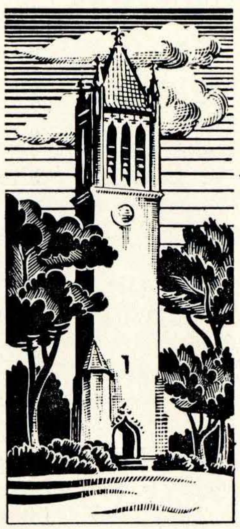
AN APPRAISAL OF FACTORS AFFECTING THE ACCEPTANCE AND USE OF FERTILIZER IN IOWA, 1953



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CONTENTS

SUMMARY

1. In 1953 Iowa State College and the Tennessee Valley Authority undertook a research project to determine (1) characteristics of Iowa farmers who use varying amounts of fertilizer and different fertilization practices, (2) informational sources important in the acceptance and use of fertilizer, (3) extent of use and handling of fertilizer on the farm and (4) quantitative relationships between fertilizer use and specified factors considered to influence fertilizer use. A scientifically selected statewide sample of 532 farms was the basis of this report.

2. The 69 percent of the farmers using commercial fertilizer are characterized, when compared with nonusers, as having (1) relatively larger amounts of capital invested in their farms, (2) larger farms, (3) more years of formal education, (4) relatively younger ages and (5) fewer years of farming experience. The fertilizer users also recognize that fertilizer has beneficial effects on crop growth and have used soil tests extensively as a basis for fertilizer use.

3. Farmers need to see and hear about increased crop yields and greater net returns from fertilizer use experienced on neighboring farms. Other farmers (neighbors) and mass media are the most important sources of information influencing farmers to accept fertilizer use. Iowa farmers go to state college representatives and to fertilizer dealers and salesmen to learn about a new fertilizer product. The stage of farmers' knowledge with respect to fertilizer use has brought about a reversal of some informational source preferences.

4. Appreciable differences in fertilizer use were indicated among areas and crops. A larger proportion of the farmers using fertilizer were in northern Iowa. Corn was fertilized more extensively than any other crop. Phosphate was used heavily on oats to secure the beneficial effect on meadow seeding planted with oats. Potash was applied in smaller amounts than the two other main plant foods.

5. Use of starter fertilizer on corn production was greatest in northeastern Iowa. However, over half of all farmers considered top-dressing on permanent pasture, as well as on supplemental pasture grasses and on land in oats as improved fertilizer use practices. The farmers recognized the need to change the crop rotation when fertilizer is used.

6. Three-fourths of the fertilizer users indicated a preference for the 80-pound bag. Fertilizer was stored on the farm for the 1953 crop season by 44 percent of the fertilizer users. Most of these farmers considered the quality of stored fertilizer to be satisfactory. On the average, farmers storing fertilizer possessed the greatest amount of capital. Thirty-seven percent of the fertilizer users reported some difficulty in spreading commercial fertilizer.

7. Owner- and tenant-operators had approximately the same fertilizer expenditures in 1953. However, tenant-operators estimated that they could profitably spend larger amounts of money for fertilizer than owner-operators. Lack of capital was the most important limitation to the use of fertilizer at the estimated optimum level. In addition, tenant-operators cited the role of the landlord in the production planning process as an important limitation to greater fertilizer use. Tenant-operators indicated a willingness to increase fertilizer expenditures if their landlords would share the costs in the same proportion that crops are shared. Approximately 50 percent of the tenants and 40 percent of the owner-operators indicated a willingness to increase fertilizer expenditures if more capital was available.

8. Nineteen percent of the owner-operators and 29

percent of the tenant-operators indicated they would use more fertilizer if they could borrow without added security. Tenant-operators indicated that they would borrow $204, on the average, if the repayment schedule was based on "timing of returns," as compared with $172 for owner-operators.

9. The amount of fertilizer used the previous year and size of farm were significantly related to the amounts of fertilizer used on owner- and tenant-operated farms.

10. The marginal or additional increase in fertilizer use for a given increase in anticipated corn-yield response is greatest when capital investment, farm size and use of fertilizer the previous year are greater. The marginal use of fertilizer is lower for higher anticipated corn-yield responses.

11. Capital investment and uncertainty of anticipated corn-yield response from 40 pounds of nitrogen applied per acre were significantly related to the rate of nitrogen application on owner-operated farms. Uncertainty of anticipated corn-yield response was negatively (significantly) related to the amount of nitrogen used per acre by tenant-operators. As the tenant controls more capital, his use of nitrogen on land in corn increases. A decrease in uncertainty about corn-yield response is positively related to an increase in nitrogen use. Nitrogen use also increases with increases in the farmer's anticipated yield response from a given input of nitrogen.

12. The greatest increase in the use of nitrogen by tenant-operators on land in corn is likely to be obtained by working with those farmers having high capital investment and a minimum amount of uncertainty with respect to anticipated corn yields on land receiving a given amount of nitrogen.

13. Equity ratio was significantly related to the difference between farmers' estimated most profitable and actual fertilizer expenditure for owner-operators. For tenant-operators, the difference decreased with an increase in their fertilizer use experience.

14. The proportion of an additional $1,000 an owner-operator would spend for fertilizer was related to the amount of fertilizer used the current year. On the other hand, the proportion of an additional $1,000 a tenant-operator would use for fertilizer was related to his capital investment.

15. Farmers' estimated yield response from various levels of nitrogen application for corn grown in the second year after meadow was significantly greater than their estimated yield response for corn grown in the first year after meadow. In general, tenant-operators estimated higher corn-yield responses from nitrogen applications than did owner-operators.

16. A demand curve for nitrogen use on corn—derived from the farmers' expected corn-yield response from nitrogen—lies to the right of a subjective demand curve for nitrogen use on corn derived by questioning farmers on nitrogen use at various nitrogen and corn prices. This suggests the degree farmers discount for risk and uncertainty.

An Appraisal of Factors Affecting the Acceptance and Use of Fertilizer in Iowa, 1953[1]

BY M. A. ANDERSON, L. E. CAIRNS, EARL O. HEADY AND E. L. BAUM[2]

Fertilizer use by Iowa farmers in recent years is an example of an important change in farm practice. The amount of fertilizer used in the state increased from 9,000 tons in 1938 to over 600,000 tons in 1953. This rapid adoption took place at a time when farm prices generally were on the upswing and when favorable fertilizer-crop price ratios existed.

Other phenomena also have favored a rapid upward trend in fertilizer use. Additional research on fertility and soil management has indicated the high response and profits to be realized from fertilizer at many locations. Agronomic research also has demonstrated that it is necessary to have a combination of improved crop varieties, heavier planting rates and fertilization, to obtain optimum corn yields. During the period 1938-53, the capital position of Iowa farmers improved greatly—encouraging a rapid adoption of a practice such as fertilization.

Fertilizer usage is expected to increase further, if relatively stable economic conditions and favorable product price–fertilizer cost ratios continue. The potential of increased fertilizer use exists in the sense that the value of crop response is considerably greater than the cost of the fertilizer on many Iowa farms. The practicability of increased fertilizer use depends particularly on the economic characteristics of farms not now using fertilizer; it depends on the attitudes of these operators toward fertilizer use and their understanding of the beneficial effects of fertilizer. Expanded fertilizer use also depends on greater knowledge of the factors associated with fertilizer use by those who are now using fertilizer but not at the most profitable level.

OBJECTIVES

In 1953 Iowa State College and the Tennessee Valley Authority undertook a research project dealing with fertilizer use in Iowa. The objectives of this study included: (1) determining the characteristics of farms and farmers who use varying amounts of fertilizer; (2) determining the informational sources important in the acceptance and use of fertilizer; (3) determining the nature of fertilization practices used and the nature of farms using them; (4) determining the quantity and pattern of fertilizer use in Iowa; and (5) predicting the functional relationship between selected variables and fertilizer use.

It was expected that data relating to these objectives would yield knowledge on economic characteristics which relate to fertilizer use. This knowledge may provide a basis for improved education, sales and production activities relating to fertilizer and its efficient integration into farming. Also, increased knowledge of factors related to a specific practice, such as fertilization, should provide some guide for educational efforts relating to other farm practices.

SAMPLE

Iowa was considered the universe for this investigation. The state was divided into nine general soil areas[3] (fig. 1), and a random proportional sample of farms was selected.[4] The sample contained a total of 532 farms.[5]

[1]Project 1248, Iowa Agricultural Experiment Station. This study was conducted under a contractual agreement between the Tennessee Valley Authority and Iowa State College. The authors express their appreciation to the members of the Agronomy, Economics and Sociology, and Statistics departments of Iowa State College for their helpful suggestions in the preparation of the questionnaire and the review of this manuscript. Appreciation is extended to Leland G. Allbaugh and John Blackmore of TVA for their helpful suggestions and critical review of this manuscript.

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[3]These nine general soil areas are described in: Guide to fertilizer use. Iowa Agr. Ext. Ser. Pam. 193. 1953.

[4]A detailed presentation of the sampling plan and methods of estimation and reliability used in this study are presented in Appendix A. Random sampling is a method of selecting a given number of farms from a population so that every farm within the population has an equal chance of being selected. The use of this statistical technique enables the researcher to draw inferences concerning fertilizer use and acceptance by all Iowa farmers from a relatively small sample.

[5]

Soil area	No. of farms in sample	Dominant soils
1	121	Webster, Nicollet, Harpster, Clarion and and Storden
2	87	Carrington, Floyd, Clyde and "plastic phase" of Carrington and Floyd
3	37	Fayette, Downs and Tama
4	88	Tama, Muscatine, Clinton, Lindley, Taintor, Mahaska and Otley
4a	30	Winterset, Sharpsburg and Shelby
5	44	Edina, Seymour, Grundy, Haig, Weller, Marion, Lindley and Shelby
6	46	Marshall
7	37	Monona, Ida and Missouri Bottomland
8	42	Marcus, Primghar, Galva and Sac
State	532	

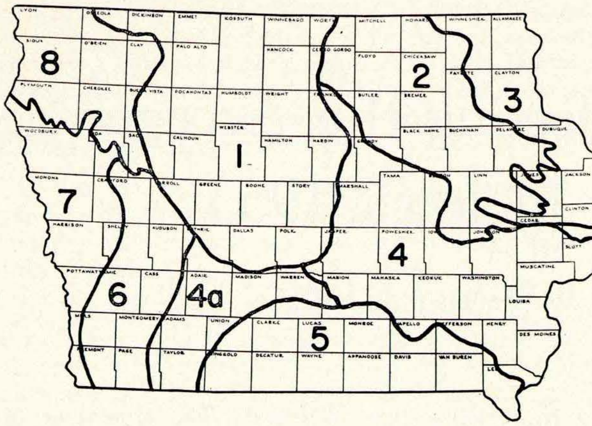

Fig. 1. Iowa soil areas in relation to fertilizer needs.

Members of the college departments of Agronomy, Economics and Sociology, and Statistics collaborated with personnel in the Agricultural Economics Branch, Tennessee Valley Authority, in preparing the questionnaire.[6] The questionnaire was designed to obtain information on farm size, ownership and tenancy arrangements, fertilizer use and handling of fertilizer on the farm, cropping practices, livestock systems, age and level of formal education of operators and other status factors. Information also was obtained on the following items: farmers' anticipations and uncertainty of anticipations of future prices for corn; farmers' ideas on use of additional capital and willingness to use more capital for fertilizer under different conditions; and sources of information important in the acceptance and use of fertilizers in Iowa.

GENERAL CHARACTERISTICS OF FERTILIZER USERS AND NONUSERS

Although fertilizer use has increased greatly in the last decade, it is still much below the level considered optimum by soil scientists, economists and successful farmers. This relatively low level of fertilizer use, or lack of use on many farms, may be related to many factors including: capital rationing, level of formal education, form of available information on fertilizers, tenure arrangements, lack of knowledge of fertilizer response and profit possibilities, beliefs concerning the value of fertilizer use, farming experience and experience with fertilizers.

To better understand these restrictions on fertilizer use, some general characteristics of farmers who do not use fertilizer were studied to determine similarities and dissimilarities between these two groups. A summary of the data is presented in this section. Users and nonusers of fertilizer are compared with respect to size of farm, tenure, age of operator, level of formal education, beliefs concerning the effects of fertilizer, and use of soil tests.

Approximately 69 percent of the farmers in Iowa were fertilizer users in 1952-53 (table 1). A fertilizer

[6]This questionnaire received U. S. Budget Bureau Approval, No. 74-5304, June 1953, prior to field enumeration.

Table 1. GENERAL CHARACTERISTICS OF FERTILIZER USERS AND NONUSERS IN IOWA, 1953.

Characteristics	Users†	Non-users	All farmers
Number in sample	365	167	532
Average size farm (acres)	204	165	192
Percent owners or part owners	56	56	56
Percent renters	44	44	44
Average owned capital (dollars)‡	31,751	19,807	28,002
Average age of operator	43	49	45
Average years farming experience	18	22	19
Education:			
Percent grade school only	48	63	52
Percent some high school	45	34	42
Percent some college	7	3	6
Total	100	100	100
Percent believed fertilizer has:			
Beneficial effect	88	63	80
Harmful effect	4	10	6
Effect not known	8	27	14
Total	100	100	100

†A fertilizer user was characterized as one who had used fertilizer in 1952 or 1953.

‡Owned capital is the cash value of the farm (if owned), livestock, feed supplies, machinery and equipment minus any mortgage or indebtedness.

user could be characterized generally as having more capital, a larger farm, more years of education and fewer years of farming experience, and being somewhat younger than the nonuser.

Size of Farm

Fertilizer users operated farms averaging 204 acres, whereas the size of nonusers' farms averaged 165 acres (table 1). The percentage of fertilizer users tended to increase with farm size (fig. 2). The proportion of fertilizer users in the largest farm size group (greater than 259 acres) was approximately twice as great as those in the smallest farm size group (less than 80 acres). The reverse relationship existed for nonfertilizer users—i.e., 29 percent of nonusers operated farms having more than 259 acres, whereas 63 percent operated farms of less than 80 acres.

Tenure of Farm Operator

Considering all owners and all tenants, there was no significant difference in the percentage of each using fertilizer (table 2). Within the owner group, however, a significantly greater proportion of part owners than of full owners used fertilizer. Similarly, within the renter group, a significantly greater proportion of operators on livestock-share farms used this practice. It is possible that the effects of form of tenure and size of farm may be confounded. The two tenure groups with the greatest percentage of users also are those averaging the greatest number of acres in farm. Part owners managed the largest size farm operations (259 acres). The average size farm man-

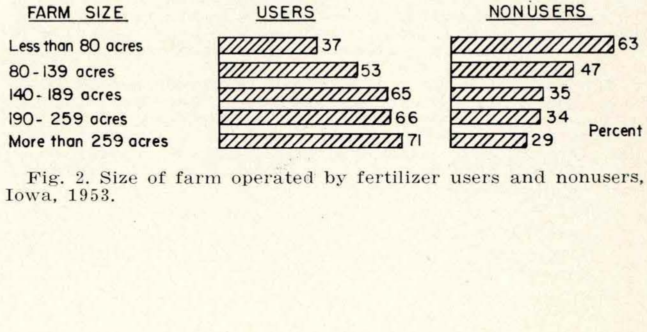

Fig. 2. Size of farm operated by fertilizer users and nonusers, Iowa, 1953.

Table 2. FERTILIZER USERS AND SIZE OF FARM OPERATION BY TYPE OF TENURE, IOWA, 1953.

Tenure	Number of farms	Number of fertilizer users	Percent users	Acres in farm	Acres owned	Acres rented
All owners	297	203	68	183	–	–
Owner-operators	231	154	67	161	161	–
Part owner-operators	66	49	74	259	140	119
All renters	235	162	69	203	–	–
Crop-share	115	75	65	201	–	201
Livestock-share	84	62	74	230	–	230
Cash and other	36	25	69	150	–	150
All farmers	532	365	69	192	–	–

aged by all owners was 183 acres; whereas all types of renter-operated farms averaged 203 acres.

Age of Operator

Fertilizer users tend to be younger and have less farming experience (table 1). The average age of farmers using fertilizer was 43 years, as compared with 49 years for those farmers not using fertilizer. Farmers who used fertilizer had farmed an average of 18 years, compared with 22 years for farmers not using fertilizer.

Level of Operator's Formal Education

The farm operator's ability to read, understand and evaluate literature on fertilizers was expected to be positively associated with the level of formal education. To test this relationship, farm operators were divided into three formal educational groupings: grade school, high school and college. A farmer was placed in the highest educational group if he had any training at that level. The proportion of nonusers who had only grade school education was greater than the proportion of users who had only this amount of education (table 1).[7]

Beliefs About Fertilizer Effects

Farmers' beliefs about the effects of fertilizer in crop production were investigated to determine if they were related to the amount used. These beliefs were classified into three categories depending on whether farmers thought fertilizer had beneficial, harmful or neutral effects on the soil. Fertilizer was considered beneficial by 87 percent of the fertilizer users, whereas only 63 percent of the nonusers believed that fertilizers had a beneficial effect (table 1).[8] The differences in beliefs about fertilizer effects between users and nonusers were highly significant.

Farmers, in general, considered fertilizer to have beneficial effects on crop growth. However, this does not indicate that they are convinced that fertilizer use is profitable—as evidenced by the 63 percent of the nonusers who believed that fertilizer use benefited crop production. These farmers may believe that fertilizer use increases crop yields but that these additional yields cost more than is added to returns. If farmers are to use fertilizer (or any other resource), they must be convinced that the practice is profitable, or the effects of tenure or other obstacles must be lessened. Since only a small proportion of the nonusers had used a soil test, it is likely that knowledge of their specific soil needs was lacking, on the part of both those who thought fertilizer was beneficial (63 percent) and those who expressed no beliefs (27 percent).

[7]The X^2 showed the differences to be highly significant, i.e., $X^2=11.5^{**}$. Two asterisks mean $P<0.01$; one asterisk means $P<0.05$. This notation for level of significance will be used hereafter.

[8] $X^2=42.6^{**}$.

Use of Soil Tests

Soil nutrient tests were obtained by a significantly larger proportion of fertilizer users than nonusers (38 and 8 percent).[9] Also, a significantly greater proportion of fertilizer users obtained soil tests for lime needs (44 and 21 percent, respectively).[10] The extensive use of soil tests on more farms would indicate specific needs for fertilizer and probably would be an influencing factor in using more fertilizer. To the farmer, soil tests indicate nutrient levels and limestone needs but do not necessarily indicate the *absolute* response from a given application of fertilizer.

Since fertilizer recommendations accompany the results of the soil test, farmers were asked whether they had followed these recommendations. Eighty-seven percent of the 161 fertilizer users who obtained soil tests followed the recommendations. Varied reasons were indicated for not following soil test recommendations. Some of these reasons were: lack of capital, nonsharing of costs by the landlord, recommendation not in a form directly applicable to his particular situation, or substitution of clover and rotated pasture for fertilizer to fulfill nitrogen needs.

INFORMATIONAL SOURCES IMPORTANT IN THE ACCEPTANCE AND USE OF FERTILIZER

Factors Influencing Fertilizer Use

Slightly over half of the farmers using fertilizers credited neighbors, friends, landlords or other farmers as the most important influencing factors in adopting the use of fertilizer. This does not preclude the possibility that they had information from other sources, but it does reflect the important contact or medium which the farmers *recalled* in arriving at their decision (fig. 3).

Mass media generally are recognized as an important source of information on new fertilizers. In this study, one-fifth of the farmers using fertilizer indicated that they were motivated to use fertilizer by

[9] $X^2=50.05^{**}$.

[10] $X^2=29.96^{**}$.

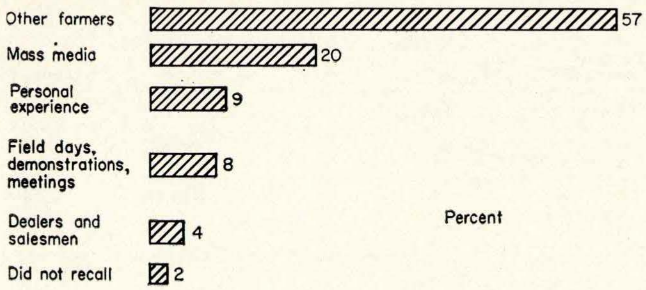

Fig. 3. Most important source of information influencing the initial use of fertilizer by Iowa farmers.

this means. Of the 20 percent crediting mass media, four-fifths claimed farm magazines, farm journals and daily papers as the most important sources influencing their use of fertilizer. One-fifth of the respondents indicated the most important sources were bulletins and other published material from Iowa State College.

Relationship of Status to Influencing Factors[11]

Educational experience. Other farmers were the most important original source of information on fertilizer use for farmers having grade school education only (62 percent). Farmers having a high school and some college education also credited this source as most important (52 and 44 percent, respectively). Those having some college education credited their acceptance of fertilizer use to a greater extent to articles in farm magazines, newspapers, bulletins and other materials from Iowa State College (46 percent). Fertilizer salesmen or dealers were a more important source of information among those with a grade school education.

Years of fertilizer experience. Thirty-four percent of the fertilizer users had fertilizer use experience extending to and beyond an 8-year period. Another third had adopted the practice "in the past 3 years" (prior to 1953). Those who started using fertilizer "in the last 3 years" (most recent acceptors) credited other farmers who told about higher yields as the most important single factor in the acceptance of fertilizer use (36 percent). In general, the influence of neighboring farmers on the acceptance of fertilizer use was the most important factor regardless of length of fertilizer experience. Twelve percent of the farmers with 3 or less years of fertilizer experience credited magazines, newspapers and farm journals as the primary source in fertilizer acceptance, whereas slightly over 20 percent of those with greater fertilizer experience credited mass media.

Years of farming experience. The experiences are divided into three main groups: those with 9 years or less of farming experience, a group who began farming following World War II; another group with 10 to 19 years' experience who had farmed largely through a period of generally rising prices; and a third group who had farmed for 20 years or more. This third group had had farming experience during an economic depression. In the latter group approximately half had had 30 years or more farming experience.

As might be expected, those who had farmed for a period of less than 10 years were influenced to a greater degree by their home farm experience (11 percent) than those who had farmed for a longer period (7 percent). Fertilizer salesmen or dealers had a greater influence among the farmers with more experience.

Tenure. Other farmers were a more important source of information among renters than among owner-operators (65 and 51 percent, respectively). Owner-operators credited farm magazines, field days and demonstrations, extension meetings and bulletins as a more important source than did renters (22 and 15 percent, respectively).

Size of farm. The farmers operating the larger farms appeared to be less dependent on other farmers and credited reading of papers and bulletins and attending meetings as relatively more important factors influencing their acceptance of the fertilizer practice. Those who operated the smaller units credited the fertilizer dealer and salesman as a relatively more important source. Other farmers likewise were an important influence to those operating the smaller-sized farms.

Capital position. Fertilizer users who owned capital above $30,000 gave relatively less credit to other farmers as a reason for starting to use fertilizer than did those farmers with less than $30,000 owned capital. Of interest is the indication that farmers with under $10,000 owned capital were more likely to credit what other farmers told them about fertilizer use than their own observation. All other capital groups credited what they had seen on other farms as the most important motivating force in adopting the use of fertilizer. The highest capital group is the only one that credited radio and television as an influence in starting to use fertilizer. This group also rated meetings held by county extension personnel much higher than other capital groups. However, excepting those in the lowest capital group, farmers credited the fertilizer salesman or dealer less than other groups. Field days and demonstrations were relatively more important to farmers in the two lowest capital groups.

SOURCES OF INFORMATION ON A NEW FERTILIZER

One of the purposes of this study was to identify the sources of information Iowa fertilizer users would depend on when a new fertilizer is placed on the market. Although the question involved a new fertilizer product, it was recognized that all respondents had had some experience in fertilizer use, i.e., an associated practice.

The question asked farmers was as follows: "If you heard of a new fertilizer that has relatively low cost and is very effective in increasing crop yields,

[11]The basic statistical data upon which this section is based may be found in Appendix B.

where would you seek information about its use?'' Ninety percent of the 365 fertilizer users identified one or more sources of information they would select (fig. 4).

Forty-four percent of fertilizer users indicated that Iowa State College was their main source of information. Grouped in this category in the order of frequency named were replies such as county agent, Iowa State College, county extension service and experiment station.

The county farm bureaus were designated by nearly 16 percent of the fertilizer users as their first choice as a source of information on a new fertilizer. Inasmuch as the county farm bureaus, at the time of the survey, were the legal sponsoring organization of the Extension Service in Iowa, this source might appropriately be added to the Iowa State College source. This would indicate that a total of 60 percent of the fertilizer users would look to the organizations or the representatives of Iowa State College as their source of information on new fertilizers.

Fertilizer dealers and salesmen were selected by 12 percent of the users as their main source of information on new fertilizers. The Production and Marketing Administration, Soil Conservation Service and vocational agriculture instructors accounted for slightly less than the fertilizer dealers and salesmen. While over 50 percent of these same farmers credited their landlord, neighbors and friends as a causative factor in starting to use fertilizer, only 4 percent said they would go to the same group for information on a new fertilizer just about to be placed on the market.

Magazines and newspapers were considerably less important as a source of additional information under these conditions. Undoubtedly, as indicated previously, the biggest role of mass media would have been in the announcement phase.

Main Source of Information: Fertilizer Use Acceptance vs. New Fertilizers

The difference between informational sources as primary motivating factors in acceptance of fertilizer use and in obtaining knowledge about a new fertilizer product are illustrated in fig. 5. For the majority of farmers, observing the better stands on other farms and hearing about higher yields resulting from fertilizer use had more influence in the acceptance of fertilizer use than in the obtaining of information on new fertilizer products. When farmers who have used fertilizer desire information about a new fertilizer product, they secure their information primarily from public agencies (Iowa State College, 44 percent, county farm bureaus, 16 percent; and USDA agencies, 9 percent). Mass media (radio, magazines, television and newspapers) played an important role (18 percent) in getting initial acceptance of fertilizer. However, there was a decrease in the relative importance of mass media in conveying basic information on a new fertilizer product.

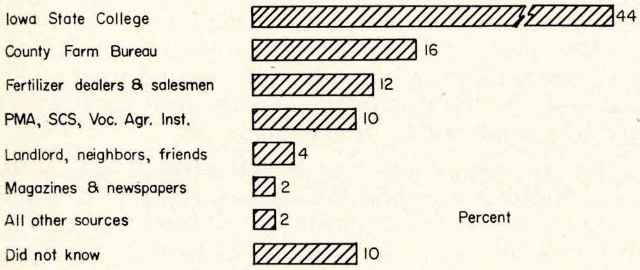

Fig. 4. Relative importance of main sources of information fertilizer users would seek on a new fertilizer.

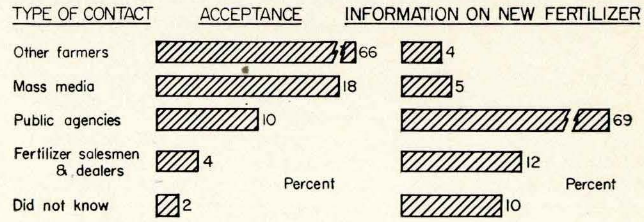

Fig. 5. Comparison of sources responsible for initial use of fertilizer and sources used to secure information on a new fertilizer.

This apparent reversal of source preference may be explained by the stage of knowledge of the farmer with respect to fertilizer use. When he was undecided whether to try fertilizer or not, he accepted the word of his friend or neighbor to confirm his preliminary opinions. His neighbors or friends were in fact the ''push'' he needed to try the practice. They were ''acceptors'' and, thus, had an influence on his decision.

USE AND HANDLING OF FERTILIZER ON THE FARM

Knowledge of the quantity of fertilizer used and related practices in Iowa is limited. Agricultural programs related to more efficient production should be developed on knowledge of the extent of fertilizer use on farms, rates of application on various soils growing different crops under variable farming systems, limitations to use, container preference and farm storage of chemical fertilizers, as well as on knowledge of other types of technical and economic information. Such information obtained from fertilizer users is presented in this section so that the relationships between status factors and fertilizer use, and the quantitative relationships of factors related to fertilizer use are better understood.

Extent of Fertilizer Use

The extent of fertilizer use by Iowa farmers is presented by nutrients used on specific crops grown in the nine soil areas. While 62 percent of the estimated 180,000 Iowa farmers used fertilizer in 1953, fertilizer was used on only 21 percent of the 34.5 million acres of farmland (tables 2-A, 2-C and 3-C in Appendixes A and C). An estimated 4½ million acres planted in corn was fertilized (table 4-C). This fertilized corn acreage amounted to 64 percent of the total crop acreage receiving chemical fertilizer. Approximately 41 percent of the corn acreage

Table 3. ESTIMATED TONNAGE OF PLANT NUTRIENTS APPLIED TO LAND IN CORN AND OTHER CROPS, IOWA, 1953.

Crop	Nitrogen (N) (thousands of tons) State est.	Nitrogen (N) 95% confidence limits	Phosphate (P_2O_5) (thousands of tons) State est.	Phosphate 95% confidence limits	Potash (K_2O) (thousands of tons) State est.	Potash 95% confidence limits
Corn	42.1	34.0 - 50.4	47.5	39.5 - 55.5	29.0	23.8 - 34.3
All other crops	12.5	11.5 - 13.4	47.5	43.0 - 52.0	6.5	4.5 - 7.4
Total	54.6	45.5 - 63.8	95.0	82.5 - 107.5	35.5	28.3 - 41.7

was fertilized, and 51 percent of the farmers in the sample applied fertilizer to land in corn. The estimated tonnage of plant nutrients used on land in corn and other crops is presented in table 3. Corn acreage received 77 percent of the nitrogen, 50 percent of the phosphate and 83 percent of the potash fertilizer applications.

A comparison of fertilizer use on land in corn and small grain in the nine Iowa soil areas is presented in table 4. The proportion of farmers using fertilizer was lowest in soil area 4 (central southeastern Iowa); areas 2 and 3 (northeastern Iowa) had the greatest proportion of farmers using fertilizer. In northeastern Iowa (areas 2 and 3), the proportion of farmers using fertilizer was twice as great as in central-southeastern Iowa (area 4), although they are contiguous areas. Soil area 4 is one of the most concentrated livestock areas in Iowa, and more manure is returned to the land than in other sections of the state. An important portion of the grain fed to livestock in this area is purchased from other areas of Iowa. In general, the percentage of farmers using fertilizer is higher in northern than in southern Iowa. Southern Iowa farmers typically operate with less capital and have lower incomes than farmers in northern Iowa.

The proportion of farmers using fertilizer on land in corn ranged from 83 percent in northern Iowa (area 2) to a low of 25 percent in southern Iowa (area 5). The major portion of the oats grown as cash crop without legume seeding is found in soil areas 1, 2 and 4. Fertilizer was applied on land in small grain with meadow seeding by 26 percent and on land in small grain without meadow seeding by 11 percent of the farmers. More farmers were inclined to fertilize their small grain and legume seeding in northwest and north-central Iowa than in other areas of Iowa. The smallest proportion of farmers

Table 4. FERTILIZER USE BY IOWA FARMERS ON LAND IN CORN, SMALL GRAIN OR OTHER CROPS, 1953.

Soil area†	Number of farmers in sample	Percent of farmers using fertilizer on: Any crop	Corn	Small grain: With meadow seeding	Small grain: Without meadow seeding
1	121	66	50	34	14
2	87	86	83	28	18
3	37	81	81	22	3
4	88	42	36	11	14
4a	30	53	27	23	3
5	44	48	25	27	9
6	46	50	44	17	4
7	37	46	40	19	5
8	42	69	48	50	5
State	532	62	51	26	11

†See fig. 1.

fertilizing small grain was located in east-central Iowa. Only in area 5 (southern Iowa) and area 8 (northwest Iowa) did a larger proportion of farmers fertilize small grain than corn, although the differences are not appreciable.

The pronounced need for phosphate to establish legume stands and the additional yield obtained from small grain are responsible for the large number of farmers fertilizing small grain with meadow seeding in area 8. Heavy applications of phosphate fertilizer in this area have been a recommended practice for many years. Fertilizer is used to get a good "catch" from meadow seeding rather than to get increased yields of oats where oats are grown primarly as a nurse crop.

Soil areas 1, 2 and 4 contain an appreciable proportion of farmers who fertilize small grain without a meadow seeding. Oats are grown in areas 1 and 2 as a cash crop. Most farmers grow oats as a nurse crop for legumes, but only a small proportion grow oats alone. Soil fertility is relatively high, but fertilizer response on land in oats is favorable. In soil area 4, the general soil fertility level is higher than in other areas; thus, yield response from fertilizer applied to land in oats is not appreciable.

NITROGEN

The rates of nitrogen application per fertilized acre in corn and oats in Iowa in 1953 averaged 18 and 9 pounds, respectively (table 5). The application of nitrogen on land in corn was greatest in western Iowa (soil areas 4a, 6, 7 and 8). The soils in these areas are generally eroded and low in organic matter and, thus, respond to nitrogen. The lowest rates of nitrogen applied per fertilized acre in corn were found in areas 2 and 3 of northeast Iowa where rotations include a large proportion of legumes and an appreciable amount of feed is brought in from other areas. There is also more dairying in these two areas of Iowa, and barnyard manure is applied regularly ahead of the corn crop providing an available source of nitrogen. However, soil areas 2 and 3 had a higher percentage of farmers who fertilized corn than in western Iowa (e.g., 81 percent in area 3 compared with 48 percent in area 8). To some extent, the difference in the average rate of application is a result of the method of application.

It is a common practice in soil areas 2 and 3 to use a fertilizer attachment on a corn planter. In this case a relatively small amount of nitrogen is applied. Few farmers use the fertilizer attachment on the corn planter in western Iowa. Here, the common method of application is to side-dress. In area 3 farmers

Table 5. FERTILIZER USE IN IOWA, BY PLANT NUTRIENTS ON LAND IN CROPS IN IOWA SOIL AREAS, 1953.

	Average amounts applied per fertilized acre on farms using fertilizer								
	Pounds nitrogen			Pounds P_2O_5			Pounds potash		
Soil area	All crops	Corn	Small grain†	All crops	Corn	Small grain†	All crops	Corn	Small grain†
State	15	18	9	27	21	39	10	13	5
1	14	18	10	28	22	39	10	13	5
2	11	11	7	26	23	39	18	20	15
3	8	8	4	21	19	45	11	14	2
4	14	16	7	27	20	42	8	9	4
4a	34	46	7	26	24	29	11	14	—
5	14	23	6	32	22	43	10	20	1
6	25	39	8	11	5	34	1	1	—
7	22	28	12	25	18	43	—	—	—
8	19	27	13	31	24	37	1	1	2

†Small grain is principally oats.

generally do not grow more than 1 year of corn following the meadow crop; thus, the current nitrogen level is expected to be relatively higher. Also, area 3 is the principal dairy section of Iowa, and larger quantities and more regular applications of manure could be expected. The rate of nitrogen applied to land in small grain did not vary as much among areas as did rate of nitrogen applied on land in corn. The lowest rate of nitrogen applied per acre in small grain was found in soil area 3 (4 pounds); areas 7 and 8 were the highest with 12 and 13 pounds of nitrogen applied per acre in small grain, respectively.

Phosphate

The average amount of phosphate (P_2O_5) used per fertilized acre in Iowa was 27 pounds, or almost twice the rate of nitrogen application in 1953 (table 5). The average rate of phosphate applied per fertilized acre in corn in Iowa amounted to 21 pounds. The average quantity of phosphate applied per fertilized acre was about the same in all areas except area 6, which was low. Also, the rate of application of phosphate on land in corn per acre fertilized was lowest in area 6. This relatively low use of phosphate fertilizer in area 6 is consistent with indications from soil tests, experimental responses to phosphates, and fertilizer recommendations made for the Marshall silt loam soils. Rates of phosphate application on land in small grain were approximately twice as high as those for fertilized land in corn. The average amount of P_2O_5 applied on land in small grain was lowest in soil area 4a (29 pounds per acre) and highest in area 3 (45 pounds per acre). Relatively heavy applications of P_2O_5 on land in small grain are used primarily to secure a favorable response from legumes or legume-grass mixtures used for pastures and planted with a small grain overseeding.

Potash

The average quantity of potash (K_2O) applied per fertilized acre in Iowa in 1953 was 10 pounds. This rate was lower than either nitrogen or phosphate applications (table 5). The average amount of potash applied on land in corn and small grain was 13 and 5 pounds, respectively. The use of potash on all fertilized cropland varied considerably among soil areas. Relatively small amounts of potash were used in western Iowa. The soils in western Iowa generally have much more adequate supplies of available potassium; therefore, applications of potash are infrequently needed at present. Potassium needs are greatest in the more poorly drained as well as the sandy soils of areas 2 and 3, particularly for land in corn. In the same areas (2 and 3) the establishment of legume seeding in the small grain depends on providing sufficient available potassium (as well as phosphorus).

The average rate of potash applied per fertilized acre in area 2 was 18 pounds; 8 to 11 pounds were used in the remaining areas. The pattern of use of potash on land in corn is similar to its use for all crops. Use of potash on corn acreage in western Iowa (areas 6, 7 and 8) was low, with use in the other areas averaging 9 to 20 pounds of potash per fertilized acre.

The use of potash on small grain is very limited except in soil area 2. On those farms where it is used, the primary purpose is for the establishment of the legume or legume-grass seeding. The average amount of potash used on land in small grain in area 2 was 15 pounds per fertilized acre, and less than 5 pounds per fertilized acre was applied in the other soil areas. The relatively low rates of use and geographical distribution as compared with nitrogen and phosphate correspond to soil fertility conditions and agronomic recommendations for Iowa.

Use of Hill or Row Fertilizer[12]

Starter fertilizers, i.e., hill or row fertilizers, such as 4-16-0, 4-16-8, 4-16-12 or 4-16-16, are applied with a special corn planter attachment. This practice is followed to give the plant a vigorous start early in the season when the availability of some plant nutrients may be low. Hill or row applications of 100-150 pounds per acre of starter fertilizer often result in additional yields of 8 to 10 bushels of corn.[13]

Fifty-four percent of all farmers using fertilizer applied starter fertilizer to their corn crop. One out of three farmers in Iowa used this method in 1953. Of the group fertilizing corn, 65 percent used starter fertilizer. However, the relative use varied widely among soil areas. This practice is followed most widely in northeast Iowa, where three-fourths of all farmers (users and nonusers) fertilize some corn at plant-

[12]Commonly referred to as "starter" fertilizer by Iowa farmers.
[13]Dumenil, Lloyd, et al. How much fertilizer for corn? Iowa Farm Science. March 1953.

Table 6. USE OF STARTER FERTILIZER ON LAND IN CORN, IOWA SOIL AREAS, 1953.

Soil area	No. of farmers in sample	No. of farmers using starter fertilizer	Percent using	Pounds per acre where applied		
				N	P	K
1	121	45	37	8	20	13
2	87	66	76	6	20	18
3	37	27	73	5	18	14
4	88	16	18	9	18	9
4a	30	2	7	7	23	18
5	44	9	20	14	24	22
6	46	1	2	8	24	16
7	37	2	5	15	21	–
8	42	9	21	9	27	2
State	532	177	33	7	20	14

ing time, as compared with farmers in southern and southwest Iowa (soil areas 4a, 5, 6 and 7) where only 9 percent of the farmers out of a sample of 157 applied starter fertilizer on land in corn (table 6).

Use of hill or row fertilizer in Iowa in 1953, in terms of plant nutrients applied per acre, approximates the recommendations by soil specialists in each of the nine soil areas. Of perhaps more significance is the average fertilizer ratio used in each of the several areas. Areas 2 and 3 approach the grade ratio of 1-4-3 (table 6). The common recommendations for these two areas are 1-4-4 and 1-4-2 ratios, while the general recommendation for starter fertilizer in western Iowa is a 1-4-0 ratio. In soil area 8, where the potassium needs are low, the ratio used is approximately 1-3-0 (table 6). Apparently, farmers are following the recommended starter fertilizer ratios more closely than recommended total rates per acre.

Approximately 20 percent of the fertilized corn acreage received two or more fertilizer applications. All methods of application were used—broadcasting, drilling, side-dressing and applying with planter attachment. Straight nitrogen fertilizer, in addition to that used in starter applications, was applied by 15 percent of the farmers using fertilizer. The average rate of application was 39 pounds per acre. The greatest usage of straight nitrogen fertilizer was found in southwestern and western Iowa.

Farm Size and Fertilizer Use

It was established earlier that the proportion of fertilizer users increased with farm size (fig. 2). An important question is the total quantities used per farm and per acre in relationship to farm size. Using average figures for five size groups, there is evidence that the larger the farms, the greater were the quantities of N, P_2O_5 and K_2O used (table 7). The one exception is the nitrogen use *per farm*. Nitrogen use on farms with 79 acres or less was 60 percent greater than for the next size group of 80-139 acres, and slightly larger than the 140-189-acre size group.

Considering the amount of fertilizer used per acre, the small-size farm group used twice as much nitrogen as the largest size group (36 and 18 pounds, respectively). The other size groups used 13, 11 and 14 pounds, respectively, for size groups 80-139, 140-189 and 190-259 acres. The same pattern did not exist for phosphate, however. The largest size group (260 acres or larger) applied 30 pounds per acre although this was not significantly larger than the other size groups.

Potash use did not vary greatly with farm size, although the smallest size group applied 14 pounds per acre, with the other farm size groups averaging from 9 to 11 pounds K_2O per acre.

Additional evidence of intensity of use on the small-size farms is revealed in the per-acre expenditure for fertilizer (table 7). Considering the entire farm, the expenditure for fertilizer per acre was more than twice as great for the small-size group as for any other. At the same time, the per-acre expenditures were not significantly different for different size groups above 80 acres.

Improved Fertilizer Practices

Farmers were asked about improved practices. The statement was worded: "We are interested in finding ways in which fertilizer can be used to give maximum profit in your area. Which, if any, of the following uses do you consider as improved uses in your area?" The alternative improved uses and nature of response are presented in table 8.

The use of ammonium nitrate as top-dressing on permanent and supplemental pasture grasses was considered an improved use by 56 percent of the farmers questioned. Top-dressing oats to increase yield and top-dressing grasses for seed production were considered improved practices by 51 percent and 41 percent, respectively. A large proportion of the farmers considered phosphate fertilizer on corn (when soil test is low), legumes at seeding time, pasture renovation and top-dressing legumes as improved practices in their areas.

Fertilizer Adoption in Relation to Crop Rotation

Commercial nitrogen may be used on many soils as a substitute for nitrogen produced by legumes on the farm. When nitrogen fertilizers are to be used for maintaining or increasing grain yields, the farmer may find it profitable to change the over-all farm pro-

Table 7. RELATIONSHIP OF FERTILIZER USE TO SIZE OF FARM, IOWA, 1953.

Farm size group	Pounds of plant nutrients used on farms using fertilizer: Per farm N	Per farm P_2O_5	Per farm K_2O	Per acre N	Per acre P_2O_5	Per acre K_2O	Fertilizer expenditure per acre
79 acres or less	668	429	269	36	23	14	$4.20
80 - 139 acres	402	829	295	13	27	10	1.83
140 - 189 acres	608	1,351	527	11	25	10	1.78
190 - 259 acres	1,069	1,732	802	14	24	11	1.74
260 acres or greater	1,934	3,111	969	18	30	9	1.78

Table 8. FERTILIZER USE PRACTICES CONSIDERED BY FARMERS TO BE IMPROVED USES, IOWA, 1953.

Type of practice	Considered an improved use		Not considered an improved use		Do not know		Inapplicable	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Fertilizing with ammonium nitrate as:								
Top-dressing grasses for seed production	150	41	40	11	81	22	94	26
Top-dressing wheat early in spring to increase yield and improve protein content	36	10	7	2	53	14	269	74
Top-dressing oats to increase yield	186	51	97	27	81	22	1	*
Top-dressing permanent and supplemental pasture grasses	206	56	75	21	77	21	7	2
Fertilizing with phosphate fertilizers for:								
Legumes at seeding time	236	65	82	22	45	12	2	1
Top-dressing legumes	197	54	95	26	71	19	2	1
Pasture renovation	203	56	76	21	78	21	8	2
Corn (when soil test is low)	252	69	58	16	52	14	3	1

*Less than 0.5 percent.

Table 9. FARMERS REPORTING ON CHANGES IN CROP ROTATION WHEN ADOPTING THE USE OF COMMERCIAL NITROGEN FERTILIZER ON CORN LAND, IOWA, 1953.

Lease arrangement	Should use different rotations when using commercial nitrogen on land in corn						
	Number no	Percent no	Number yes	Percent yes	Do not know	Percent do not know	Total
Owner-operator	49	32	55	36	50	32	154
Part owner-operator	21	43	24	49	4	8	49
Renter, crop-share	24	32	42	56	9	12	75
Renter, livestock-share	28	45	20	32	14	23	62
Cash and other	9	36	14	56	2	8	25
Total	131	36	155	42	79	22	365

duction plan. Since legumes are a source of livestock feed as well as of nitrogen and organic matter, the number of forage-consuming livestock affects the profitability of using commercial or homegrown nitrogen.

As suggested by the data, the extent to which farmers' thinking has become oriented to the possibilities of changing their farm plans when using commercial fertilizers is presented below. To get some information on this aspect of fertilizer use in the over-all farm plan, the following question was asked of the farmers using fertilizer: "Do you think you should use a different rotation when you use commercial nitrogen on land in corn as compared with using no nitrogen?" Thirty-six percent of the farmers answered "no" while 42 percent answered "yes" (table 9). The remaining 22 percent answered "don't know." When compared with livestock-share renters, a somewhat larger percent of the crop-share and cash-rent farm operators indicated that a change in rotation should accompany the use of commercially produced nitrogen fertilizer.

These findings indicate that many farmers are aware of the economic opportunities for changing rotations when commercial nitrogen fertilizer is used on land in corn. There is a slightly greater tendency for farm operators with less livestock to favor this type of change. An appreciable segment of farm operators (22 percent) apparently do not have enough information to arrive at a decision on this subject.

Greatest uncertainty was expressed by the owner-operator group; 32 percent did not know whether they should use different rotations when using commercial nitrogen on their corn acreage, and another 32 percent indicated that nitrogen could not substitute for the legume in the rotation. Owner-operators may feel that they have their cropland in such a state of fertility that a variation of their present cropping plan may result in crop decreases. Also, their replies may not have been made with respect to the substitution question *per se* but they may have thought that forage as a feed for livestock might yield greater economic returns. Owner-operators may view any change from the present production plan, when uncertainty exists, as a capital risk. Therefore, they are inclined to follow a "wait and see" pattern. The crop-share and cash renters face no such risks and, hence, may react more favorably to the suggestion of changing their rotations when using commercial nitrogen on corn land.

Physical Limitations in Use

The amount of fertilizer a farmer uses may, to some extent, depend on the convenience and ease of use. Ease of use becomes especially important if the fertilizer is applied when there are other important needs for labor. For example, if a farmer has a limited time to plant his corn, delay associated with the difficulties in fertilizing with a planter attachment may, in his mind, be costly in terms of reduced crop yield because of untimeliness in planting. Experiences and preferences in using fertilizer are presented below, i.e., the kinds of difficulties and the farmers' estimates of additional value of granulated as compared with ungranulated fertilizer.

Thirty-seven percent of the farmers using fertilizer reported difficulties in spreading commercial fertilizer. Of the difficulties reported, 66 percent were related to lumpiness, stickiness and consequent clogging of the fertilizer spreader, 16 percent were related to

Table 10. PREMIUM THAT FARMERS USING FERTILIZER INDICATED GRANULAR FERTILIZER IS WORTH OVER REGULAR FERTILIZER PER TON, IOWA, 1953.

Amount granular is worth over regular fertilizer (dollars)	No. of farmers using fertilizer	Percent of those reporting
Inapplicable	150	–
No report	37	–
0.00	23	13
1.00	12	7
2.00	56	31
3.00	28	16
4.00	15	8
5.00	24	13
6.00	1	1
7.00	2	1
8.00	3	2
10.00	11	6
12.00	2	1
15.00	1	1
Total	365	–

Table 11. SIZE OF FERTILIZER CONTAINER PREFERRED BY FARMERS USING FERTILIZER, IOWA, 1953.

Container bag	Number of farmers	Percent of farmers
No report	24	7
Bulk	12	3
80-pound bag	288	79
100-pound bag	10	3
50-pound bag	27	7
Bulk for oats; 80-pound for others	1	*
No preference	3	1
Total	365	100

*Less than 0.5 percent.

degree of granulation (too fine or powdery), and 18 percent were miscellaneous reasons.

Farmers who used fertilizer estimated the additional amount of money they would pay for better granulated fertilizer to help overcome some of these difficulties. These estimates of the additional value of granulated over ungranulated fertilizer are presented in table 10. The most common premium of granular fertilizer over regular fertilizer given by farmers was $2 per ton. The average of the premium was $3.30; however, 13 percent of the farmers answering this question indicated that they would pay no more for a well-granulated fertilizer.

Container Preference

The majority of farmers (79 percent) using fertilizer preferred to handle fertilizer in 80-pound bags (table 11). Bulk fertilizer was preferred third, relative to 80- and 50-pound bags.

The knowledge of the availability of commercial or bulk spreading services, by soil areas and for farmers using fertilizer, is presented in table 12. The importance of bulk spreading services has increased recently for superphosphates, mixed fertilizer and nitrogenous fertilizers (particularly anhydrous ammonia). Purchasing the services in the form of bulk spreading is a convenience and an economy for many farmers operating small-size farms or large-size farms with limited capital and labor resources.

Farm Storage of Fertilizer

Fertilizer is bought and used primarily in the spring. The seasonal pattern of fertilizer use results in many diseconomies in production and marketing. Fertilizer dealers, by offering seasonal price discounts, may attempt to induce farmers to purchase fertilizer in the "off-season" and store it on the farm until used. Forty-four percent of the farmers using fertilizer stored part of it on the farm for the 1953 crop season. The greatest proportion of farmers considered the storing qualities of the fertilizer as good (fig. 6).

The farmer investigating the profitability of storing needs to consider (a) the retail supply of fertilizer at the time of application and, hence, the possible loss resulting from short supply, (b) the cost of storing fertilizer on the farm, (c) seasonal differences in price per ton of fertilizer and (d) returns on alternative investments or interest which might be earned on the funds if not invested in stored fertilizer. The saving from buying fertilizer at reduced prices in the off-season must be balanced against possible loss in quality; but more important is the possible alternative opportunity cost of the money invested in fertilizer during the storage period. In the case of a farmer with enough capital so that his investment in fertilizer storage returns only 3 to 4 percent interest, the opportunity cost is not large. However, a farmer who has little capital may be foregoing appreciable returns (from use of capital in other enterprises) by buying and storing fertilizer in an off-season.

The proportion of farmers storing fertilizer in relation to the amount of owned capital is presented in fig. 7. In general, the percentage of farmers stor-

Table 12. KNOWLEDGE OF AVAILABILITY OF COMMERCIAL FERTILIZER SPREADING SERVICE IN LOCALITY AMONG FARMERS USING FERTILIZER, IOWA, 1953.

Area	Fertilizer spreading service available in locality		No fertilizer spreading service in locality	Farmers not answering	Total number of farmers in sample using fertilizer
	Number	Percent			
1	54	62	20	13	87
2	50	65	10	17	77
3	12	39	9	10	31
4	26	58	9	10	45
4a	6	30	6	8	20
5	9	34	13	5	27
6	21	84	4	0	25
7	16	73	3	3	22
8	21	68	8	2	31
Total	215	59	82	68	365

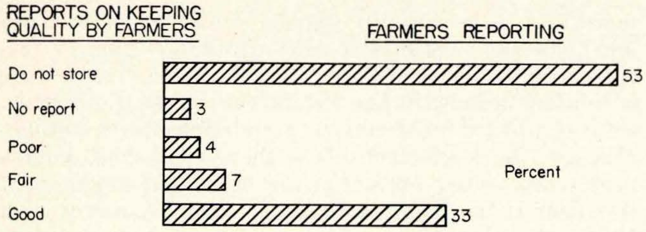

Fig. 6. Keeping qualities of farm-stored fertilizer observed by farmers using fertilizer, Iowa, 1953.

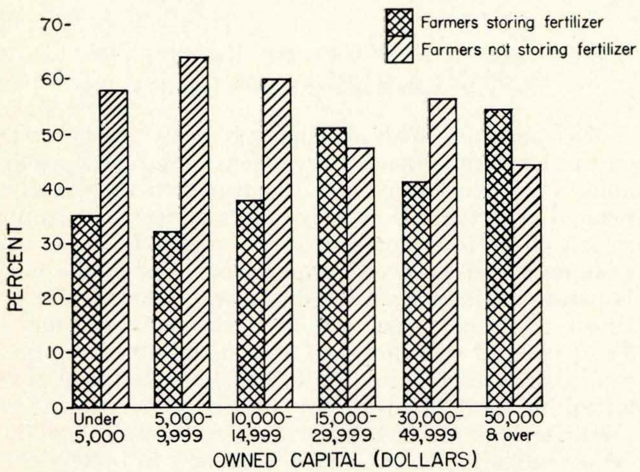

Fig. 7. Distribution of farmers using and storing fertilizer by owned capital position, Iowa, 1953.

ing the fertilizer increases as the amount of owned capital increases. The availability of capital is no doubt one reason for this increase. Tenant-operators tend to have less owned capital than owner-operators. Uncertainty of tenure may limit farm storage of fertilizer since the tenant may move from the farm before the next crop season.

The large proportion of farmers who do not store fertilizer on the farm (196, or 53 percent) provides a great potential for off-season purchase and storage (fig. 6). Dealers may need to make more credit available to farmers and perhaps larger seasonal discounts if they wish to increase fertilizer storage on farms.

RELATIONSHIPS BETWEEN TENURE AND EXTENT OF FERTILIZER USE

The use of fertilizer varies from nonuse to high levels of use on farms in a given locality. Variation in fertilizer use has been associated with certain economic and noneconomic status factors.[14] The relationships between status factors (associated with tenure and fertilizer use, such as operator's capital position) and the effect of risk and uncertainty (with respect to length of tenure and ability to acquire capital) are presented in this section.

Extent of Fertilizer Expenditures Considered Most Profitable

Owners and part owner-operators spent approximately the same amount of money for fertilizer in 1953 as tenant-operators—$343 and $321, respectively (table 13). As indicated previously, tenant farms averaged larger in size than owner-operated farms. Owners and part owner-operators spent an average of $1.87 per acre for fertilizer, tenants spent only $1.58. Tenants considered $534 for the farm ($2.63 per acre) as the average fertilizer expenditure necessary for maximum profits as compared with an average of $434 for the farm ($2.37 per acre) by owners and part owner-operators.

The difference between actual and estimated most profitable expenditure for fertilizer amounted to $212 for tenant-operators and $91 for the owner group. The estimated most profitable expenditure may have been greater for tenant-operators because this group, on the average, was using less fertilizer per acre and operated larger farm units. Also, present soil-depleting crop rotations prevalent on many tenant-operated farms should result in relatively greater response to fertilizer use.[15] These factors may partially explain why tenant-operators estimate a greater optimum fertilizer expenditure than owner-operators. Certain aspects of uncertainty and cost-sharing provisions related to tenancy may limit fertilizer expenditures below the most profitable level—e.g., tenants' shorter capital position and their relatively greater difficulty in obtaining credit for fertilizer purchases.

In general, lack of capital was the reason most often given as holding fertilizer expenditures below the level considered most profitable (fig. 8). Many farmers disclosed that there was a lack of informa-

[14]Cf., Wilkening, Eugene A. Acceptance of improved farm practices in three coastal plain counties. N. C. Agr. Exp. Sta. Tech. Bul. 98. May 1952; and Dimit, Robert M. Diffusion and adoption of approved farm practices in 11 counties in southwest Virginia. Unpublished Ph.D. thesis, Iowa State College Library, Ames, Iowa. 1954.

[15]Heady, Earl O. and Jensen, Harald R. The economics of crop rotations. Iowa Agr. Exp. Sta. Res. Bul. 383. 1951. p. 456, table 8.

Table 13. EXPENDITURES AND ESTIMATED MOST PROFITABLE EXPENDITURES FOR FERTILIZER UNDER VARIOUS TENURE SITUATIONS, IOWA, 1953.

Tenure	Dollars spent on fertilizer in 1953	Estimated amount could spend profitably on fertilizer in 1953	Dollars would have spent for fertilizer if owned farm	Additional dollars of fertilizer if landlord would share cost
Owner-operators / Part owner-operators	$343	$434	–	–
All tenant-operators	321	534	$453	$164
Tenants (related)	314	598	447	185
Tenants (nonrelated)	327	488	457	155

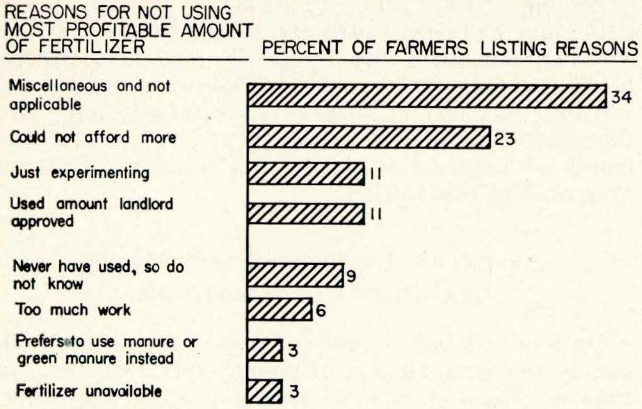

Fig. 8. Farmers' reasons for not using estimated most profitable amount of fertilizer, Iowa, 1953.

tion about crop response and profitability of fertilizer use. For example, 20 percent of the farmers responded that they "used this amount because I was just experimenting" or "never used that amount so do not know." Eleven percent of the farmers in the sample indicated that they followed the decision-making policy of the landlord by applying the amount of fertilizer approved by him.

Estimated Fertilizer Expenditures if Tenant Owned Farm

By achieving farm ownership, tenant-operators may remove some of the limitations resulting from uncertainty and fertilizer cost-sharing methods. The average amount of fertilizer expenditure tenant-operators indicated that they would have made for fertilizer in 1953, if they had owned the farm, was $453 (table 13). This estimated expenditure amounted to $132 more than they actually spent. However, it was $81 less than their estimated most profitable level of fertilizer expenditure. These data indicate that tenure is related, at least in the tenant's mind, to the fertilizer expenditure as if tenure restrictions were not applicable. Lack of capital was the second most important reason cited for not using estimated amounts of fertilizer if the tenant owned the farm he operated in 1953. Another reason for not using larger amounts of fertilizer was that the tenant did not plan to remain long on the farm he was then operating (table 14).

Additional Fertilizer Expenditure if Landlord Shares Costs

The possible effect of sharing costs and returns on the fertilizer intensity level considered most profitable to a tenant-operator is illustrated in the example presented in table 15.[16] Five rates of fertilizer application on corn are presented in column 1, while the amount added from one application level to the next is presented in column 2. The cost of the added fertilizer at 10 cents per pound is shown in column 3. Total yield of corn for each level of fertilizer application is presented in column 5, and the amount of corn added to total yield by an additional increment of fertilizer is shown in column 6. For example, the first 20 pounds of fertilizer added 8 bushels to total yield; the second 20 pounds, 6 bushels; and the fifth increment of fertilizer, only 1 bushel. The value of the added corn yield indicated in column 6 is presented in column 7. Columns 8 and 9 indicate the value of the added yield to an owner-operator and to a tenant who pays a rent equal to half of the corn yield.

[16]Adapted from Heady, Earl O. and Kehrberg, Earl W. Relationship of crop-share and cash leasing systems to farming efficiency. Iowa Agr. Exp. Sta. Res. Bul. 386. 1952. pp. 659-660.

Table 14. TENANT-OPERATORS' REASONS FOR NOT USING ESTIMATED AMOUNTS OF FERTILIZER THEY WOULD HAVE USED IF THEY OWNED THE FARMS THEY WERE OPERATING, IOWA, 1953.

Reason	Farms where landlord shared costs		Farms where landlord did not share costs	
	Number of farmers	Percent	Number of farmers	Percent
1. Could not afford more	5	13	18	21
2. Used amount landlord approved	11	29	35	40
3. Renter does not plan to stay	2	5	8	9
4. Just experimenting	1	3	11	13
5. Unavailable	0	0	3	3
6. Irrelevant	4	10	0	0
7. No response	15	40	12	14
Total	38	100	87	100

Table 15. EFFECT OF RENTAL ARRANGEMENTS ON TENANT PROFITS AND ON INTENSITY OF FERTILIZER USE ON LAND IN CORN (HYPOTHETICAL DATA).

Pounds fertilizer applied	Added pounds ferti-lizer	Cost of added fertilizer at 10 cents pound: Total cost	Cost of added fertilizer at 10 cents pound: Half of cost	Total yield of corn (bu.)	Added yield from fertilizer (bu.)	Value of corn added at $1.10 bushel	Value added for: Owner-operator	Value added for: Half-share tenant
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0	0	$0.00	$0.00	50	0	$0.00	$0.00	$0.00
20	20	2.00	1.00	58	8	8.80	8.80	4.40
40	20	2.00	1.00	64	6	6.60	6.60	3.30
80	20	2.00	1.00	68	4	4.40	4.40	2.20
100	20	2.00	1.00	70	2	2.20	2.20	1.10
120	20	2.00	1.00	71	1	1.10	1.10	0.55

Table 16. RELATION OF COST SHARING TO FERTILIZER EXPENDITURES BY TENANT-OPERATORS, IOWA, 1953.

	Dollars would have spent if owned farm in 1953	Dollars actually spent for fertilizer in 1953	Difference (dollars)
Landlord shared costs	543	409	134
Landlord did not share costs	308	271	37
Difference	235	138	97

Table 17. RELATION OF TENURE TO POSSIBLE USE OF MORE FERTILIZER IF CAPITAL WERE AVAILABLE, IOWA, 1953.†

Tenure	Number farmers in sample	Would use more fertilizer if had more capital		Would not use more fertilizer if had more capital	
		Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Owner–operators / Part owner-operators	297	126	42	154	52
All tenant-operators	235	126	54	105	45
Tenants (related)	138	73	53	62	45
Tenants (nonrelated)	97	53	55	43	44

†The difference between totals and 100 percent is accounted for by farmers not reporting on the question.

It is profitable for an owner-operator, provided he has sufficient capital, to add the fourth 20-pound increment of fertilizer (apply 100 pounds in total), since the added cost ($2 in column 3) of the fourth fertilizer increment is less than the added return ($2.20 in column 8) from the additional increment of yield (2 bushels in column 6). The fifth increment of fertilizer is not profitable, since the added 20 pounds cost $2 (column 3) but add only $1.10 (column 8) to returns.

A different situation exists for the tenant who pays a half share rent but purchases all of the fertilizer. Under this arrangement, his added return is indicated in column 9, and his added cost is indicated in column 3. In this case, it is profitable for him to add only the third increment of fertilizer. The fourth increment is not profitable since its cost is $2 (column 3), and the return is $1.10 (column 9). Thus, the share-rent tenant would use less fertilizer per acre than the owner-operator in maximizing profits.

The data presented in table 16 were obtained to determine to what extent the nonsharing of fertilizer costs by landlords reduced fertilizer use. These data indicate that, where the landlord shared the cost, the amount spent on fertilizer was $138 more per farm than where the costs were not shared. Evidently, tenant managers grasp the essence of the logic presented previously—i.e., the response for small increments of fertilizer, particularly on rented farms where a heavy row-crop program is followed, is sufficient to enable the tenant to make a profit even if the landlord receives a share of the crop but does not pay any of the fertilizer cost.

However, for heavier rates of fertilization, added investment in this practice may not be profitable for the tenant—even though it is profitable for the owner or the share tenant on a farm where the landlord pays part of the cost of fertilizer. A significantly greater proportion of tenants used fertilizer on farms where costs were shared as compared with farms where costs were not shared (table 14). Also the relative difference in fertilizer expenditures is greater on a per-acre than on a per-farm basis, with the expenditure outlay being greatest on farms where fertilizer costs are shared.

Tenant-operators indicated they would be willing to spend more for fertilizer if the landlord would share costs in the same proportions as crops are shared. The average additional expenditure ($164) gives some evidence that farm renters consider that not sharing costs in the same proportion as returns limits the amount of money they could spend profitably for fertilizer (table 13). The average actual expenditures for fertilizer and the average amount the tenant said he would have spent if he owned the farm are presented in table 16. Where the landlord did not share fertilizer costs, the level of use was lower than where costs were shared.

Extent of Estimated Fertilizer Use if Capital Is Not Limited

Many farmers were not using fertilizer at the level that they considered to be most profitable (table 13). Capital limitations as an obstacle to fertilizer use were indicated by 54 percent of the renters as compared with 42 percent of the owners and part owner-operators (table 17). Some farmers indicated that they would not use more fertilizer if additional funds were available. This group may have had enough funds to use the amount of fertilizer they considered optimum, but considered alternative uses for these funds more profitable than using them for fertilizer. That a greater percentage of tenant farmers were restricted by capital is indicative of a greater capital shortage among them than among owner-operators.

Availability of Additional Funds

Most of the farmers indicated that additional capi-

Table 18. AVAILABILITY AND USE OF LOAN CAPITAL FOR FERTILIZER, BY TYPE OF TENURE, IOWA, 1953.†

Tenure	Number farmers in sample	Is it possible to borrow funds for fertilizer use?				Did you borrow funds for fertilizer?			
		No	Percent	Yes	Percent	No	Percent	Yes	Percent
Owner-operators / Part owner-operators	297	18	6	241	81	277	93	11	4
All tenant-operators	235	16	7	186	79	215	92	15	6
Tenants (related)	138	9	6	109	79	124	90	10	7
Tenants (nonrelated)	97	7	7	77	79	91	94	5	5

†The difference between the total of the "no" and "yes" columns and 100 percent is accounted for by farmers not reporting on the question.

Table 19. RELATIONSHIP BETWEEN LEVEL OF RISK AND BORROWING OF ADDITIONAL FUNDS FOR FERTILIZER, BY TENURE GROUP, IOWA, 1953.†

Tenure	Number farmers in sample	Would use more fertilizer if could borrow without added security				Money willing to borrow for fertilizer with repayment schedule
		No	Percent	Yes	Percent	
Owner-operators / Part owner-operators	297	221	74	57	19	$172
All tenant-operators	235	158	67	68	29	204
Tenants (related)	138	87	63	45	33	201
Tenants (nonrelated)	97	71	73	23	24	208

† The difference between the total of the "no" and "yes" columns and 100 percent is accounted for by farmers not reporting on the question.

tal could be borrowed for increased fertilizer use. Eighty-one percent of the owner and part owner-operator group and 79 percent of the tenant-operators indicated they could borrow funds specifically for fertilizer use. Owners might be expected to have less trouble borrowing money than tenants, but the basic data for table 18 do not indicate a significant difference.

Even though most farmers indicated they could borrow funds for fertilizer, only 4 percent did borrow funds for fertilizer. The small number borrowing for fertilizer may be partly explained as follows: Farmers may purchase fertilizer from their own funds and borrow funds for general operating expense with livestock or other assets as security. It is doubtful if 80 percent of the farmers could actually borrow for fertilizer even though they stated that they thought they could.

There is still a disparity between (1) actual spending and (2) expenditure considered most profitable by the farmers. It is not explained by the borrowing activities expressed above. Some farmers do not consider it proper to borrow for production. Others may not want to take the risk involved in borrowing an added $100 to $500 for fertilizer even though it is a prospectively profitable investment.

Relationship Between Level of Risk and Use of Additional Funds for Fertilizer

On the basis of data presented earlier, it seems that a more efficient use of fertilizer might be obtained if risks involved in borrowing money for fertilizer were reduced. Risk in using borrowed money for fertilizer may be reduced in several ways. While these methods are not analyzed in this study, the data in table 19 indicate that 25 percent of the farmers interviewed would use more fertilizer if they could do so without mortgaging other assets and could have a repayment schedule corresponding to returns from fertilizer.

Nineteen percent of the owners and part owner-operators indicated they would use more fertilizer if they could borrow without added security as compared with 29 percent in the renter group (table 19). The number of farmers (20 to 30 percent) indicating that they would borrow under these conditions illustrate self-rationing of capital. Self-rationing of capital occurs when a farmer voluntarily limits his borrowing to an amount less than loan firms would be willing to provide.

Borrowing With a Loan Repayment Schedule

To investigate the possible effects of a repayment schedule on fertilizer use, farmers were asked how much money they would have been willing to borrow for fertilizer in 1953 if the repayment schedule were to correspond with the expected rate of returns; that is, a payment schedule which assumes all returns from nitrogen is in the first year and the return from phosphate on grass and legume seeding is one-third at the end of the first year, one-half at the end of the second year and the remainder at the end of the third year? This method allows payment to be made as returns from fertilizer inputs are obtained. The effect would be to reduce the risk involved in borrowing money for fertilizer.[17]

[17]This repayment schedule may not be much aid to tenants, however, since many may not plan more than 1 year in advance, because of the possibility of not being on the farm the next year. Thus, unless there were some arrangements for the payments to be taken over by the landlord or the next tenant, the situation may not be much improved. The amount to be borrowed under repayment schedule for tenants averaged $204, while the

Functional Relationships of Variables Related to Fertilizer Use

Previous sections have dealt mainly with the characteristics of fertilizer users, the pattern of fertilizer use and some fairly discrete attributes related to fertilizer use. The sections which follow represent an attempt to make quantitative predictions of the relationship of the quantity of fertilizer used and selected variables which appear important in the farmer's decision-making environment. It is quite obvious that not all of the factors or variables related to fertilizer use can be quantified or measured. The variance in fertilizer use unexplained by the variables described below must be attributed to other factors such as custom, inertia, economic uncertainty, lack of technical education and the like.

In the following analysis, regression equations have been derived to estimate the quantitative relationships between fertilizer use and selected variables. For the regression analysis, it was not possible to quantify such variables as type of soil, type of lease, climate and similar aspects of the farm environment. The initial variables considered in the regression analyses included working capital, equity, anticipated yield response from fertilizer, fertilizer used in the previous year, anticipated product price, uncertainty about expectations and size of farm. Some of these variables were later omitted from the analysis because they could not be measured with sufficient accuracy or over a sufficient range. Only the three northern soil areas (1, 2 and 8) were selected for this particular analysis.[18] This restriction was used as an attempt to obtain a more homogeneous population with respect to the variables held constant (e.g., soil, climate, etc.).

Some additional variables were included in a preliminary regression analysis. Where their t values[19] were less than the magnitudes acceptable at a 30-percent probability level (the level arbitrarily selected as appropriate for data of the nature included in this study), they were omitted from the analysis. Statistics related to these variables are presented in Appendix D.

Several regression estimates were completed. These include predictions of: (1) total fertilizer use for both owner-operated and tenant-operated farms, (2) nitrogen used on corn for both owner-operated and tenant-operated farms, (3) the difference between actual use of fertilizer and the quantity of fertilizer estimated by farmers to be most profitable for both types of tenure, (4) the proportion of $1,000 additional capital used for fertilizer under both types of tenure, (5) yield variability or uncertainty in relation to fertilizer use for both owner-operated and tenant-operated farms and (6) farmers' subjective demand curve for nitrogen on corn for both types of tenure and for both first-year and second-year corn. The variables used in these predictions and the resulting statistics are presented below.

Function Used

The logarithmic equation has been used for most of the estimates. This equation,

$$Y = \alpha X_1^{B_1} X_2^{B_2} \quad . \quad . \quad . \quad . \quad X_n^{B_n},$$

permits the interaction of variables with a minimum number of parameters[20] to be determined and allows the expression of curvilinear relationships. Restrictions imposed by this form of equation are that the elasticity of each variable is constant, and the marginal values are either increasing, decreasing or constant throughout the range. The assumption of constant elasticity is justified only if it approximates the actual relationship in the range of data being examined. Advantages in ease of computation and interpretation from using the logarithmic equation will usually offset a small increased amount of error in estimates relative to other applicable algebraic equations. However, as illustrated later, a quadratic equation better fits the anticipated corn-yield responses from nitrogen fertilizer use than the logarithmic equation.

Relationships Among Extent of Total Fertilizer Use and Certain Capital and Physical Factors[21]

EXTENT OF TOTAL FERTILIZER USE PER FARM

Owner-operated farms. The final variables related to the extent of owner-operators' use of all fertilizer were capital investment, fertilizer used the previous year and size of farm. The summary of the regression analyses of extent of all fertilizer used and related variables for both owner- and tenant-operated farms is presented in table 20.

Size of farm was highly significant and most closely related to the extent of total fertilizer use by owner-operators. A 1-percent change in farm size was positively associated with an average of 0.64-percent change in tons of all fertilizer used per farm—a less than proportional relationship. The amount of total fertilizer used in previous year was highly significant and positively associated with use in the current year. This relationship is in accord with the general upward trend in fertilizer use in Iowa. A satisfactory estimate of the relationship between capital investment and amount of fertilizer used per farm was not obtained because of the relatively high degree of

(footnote 17, continued)

owners and part owner-operators averaged $172 (table 19). Since the average amount to be borrowed by the tenants was larger than the amount to be borrowed by owner-operators, the uncertainty of tenure may be offset by other factors. The soil on tenant farms may be rundown from poor rotations and, thus, the yield response may be large enough to offset the uncertainty involved.

[18]This analysis, therefore, is representative of soil areas 1, 2 and 8 for the year 1953.

[19]The data resulted from a cluster sample. Statistical techniques for a random sample have been used for a cluster sample; therefore, the t values should be considered as a convenient estimate.

[20]The regression analysis was carried out in the standard form with the logarithm of Y as the dependent variable and the logarithms of X_i as independent variables. The exponents B_i (b'_i = standard partial regression coefficients) are the partial regression coefficients computed in the conventional way.

[21]Detailed statistical summaries of regression analyses contained in this section are presented in Appendix D.

Table 20. SUMMARY OF REGRESSION ANALYSES OF FERTILIZER USE PER FARM AND RELATED VARIABLES, THREE SOIL AREAS OF IOWA, 1953.

Owner-operated farms

Variables:

- (Y) Tons of all fertilizer used per farm
- (X_1) Capital investment
- (X_5) Amount of fertilizer used during previous year
- (X_6) Acres in farm

$$\widehat{Y} = 0.2720\ X_1^{-0.1081}\ X_5^{0.1458}\ X_6^{0.6424} \quad (1)$$

$R_{y\,0.156} = 0.7130$, d.f. = 65

$b'_{y\,1.56} = -0.1010$‡

$b'_{y\,5.16} = 0.3687$**

$b'_{y\,6.15} = 0.5392$**

Tenant-operated farms

Variables:

- (Y) Tons of all fertilizer used per farm
- (X_2) Capital investment
- (X_8) Anticipated corn-yield response from 40 pounds of nitrogen per acre
- (X_9) Amount of fertilizer used during previous year
- (X_{10}) Acres in farm

$$\widehat{Y} = 0.0457\ X_2^{0.1443}\ X_8^{0.2006}\ X_9^{0.1185}\ X_{10}^{0.5699} \quad (2)$$

$R_{y\,0.2,8,9,10} = 0.5576$, d.f. = 62

$b'_{y\,2.8,9,10} = 0.1404$‡

$b'_{y\,8.2,9,10} = 0.1693$†

$b'_{y\,9.2,8,10} = 0.3844$**

$b'_{y\,10.2,8,9} = 0.2777$*

** = $P<0.01$; * = $P<0.05$; † = $P<0.20$; ‡ = $P<0.30$.

correlation between capital investment and size of farm (table 1-D, Appendix D).

Tenant-operated farms. The variables related to total fertilizer used per farm for tenant-operators were: capital investment, expected yield response, total fertilizer used the previous year and size of farm in acres. The data secured for tenant-operated farms yielded a relatively significant relationship between total fertilizer used and capital investment (table 20).[22] A 1-percent change in capital was positively associated with a 0.14-percent change in tons of fertilizer used per farm. The anticipated corn-yield response from the use of 40 pounds of nitrogen per acre was relatively significant in relation to total fertilizer use per farm. The relationship of the extent of total fertilizer use during the previous year to total fertilizer use during year considered was highly significant; and size of farm operated by tenants was significantly related to the tonnage of fertilizer use.

Marginal Use of Total Fertilizer Used on All Crops, Related to Anticipated Corn-Yield Response

The marginal (incremental) or additional use of fertilizer on all crops, as related to unit changes in anticipated corn-yield response to nitrogen, may be obtained by taking the partial derivative of the estimating (regression) equation with respect to the anticipated corn-yield response and by holding the other variables of the equation constant.[23] The results of such an analysis are presented in table 21.[24]

[22]The minimum acceptable level of significance was selected at $P<0.30$. A level of significance between $P<0.30$ and $P<0.06$ was considered relatively significant; $P<0.05$ significant; and $P<0.01$, highly significant.

[23]Variables X_2, X_9 and X_{10} of equation (2), table 20, are held constant.

[24]The marginal (incremental) effects of the other related variables on fertilizer use are presented in tables 5-D to 7-D, Appendix D.

The marginal use of fertilizer (all nutrients) is 0.0474 ton when expected corn-yield response to 40 pounds of nitrogen is 10 bushels and all the other related variables are held constant at half the average for all farms; 0.1184 ton of fertilizer when all other variables are fixed at a 50-percent-greater level than the average for all farms. For any given anticipated corn-yield response to 40 pounds of nitrogen, marginal use of all fertilizer increases with increases in the level of the other variables—namely, capital investment, farm size and total use of fertilizer during the previous year—at a 50-percent-greater level than the average of all farms. Marginal use of fertilizer decreases with increases in the anticipated corn-yield response to 40 pounds of nitrogen per acre (table 21).

Extent of Nitrogen Use

Owner-operated farms. The amount of nitrogen fertilizer farmers use on corn depends on many of the same variables related to the amount of fertilizer used per farm. Hence, a regression analysis, similar to the one for total fertilizer use per farm, was completed for nitrogen use on land in corn. This additional analysis for nitrogen use on corn land was possible because additional questions were asked specifically about corn. The variables related to pounds of nitrogen used per acre in corn were capital investment, equity ratio (ratio of owned capital to total capital) and uncertainty of anticipated corn-yield response from 40 pounds of nitrogen applied per acre. Capital investment was positively related to nitrogen use per acre in corn; equity ratio and nitrogen use per acre in corn were negatively related (table 22). The negative relationship between nitrogen use and equity ratio may result because a large proportion of the owner-operators have an equity ratio of 1, or very close to it.[25]

The uncertainty of corn-yield response was *positively* and significantly associated with nitrogen used per acre in corn (table 22)—though the opposite relationship might be expected—the greater the uncertainty, the smaller the quantity of fertilizer resource used. Since the anticipated yield response was positively associated with the degree of uncertainty of yield response, the effects of anticipated corn-yield responses may have offset the effects of uncertainty of yield response in the regression analysis. The positive relationship (correlation coefficient of 0.25) between anticipated corn-yield response and uncertainty of yield response was not large enough, however, to be significant at the 5-percent level of probability. The estimates of this study appear inconclusive with respect to these relationships. They need to be studied further with a survey designed and controlled specifically for these purposes.

Tenant-operated farms. Capital investment, uncertainty of anticipated corn-yield response and anticipated corn-yield response were related to nitrogen use on land in corn for tenants (table 22). Holding anticipated corn-yield response and uncertainty of yield response constant, a change of 1 percent in capital

[25]An equity ratio of 1 indicates no outstanding debts.

Table 21. MARGINAL USE OF FERTILIZER AT VARIOUS LEVELS OF ANTICIPATED CORN-YIELD RESPONSE FROM 40 POUNDS OF NITROGEN, TENANT-OPERATED FARMS, IOWA, 1953.

Anticipated corn-yield response to 40 pounds of nitrogen	Other variables held at: Half the average for all farms	Average for all farms	50-percent-greater level than the average for all farms
(bushels)		(tons of fertilizer)	
10	0.0474	0.0845	0.1184
15	0.0342	0.0611	0.0856
17.73 (mean)	0.0300	0.0534	0.0749
20	0.0272	0.0486	0.0680
25	0.0228	0.0406	0.0569

investment by the tenant was *positively* associated with a 0.17-percent change in the use of nitrogen on land in corn. On the other hand, a change of 1 percent in uncertainty of anticipated corn-yield response, holding the other variables constant, was *negatively* associated with 0.20-percent change in the amount of nitrogen used per acre of land in corn. A 1-percent change in anticipated corn-yield response, other variables held constant, was *positively* associated with a 0.26-percent change in the amount of nitrogen used on land in corn.

These relationships are in the direction which might be predicted, given the logic of managerial economics. That is: (1) As the tenant controls more capital, his use of nitrogen on land in corn increases. (2) A decrease in uncertainty about corn-yield response is related to an increase of nitrogen use. (3) Nitrogen use also increases as the anticipated yield response from a given input of nitrogen increases.

Marginal Use of Fertilizer and Related Variables — Tenant-Operated Farms

The marginal (incremental) effect of a given variable on nitrogen use was determined by taking the partial derivative of the nitrogen use (regression) equation with respect to the variable under consideration.

Table 22. SUMMARY OF REGRESSION ANALYSES OF NITROGEN USED PER ACRE IN CORN AND RELATED VARIABLES, IOWA, 1953.

Owner-operated farms

Variables:

- (Y) Pounds of nitrogen applied per acre in corn
- (X_2) Capital investment
- (X_3) Equity ratio (ratio of owned capital to total capital)
- (X_7) Uncertainty of corn-yield response from 40 pounds of nitrogen applied per acre

$$\hat{Y} = 4.1130\ X_2^{0.2764}\ X_3^{-0.5862}\ X_7^{0.2479} \qquad (1)$$

$R_{y\ 0.237} = 0.4756$, d.f. = 40

$b'_{y\ 2.37} = 0.2668$†

$b'_{y\ 3.27} = -0.1609$§

$b'_{y\ 7.23} = 0.3028$*

Tenant-operated farms

Variables:

- (Y) Pounds of nitrogen applied per acre in corn
- (X_2) Capital investment
- (X_7) Uncertainty of corn-yield response from 40 pounds of nitrogen applied per acre
- (X_8) Anticipated corn-yield response from 40 pounds of nitrogen per acre

$$\hat{Y} = 2.0160\ X_2^{0.1654}\ X_7^{-0.2012}\ X_8^{0.2574} \qquad (2)$$

$R_{y\ 0.278} = 0.3037$, d.f. = 52

$b'_{y\ 2.78} = 0.1253$§

$b'_{y\ 7.28} = -0.2311$†

$b'_{y\ 8.27} = 0.1664$§

** = $P<0.01$; * = $P<0.05$; † = $P<0.10$; ‡ = $P<0.20$; § = $P<0.30$.

With nitrogen use per acre in corn negatively associated with a unit change in uncertainty of yield, the decrease is 0.154 pound of nitrogen per acre when uncertainty about anticipated corn yield is 15 bushels, while capital investment and anticipated yield response are held at their geometric means. The decrease is 0.115 pound of nitrogen per acre with capital investment and anticipated yield response held at half of their geometric means; 0.183 pound of nitrogen per acre when these variables are held at a level 50 percent greater than their geometric means and when the anticipated corn-yield response is 15 bushels (table 23).

Marginal changes (increases) in the use of nitrogen in relation to incremental changes in capital investment (other variables held constant)[26] are presented in table 24. Table 25 shows marginal changes (increases) in the use of fertilizer in relation to incremental changes in anticipated corn-yield response (other variables held constant).

A change in the tenant farmer's capital investment from $5,000 to $6,000 (with anticipated corn-yield response and degree of uncertainty of yield held constant at the average for all farms) was associated with a marginal change of 0.305 pound of nitrogen used per acre in corn. Fertilizer use would not be proportional to the amount of capital added because part of the funds would be used for other investment alternatives. An increase in capital investment from $12,000 to $13,000 under similar conditions, was associated with an incremental increase of 0.142 pound of nitrogen per acre in corn (table 24).

An incremental change in the tenant farmer's anticipated corn-yield response to 40 pounds of nitrogen per acre at the 5-bushel level was associated with an incremental change of 0.398 pound of nitrogen applied per acre in corn. However, an incremental change in anticipated corn-yield response at the 25-bushel level was associated with an incremental change of 0.120 pound of nitrogen applied per acre in corn (table 25).[27] The greatest increase in the use of nitrogen on corn land may be obtained by increasing the anticipated corn-yield response by those farmers having high capital investment and a minimum amount of uncertainty with respect to corn-yield response.

[26]Variables X_7 and X_8 of equation (2), table 22, are held constant.

[27]Variables X_2 and X_7 of equation (2), table 22, are held constant.

Table 23. MARGINAL USE OF NITROGEN ASSOCIATED WITH INCREMENTAL CHANGES IN UNCERTAINTY ABOUT ANTICIPATED CORN-YIELD RESPONSE, TENANT-OPERATED FARMS, IOWA, 1953.

Uncertainty about anticipated corn-yield response†	Incremental changes (i.e., decrease) in pounds of nitrogen used per acre in corn related to changes in uncertainty about corn-yield response, with other factors held constant at: Half the average for all farms	Average for all farms	50-percent-greater than average for all farms
(mean square error)		(pounds of nitrogen)	
5	– 0.431	– 0.577	– 0.685
15	– 0.115	–0.154	– 0.183
23.03 (mean)	– 0.069	– 0.092	– 0.109
45	– 0.031	–0.041	– 0.049
60	– 0.022	– 0.029	– 0.035

†Uncertainty or variability has been measured by mean square error.

Table 24. MARGINAL USE OF NITROGEN ASSOCIATED WITH $1,000 CHANGE IN CAPITAL INVESTMENT, AT VARIOUS LEVELS OF CAPITAL INVESTMENT, TENANT-OPERATED FARMS, IOWA, 1953.

Capital investment	Incremental change in pounds of nitrogen used per acre in corn associated with a change in $1,000 of capital investment, with other variables at: Half average for all farms	Average for all farms	50 percent greater than average for all farms	X_7 half average, X_8 50 percent greater than average†	X_8 half average, X_7 50 percent greater than average†
(dollars)			(pounds of nitrogen)		
5,000	0.293	0.305	0.312	0.389	0.235
7,500	0.209	0.217	0.222	0.277	0.167
11,460	0.147	0.152	0.156	0.194	0.117
12,500	0.136	0.142	0.145	0.181	0.111
15,000	0.117	0.121	0.125	0.155	0.094

†X_7 = uncertainty of corn-yield response from 40 pounds of nitrogen per acre. X_8 = anticipated corn-yield response from 40 pounds nitrogen per acre.

Table 25. MARGINAL USE OF NITROGEN ASSOCIATED WITH CHANGES IN ANTICIPATED CORN-YIELD RESPONSE AT VARIOUS LEVELS, TENANT-OPERATED FARMS, IOWA, 1953.

Anticipated corn-yield response	Incremental change in pounds of nitrogen used per acre in corn associated with changes in anticipated corn-yield response, with other variables at: Half average for all farms	Average for all farms	50 percent greater than average for all farms	X_7 half average, X_2 50 percent greater than average†	X_2 half average, X_7 50 percent greater than average†
(bushels)			(pounds of nitrogen)		
5	0.453	0.442	0.435	0.543	0.363
10	0.240	0.234	0.231	0.288	0.192
18	0.157	0.153	0.151	0.188	0.126
20	0.144	0.140	0.138	0.172	0.155
25	0.122	0.119	0.117	0.145	0.098

†X_2 = capital investment. X_7 = uncertainty of corn-yield response from 40 pounds of nitrogen per acre.

Relationships Between Estimated Most Profitable and Actual Fertilizer Expenditure and Related Variables

The regression analysis of this section deals with the difference between farmers' actual expenditures for fertilizer and the expenditures which they viewed as being most profitable.

The difference between actual fertilizer expenditures and farmers' estimated most profitable fertilizer expenditure will be referred to as the "difference." This difference indicates a restriction to the optimum economic use of fertilizer by the farm operator. In the analyses presented below, the independent variables of fertilizer use experience, capital investment, equity ratio and amount of manure applied per acre are used to predict this difference as the dependent variable.

Owner-operated farms. Measures of corn-price uncertainty and uncertainty with respect to anticipated corn yields apparently were not significantly related to the difference variable (table 14-D, Appendix D). However, capital investment and equity ratio were related (significantly at the probability levels used in this study) to the difference variable for owner-operated farms. A 1-percent change in capital investment (equity ratio held constant) was positively associated with a 0.64-percent change in the difference (table 26). However, a 1-percent change in equity ratio (capital investment held constant) was negatively associated with a 2.69-percent change in the difference.

Those owner-operators having greater capital investments in their farms considered themselves furthest from their estimated optimum level of fertilizer use. On the other hand, those owner-operators in the most favorable equity positions considered themselves nearest their estimated optimum level of fertilizer use.

Table 26. SUMMARY OF REGRESSION ANALYSES OF THE DIFFERENCE BETWEEN ESTIMATED MOST PROFITABLE FERTILIZER EXPENDITURES AND ACTUAL FERTILIZER EXPENDITURE, AND RELATED VARIABLES, IOWA, 1953.

Owner-operated farms

Variables:

- (Y) Difference (estimated most profitable fertilizer expenditure minus actual fertilizer expenditure)
- (X_2) Capital investment
- (X_3) Equity ratio (ratio of owned capital to total capital)

$\hat{Y} = 0.0829\ X_2^{0.6389}\ X_3^{-2.6911}$

$R_{y\ 0.23} = 0.3068$, d.f. = 71

$b'_{y\ 2.3} = 0.2180$†

$b'_{y\ 3.2} = -0.2272$*

Tenant-operated farms

Variables:

- (Y) Difference (estimated most profitable fertilizer expenditure minus actual fertilizer expenditure)
- (X_1) Extent of fertilizer experience
- (X_2) Capital investment
- (X_6) Manure used per acre

$\hat{Y} = 0.0641\ X_1^{-0.8202}\ X_2^{0.3469}\ X_6^{0.2793}$

$R_{y\ 0.126} = 0.3326$, d.f. = 85

$b'_{y\ 1.26} = -0.2348$†

$b'_{y\ 2.16} = 0.1485$‡

$b'_{y\ 6.12} = 0.1764$†

* = $P<0.05$; † = $P<0.10$; ‡ = $P<0.20$.

Apparently the difference increases as farm size (reflected by capital investment) increases. Hence, it is expected that the greatest potential for future increases in total fertilizer use per farm still exists on relatively large owner-operated farms in Iowa—even though these farmers are now using the largest amounts of fertilizer.

Tenant-operated farms. The variables related significantly to the difference variable for tenant-operated farms were extent of farmer's experience, capital investment and manure used per acre. A 1-percent change in the tenant's fertilizer experience (capital investment and manure used per acre held constant) was negatively associated with an 0.82-percent change in the difference (table 26). That is, if the tenant was then using a relatively large amount of fertilizer, there was a smaller gap between actual use and level of use thought to be most profitable. The size of this gap, then, increases with the smallness of the quantity of fertilizer used previously. A 1-percent change in the tenant's capital investment (fertilizer use experience and use of manure per acre held constant) was positively associated with a 0.28-percent change in the difference. Again, the farmers with the most capital are those who feel that they could use the largest amounts of additional fertilizer, if they were to maximize profits.

Gaining experience in fertilizer use is a time-consuming process. Therefore, since an increase in fertilizer use experience is associated with a decrease between actual fertilizer use and estimated optimum fertilizer use, any process designed to speed up the dissemination of information about the effects and profitableness of using fertilizer should result in greater fertilizer use.

Relationships Between the Use of Additional Capital for Fertilizer and Related Variables

When a farmer is confronted with the opportunity to obtain additional capital, he is faced with making the decision of where he can most profitably use this resource—the use or uses where the greatest marginal returns can be obtained. This marginal return may be in the form of direct satisfaction from new machinery or home facilities as well as from dollar returns.

Since this study did not include direct measurements of the attractiveness of alternative investment of funds, certain variables were selected which might be related to these alternatives. In the survey questionnaire, farmers were asked how they would spend an additional $1,000 if it were made available. The proportion of the $1,000 they would spend for fertilizer is the variable to be predicted. Using this proportion as the dependent variable, a regression equation was derived with the following independent variables: fertilizer used in the current year, total capital investment, capital investment in livestock and anticipated yield response the farmer expects from fertilizer.

Owner-operated farms. The amount of fertilizer used in the current year was the only variable significantly related to the proportion of the $1,000 to be used for fertilizer. This relationship indicates that those farmers already using the most fertilizer would be willing to spend the largest proportion of the additional $1,000 for fertilizer. A change of 1 percent in the amount of fertilizer used in the current year was positively related to a 0.22-percent change in the proportion of additional $1,000 to be used for fertilizer (table 27). Evidently, those farmers who have ventured to use larger amounts of fertilizer best understand this practice and the yield responses from it.

Tenant-operated farms. Capital investment was the only variable significantly related to the proportion of an additional $1,000 to be used for fertilizer. A 1-percent change in capital investment was positively associated with a 0.24-percent change in the proportion of additional $1,000 to be used for fertilizer (table 27). This relationship suggests that tenant farmers who have a greater capital investment also think it would be to their advantage to invest a larger proportion of the additional $1,000 for fertilizer. Alternatively, the data may suggest that, if the tenant has more capital, he has already exploited investment opportunities in crops, livestock, buildings or machin-

Table 27. SUMMARY OF REGRESSION ANALYSES OF USE OF AN ADDITIONAL $1,000 CAPITAL AND RELATED VARIABLES, IOWA, 1953.

Owner-operated farms

Variables:

- (Y) Proportion of an additional $1,000 spent for fertilizer
- (X_1) Extent of fertilizer use

$\hat{Y} = 3.8730\ X_1^{0.2243}$

$r = 0.3003$‡, d.f. = 20

Tenant-operated farms

Variables:

- (Y) Proportion of additional $1,000 spent for fertilizer
- (X_2) Capital investment

$\hat{Y} = 7.7520\ X_2^{0.2397}$

$r = 0.4096$†, d.f. = 24

† = $P<0.10$; ‡ = $P<0.30$.

ery which may return more than fertilizer. Hence, a larger proportion of added capital may be used profitably for fertilizer.

The analysis presented in this section is based on a sample designed mainly to provide descriptive characteristics of fertilizer use. Failure to find significant relationships between use of fertilizer and additional capital, and other variables, may result because the sample design was not most appropriate for the purposes. Perhaps a sample carefully stratified by the important independent variables would have been more effective for the analysis. It would have allowed for a much greater range of observation for some variables than were encountered in this study. Also, it would have allowed for less variance in other variables (i.e., greater homogeneity within a "treatment") which were considered to be "constants" for this analysis. Additional considerations, such as these should be included in future studies which attempt to provide predictions of the use of capital and fertilizer.

Relationships Between Anticipated Yield Variability and Related Variables

This section deals with farmers' anticipated yield response for nitrogen in corn. Regression equations have been derived separately for tenant- and owner-operated farms.

Owner-operated farms. Fertilizer use experience and expected yield response were significantly related to anticipated yield variability on owner-operated farms. If fertilizer use experience was increased 1 percent (holding the expected yield response constant) the anticipated variability of corn-yield response was negatively associated (i.e., declined) by 0.45 percent. Increased fertilizer use experience appears to decrease the uncertainty of corn yield expected from applications of nitrogen fertilizer. If the expected yield response was changed 1 percent (holding fertilizer use experience constant) the uncertainty of expected corn-yield response was positively associated (i.e., increased) by 0.55 percent (table 28).

Table 28. SUMMARY OF REGRESSION ANALYSES OF ANTICIPATED VARIABILITY OF CORN-YIELD RESPONSE AND RELATED VARIABLES, IOWA, 1953.

Owner-operated farms

Variables:

(Y) Expected variability of corn-yield response
(X_1) Extent of fertilizer experience
(X_3) Anticipated corn-yield response from 40 pounds of nitrogen applied per acre

$\hat{Y} = 7.2880\ X_1^{-0.4464}\ X_3^{0.5538}$

$R_{y\ 0.13} = 0.2681$, d.f. = 52

$b'_{y\ 1.3} = -0.1759\dagger$

$b'_{y\ 3.1} = 0.1998\dagger$

Tenant-operated farms

Variables:

(Y) Expected variability of yield response
(X_3) Anticipated corn-yield response from 40 pounds of nitrogen applied per acre

$\hat{Y} = 12.0100\ X_3^{0.2503}$

$r = 0.0200\S$, d.f. = 63

† = P<0.15 ; ‡ = P<0.20 ; § = P<0.30.

Table 29. SUBJECTIVE CORN-YIELD RESPONSE FUNCTIONS BY SOIL AREA, TENURE AND FIRST- AND SECOND-YEAR CORN, IOWA, 1953.

Soil area	Soil associations	Tenure	Year after meadow	$Y = b_1N + b_2N^2$ b_1	b_2
1	Clarion-Webster	Owner	1	0.47259	−0.0022363
			2	0.55951	−0.0028466
		Tenant	1	0.49604	−0.0021781
			2	0.57997	−0.0028396
2	Carrington-Clyde	Owner	1	0.57725	−0.0027259
			2	0.53108	−0.0023873
		Tenant	1	0.55019	−0.0023535
			2	0.61651	−0.0027309
8	Marcus-Primghar-Galva-Sac	Owner	1	0.48788	−0.0024799
			2	0.61830	−0.0026985
		Tenant	1	0.53279	−0.0027388
			2	0.70960	−0.0039776
1, 2 and 8	Three soil areas, pooled	Owner	1	0.50187	−0.0024197
			2	0.56303	−0.0026749
		Tenant	1	0.52566	−0.0023394
			2	0.61498	−0.0029572
		Combined	1	0.51388	−0.0023611
			2	0.59071	−0.0028196
			1 and 2	0.55230	−0.0025903

Tenant-operated farms. The anticipated corn-yield response was the only variable found to be significantly associated with anticipated yield variability on tenant farms. A change in the expected corn-yield response by 1 percent was associated with a 0.25-percent change variability of yield response (table 28). The tenant's experience with fertilizer did not seem to be related to expected variance of corn-yield response. This lack of relationship may be explained by the fact that tenants move more often than owner-operators and thus have their experience with fertilizer use under a greater variety of conditions. This situation may cause difficulties in estimating anticipated yield on tenant farms at the time of study.

Farmers' Anticipated Crop-Yield Response and Demand Functions as Related to Fertilizer Use and Prices

When farmers make decisions on the amount of fertilizer to use, they most likely have some notion about the increased yield to be expected from various uses of fertilizer. For example, a farmer may expect a corn-yield increase of 10, 17, 22 and 25 bushels of corn per acre as a response from an application of 20, 40, 80 and 120 pounds of nitrogen per acre. This section includes a summary of the yield response farmers in the three soil areas (1, 2 and 8) expected from various quantities of nitrogen on corn. These data should provide some notion of whether farmers, on the average, have sufficient knowledge of fertilizer response. If the expected response appears low relative to agronomic research and possibilities, fertilizer use might well be increased by further education on responses. The relationship between anticipated yield increases and fertilizer application is termed the "anticipated yield response function" in the discussion below.

Anticipated Corn-Yield Response to Nitrogen

To measure farmers' expected response functions by

Table 30. ANTICIPATED CORN-YIELD RESPONSE ESTIMATED FROM SUBJECTIVE RESPONSES FOR CORN GROWN FIRST AND SECOND YEAR AFTER MEADOW, BY SOIL AREA AND TENURE GROUP, IOWA, 1953.

Rate of application nitrogen (pounds)	Soil area 1, Clarion-Webster		Soil area 2, Carrington-Clyde		Soil area 8, Marcus-Primghar Galva-Sac		Average for the 3 soil areas		Combined
	Owner	Tenant	Owner	Tenant	Owner	Tenant	Owner	Tenant	
Corn first year after meadow, bushels									
20	8.6	9.0	10.5	10.1	8.8	9.6	9.1	9.6	9.3
40	15.3	16.4	18.7	18.2	15.6	16.9	16.2	17.3	16.8
80	23.5	25.7	28.7	29.0	23.2	25.1	24.7	27.1	26.0
120	24.5	28.2	30.0	32.1	22.9	24.5	25.4	29.4	27.7
Corn second year after meadow, bushels									
20	10.1	10.5	9.7	11.2	11.3	12.6	10.2	11.1	10.7
40	17.8	18.7	17.4	20.3	20.4	22.0	18.2	19.9	19.1
80	26.5	28.2	27.2	31.8	32.2	31.3	27.9	30.3	29.2
120	26.2	28.7	29.4	34.7	35.3	27.9	29.0	31.2	30.3

varying quantities of nitrogen applied to corn, a regression equation was derived relating farmers' subjective yield estimates and level of nitrogen use. Two regression equations (quadratic and logarithmic) were employed initially. Since the quadratic equation provided more efficient estimates than the logarithmic function, it was used to develop the predictions which follow. In this function, $Y = a + b_1N + b_2N^2$, Y is the total expected response in corn yield (above a zero rate of fertilizer application), and N is the amount of nitrogen in pounds. These estimates were obtained by asking farmers to estimate the yield responses expected respectively from applications of 20, 40, 80 and 120 pounds of nitrogen per acre for first- and second-year corn.

The anticipated response functions showing the average relationship between pounds of nitrogen applied per acre in corn and farmers' anticipated corn-yield responses were computed separately for each of two tenure groups (owner-operator and tenant-operator) in each of three soil areas (1, 2 and 8). Corn-yield response functions were also computed separately for first- and second-year corn for each of the above tenure groups and soil areas. The estimates of the average anticipated corn-yield response for various levels of nitrogen application presented in table 30 are derived from the yield-response equation presented in table 29.

The regression equations for the yield response of second-year corn were significantly greater than for first-year corn.[28] This relationship is to be expected, i.e., the nitrogen readily available to the corn crop immediately following meadow is largely consumed. Thus, responses to nitrogen applied on second-year corn are nearly always greater than on first-year corn following a good meadow. The tenant-operators' estimates of corn-yield response tended to be higher than owner-operators' estimates. The differences, however, were not significant at the 5-percent level of probability.

Comparison of Farmers' Anticipated and Experimental Corn-Yield Response Functions

It is of interest to compare farmers' estimates of corn-yield response with results from actual agronomic experiments to determine the average size of difference between them. Experimental yield response estimated from actual experiments in soil area 2 and yield response estimated by farmers in soil area 2 are presented in table 31. The average corn-yield response estimated by farmers and by experimentation are similar. The closeness of the average estimates do not, however, indicate that all farmers make accurate estimates of yield response. Some farmers were considerably above the average; some were considerably below. Many of the farmers who estimated yield responses for 20- and 40-pound nitrogen applications per acre did not estimate yield response for higher levels of application. Forty-two percent of 198 farmers did not estimate yield response for 80 pounds or more of nitrogen.

A smaller percentage did not estimate corn-yield responses for the 20- and 40-pound levels. Some farmers estimated a yield response of 10 bushels whether 20 or 120 pounds of nitrogen per acre were applied. The farmers' average estimated corn-yield response for area 2 compared closely with an estimated yield response. However, the wide variation in response patterns and the large percentage of farmers not giving yield estimates indicate that there is still much need for dissemination of sound yield information.[29]

Derived Demand for Nitrogen

A "derived demand schedule" for nitrogen was

[28]The difference is significant at the 0.01-level of probability. The statistics for this test are given in table 23-D, Appendix D.

[29]The farmers' estimates of yields for the area represent an unbiased estimate for the particular soil area. It is doubtful, however, that the same can be said about experimental results, since they represent a "judgment location" of particular experiments.

Table 31. CORN-YIELD RESPONSES ESTIMATED FROM FARMERS' ANTICIPATED CORN-YIELD RESPONSE FUNCTION AND EXPERIMENTAL RESPONSE FUNCTION, SOIL AREA 2, IOWA, 1953.

Pounds of nitrogen	Estimated corn-yield response from nitrogen estimated with: Farmers' anticipated response function† (bushels)	Experimental response‡ (bushels)
20	10.3	12.0
40	18.5	16.0
80	29.0	- -

†Estimates derived from farmers' anticipated response function.

‡FSR-89. Estimates from unpublished experimental data, Department of Agronomy, Iowa State College, Ames, Iowa.

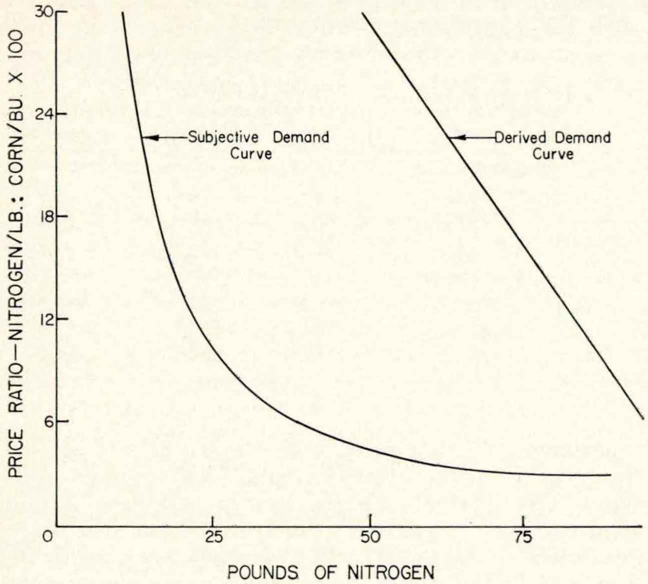

Fig. 9. Derived demand and subjective curves for nitrogen fertilizer.

computed from the farmers' estimated corn-yield response function. This demand schedule reflects the levels of nitrogen use which would have been most profitable on the basis of (a) farmers' notions of the nitrogen-response function for corn, and (b) various price-cost situations (i.e., various combinations of corn-price and nitrogen-costs). The demand schedule is plotted as the upper curve in fig. 9. The derivation of one point on the derived demand curve is illustrated in table 32.

Inputs or various levels of nitrogen are listed in column 1. Anticipated corn-yield responses corresponding to the nitrogen levels are presented in column 2. These have been derived from the equation presented earlier of farmers' anticipated yield responses from nitrogen. They are simple averages of the first- and second-year response functions (discussed previously). The value of the total yield response in column 2 is shown in column 3. The cost of nitrogen (shown in column 1) is presented in column 4. The difference between the value of the total yield response and the total cost is in column 5. The largest difference, a net return of $23.88, is for 80 pounds of nitrogen. Hence, using simple methods of calculation, this quantity of nitrogen would be most profitable with corn at $1.30 per bushel and nitrogen at 15 cents per pound. However, in the calculations underlying the derived demand curve of fig. 9, more "exact" procedures were used (i.e., the price ratio was equated to the derivative of the farmers' anticipated response function). This example refers to a single point on the derived demand function. The same procedure was used in computing other points on the curve.

These types of data indicate the amount of nitrogen, as an average for first- and second-year corn, which would be most profitable under various corn-fertilizer price ratios, given (1) farmers' estimates of the response function and (2) unlimited capital. A farmer, however, may not use fertilizer to this optimum level, even though he has the estimates of yield response presented earlier. The farmer may discount the returns because of uncertainty; he may have only a limited amount of capital and need to use funds elsewhere in the business where they return more. Here, it is the return from fertilizer as compared with the return from other enterprises which determines the amount which should be used for fertilizer. In other words, the farmer must arrive at some notion of the percentage return on his money invested in fertilizer. These results must be compared formally or informally with similar figures for other investment opportunities. Column 6 of table 32 shows the nature of these figures, based on farmers' response functions (i.e., the first- and second-year average) presented earlier with corn at $1.30 per bushel and nitrogen at 15 cents per pound. They would differ for other price situations. In this case, however, if the farmer could get a return of 150 percent on hog feed, he would not invest up to 60 pounds of nitrogen where the percent return is only 107.[30] Further evidence of these gaps which prevent equating marginal costs and returns for fertilizer is given by the subjective demand estimates which follow.

Subjective Demand Function for Nitrogen

The "derived demand curve" was computed to indicate the levels of nitrogen use which would have been most profitable if (a) farmers tried to equate

[30]These are merely examples and represent a simple weighting of results from first- and second-year corn anticipated response functions. The percent returns are computed on the basis of marginal products (i.e., the derivatives) at "exactly" the total nitrogen inputs of column 1.

Table 32. ANTICIPATED CORN-YIELD RESPONSE FROM NITROGEN, COST AND RETURNS FROM NITROGEN USED ON LAND IN CORN, IOWA, 1953.

Pounds of N	Anticipated corn-yield response in bushels	Value of corn from N†	Cost of nitrogen‡	Net return from use of nitrogen	Percent return on last dollar invested in nitrogen
(1)	(2)	(3)	(4)	(5)	(6)
20	10.0	$13.00	$ 3.00	$10.00	287
40	17.9	23.27	6.00	17.27	200
60	23.8	30.94	9.00	21.97	107
80§	27.6	35.88	12.00	23.88	20
100	29.3	38.09	15.00	23.09	–66
120	29.0	37.70	18.00	17.70	–160

†$1.30 per bushel of corn.
‡$0.15 per pound of nitrogen.
§Optimum level of nitrogen use is 84 pounds.

Table 33. SUBJECTIVE DEMAND SCHEDULES FOR NITROGEN, AREAS BY TENURE, IOWA, 1953.

Price of nitrogen per pound	Price corn per bushel	Price ratio x100	Soil area 1, Clarion-Webster		Soil area 2, Carrington-Clyde		Soil area 8, Marcus-Primghar-Galva-Sac		Average for 3 soil areas		Over-all schedule
			Owner	Tenant	Owner	Tenant	Owner	Tenant	Owner	Tenant	
			(pounds of nitrogen)								
$0.06	$2.00	3.0	83	67	80	70	62	53	80	66	72
0.075	2.00	3.8	66	54	69	58	52	46	64	55	59
0.075	1.50	5.0	51	42	52	48	43	39	49	44	47
0.126	2.00	6.3	40	34	41	40	36	34	40	37	38
0.075	1.00	7.5	34	29	34	35	32	31	34	32	33
0.126	1.50	8.4	30	26	30	32	29	29	30	29	30
0.075	0.75	10.0	26	22	25	28	26	26	26	25	26
0.126	1.00	12.7	20	18	20	24	21	23	20	21	21
0.126	0.75	16.9	15	14	15	19	17	19	16	17	16
0.15	0.50	30.0	9	8	8	13	11	14	9	11	10

the marginal costs and marginal returns from using fertilizer, (b) their estimates of returns had been based on the average of their first- and second-year corn response function, and (c) price ratios were at various levels. However, because of the capital and uncertainty conditions outlined above, farmers would not necessarily use fertilizer at the indicated levels.

This study does, however, provide a basis for estimating how much nitrogen farmers would use per acre of corn if price ratios were at different levels. These figures have been used to derive a *subjective* demand curve for nitrogen on corn (pounds per acre). It differs from the *derived* demand curve (see last section) in this respect: The subjective demand curve indicates the per-acre level of fertilization farmers suggest they actually would use, considering their capital, uncertainty and knowledge situations; the derived demand curve suggests the level which would have been most profitable, considering the restraints mentioned previously. The regression equation for the subjective demand function is presented below. Q refers to the quantity of ammonium nitrate (33 percent nitrogen) and P refers to the price ratio.[31]

$$Q = 65.33\ P^{-0.86672}$$

The schedule of quantities derived from this equation for various price ratios is presented in the last column (over-all schedule) of table 33. These values are presented as the lower curve (subjective demand curve) in fig. 9. The subjective demand schedules for each of three soil areas (1, 2 and 8) and by tenure group (owner and renter) which were derived from similar equations are also presented in table 33.

[31]The price ratio is the ratio of the price of nitrogen per pound to the price of corn per bushel multiplied by 100. For example, when the price per pound of nitrogen is $0.06, dividing $0.06 by $2 and multiplying by 100 yields a price ratio of 3.0, which is the first number listed in the price ratio column of table 32.

APPENDIX A

SAMPLING, ESTIMATION AND RELIABILITY MEASURES

Sampling Procedures

The universe for this investigation is the state of Iowa. Independent estimates for each of the nine soil areas in the state were made possible by considering these soil areas separately in the sample design. Each soil area was delineated following township boundaries; the number of farms within each area was extrapolated from the 1950 census.[32]

Following soil areas and township boundaries, 150 strata of approximately equal size in number of farms (average of 1,355 farms) were created throughout the state.[33] Two sampling units were drawn from each of the strata.[34] All zones, open country, urban and rural areas were sampled. Farms in rural areas and urban locations were identified with open-country sampling units lying contiguous to these areas. The area sampling units were ½ to 1½ square miles in area.

This statified random sample design with a constant sampling rate of 1/338.6 permits unbiased estimates for each soil area, or any combination thereof, by multiplying the sample total by the inverse of the sampling rate, i.e., 338.6.

Interviewers identified farms in the sample by means of the headquarters rule.[35] By this method each farm had one and only one chance of being included in the sample.

The total number of farms in the sample is 532.

[32]Since relevant census data are not published on a township basis, the number of farms for each township was estimated by the township average for each county where a county was not entirely in one soil area.

[33]King, A. J. and Jessen, R. J. The master sample of agriculture. Jour. Amer. Stat. Assn. 40: 38-56. 1945.

[34]The expected size of each sampling unit was two farms.

[35]The farm is considered to be in a segment if the location of the farm headquarters lies within its boundaries.

TABLE 1-A.

Soil area	Number of census farms (1950)	Number of strata	Number of segments†
1	43,519	32	64
2	30,940	23	46
3	16,153	12	24
4	36,227	27	54
4a	14,821	11	22
5	20,411	15	30
6	15,097	11	22
7	10,966	8	16
8	15,025	11	22
Total	203,159	150	300

†A segment is a sampling unit designated in the sample.

Table 2-A. ESTIMATES AND RELATIVE SAMPLING ERRORS, NUMBERS OF FARMS AND ACRES PER FARM IN IOWA.

Item	Sample total	State estimate†	Relative sampling error (%)‡	95-percent confidence limits§
Number of farms	532	180,135††	2.59	170,804–189,466
Acres in farm	102,026	34,546,004††	3.74	31,961,962-37,130,046

†Obtained by multiplying the sample totals by the inverse of the sampling rate, 338.6.
‡Computed by the use of analysis of variance for a stratified random sample.
§The 95-percent confidence limits are calculated: Estimate ± (2)(R.S.E.%)(Estimate). For example, we are 95 percent confident that the interval 170,804-189,466 includes the "true" total number of farms in Iowa.
††In this study, all the land operated by one person or partnership was defined as one farm if the land was in Iowa. Since the estimate of 34,546,004 acres in farm agrees so closely with the 1950 census figure of 34,264,639, it is feasible that the discrepancies between the 1953 survey estimate of 180,135 farms and the 1950 census figure, 203,159, are due to differences in definition and the continual consolidation of farms.

Information was obtained on 478 of the 532 designated for interview. Field substitutions from the nearest farm, not in the sample area, were made from 43 farms on which information was not obtainable at the time of the field work.[36] These figures represent a completion rate of 90 percent on the originally designated farms, and 98 percent of all the farms, including the substitutes.

Estimation and Reliability Procedures

Unbiased estimates of Iowa totals were obtained by multiplying any of the sample totals by the inverse of the sampling rate which in this case was 338.6:

$$\hat{T} = 338.6 \sum_{i=1}^{150} \sum_{j=1}^{2} x_{ij} ;$$

[36]Reasons for substitutions were: (1) not at home after three calls (on vacation, etc.), (2) illness and (3) refusals (less than 1 percent of the total, however). The remaining 11 farms were improperly identified or the interviewer could not obtain a proper substitution. Information from farmers in the same or adjoining segments were randomly selected for duplication in the tabulation of the data for these 11 farms.

where $\hat{T}$, for example, could be the estimate of the total number of the farms in Iowa, and x_{ij} the total number of farms in the j^{th} segment of the i^{th} stratum.

The estimated variance of this estimate is obtained from the within-strata mean square in an analysis of variance.

To estimate averages, a ratio estimator was used:

$$\bar{x} = \hat{T}_1 / \hat{T}_2 ;$$

where, for example, $\bar{x}$ could be the estimated acres per farm, $\hat{T}_1$ the estimated total acres of land in farms, and $\hat{T}_2$ the estimated total number of farms.

The estimated variance of this estimator may be obtained through the use of an analysis of variance and covariance.

The following estimates and relative sampling errors of these estimates are presented in table 2-A.[37]

[37]The methodology used in the estimation of a total, relative sampling error and ratio estimates, may be found in: Cochran, W. G. Sampling techniques. John Wiley and Sons, Inc., New York. 1953.

APPENDIX B

STATISTICAL SUMMARY OF INFORMATIONAL SOURCES IMPORTANT IN THE ACCEPTANCE AND USE OF FERTILIZER

Table 1-B. PERCENTAGE DISTRIBUTION OF FERTILIZER USERS ACCORDING TO MOST IMPORTANT ORIGINAL SOURCE OF INFORMATION AND EDUCATIONAL EXPERIENCE.†

	Educational experience				
Most important source of information	Grade school	Some high school	Completed high school	Some college	Total
Number reporting	175	50	115	25	365
Percent	100	100	100	100	100
Noticed better stands on other farms	33.1	38.0	35.7	12.0	33.2
Other farmers told about higher yields	28.6	14.0	20.0	32.0	24.1
Reading articles in farm magazines and papers	14.3	18.0	16.5	32.0	16.7
Experience on home farm before starting on own	9.2	8.0	9.6	4.0	8.8
Attending field days and demonstrations	1.7	10.0	7.8	4.0	4.9
Fertilizer salesman or dealer	5.7	2.0	2.6	0.0	3.8
Attending meetings by county extension personnel	1.7	6.0	4.4	0.0	3.0
Reading bulletins, *Iowa Farm Science* and other materials from Iowa State College	2.3	0.0	1.7	12.0	2.5
Heard program on radio or television	1.7	0.0	0.0	0.0	0.8
Did not remember	1.7	4.0	1.7	4.0	2.2

†$X^2 = 45.32$*.

Table 2-B. PERCENTAGE DISTRIBUTION OF FERTILIZER USERS ACCORDING TO THE MOST IMPORTANT ORIGINAL SOURCE OF INFORMATION AND YEARS OF FERTILIZER EXPERIENCE.†

	Years of fertilizer experience			
Most important source of information	1 - 3 years	4 - 7 years	8 years and over	Total
Number reporting	114	127	124	365
Percent	100	100	100	100
Noticed better stands on other farms	28.9	33.1	37.1	33.2
Other farmers told about higher yields	36.0	16.5	21.0	24.1
Reading articles in farm magazines and papers	11.4	22.1	16.2	16.7
Experience on home farm before starting on own	5.3	8.7	12.1	8.8
Attending field days and demonstrations	6.1	5.5	3.2	4.9
Fertilizer salesman or dealer	7.9	0.8	3.2	3.8
Attending meetings by county extension personnel	0.0	5.5	3.2	3.0
Reading bulletins, *Iowa Farm Science* and other materials from Iowa State College	0.9	3.9	2.4	2.5
Heard program on radio or television	1.8	0.0	0.8	0.8
Did not remember	1.7	3.9	0.8	2.2

†$X^2 = 41.43^{**}$.

Table 3-B. PERCENTAGE DISTRIBUTION OF FERTILIZER USERS ACCORDING TO THE MOST IMPORTANT ORIGINAL SOURCE OF INFORMATION AND YEARS OF FARMING EXPERIENCE.†

	Years of farming experience			
Most important source of information	1 - 9 years	10 - 19 years	20 years and over	Total
Number reporting	115	106	144	365
Percent	100	100	100	100
Noticed better stands on other farms	33.1	38.7	29.2	33.2
Other farmers told about higher yields	28.7	16.0	26.4	24.1
Reading articles in farm magazines and papers	15.7	21.7	13.9	16.7
Experience on home farm before starting on own	11.3	8.5	6.9	8.8
Attending field days and demonstrations	6.1	5.7	3.5	4.9
Fertilizer salesman or dealer	0.0	1.9	8.3	3.8
Attending meetings by county extension personnel	1.7	0.9	5.5	3.0
Reading bulletins, *Iowa Farm Science* and other materials from Iowa State College	1.7	3.8	2.1	2.5
Heard program on radio or television	0.0	0.0	2.1	0.8
Did not remember	1.7	2.8	2.1	2.2

†$X^2 = 35.05^{**}$.

Table 4-B. PERCENTAGE DISTRIBUTION OF FERTILIZER USERS ACCORDING TO MOST IMPORTANT ORIGINAL SOURCE OF INFORMATION BY TENURE GROUPS.†

	Tenure		
Most important source of information	Owners, part-owners	Renters	All farmers
Number reporting	203	162	365
Percent	100	100	100
Noticed better stands on other farms	32.5	33.9	33.2
Other farmers told about higher yields	18.3	31.6	24.1
Reading articles in farm magazines and papers	19.2	13.6	16.7
Experience on home farm before starting on own	7.4	10.5	8.8
Attending field days and demonstrations	4.9	4.9	4.9
Fertilizer salesman or dealer	5.9	1.2	3.8
Attending meetings by county extension personnel	5.4	0.0	3.0
Reading bulletins, *Iowa Farm Science* and other materials from Iowa State College	2.9	1.8	2.5
Heard program on radio or television	1.5	0.0	0.8
Did not remember	2.0	2.5	2.2

†$X^2 = 25.96^{**}$

Table 5-B. PERCENTAGE DISTRIBUTION OF FERTILIZER USERS ACCORDING TO THE MOST IMPORTANT ORIGINAL SOURCE OF INFORMATION FOR DIFFERENT FARM-SIZE GROUPS.†

Most important source of information	Size of farm: 139 acres or less	140-189 acres	190-259 acres	260 acres or more
Number reporting	81	127	73	84
Percent	100	100	100	100
Noticed better stands on other farms	30.9	37.0	31.5	31.0
Other farmers told about higher yields	24.7	24.4	30.1	17.8
Reading articles in farm magazines and papers	13.6	15.7	19.2	19.0
Experience on home farm before starting on own	11.1	7.1	13.7	4.8
Attending field days and demonstrations	6.2	4.7	1.4	7.1
Fertilizer salesman or dealer	8.6	3.1	0.0	3.6
Attending meetings by county extension personnel	1.2	2.4	4.1	4.8
Reading bulletins, *Iowa Farm Science* and other materials from Iowa State College	1.2	2.4	0.0	5.9
Heard program on radio or television	0.0	0.0	0.0	3.6
Did not remember	2.5	3.2	0.0	2.4

†$X^2 = 40.16$*.

Table 6-B. PERCENTAGE DISTRIBUTION OF FERTILIZER USERS ACCORDING TO MOST IMPORTANT SOURCE OF INFORMATION AS AFFECTED BY CAPITAL POSITION.†

Most important source of information	Capital groups: Less than 9,999	10,000 to 14,999	15,000 to 29,999	30,000 to 49,999	More than 50,000	Total
Number reporting	89	55	78	59	77	358
Percent	100	100	100	100	100	100
Noticed better stands on other farms	28.1	40.0	32.0	35.6	36.3	33.8
Other farmers told about higher yields	36.0	18.2	28.2	13.6	16.9	23.8
Reading articles in farm magazines and papers	12.4	18.2	19.3	16.9	19.5	17.0
Experience on home farm before starting on own	10.1	3.6	11.5	6.8	7.8	8.4
Attending field days and demonstrations	5.6	7.3	3.8	3.4	2.6	4.5
Fertilizer salesman or dealer	0.0	7.3	2.6	11.9	1.3	3.9
Attending meetings by county extension personnel	1.1	3.6	0.0	1.7	9.1	3.1
Reading bulletins, *Iowa Farm Science* and other materials from Iowa State College	2.2	0.0	1.3	8.5	1.3	2.5
Heard program on radio or television	0.0	0.0	0.0	0.0	3.9	0.8
Did not remember	4.5	1.8	1.3	1.7	1.3	2.2

†$X^2 = 67.14$.*

Table 7-B. PERCENTAGE DISTRIBUTION FOR SOURCE OF INFORMATION FERTILIZER USERS WOULD SEEK ON A NEW FERTILIZER BY EDUCATIONAL EXPERIENCE.†

Information source	Educational experience: Grade	Some high school	Completed high school	Some college	Total
Number reporting	175	50	115	25	365
Percent	100	100	100	100	100
Iowa State College	39.4	36.0	47.8	80.0	44.4
County Farm Bureau	14.9	16.0	19.1	8.0	15.9
Fertilizer dealer or salesman	14.3	6.0	13.9	4.0	12.3
Production Marketing Administration office	6.3	10.0	0.9	0.0	4.7
Landlord, neighbors, friends	6.3	4.0	1.7	0.0	4.1
Soil Conservation Service	5.2	4.0	1.7	0.0	3.6
Magazines and newspapers	1.1	2.0	4.4	4.0	2.4
Other	1.1	4.0	3.5	0.0	2.2
Vocational agriculture department	1.7	0.0	0.0	0.0	0.8
Did not know	9.7	18.0	7.0	4.0	9.6

†$X^2 = 45.67$*.

Table 8-B. PERCENTAGE DISTRIBUTION FOR SOURCE OF INFORMATION FERTILIZER USERS WOULD SEEK ON A NEW FERTILIZER BY TENURE GROUPS.†

Information source	Tenure: Owners, part-owners	Renters	All farmers
Number reporting	203	162	365
Percent	100	100	100
Iowa State College	37.9	52.5	44.4
County Farm Bureau	18.7	12.2	15.9
Fertilizer dealer or salesman	13.8	10.5	12.2
Production Marketing Administration office	3.0	6.9	4.7
Landlord, neighbors, friends	3.4	4.9	4.1
Soil Conservation Service	4.0	3.1	3.6
Magazines and newspapers	4.0	0.6	2.4
Other	2.9	1.2	2.2
Vocational agriculture department	1.0	0.6	0.8
Did not know	11.3	7.4	9.6

†$X^2 = 17.75$*.

APPENDIX C

FERTILIZER USE ESTIMATES FOR IOWA AND IOWA SOIL AREAS

Table 1-C. ESTIMATED NUMBER OF FARMERS USING FERTILIZER IN IOWA, 1953.

Soil area	Sample total	State estimate	Relative sampling error (%)	95-percent confidence limits
1	80	27,088	7.81	22,857 - 31,319
2	75	25,395	8.94	20,854 - 29,936
3	30	10,158	12.02	7,716 - 12,600
4	37	12,528	20.85	7,304 - 17,752
4a	16	5,418	25.00	2,709 - 8,127
5	21	7,111	19.63	4,319 - 9,903
6	23	7,788	15.68	5,346 - 10,230
7	17	5,756	22.01	3,222 - 8,290
8	29	9,819	9.12	8,028 - 11,610
Total	328	111,061	4.17	101,799-120,323

Table 2-C. ESTIMATED TOTAL ACREAGE IN FARM, IOWA, 1953.

Soil area	Sample total	State estimate	Relative sampling error (%)	95-percent confidence limits
1	22,931	7,764,437	5.94	6,842,090 - 8,686,783
2	15,079	5,105,749	13.55	3,722,229 - 6,489,269
3	7,233	2,482,954	14.27	1,774,264 - 3,191,644
4	15,649	5,298,751	7.48	4,506,089 - 6,091,414
4a	5,825	1,972,345	21.99	1,104,852 - 2,839,838
5	9,094	3,079,228	14.07	2,212,751 - 3,945,706
6	9,529	3,226,519	7.49	2,743,337 - 3,709,702
7	7,869	2,664,443	16.90	1,763,767 - 3,565,119
8	8,717	2,951,576	8.16	2,469,748 - 3,433,404
Total	102,026	34,546,002	3.74	31,961,808 - 37,130,199

Table 3-C. ESTIMATED ACREAGE FERTILIZED IN IOWA, 1953.

Soil area	Sample total	State estimate	Relative sampling error (%)	95-percent confidence limits
1	6,306	2,135,212	12.19	1,614,783 - 2,655,640
2	5,221	1,767,831	12.91	1,311,398 - 2,224,263
3	1,383	468,284	22.02	262,076 - 674,491
4	1,890	639,954	20.23	380,925 - 898,830
4a	589	199,435	66.10	0 - 463,205
5	704	238,374	31.58	87,697 - 389,051
6	1,052	356,207	27.73	158,803 - 553,611
7	1,413	478,442	24.38	245,146 - 711,737
8	2,545	861,737	19.11	532,279 - 1,191,195
Total	21,103	7,145,476	6.57	6,206,538 - 8,084,414

Table 4-C. ESTIMATED CORN ACREAGE FERTILIZED IN IOWA, 1953.

Soil area	Sample total	State estimate	Relative sampling error (%)	95-percent confidence limits
1	3,892	1,317,831	16.19	891,195 - 1,744,467
2	3,941	1,334,423	14.30	952,820 - 1,716,025
3	1,065	360,609	20.95	209,593 - 511,625
4	1,244	421,218	21.20	242,776 - 599,661
4a	410	138,826	91.44	0 - 392,776
5	323	109,368	57.61	0 - 235,327
6	738	249,887	38.93	55,192 - 444,582
7	823	278,668	34.76	84,989 - 472,347
8	1,074	363,656	30.19	144,244 - 583,069
Total	13,510	4,574,486	8.43	3,803,155 - 5,345,817

Table 5-C. ESTIMATED NUMBER OF FARMS USING FERTILIZER ON VARIOUS CROPS IN IOWA, 1953.

Crop group	Sample total	State estimate	Relative sampling error (%)	95-percent confidence limits
Corn	269	91,083	4.51	82,867 - 99,299
Small grain and meadow seeding	139	47,065	7.16	40,325 - 53,805
Small grain and green manure seeding	16	5,418	25.00	2,709 - 8,127
Small grain without seeding	57	19,300	12.77	14,371 - 24,229
Legume	40	13,544	14.14	9,714 - 17,374
Permanent pasture	10	3,386	31.62	1,245 - 5,527
Rotation pasture	17	5,756	24.25	2,964 - 8,548
Other crops	20	6,772	25.98	3,253 - 10,291

Table 6-C. ESTIMATED QUANTITIES OF PLANT FOOD APPLIED ON CORN ACREAGE FERTILIZED, IOWA, 1953.

Soil area	Nitrogen				Phosphate				Potash			
	Sample total (lbs.)	State estimate (lbs.)	Relative sampling error (percent)	95–percent confidence limits	Sample total (lbs.)	State estimate (lbs.)	Relative sampling error (percent)	95–percent confidence limits	Sample total (lbs.)	State estimate (lbs.)	Relative sampling error (percent)	95-percent confidence limits
1	69,403	23,499,856	16.95	15,533,275 – 31,466,437	83,975	28,433,935	15.23	19,772,886 - 37,094,984	52,488	17,772,437	16.61	11,868,269 - 23,676,605
2	44,014	14,903,140	19.71	9,028,430 - 20,777,850	89,348	30,253,233	13.08	22,339,135 - 38,167,331	78,412	26,550,303	12.51	19,907,310 - 33,193,297
3	8,668	2,934,985	26.11	1,402,481 - 4,467,488	19,872	6,728,659	23.26	3,598,641 - 9,858,678	15,168	5,135,885	26.27	2,437,581 - 7,834,188
4	20,398	6,906,763	22.70	3,770,988 - 10,042,537	25,126	8,507,664	22.08	4,750,558 - 12,264,769	11,703	3,962,636	24.32	2,035,325 - 5,889,947
4a	18,779	6,358,569	63.71	0 - 14,460,590	10,020	3,392,772	63.26	0 - 7,685,204	5,760	1,950,336	100.00	0 - 5,851,008
5	7,572	2,563,879	59.02	0 - 5,590,286	7,025	2,378,665	50.47	0 - 4,779,678	6,317	2,138,936	55.86	0 - 4,189,836
6	28,504	9,651,454	32.49	3,379,905 - 15,923,004	3,564	1,206,770	46.78	77,878 - 2,335,663	384	130,022	100.00	0 - 390,067
7	23,032	7,798,635	34.29	2,450,448 - 13,146,822	14,500	4,909,700	42.08	777,764 - 9,041,636	----	--------	----	------ - ------
8	28,591	9,680,913	22.80	5,266,584 - 14,095,241	26,188	8,867,257	41.40	1,525,054 - 16,209,459	1,414	478,780	78.78	0 - 1,233,181
Total	248,961	84,298,194	9.79	67,792,460 - 100,803,929	279,618	94,678,655	8.48	78,621,227 – 110,736,083	171,646	58,119,336	9.10	47,541,472 - 68,697,200

Table 7-C. ESTIMATED TOTAL QUANTITY OF PLANT FOOD ON ALL ACREAGE FERTILIZED, IOWA, 1953.

Soil area	Nitrogen				Phosphate				Potash			
	Sample total (lbs.)	State estimate (lbs.)	Relative sampling error (percent)	95–percent confidence limits	Sample total (lbs.)	State estimate (lbs.)	Relative sampling error (percent)	95–percent confidence limits	Sample total (lbs.)	State estimate (lbs.)	Relative sampling error (percent)	95-percent confidence limits
1	90,825	30,753,345	15.42	21,269,013 - 40,237,677	178,308	60,375,089	10.90	47,213,368 - 73,536,809	64,244	21,753,018	17.81	14,044,496 - 29,501,541
2	56,111	18,999,185	17.42	12,379,869 - 25,618,501	135,055	45,729,623	10.86	35,795,438 - 55,663,808	96,023	32,513,388	12.91	24,118,478 - 40,908,298
3	11,378	3,852,591	26.44	1,815,341 – 5,889,841	29,667	10,045,246	24.89	5,044,801 - 15,045,691	15,807	5,352,250	25.68	2,603,495 - 8,101,005
4	25,630	8,678,318	18.58	5,453,455 - 11,903,181	51,453	17,421,986	23.20	9,338,249 - 25,505,722	14 828	5,020,761	25.79	2,431,148 - 7,610,374
4a	19,930	6,748,298	58.99	0 - 14,710,615	15,301	5,180,919	41.84	845,484 - 9,516,353	6,374	2,158,236	90.62	0 - 6,069,744
5	9,694	3,282,388	46.99	197,600 - 6,367,176	22,373	7,575,498	26.74	3,524,149 - 11,626,847	7,181	2,431,487	45.07	2,391,288 - 4,623,244
6	30,692	10,392,311	30.22	4,111,198 - 16,673,424	13,837	4,685,208	38.73	1,056,093 - 8,314,323	384	130,022	100.00	0 - 390,067
7	31,051	10,513,869	31.77	3,833,357 - 17,194,381	35,813	12,126,282	22.64	6,635,544 - 17,617,019	----	--------	----	------ - ------
8	47,353	16,033,726	17.29	10,489,264 - 21,578,188	78,659	26,633,937	25.32	13,146,484 - 40,121,391	3,588	1,214,819	59.14	0 - 2,651,915
Total	322,664	109,254,031	8.39	90,921,205 - 127,586,857	560,466	189,773,788	6.58	164,799,667 - 214,747,908	208,429	70,574,059	9.16	57,644,957 - 83,503,162

APPENDIX D

SUMMARY OF STATISTICAL ANALYSIS—QUANTITATIVE RELATIONSHIPS OF FACTORS RELATED TO FERTILIZER USE

Table 1-D. CORRELATION COEFFICIENTS, TONS FERTILIZER USED, OWNER-OPERATED FARMS, IOWA, 1953.

	X_1	X_2	X_3	X_4	X_5	X_6	Y
X_1 = Capital investment	1.0000	0.1213	–0.0609	–0.0200	0.3782	0.5749	0.3484
X_2 = Equity ratio		1.0000	–0.0496	–0.2256	–0.0932	–0.2505	–0.1708
X_3 = Certainty ratio			1.0000	0.3806	–0.0484	–0.1148	–0.0946
X_4 = Skewness				1.0000	0.0150	0.1540	0.1090
X_5 = Fertilizer used in 1952					1.0000	0.4081	0.5506
X_6 = Acres in farm						1.0000	0.6316
Y = Tons fertilizer per farm							1.0000

Table 2-D. STANDARD PARTIAL REGRESSION COEFFICIENTS AND t VALUES, TONS FERTILIZER USED, OWNER-OPERATED FARMS, IOWA, 1953.

Y = Tons fertilizer used per farm	Correlation coefficient r_{iy}	Standard partial regression coefficients B_i	Values of t for regression coefficient
X_1 = Capital investment	0.34845	–0.10162	0.86
X_2 = Equity ratio	–0.17085	0.01601	0.16
X_3 = Certainty ratio	–0.09463	–0.03643	0.35
X_4 = Skewness	0.10902	0.03610	0.36
X_5 = Fertilizer used in 1952	0.55057	0.37066	3.73
X_6 = Acres in farm	0.63160	0.53319	4.29
Multiple correlation coefficient (R)		0.714	
X_1	0.34845	–0.10099	0.93
X_5	0.55057	0.36871	5.67
X_6	0.63160	0.53917	5.75
Multiple correlation coefficient (R)		0.712	

Table 3-D. CORRELATION COEFFICIENTS, TONS OF FERTILIZER USED, TENANT-OPERATED FARMS, IOWA, 1953.

	X_1	X_2	X_3	X_4	X_5	X_6	X_8	Y_9	X_{10}	Y
X_1 = Expected price of corn	1.0000	–0.1441	–0.0776	–0.0467	–0.2233	–0.1351	–0.0539	–0.1090	–0.1125	–0.1274
X_2 = Capital investment		1.0000	–0.0989	–0.0108	0.0170	–0.0510	0.1101	0.1047	0.2217	0.2608
X_3 = Equity ratio			1.0000	–0.0246	–0.0066	0.0266	–0.2217	0.0746	0.0222	–0.0947
X_4 = Price range				1.0000	0.9834	0.1220	0.0940	–0.0187	–0.1198	0.0108
X_5 = Certainty ratio					1.0000	0.1475	0.1118	–0.0001	–0.0933	0.0278
X_6 = Skewness						1.0000	–0.0072	0.1786	–0.0820	–0.0371
X_8 = Expected yield response							1.0000	0.0009	0.1214	0.2188
X_9 = Fertilizer used in 1952								1.0000	0.0360	0.3893
X_{10} = Acres in farm									1.0000	0.3155
Y = Tons fertilizer per farm										1.0000

Table 4-D. STANDARD PARTIAL REGRESSION COEFFICIENTS AND t VALUES, TONS FERTILIZER USED, TENANT-OPERATED FARMS, IOWA, 1953.

Y = Tons fertilizer used per farm	Correlation coefficient r_{iy}	Standard partial regression coefficient B_i	Values of t for regression coefficient
X_1 = Expected price of corn	–0.12740	–0.02588	0.24
X_2 = Capital investment	0.26079	0.13750	1.24
X_8 = Expected yield response	0.21878	0.16848	1.57
X_9 = Fertilizer used in 1952	0.38928	0.38183	3.55
X_{10} = Acres in farm	0.31552	0.27541	2.50
Multiple regression coefficient (R)		0.558	
X_2	0.26079	0.14037	1.28
X_8	0.21878	0.16928	1.59
X_9	0.38928	0.38443	3.62
X_{10}	0.31552	0.27768	2.55
Multiple regression coefficient (R)		0.558	

Table 5-D. ADDITIONAL TONS OF FERTILIZER USE, TENANT-OPERATED FARMS, ASSOCIATED WITH $1,000 INCREASE IN CAPITAL INVESTMENT, IOWA, 1953.

Existing capital investment	Additional tons of fertilizer used per $1,000 increase in capital investment with other factors at: Average for all farms	Half the average for all farms	50-percent-greater than the average for all farms
$ 5,000	0.121	0.066	0.174
7,500	0.086	0.047	0.123
11,168	0.061	0.033	0.088
12,500	0.055	0.030	0.080
15,000	0.047	0.026	0.068

Table 6-D. ADDITIONAL TONS OF FERTILIZER USE PER TENANT-OPERATED FARMS, ASSOCIATED WITH A 1-BUSHEL INCREASE IN EXPECTED YIELD RESPONSE OF CORN, IOWA, 1953.

Expected corn-yield response (bushels)	Additional tons of fertilizer use per bushel increase in yield response, with other factors at: Average for all farms	Half the average for all farms	50-percent-greater than the average for all farms
10	0.0845	0.0474	0.1184
15	0.0611	0.0342	0.0856
17.73	0.0534	0.0300	0.0749
20	0.0486	0.0272	0.0680
25	0.0406	0.0228	0.0569

Table 7-D. ADDITIONAL TONS OF FERTILIZER USE PER TENANT-OPERATED FARM ASSOCIATED WITH A 1-ACRE INCREASE IN SIZE OF FARM, IOWA, 1953.

Size of farm (acres)	Additional tons of fertilizer used per acre increase in farm size with other factors at: Average for all farms	Half the average for all farms	50-percent-greater than the average for all farms
100	0.0199	0.0144	0.0241
140	0.0172	0.0124	0.0208
174.7	0.0154	0.0113	0.0189
200	0.0148	0.0106	0.0178
250	0.0134	0.0097	0.0162

Table 8-D. CORRELATION COEFFICIENTS, POUNDS OF NITROGEN USED PER ACRE OF CORN, OWNER-OPERATED FARMS, IOWA, 1953.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	Y
X_1 = Expected price of corn	1.0000	0.0065	−0.0239	−0.1308	−0.3335	−0.5321	0.1129	0.1366	0.0453
X_2 = Capital investment		1.0000	0.0075	0.0650	0.0740	0.1623	0.0272	0.1035	0.2739
X_3 = Equity ratio			1.0000	−0.1479	−0.1367	−0.1452	−0.3461	−0.0051	−0.2637
X_4 = Price range				1.0000	0.9767	0.4580	0.2830	0.2591	−0.0879
X_5 = Certainty ratio					1.0000	0.5564	0.2518	0.2136	0.0863
X_6 = Skewness						1.0000	0.1906	0.1217	0.0890
X_7 = Expected yield uncertainty							1.0000	0.2500	0.3657
X_8 = Expected yield response								1.0000	0.0032
Y = Lbs. nitrogen per acre on corn									1.0000

Table 9-D. STANDARD PARTIAL REGRESSION COEFFICIENTS AND t VALUES, POUNDS OF NITROGEN USED PER ACRE OF CORN, OWNER-OPERATED FARMS, IOWA, 1953.

Y = Pounds nitrogen per acre	Correlation coefficients r_{iy}	Standard partial regression coefficients B_i	Values of t for regression coefficient
X_2 = Capital investment	0.27386	0.26683	1.92
X_3 = Equity ratio	−0.26365	−0.16086	1.09
X_7 = Yield response uncertainty	0.36573	0.30280	2.04
Multiple correlation coefficient (R)		0.4756	

Table 10-D. STANDARD PARTIAL REGRESSION COEFFICIENTS AND t VALUES, POUNDS OF NITROGEN USED PER ACRE OF CORN, TENANT-OPERATED FARMS, IOWA, 1953.

Y = Pounds nitrogen per acre	Correlation coefficients r_{iy}	Standard partial regression coefficients B_i	Values of t for regression coefficient
X_1 = Expected price corn	−0.10495	−0.07732	0.57
X_2 = Capital investment	0.14755	0.11423	0.85
X_7 = Yield response uncertainty	−0.21198	−0.23156	1.72
X_8 = Expected yield response	0.14879	0.16128	1.19
Multiple correlation coefficient (R)		0.313	
X_2	0.14755	0.12527	0.94
X_7	−0.21198	−0.23110	1.73
X_8	0.14879	0.16642	1.24
Multiple correlation coefficient (R)		0.304	

Table 11-D. ADDITIONAL POUNDS OF NITROGEN USED PER ACRE OF CORN ASSOCIATED WITH $1,000 INCREASE IN CAPITAL INVESTMENT, TENANT-OPERATED FARMS, IOWA, 1953.

Existing capital investment	Additional pounds of nitrogen used per acre per $1,000 increase in investment, with other factors at: Average for all farms	Half the average for all farms	50-percent-greater than the average for all farms
$ 5,000	0.305	0.293	0.312
7,500	0.217	0.209	0.222
11,460	0.152	0.147	0.156
12,500	0.142	0.136	0.145
15,000	0.121	0.117	0.125

Table 12-D. CORRELATION COEFFICIENTS, POUNDS OF NITROGEN USED PER ACRE OF CORN, TENANT-OPERATED FARMS, IOWA, 1953.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	Y
X_1 = Expected price of corn	1.0000	–0.1495	–0.1003	–0.0178	–0.2294	–0.2008	–0.0115	–0.0819	–0.1050
X_2 = Capital investment		1.0000	–0.1029	–0.0147	–0.0194	–0.0799	–0.0226	0.1026	0.1476
X_3 = Equity ratio			1.0000	–0.0549	–0.0195	–0.0408	–0.0433	–0.2712	–0.0028
X_4 = Price range				1.0000	0.9771	0.1087	0.1881	0.2042	–0.0928
X_5 = Certainty ratio					1.0000	0.1483	0.1849	0.2186	–0.0654
X_6 = Skewness						1.0000	0.0571	–0.0476	–0.0683
X_7 = Expected yield uncertainty							1.0000	0.1319	–0.2120
X_8 = Expected yield response								1.0000	–0.1488
Y = Lbs. nitrogen per acre on corn									1.0000

Table 13-D. ADDITIONAL POUNDS OF NITROGEN USED PER ACRE OF CORN ASSOCIATED WITH A 1-BUSHEL INCREASE IN EXPECTED YIELD RESPONSE, TENANT-OPERATED FARMS, IOWA, 1953.

Expected yield response (bushels)	Additional pounds of nitrogen used per acre per bushel yield response, with other factors at:		
	Average for all farms	Half the average for all farms	50-percent-greater than the average for all farms
5	0.398	0.388	0.314
10	0.237	0.232	0.187
18	0.155	0.152	0.122
20	0.142	0.139	0.112
25	0.120	0.118	0.095

Table 14-D. CORRELATION COEFFICIENTS, DIFFERENCE BETWEEN ESTIMATED MOST PROFITABLE EXPENDITURE FOR FERTILIZER AND ACTUAL EXPENDITURE FOR FERTILIZER, OWNER-OPERATED FARMS, IOWA, 1953.

	X_1	X_2	X_3	X_4	X_5	X_6	Y
X_1 = Fertilizer use experience	1.0000	0.0880	0.0994	–0.0998	–0.0749	0.2777	–0.0780
X_2 = Capital investment		1.0000	0.0508	0.0920	0.1039	0.1746	0.2065
X_3 = Equity ratio			1.0000	0.0314	–0.0477	0.0789	–0.2161
X_4 = Price range				1.0000	0.9745	–0.0102	0.0832
X_5 = Certainty ratio					1.0000	–0.0287	0.0983
X_6 = Manure used per acre						1.0000	–0.0133
Y = "Difference"							1.0000

Table 15-D. STANDARD PARTIAL REGRESSION COEFFICIENTS AND t VALUES, DIFFERENCE BETWEEN ESTIMATED MOST PROFITABLE FERTILIZER EXPENDITURE AND ACTUAL FERTILIZER EXPENDITURE, OWNER-OPERATED FARMS, IOWA, 1953.

Y = Difference between actual fertilizer use and farmers' estimate of most profitable use	Correlation coefficients r_{iy}	Standard partial regression coefficients B_i	Values of t for regression coefficient
X_2 = Capital investment	0.20649	0.21101	1.85
X_3 = Equity ratio	–0.21609	–0.22367	1.97
X_5 = Certainty ratio	0.09833	0.06574	0.58
Multiple regression coefficient (R)		0.314	
X_2	0.20649	0.21802	1.94
X_3	–0.21609	–0.22716	2.00
Multiple regression coefficient (R)		0.307	

Table 16–D. CORRELATION COEFFICIENTS, DIFFERENCE BETWEEN FARMERS' ESTIMATES OF MOST PROFITABLE FERTILIZER EXPENDITURE AND ACTUAL EXPENDITURES, TENANT-OPERATED FARMS, IOWA, 1953.

	X_1	X_2	X_3	X_4	X_5	X_6	Y
X_1 = Fertilizer use experience	1.0000	0.2138	---	---	---	–0.0358	–0.2094
X_2 = Capital investment		1.0000	0.0944	--	---	0.2724	0.1463
X_3 = Equity ratio			1.0000	--	---	---	–0.0642
X_4 = Price range				1.0000	--	---	0.0156
X_5 = Certainty ratio					1.0000	--	0.0199
X_6 = Manure used per acre						1.0000	0.2253
Y = "Difference"							1.0000

Table 17–D. STANDARD PARTIAL REGRESSION COEFFICIENTS, AND t VALUES, DIFFERENCE BETWEEN FARMERS' ESTIMATES OF MOST PROFITABLE FERTILIZER EXPENDITURE AND ACTUAL EXPENDITURE, TENANT-OPERATED FARMS, IOWA, 1953.

Y = Difference between actual fertilizer use and farmers' estimate of most profitable use	Correlation coefficients r_{iy}	Standard partial regression coefficients B_i	Values of t for regression coefficient
X_1 = Fertilizer use experience	–0.20938	–0.23482	2.05
X_2 = Capital investment	0.14631	0.14846	1.36
X_6 = Manure used per acre	0.22525	0.17641	1.65
Multiple correlation coefficient (R)		0.333	

Table 18–D. CORRELATION COEFFICIENTS, PERCENT OF ADDITIONAL $1,000 AVAILABLE FOR FARM BUSINESS THAT OWNER-OPERATOR WOULD SPEND FOR FERTILIZER, IOWA, 1953.

	X_1	X_2	X_3	Y
X_1 = Fertilizer used current year	1.0000	0.4669	0.5963	0.3003
X_2 = Capital investment		1.0000	0.6706	0.0286
X_3 = Capital invested in livestock			1.0000	0.1441
Y = Percent of additional $1,000 operator would spend for fertilizer				1.0000

Table 19-D. CORRELATION COEFFICIENTS, PERCENT OF ADDITIONAL $1,000 AVAILABLE FOR FARM BUSINESS THAT TENANT-OPERATOR WOULD SPEND FOR FERTILIZER, IOWA, 1953.

	X_1	X_2	X_3	X_4	Y
X_1 = Fertilizer used current year	1.0000	0.2799	0.0635	–0.0202	0.2469
X_2 = Capital investment		1.0000	0.7568	0.0159	0.4096
X_3 = Capital invested in livestock			1.0000	–0.0233	0.2189
X_4 = Expected yield response				1.0000	0.1026
Y = Percent of additional $1,000 operator would spend for fertilizer					1.0000

Table 20-D. STANDARD PARTIAL REGRESSION COEFFICIENTS AND t VALUES, PERCENT OF ADDITIONAL $1,000 AVAILABLE FOR FARM BUSINESS THAT TENANT-OPERATOR WOULD SPEND FOR FERTILIZER, IOWA, 1953.

Y = Percent of additional $1,000 spent for fertilizer	Correlation coefficients r_{iy}	Standard partial regression coefficients B_i	Values of t for regression coefficient
X_1 = Fertilizer used current year	0.24690	0.11960	0.57
X_2 = Capital investment	0.40959	0.49863	1.57
X_3 = Capital invested in livestock	0.21894	–0.16385	0.53
X_4 = Expected yield response	0.10262	0.09325	0.48
Multiple correlation coefficient (R)		0.455	
X_1	0.24690	0.14613	0.73
X_2	0.40959	0.3671	1.84
X_4	0.10262	0.0997	0.52
Multiple correlation coefficient (R)		0.443	

Table 21-D. CORRELATION COEFFICIENTS, EXPECTED VARIABILITY OF CORN-YIELD RESPONSE, OWNER-OPERATED FARMS AND TENANT-OPERATED FARMS, IOWA, 1953.

	X_1	X_2	X_3	Y
Owner-operated farms				
X_1 = Fertilizer use experience	1.0000	0.6917	–0.0142	–0.1787
X_2 = Fertilizer used previous year		1.0000	0.1377	–0.0329
X_3 = Expected yield response			1.0000	0.2023
Y = Expected variance of corn-yield response				1.0000
Tenant-operated farms				
X_1 = Fertilizer use experience	1.0000	0.4204	–0.0036	0.0189
X_2 = Fertilizer used previous year		1.0000	–0.0068	–0.0653
X_3 = Expected yield response			1.0000	0.1398
Y = Expected variance of corn-yield response				1.0000

Table 22-D. STANDARD PARTIAL REGRESSION COEFFICIENTS AND t VALUES, OPERATOR'S EXPECTED VARIABILITY OF CORN-YIELD RESPONSE, OWNER-OPERATED FARMS AND TENANT-OPERATED FARMS, IOWA, 1953.

Y = Expected variance of corn-yield response	Correlation coefficients r_{iy}	Standard partial regression coefficients B_i	Values of t for regression coefficient
Owner-operated farms			
X_1 = Fertilizer use experience	–0.17872	–0.17588	1.32
X_3 = Expected yield response	0.20233	0.19983	1.50
Multiple correlation coefficient (R)		0.268	
Tenant-operated farms			
X_3 = Expected yield response	0.17982	0.13979	1.09
Correlation coefficient (r)		1.140	

Table 23-D. F TEST FOR DIFFERENCE BETWEEN EXPECTED YIELD RESPONSE FUNCTIONS FOR CORN GROWN FIRST AND SECOND YEAR AFTER MEADOW.

Source	Degrees of freedom	Sums of squares	Mean square
Total	920	543,371	----
Reduction due to pooled regressions	2	439,825	----
Reduction due to individual regressions	4	441,173	----
Deviations from pooled regressions	918	103,548	----
Deviations from individual regressions	916	102,198	111.6
Difference between pooled and individual	2	1,348	674**

** = $P<0.01$.