SMALL PROGRAMMABLE CALCULATORS FOR COMPUTING STATISTICAL TESTS

Charles W. Averre[1]

Volume 2 of Insecticide and Acaricide Tests contains]96 reports on field evaluation of chemicals for controlling insects and mites. All these field experiments were important and involved a great deal of effort and expense. However, 36% of the reports have no statistical confidence limits or results and interpretation of statistical tests. Statistical treatment of research data is extremely useful, if not necessary, in interpreting results and drawing valid conclusions from field experiments. The reasons for replicating field experiments in a proper design are twofold: (1) to have greater confidence in the results obtained and (2) to measure the inherent variability in the experiment and, by application of appropriate statistical tests, to determine differences among treatments that are due to treatment effects and not to natural variability. These and other considerations on the design of field experiments, selection of proper statistical tests, and interpretation of results are discussed in an article by Dr. Larry A. Nelson in Volume I, Insecticide and Acaricide Tests. Probably the principal reasons for the lack of statistical analysis in many reports is the time consuming and complex nature of the computations required and the problems associated with arithmetic errors. These problems have been somewhat alleviated in recent years by increasing availability of computing centers and consulting statisticians at most universities and in private industry. These services are indispensable for processing data from large, complex tests. However, computing services are not without drawbacks, especially for the less complex smaller field experiments. These drawbacks include data which must be submitted in special format, charges for the service, instructions which may be misunderstood, and "turn around time" which often exceeds a week or even a month. For some entomologists, computing services may be virtually unavailable.

A large proportion of the field experiments reported in Insecticide and Acaricide Tests are simple and involve only a dozen or so treatments with three to six replications (usually four) in a randomized complete blocks design. Results are reported as insects observed and crop response. For this type of field experiment the "least significant difference" (L.S.D.) and Duncan's New Multiple Range tests are, within certain limitations, well suited and widely accepted as aids in evaluating results and making conclusions. A general treatise on these statistical tests and general field plot techniques is LeClerg, E. L., W. H. Leonard, and A. G. Clark. 1966. Field Plot Technique. Second Edition. Burgess Publishing Company. 426 South Sixth Street, Minneapolis, Minnesota 55415. 373 pages.

In the last few years small, portable, electronic calculators with very sophisticated capabilities have become readily available at very reasonable prices. We have found the TI SR-52 (Texas Instrument, Inc., Dallas, Texas) very useful for analyzing our field plot data. It is a hand held calculator that has the capacity to program 223 steps which can be stored on magnetic cards for future use. It lists for $295.95 but is available from many sources for under $230. A printing attachment that can also be programmed for selective printing is available for about the same price. Many preprogrammed cards in specialized areas are available for about $30.00 from the manufacturer. The statistics library contains many useful tests such as various regressions, "t" test, and chi-square; the L.S.D. and Duncan's New Multiple Range tests are not available as of this writing. However, we have developed a program for these tests for a randomized complete blocks designed experiment involving up to eight replications which will display treatment means, grand total, degrees of freedom of error, F (treatments), F (replicates), L.S.D., coefficient of variation (%), and error mean square; the standard error of mean is programmed to be multiplied by the Studentized Ranges to display Rp values for Duncan's New Multiple Range test. Intermediate statistics, such as sum of treatments per replication, c.f., Σx^2, etc., can also be displayed from memory registers by a three key sequence. The complete program involves two cards that are used sequentially. The first card converts the experimental data to required units, such as kilograms per hectare if desired; it also calculates treatment means, calculates sums of squares, and can be modified by the user to perform the following transformations: linear, square root, logarithmic, and arcsine. The second card calculates degrees of freedom of error and displays the values of significance, etc. The practical limiting factor still remains the problem of entering the numbers accurately. Other statistical tests not available from the manufacturer can be programmed in a like manner. The speed in which an analysis of variance to give L.S.D. values is worth noting. For example, a randomized complete blocks designed test with ten treatments, five replications, and data composed of two and three digit numbers can be done in six to ten minutes. In addition, the calculator is useful in performing routine, time consuming laboratory and field calcutions. Because this system is relatively inexpensive and is readily available from local sources, many plant pathologists reporting field tests may find it useful. The "Users Directions" and the programming sequence are given below as a guide to developing your own applications.

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[1]Department of Plant Pathology, North Carolina State University, Raleigh, North Carolina 27607.

USERS DIRECTIONS

for

the TI SR-52 calculator program for two-way analysis of variance of a randomized
complete blocks design test: treatment means, F (treatments), F (replicates),
L.S.D., C.V. (%), $S_{\bar{x}}$, and error mean square.

1) Insert CARD I both ways to program calculator. (See owner's manual).

2) Enter conversion factor. If none is needed enter 1. PRESS: E'.

3) Enter data by treatment. PRESS: A.
      (If an error entry was made prior to pressing A, PRESS CE and enter the proper number.
      If A has been pressed, reenter the error, PRESS A' and E, and then enter the proper number).

4) Obtain treatment means. PRESS: B.

5) Continue steps 3 and 4 until all treatment means have been obtained.

6) Check grand total. PRESS: C.

7) PRESS D. (This starts the computation for degrees of freedom of error that will be displayed later.)

8) Insert CARD II both ways. (See owner's manual, do not press CLR).

9) Display degrees of freedom of error. PRESS: 2nd rset RUN.

10) Enter "t" value obtained from statistical table. PRESS: A'.

11) Display F value for treatments. PRESS: B.
      (The F value must be as large or larger than the number found in the statistical table under d.f.
      error on the left and d.f. of treatment on the top of the table. If the calculated F (treatments)
      is smaller than the number in the table, report "N.S.").

12) Display F value for replicates. PRESS: C.

13) Display L.S.D. PRESS: D.

14) Display C.V. PRESS: E.

15) Display error mean square. PRESS: E'.

16) To compute and display Duncan's Multiple Range groupings (Rp), enter appropriate "significant studentized
    ranges" from statistical table. PRESS: A.

17) Intermediate statistics in the calculations are stored in memory registers 00 through 19 and may be
    displayed by PRESSING: RCL _ _. The contents of the memory registers are given following the program
    listings.

18) TRANSFORMATIONS. On CARD I locations 014 through 021 have been reserved for entering appropriate keys
     into the program for different transformations. These locations on the program are occupied with the
     dummy entry RUN (code 91). (Note: Entry corrections involving A' will not work). In order to enter a
     transformation proceed as follows:

A) Program the calculator in the usual manner with CARD I.

B) PRESS: GTO 0 1 3 LRN. (The following should be displayed: 013 91).

C) Select the desired transformation (see below) and key in the stated sequence; do not exceed eight
    entries but do not count the LRN or 2nd keys.

D) Once the calculator has been programmed for a transformation, the user may want to record the modified
    program on another CARD for later use. (See owner's manual for recording a magnetic card).

   I) Linear transformation or coding --

            ADDITION: + desired number = LRN

            SUBTRACTION: - desired number = LRN

            MULTIPLICATION: X desired number = LRN (Multiplication factors are normally entered
                    by using E'; see step 1 in Users Directions)

            DIVISION: ÷ desired number = LRN

   II) Square root transformation -- (This is used to transform data that follows the skewed Poisson
        distribution in which the mean and variance are equal or proportional and effects are non-additive.
        Data are whole numbers such as counts of weeds in a plot, insects caught in traps, number of
        wireworms per unit area, and number of bacterial colonies per petri dish. Various transformations
        have been used:

            $\sqrt{x}$: 2nd $\sqrt{}$ LRN (Used when numbers vary from 10 to 100)

            $\sqrt{x + .5}$: + . 5 = 2nd $\sqrt{}$ LRN (Used when numbers include many values under 10 and 0)

   III) Logarithmic transformation -- (This transformation is applicable to data based on counts similar
         to those applicable to square root transformations. It is also appropraite for percentages and
         measurements. It is generally useful where the means are widely divergent.)

            log x: 2nd log LRN

            log x + 1: + 1 = 2nd log LRN (Used when some numbers are under 10)

   IV) Arcsine transformation or angular -- (The angular transformation is appropriate for data based on
        percentages, fractions, or proportions because they tend to have a binomial distribution. It is
        especially applicable if the data is based on less than 100 observations and percentage values
        are less than 15 or above 85. However, continuous data based on an arbitrary constant (such as
        yields as a percent of check) and data to show concentrations (such as damaged seed as a percent
        of sample weight) need not be transformed. The transformation is appropriate when the original
        data are discrete based on a determinate number of cases (such as percent diseased plants) in the
        population sampled.)

            $p = Sin^2 \theta$ or $sin^{-1} \sqrt{x \div 100}$: ÷ 1 0 0 = 2nd $\sqrt{}$ INV SIN LRN

PROGRAM SEQUENCE FOR TI SR-52 CALCULATOR FOR TWO-WAY ANALYSIS OF VARIANCE FOR L.S.D., DUNCAN'S

MULTIPLE RANGE TESTS, AND OTHER STATISTICS (Charles W. Averre, N. C. State Univ.)

CARD I

Loc	Keys	Comments	Loc	Keys	Comments	Loc	Keys	Comments
1	LBL E' STO 1 7	enter convers'n	85	LBL B RCL 1 1	Σ (sums)^2	172	0 7 x^2 SUM 0	
6	HLT		90	X^2 SUM 1 6 (		177	9 RCL 0 8 x^2	
7	LBL A X RCL 1	enter data X	95	RCL 1 1 ÷ RCL	x treatments	182	SUM 0 9	
12	7 = RUN RUN RUN	conversion	100	1 2) STO 1		185	RCL 1 3 STO 1	transfer 13 to 10
17	RUN RUN RUN RUN RUN	transformation	105	4 RCL 1 1 SUM	Σ x	190	0	
22	B' STO 1 4 SUM		110	1 5 1 SUM	count treatm's	191	RCL 1 9 ÷ RCL	number of repli's
27	1 1 x^2 B' SUM	Σ x per column	115	8 0 STO 1 1	clear regist's	196	1 8 = STO 1	
32	1 3 1 C' SUM	Σ x^2	120	STO 1 2 RCL 1	display x trt	201	9 RCL 1 5 HLT	
37	1 2 1 B' SUM	n per column	125	4 HLT		206	LBL E 1 INV SUM	press after error
42	1 9 RCL 1 4		127	LBL C RCL 0 1	Σ (totals)^2	211	1 2 HLT	correction
47	IND SUM 1 2 INV	Σ x by line	132	x^2 SUM 0 9 RCL		214	LBL D RCL 1 8	deg. of freedom
52	stf 1 HLT		137	0 2 x^2 SUM 0		219	X RCL 1 9 HLT	of error
55	LBL A' stf 1 GTO	correction for	142	9 RCL 0 3 x^2				
60	0 0 8 LBL B'	error entry	147	SUM 0 9 RCL 0				
65	iff 1 0 7 0		152	4 x^2 SUM 0 9				
70	rtn +/- rtn LBL C'		157	RCL 0 5 x^2 SUM				
75	iff 1 0 8 0		162	0 9 RCL 0 6				
80	rtn - 1 = rtn		167	x^2 SUM 0 9 RCL				

CONTENTS OF MEMORY REGISTERS

No.	Contents	No.	Contents
00	not used	10	Σ x^2
01	total line 1 (replicate 1)	11	Σ x by column (treatments)
02	otoal line 2 (replicate 2)	12	count by line
03	total line 3 (replicate 3)	13	Σ x^2
04	total line 4 (replicate 4)	14	x, and treatment mean
05	total line 5 (replicate 5)	15	Σ x
06	total line 6 (replicate 6)	16	Σ (sums)^2
07	total line 7 (replicate 7)	17	conversion factor
08	total line 8 (replicate 8)	18	number of treatments
09	Σ (totals)^2	19	number of replicates

CARD II

Loc	Keys	Comments	Loc	Keys	Comments	Loc	Keys	Comments
1	- RCL 1 8 -	degrees of	79	0 7 = STO 0		156	LBL A X (RCL	sm
6	RCL 1 9 + 1	freedom error	84	6 RCL 0 6 ÷	MS treatments	161	1 1 ÷ RCL 1	
11	= STO 1 2 HLT		89	(RCL 1 8 -		165	9) $\sqrt{}$ = HLT	
			94	1) = STO 1				
16	LBL A' STO 1 3	enter "t" value	99	4 RCL 0 5 ÷	MS replicates	170	LBL D (RCL 1	L.S.D.
21	HLT		104	(RCL 1 9 -		175	1 X 2 ÷ RCL	
22	LBL B RCL 1 5	c.f.	109	1) = STO 1		180	1 9) $\sqrt{}$ X	
27	x^2 ÷ (RCL 1		114	7 RCL 0 8 -	MS error	185	RCL 1 3 = HLT	
32	9 X RCL 1 8		119	RCL 0 5 - RCL				
37	) = STO 0 7		124	0 6 = ÷ RCL		190	LBL E RCL 1 1	C.V. (%)
42	RCL 1 0 - RCL	S.S. totals	129	1 2 = STO 1		195	$\sqrt{}$ X 1 0 0	
47	0 7 = STO 0		134	1		200	÷ (RCL 1 5	
52	8 RCL 0 9 ÷	S.S. replicates	135	RCL 1 4 ÷ RCL	F (treatments)	205	÷ (RCL 1 8	
57	RCL 1 8 = -		140	1 1 = HLT		210	X RCL 1 9)	
62	RCL 0 7 = STO					215	) = HLT	
67	0 5		144	LBL C RCL 1 7	F (replicates)	218	LBL E' RCL 1 1	display error
69	RCL 1 6 ÷ RCL	S.S. treatments	149	÷ RCL 1 1 =		223	HLT	mean square
74	1 9 = - RCL		154	HLT				

CONTENTS OF MEMORY REGISTERS

No.	Contents	No.	Contents
00	not used	10	*Σ x^2
01	*total line 1 (replicate 1)	11	error mean square
02	*total line 2 (replicate 2)	12	d. f. error
03	*total line 3 (replicate 3)	13	"t" value
04	*total line 4 (replicate 4)	14	mean square of treatments
05	Σ of squares replicates	15	*Σ x
06	Σ of squares treatments	16	*Σ (sums)^2
07	correction factor (c.f.)	17	mean square of replicates
08	Σ of squares totals	18	*number of treatments
09	*Σ (totals)^2	19	*number of replicates

*Obtained from execution of program on CARD I.