applications will be necessary until rodenticide acceptance and vole population reductions from single applications are improved. Although hand-placed rodenticide applications were somewhat effective in early November, these applications were made in blocks where vole-infested trees were not numerous and thus the greater cost of this application technique per acre could be justified. The cost of hand-placement techniques precludes its use when large acreages are to be treated.

   Based on cost data, growers managing 100 acres or more should initially broadcast a rodenticide; then, after an inspection, reapply either by manual broadcast if a light infestation is found, or by hand-placement in holes if heavy infestations are apparent.

Literature Cited

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Table 1. Rodenticide treatment and control data for 14 trials in which fruit growers made all applications.

Plot No.	Treat-ment	Appli-cation Method*	Appli-cation Date	Pre-treat-ment Activity (%)	Post-treat-ment Activity (%)	Reduction in Activity (%)
1	Rozol	HPH	Nov. 10	108**	69	-31
2	ZPAG	HPH	Nov. 3	154**	48	-52
3	Ramik	HPS	Nov. 5	27**	44	-56
4	Volid	HPS	Nov. 4	83**	11	-89
5	Volid	MB	Nov. 11	70	76	+ 6
6	Rozol	GS	Nov. 8	17	13	- 4
7	Ramik	McB	Nov. 13	55	30	-25
8	Rozol	GS	Nov. 4	22	31	+ 9
9	ZPAG	McB	Nov. 11	14	14	0
10	Volid	MB	Nov. 7	60	60	0
11	ZPAG	MB	Nov. 7	52	52	0
12	ZPAG	MB	Nov. 9	20	42	+22
13	Volid	MB	Nov. 13	48	51	+ 3
14	Rozol	GS	Nov. 4	27	12	-15

* HPH - Hand placement in hole
HPS - Hand placement under station
MB - Manual broadcast
GS - Ground spray
McB - Machine broadcast

** Total number of active trees by inspection. Post-treatment activity was checked only at these trees.

Table 2. Economic analysis of rodenticide application methods used in 14 field trials in Ulster County, NY. All cost rates are from Gerling (1981).

Application Method	Sample Size	Actual Application Rate/Acre	Labor Cost/ Acre[a]	Equipment Cost/ Acre	Other Cost/Acre	Total Cost/Acre
Hand placement under station	2	1.5-6 lbs	$19-24	-	$1.50[b]	$20.50-25.50
Hand placement in holes	2	1.5-3 lbs	$15	-	-	$15.00
Manual broadcast	5	9-12 lbs	$ 1.20	-	-	$ 1.20
Machine broadcast	2	10 lbs	$ 1.80	$2.13[c]	-	$ 3.93
Ground spray	3	100 gals	$ 3.00	$9.78[d]	-	$12.78

[a]Labor is included at the rate of $6.00 per hour. This should include the employer's share of social security, workmen's compensation insurance, and the cash cost of any benefits.

[b]Stations are tar-paper shields used at each tree and pro-rated over a 10-year period.

[c]The equipment costs were based on operating costs for a 40 hp diesel tractor and a 3-pt spreader.

[d]The equipment costs were based on operating costs for a 60 hp diesel tractor and an airblast sprayer.

Table 3. Summary of pine vole population changes as a result of rodenticide treatments applied in Nov.-Dec., 1981. Numbers are the percent changes in treated pine vole populations.

Rodenticide	Plot No. 1	2	3	4	5	Mean
ZPAG	0	-21	-72	-16	-100	-41.8
Rozol	-27	-76	-72	-69	- 87	-66.2
Ramik	+57	-47	-56	0	- 69	-23.0
Volid	0	-42	-75	-53	0	-34.0
Control	+200	+44	0	-25	+ 20	+47.8

Table 4. ANOVA for pine vole population changes for all plots treated with rodenticides in Nov.-Dec., 1981.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Statistical Significance
Between treatments	4	36,761.8	9190.4		
Within treatments	20	55,916.4	2795.8	3.29	$p<.05$
Total	24	92,678.2			

Table 5. Regression statistics of the percent pine vole population reduction of 4 rodenticides on vegetation moisture content during the first 3 trials conducted in Ulster County, NY.

Rodenticide	Slope	Intercept	R^2	P
ZPAG	-3.86	215.04	.94	.01*
Rozol	-5.62	326.60	.94	.01*
Ramik	.75	.19	.01	$<.5$
Volid	-4.53	252.85	.93	.01*

Table 6. Rodenticide effectiveness on grower-treated blocks, Fall 1982.

Rodenticide	Pre-Treatment Activity (%)	Post-Treatment Activity (%) 1	Post-Treatment Activity (%) 2	Reduction in Activity (%) 1	Reduction in Activity (%) 2	Reduction in Activity (%) Total
Rozol	84	60		-24		-24
Rozol	48	14		-34		-34
Rozol	27	21		- 6		- 6
Rozol	56	37	20	-19	-17	-36
Maki	42	16		-26		-26
Maki	34	20	7	-14	-13	-27
Laqberry	74	30		-44		-44
Laqberry	34	13	8	-21	- 5	-26
Volid	76	29		-47		-47
Volid	55	35	3	-20	-32	-52
Volid	48	15		-33		-33
Volid	59	38	13	-21	-25	-46
Ramik	25	20		- 5		- 5
Ramik	39	13		-26		-26
Ramik	20	17	15	- 3	- 2	- 5
Ramik	44	16	2	-28	-14	-42

Table 7. Rodenticide application costs. All cost rates are from Gerling (1981).

Rodenticide	% Reduction	Cost* Per Tree	Acre
Rozol	$ 5.36	$ .19	$12.87
Rozol	3.62	.30	24.60
Rozol	20.12	.11	8.05
Rozol	2.88	.24	25.91
Maki	5.12	.24	22.17
Maki	5.57	.75	21.50
Laqberry	2.96	.49	32.56
Laqberry	9.62	.74	31.26
Volid	3.69	.76	86.66
Volid	4.74	.85	35.18
Volid	8.80	.27	19.35
Volid	3.29	.44	37.88
Ramik	24.60	1.07	30.75
Ramik	1.36	.12	17.75
Ramik	68.50	.53	34.25
Ramik	2.98	.36	27.79

* The equipment costs, where applicable, were based on operating costs for a 60-hp diesel tractor and 3-pt spreader. All labor costs were included at the rate of $6.00 per hour. This should include the employer's share of social security, workmen's compensation insurance, and the cash cost of any benefits.

Table 8. Rodenticide applications on grower-treated blocks, Fall 1982.

Rodenticide	Acres	Application Rate (Lbs/Acre)	Method of Application*	Dates of Application 1	2
Rozol	10	10	McB	11/1	
Rozol	5	20	MB	11/7	
Rozol	15	5	MB	11/8	
Rozol	4	7	MB	11/9	11/19
Maki	6	13	MB	11/7	
Maki	7	5	MB	11/15	12/7
Laqberry	4	20	McB	11/1	
Laqberry	8	4	MB	11/15	12/2
Volid	2	45	McB	11/1	
Volid	7	3	MB	11/15	12/2
Volid	15	9	MB	11/15	
Volid	4	8	MB	11/9	11/19
Ramik	2	5	MB	11/16	
Ramik	4	22	MB	11/7	
Ramik	10	7	MB	11/8	11/27
Ramik	4	8	MB	11/9	11/19

*McB - machine broadcast
MB - hand broadcast

Table 9. Comparison of bait effectiveness for 5 rodenticides as determined by the average percent reduction in activity.

Rodenticide	Sample Size	Percent Activity Reduction Range	Mean	F Value	Probability
Rozol	5	6-34	20.00	1.18	n.s. (p>.25)
Maki	3	13-26	17.67		
Laqberry	3	5-44	23.33		
Volid	6	20-47	29.67		
Ramik	6	2-28	13.00		

Table 10. Vole population changes comparing combined rodenticide effectiveness on low (<25% activity), moderate (25-50% activity,) and high (>50% activity) populations.

Starting Population Level	Sample Size	Reduction of Activity (%) Range	Mean	F Value	Probability
Low	6	2-14	7.00	10.93	p<.01
Moderate	11	6-34	23.82		
High	6	19-47	29.17		

Table 11. Results of a comparison of one and two bait applications considering the percent activity remaining on the block after the baits are applied. All baits are combined.

Number Bait Applications	Sample Size	Remaining Activity (%) Range	Mean	T-stat.	Probability
1	9	13-60	24.22	2.79	p<.05
2	7	2-20	9.71		

Table 12. Cost data generated from five rodenticide baits and the results of the ANOVA's on cost per acre, cost per tree, and cost per percent reduction.

Rodenticide	Average % reduction	cost tree	per acre	pound
Rozol	$8.00	$ .21	$17.86	$1.05
Maki	5.34	.50	21.84	1.55
Laqberry	6.29	.62	31.91	1.43
Volid	5.11	.58	44.77	1.75
Ramik	24.36	.52	27.64	1.15
F-value	.67	.94	1.17	
Probability	n.s. (p>.25)	n.s. (p>.25)	n.s. (p>.25)	

Table 13. Comparison of three population classes (high, >50% activity; moderate, 25-50% activity; low, <25% activity) on the basis of cost per tree, cost per acre, and cost per percent reduction. All cost estimates derived from Gerling (1981).

Initial Population Level	Sample Size	Average cost per tree	acre	% reduction
Low	6	$ .42	$17.85	$34.60
Moderate	11	.26	16.89	5.77
High	6	.35	17.78	3.91
F-value		.37	1.37	5.82
Probability		n.s.(p>.25)	n.s.(p>.25)	sig.(p<.05)

Table 14. Rodenticide effectiveness on comparative test plots for the Fall 1982 study.

Rodenticide	Percent Change in Activity Plot No. 1	2	3	Mean
Rozol	-8	-12	+5	-5
Laqberry	-16	-4	-10	-10
Maki	-4	0	-10	-4.7
Volid	-2	-14	-17	-11
Ramik (50) 10 lbs/a	-4	+2	+8	+2
Ramik (50) 20 lbs/a	-5	-3	+15	+2.3
Ramik (200) 10 lbs/a	-	-	-30	-
Ramik (200) 20 lbs/a	-	-	-26	-

F-value: 1.61 (p>.10)

Table 15. Application costs per acre with and without a monitoring program. Population levels high (>50% activity), moderate (25-50% activity), or low (<25% activity).

Initial Index	Population Level	No. Applications	Second Index	Population Level	Total Cost w/Index	w/o Index
VSI	High	2	ASI	Moderate	$60	$35
VSI	High	2	ASI	Low	60	36
VSI	Moderate	2	ASI	Low	60	35
VSI	Low	2	ASI	Low	61	36