Time-Saving Techniques and Increased Accuracy Using the Punched Card System in Experimental Work

G. J. HoGABOAM"

Introduction

A bibliography of the important papers concerning the use of the punched card system in science, statistics and education was published in 1950 (5) [3]. Most of these papers, however, were written before the punched card calculators were introduced. These machines greatly simplify such operations as multiplication and division. Armstrong (1) gives a good description of capabilities of present available punched card equipment as well as an estimate of their monthly rental rates.

It is the purpose of this paper to point out some additional advantages to be gained by using the punched card machine from start to finish of an experiment.

Discussion

As soon as the design of an experiment is decided upon the cards for the experiment can be punched and verified for accuracy. One card is punched for each plot. This card should contain all the identifying information that is to be entered in the field book concerning the plot as well as all sorting information needed for the analysis.

By punching the plot cards at this time, these cards may be used by the tabulating machine to print the field book and packet labels. Various sizes and types of paper are available on which to print the field book. The cards may be sorted to any desired field arrangement before printing the field book. After the field book is printed the pages may be separated, the edges trimmed, and bound into a semipermanent or permanent book. Whenever gummed paper labels can be employed for seed packet or treatment identification, these labels may be machine-printed to contain any of the following information: entry or treatment number, plot number, and identification of seed or treatment (may be expressed as numbers, letters or a combination of both) .

By handling the early phases of any sizable experiment in this manner the experimenter can expect to save approximately 80 percent of the time required to prepare the field book and packet labels. This method also practically eliminates any chance for transcribing errors since the printing of all information is machine-copied from a single set of cards. Furthermore, with a machine-printed field book, it is unnecessary to rearrange the data before presenting the book to the punched card operator for transcription and verification onto the respective punched cards.

Frey, Rossman and Taschner (2) point out the value of prepunching several experimental designs on master cards. With such a set of master

[1] Cooperative investigations of the Field Crops Branch, Agricultural Research Service, U. S. Department of Agriculture, and the Michigan Agricultural Experiment Station (Journal Article 1.615 of Michigan Station).

[2] Research Agronomist, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, East Lansing, Michigan.

[3] Numbers in parentheses refer to literature cited.

cards at hand, the cards may be cut for a new experiment and the field book and packet labels printed in a matter of a lew hours. Another advantage gained by the punched card system is the ability to get a quick summary ol data during the growing season, if needed.

To get an idea ol the saving of time and money *in* analyzing experiments by the punched card system, a study was made of a series of analyses. Seventeen experiments were analyzed by IBM machines. These were made up of nine 8x8 Latin squares, one 8x6 random block, five 12x8 random blocks and two 12x6 random blocks. Each of these experiments was analyzed for five separate classifications except for two experiments which were analyzed for only one classification. A total of 77 separate analyses were taken as far as SS Net for the total, all variables and remainder. It was found that the completed IBM analysis cost only one-third as much as the conventional method in both time and money. It should be pointed out, however, that these calculations were made on IBM machines rented and operated by Michigan State College and no charges are included for overhead expenses or profit. Ryser (6) reported greater accuracy and a large saving of time by the IBM method even when the analyses were taken only as far as all total sums needed in the analyses.

Perhaps the most difficult part of the punched card system is knowing how to set up the problem for the machine operators and explain it in such a way that they will understand what is needed. One of our prepunched 8x8 Latin square designs is shown below with a copy of the instructions given to the IBM operator for all operations including its analysis.

Instructions to Set up Experiment

Table 1.—The Design: Experiment Number I by Entry Number.

Col.	1	2	3	4	5	6	7	8
Row								
8	7	8	3	1	6	4	2	5
7	2	3	6	4	1	7	5	8
6	4	5	8	G	3	1	7	2
5	6	7	2	8	5	3	1	4
4	8	1	4	2	7	5	3	6
3	5	6	1	7	4	2	8	3
2	1	2	5	3	8	6	4	7
1	3	4	7	5	2	8	6	1

Punch the year "53" in all cards. Copy the plot numbers and entry numbers onto the cards from "The Design: By Field Book Arrangement." (Table 2) . Check the transcription on the verifier. On the sorter and card counter check to see that there are: eight cards for each row (IBM col. 5) , eight cards for each column (IBM col. 6) , and eight cards in each entry number (IBM col. 7) . Report any discrepancies. Arrange the cards in order of increasing plot numbers and print an original and the desired number of carbon copies of the field book. Leave a two-inch margin on top for binding and a two-inch margin on the left for seed lot identification. Print 32 plots on a page. Leave two spaces between the plot number and the entry number so these are readily distinguishable.

Table 2.—The Design: By Field Book Arrangement.

Seed Lot	Plot Number[1]			Entry Number
	(3-4)	(5)	(6)	(7)[2]
	1	1	1	3
	1	1	2	4
	1	1	3	7
	1	1	4	5
	1	1	5	2
	1	1	6	8
	1	1	7	6
	1	1	8	1
	1	2	1	1
	1	2	2	2
		etc.		
	1	8	7	2
	1	8	8	5

[1] The plot number is a combination of experiment number, row number, and column number in that order from left to right.

[2] Numbers separated by parentheses indicate column numbers on IBM card.

Table 3.—IBM Card Setup.

IBM Column	Item
1-2	Year
3-4	Experiment number } plot number
5	Row number }
6	Column number }
7	Entry number
10-14	Beets per acre
15-19	Tons per acre
20-23	Percent sucrose
24-27	Percent purity
28-32	Pounds sucrose per acre
33-35	Number beets per plot
36-38	Weight per plot
39-42	Factor for beets per acre
43-47	Factor for tons per acre

Note: IBM columns 8-9 left vacant intentionally so that data in subsequent columns will correspond to similar items in IBM card set up for 12x8 designs.

Instructions to Analyze Data

Transcribe the data from the field book onto the appropriate IBM cards according to previous instructions on IBM card set up (Table 3) . Check the transcriptions for accuracy on the verifier.

Instructions for converting plot data to a per acre basis:

I. Number of beets per acre (10-14) [4].

Multiply number of beets per plot (33-35) by the factor for number of beets per acre (39-42) . One factor for each experiment. Round answer to nearest whole number and punch in Col. (10-14) . Example: In experiment one located at the Ballinger Farm, plot number 111 contained 204 beets. The factor for number of beets per acre in this experiment is 97.24. 204 x 97.24 = 19,836.96, record as 19,837.

II. Tons of beets per acre (15-19) .

Weight per plot (36-38) x factor for tons of beets per acre (43-47) and round the answer to three places to the right of the decimal point. Example: In experiment one located at the Ballinger Farm, the weight of plot 111 was 176 lbs. and the factor is .04862. 176 x .04862 = 8.55712, record as 08.557.

III. Pounds of sucrose per acre (28-32) .

Multiply tons of beets per acre (15-19) by the percent sucrose (20-23) and multiply that answer by 2,000 in all cases. Round answer to the nearest pound. Record in Col. (28-32). Example: Experiment one, plot 111, Col. (15-19) = 08.557, col. (20-23) = 20.70 percent. 8.557 x .2070 x 2000 = 3542.5980000, record as 3543 in col. (28-32) .

ANALYSIS: Analyze each experiment for the following classifications: number of beets per acre (10-14) , tons of beets per acre (15-19) , percent sucrose (20-23) , percent purity (24-27) , and pounds of sucrose per acre (28-32) . For each analysis of each experiment:

[4] Numbers in parentheses in "Instructions to Analyze Data" indicate IBM columns.

1. Square each master card (plot card) and list the grand sunt, grand sum of squares and grand card count.

2. Make summary cards for the following sortings (controlled variable) :

Table 4.

Sortings		**IBM Column**	**Number of summary cards needed**
Row	nmary card.	**5 6**	**S**
Column		**7**	**8 8**
Entry Number			
Put totals on each sun			

Row	5	S
Column	6	8
Entry Number	7	8

Put totals on each summary card.

3. Square totals on each summary card and list for each sorting: the sum, the sum squared, and card count for each summary card; the grand sum, the grand sum of squares, and the grand card count.

4. Determine CT (Correction Term) for each analysis by squaring the grand sum for the experiment (obtained in instruction 1) and dividing by the grand card count (obtained in instruction 1) .

5. Divide the grand sum of squares (obtained in instruction 3) by the card count listed by individual summary cards. Determine this for each sorting, viz., by rows, by columns, and by entry number.

6. Subtract the CT (obtained in instruction 4) from (a) : each answer obtained in instruction 5, and (b) : from the grand sum of squares of individual plots (obtained in instruction 1) .

7. From the value obtained in 6 (b) subtract all the values obtained in 6 (a) (by rows, by columns, and by entry number) . This answer is the remainder.

8. List items in the order indicated below:

Grand sum of squares	Answer obtained in 6 (b)
Row	Answer obtained in 6 (a)
Columns	Answer obtained in 6 (a)
Entry number	Answer obtained in 6 (a)
Remainder	Answer obtained in 7
CT	Answer obtained in 4

9. Arrange the individual plot cards by entry number and list: plot number, entry number, pounds of sucrose per acre, tons per acre, percent sucrose, percent purity, and number of beets per acre. Give sub-totals by entry number and grand totals by experiment number.

Discussion

The accuracy of the calculations may be checked by comparing all grand totals for each analysis, by checking card counts for discrepancies, and by checking the reasonableness of the figures *in* the net sums of squares column (obtained in instruction 8) . The final listing by entry number should also be checked for reasonableness.

The analysis of a randomized block is very similar to the preceding example of a Latin square analysis. Homeyer, Clem and Federer (4) give detailed instructions for the analysis of most types of lattice designs by the punched card method. However, this article was written before the punched card calculators were in operation, hence their procedure can be somewhat simplified. Split plot designs are also well adapted to the punched card machine method of analysis. The author has conducted 20 analyses of a split-split-split plot design, containing 384 plots, on the IBM machines. This experiment (3) could not have been handled in such detail had the IBM machines not been available.

Summary

While appreciable savings of time *And* money have resulted from the punched card analysis of data, further savings may be realized through preparations of field books and gummed labels with the punched card machine. Also, fewer chances for human error occur by the extended use of the punched card machine method.

ACKNOWLEDGMENT

Acknowledgment is made to Norma Taschner, Tabulating Service, Michigan State College, for help in connection with the IBM equipment and its capabilities.

Literature Cited

(1) ARMSTRONG, LAWRENCE W.
1951. "The application of punch card equipment to statistical pro cessing," a lecture presented in the Department of Agriculture Auditorium, May 16, 1951, copies of which may be obtained from: Office of the Administrator, Agricultural Research Service, U. S. Department of Agriculture, Washington, D. C.

(2) FREY, K. J., ROSSMAN, E. C. and TASCHNER, N.
"The prepunching of IBM cards with plot code numbers," note for Agronomy Journal, to be published at a later date.

(3) HOGABOAM, G. J., BOCKSTAHLHR, H. W., FRENCH, GEORGE W., and GRIGSBY, BUFORD H.
1954. "Stand and yield of sugar beets and weed populations as affected by: (1) broadcast fertilization, *(2)* mechanical thinning techniques, (3) application of herbicides, (4) interactions of fertilization, thinning, and herbicides. Proc. Amer. Soc. Sugar Beet Tech. 8 (I): 95-105.

(4) HOMEYER. PAUL G., CLEM, MARY A., and FEOERER, WALTER T.
1947. "Punched card and calculating machine methods for analyzing lattice experiments including lattice squares and the cubic lattice," Research Bulletin 347, April, 1947, Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa.

(5) International Business Machines Corporation.
1950. "Bibliography *on* the use of the IBM machines in science, statistics, and education," January, 1950.

(6) RYSER, GEORGE K., and CRANDALL, BLISS H.
1952. "Adaptation of the IBM card system to analysis of sugar beet varietal data." Proc. Amer. Soc. Sugar Beet Tech. pp. 421-425.