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ECONOMIC APPRAISAL OF FERTILIZER USE IN ETHIOPIA

BY

© GETACHEW TECLE-MEDHIN

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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The undersigned certify that they have read and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Economic Appraisal of Fertilizer Use in Ethiopia," submitted by Getachew Tecle-Medhin in partial fulfilment of the requirements for the degree of Master of Science.

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Date May 16, 1972

ABSTRACT

This study analyzes the profitability of commercial fertilizer use to Ethiopian farmers under the existing cultural practices and tenure systems. This analysis was accomplished by testing the statistical significance of physical yield increases due to applications of varying types and amounts of fertilizer on test plots across Ethiopia. Partial budget analyses were then used to calculate net returns from the highest yield-increasing treatment or treatments for each crop in each of the 13 study regions, under three existing tenure arrangements.

Variance analysis was used to test yield increases for statistical significance. Following this, the new multiple range test was used to determine the highest yield-increasing treatment. Data for these analyses were obtained from the FAO Freedom from Hunger Campaign Fertilizer Demonstration Studies for the years 1967-68, 1968-69, and 1969-70 in thirteen regions on five crops.

The variance analysis showed a significant yield increase at a 99 per cent significance level for all regions and crops with the exception of wheat in one region and barley in two regions. Also, the new multiple range test revealed that for all crops in all regions the highest yield increase resulted from NP and NPK fertilizer applications. These two treatments did not show any significant difference in yield response.

The partial budget analysis suggests high net returns for owner-operators using fertilizer. An exception occurred in one region for barley where the loss was $Eth 29.29 per hectare. The net return for tenants who paid all fertilizer costs and only received two-thirds of the crop, was negative or very low for most cases. However, in the

situation where a tenant shared half the added cost of fertilizer with his landlord and received half the increased crop, the net returns were higher than the two-thirds crop-share tenant. However, they were not as high as those received by the owner-operator.

Therefore the following conclusions and recommendations evolve from the study. Fertilizer use in Ethiopia is a profitable venture for owner-operators and, although unattractive to two-thirds crop-share tenants, is worthwhile for one-half crop-share tenants. This implies that, in order to increase crop yields, landlords should share in fertilizer costs.

Also, in order to facilitate the profitable introduction of fertilizer to Ethiopia, it is suggested that government policy be established to provide credit for fertilizer purchase, setting floor prices on the common crops, and land tenure improvement.

ACKNOWLEDGEMENTS

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INTRODUCTION

> A hungry world needs food. If the soils, the people, and the skills of modern science can be brought into proper relationship, an efficient agriculture can supply the food. One can see how enormous the task is and still assert that it is manageable.[1]

Although Ethiopia has been more or less self-sufficient in food crop production in the past, the rate of increase in this area is now lagging behind the rate of population growth. In fact, a number of people conducting studies in this field have predicted a food shortage problem in Ethiopia in the very near future.

> Ethiopia has been barely self-sufficient in cereal grains since the mid-1950's. There is serious question whether or not the country can continue to meet the grain requirement of an expanding population during the next decade and further [sic] future unless production is materially increased.[2]

The problem is not only the fear of future food shortage, but also the fact that the current supply of food for the masses is of very inferior quality and falls below the standard per capita calorie intake requirements. Eichberger[3] concluded from his food production and consumption study that the volume of domestic food production available for human consumption is sufficient to provide only a relatively low

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[1] Vladimir Ignatieff, ed., Efficient Use of Fertilizers, FAO Agricultural Studies No. 9 (Washington, D.C.: FAO, August, 1949), p. 1.

[2] Clarence J. Miller et al., Production of Grains and Pulses in Ethiopia, Report No. 10 (Menlo Park, California: Stanford Research Institute, 1969), p. 1.

[3] W.G. Eichberger, "Food Productión and Consumption in Ethiopia" (unpublished study, Ministry of Agriculture, Addis Ababa, Ethiopia, May 1968), p. 31.

level of living. He estimated the average per capita calorie intake to be 1,622 per day. The problem is aggravated by uneven distribution of the available food grown. "The dietary level is low enough, however, so that without doubt in some areas of the nation, large segments of the population are suffering from malnutrition which predisposes the population in those areas to various diseases."[1]

These studies and day-to-day observations of rural life in Ethiopia reveal the existence of this problem. Therefore, to provide a sufficient amount and quality of food for current consumption as well as for the coming years, Ethiopia has to develop methods of increasing its agricultural productivity.

The total agricultural produce of a country can be increased by increasing the productivity of the land currently under cultivation, by increasing the amount of land to be cultivated or by employing both methods. Many authorities on agricultural production in developing countries argue that traditional farmers of less developed countries have utilized the traditional farm inputs efficiently. They have come to the conclusion that any reorganizing of the existing factors of production will have very little effect on increasing the agricultural production. Hence, the only way to increase the farm product in countries like Ethiopia is to introduce new factor inputs, such as improved seeds, fertilizers, pesticides, irrigation, and management skills. Of these new inputs, fertilizer has taken the lead in Ethiopia in recent years.

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[1] Ibid., p. 31.

The Development of Fertilizer Use in Ethiopia

Ethiopian agriculture is a traditional agriculture. Its tools and cultural practices have been used for many centuries, and the methods of fertilizing the soil are no exception. Depending upon the population density and the tradition of an area, different ways of adding nutrients to the soil exist. The most common methods are crop rotation, fallowing, and manuring. In some areas soil burning is also used.

Until the 1967 cropping season, the phrase "commercial fertilizer" was not in the language of common farmers in the country. Some fertilizer was in use on plantation farms, such as the Wongi and Shoa Sugar Estates and on some fruit and vegetable farms.

From 1956 to 1958, H.F. Murphy, a soil scientist at the College of Agriculture in Ethiopia, set up a few fertilizer observation trials at Debre Zeit Agricultural Experiment Station and the College Farm at Alemaya. Even though the observation was conducted in small areas and for only a few years, Murphy has indicated that in the Debre Zeit area the response of fertilizer on teff, wheat, and alfalfa was good. However, due to the high cost of fertilizer in comparison to that of grain, his study showed that fertilizer use was unprofitable. In 1964, he again conducted a study on vegetables, corn, and sorghum on the College Farm and on farms around the College. He made the following conclusion about his study:

> The general data on the use of fertilizers for vegetables under irrigation show their use to be highly profitable. The observations and data on the use of fertilizers for corn and sorghum under natural rainfall conditions show a need, but the results are far less convincing economically, than for the vegetables.[1]

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[1]H.F. Murphy, A Report on the Fertility Status and Other Data on Some Soils of Ethiopia, HSIU No. 44 (Dire Dawa: College of Agriculture, 1968), p. 515.

In 1967, the FAO Freedom From Hunger Campaign, in collaboration with the Ministry of Agriculture, included the launching of a nationwide fertilizer demonstration programme. In that year 469 trial plots were established in the provinces of Shoa, Kaffa, Arussi, Wellenga, Wellow, and Sidamo. In 1968-69 and 1969-70, 848 and 1,139 trials respectively were conducted. In 1968-69, the provinces of Begemider, Eriteria, Gojam, Hararghe, and Tigre were included, and in 1969-70, the province of Gemu Gofa was also added. Of the fourteen provinces in Ethiopia, the 1969-70 programme included twelve.

The aim of the program has been to demonstrate to farmers the relative increase in yield due to fertilizer application. In its three years of operation, the programme, with other inputs held constant, has been successful in demonstrating the increase in physical yield. As a result, farmers who have seen the difference in yield between unfertilized and fertilized fields have expressed their desire to use fertilizers. Raymond E. Borton and his associates, who studied the agriculture of one of the areas participating in the programme, reported the feeling of the farmers as follows: "The farmers in the area were generally pleased with the trial results. Many of them asked how and where they could obtain fertilizer for the following year."[1]

The farmers' wish to use fertilizer indicates that they have recognized the physical yield increases due to fertilizer. But the following question must yet be resolved: Is the application of fertilizer alone under existing cultural practices, quality of seeds, land

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[1] Raymond E. Borton et al., A Development Program for the Ada District, Based on Socio-Economic Survey, Report No. 14 (Menlo Park, California: Stanford Research Institute, 1969), p. 69.

tenure arrangements, and market structure a profitable venture? The aim of this thesis is to examine this question.

Objectives

This study has two objectives. The first is to test whether or not the increase in yield from different nutrient treatment is statistically significant. The second and major objective is to measure the profitability of applying the level or levels of nutrients that gave the highest significant yield increase for a given crop on:

1. Owner operated farms;
2. Two-thirds crop-share lease, where the tenant covers all the added cost; and
3. Fifty-fifty crop-share lease, where the added cost is shared equally between the tenant and the landlord.

Sources of Data

The three kinds of information required for this study were: the yield from fertilizer trials, the price of grain, and the fertilizer cost. The yield data for three years of trials were obtained from the Ministry of Agriculture Extension Service Division. Five years of grain wholesale prices for major cities in each study region were obtained from the Ethiopian Grain Corporation's head office. From the wholesale price, the price farmers receive in local markets was imputed. The details of this imputation are covered in Chapter 4 under the subheading of "Price Farmers Receive." Fertilizer costs at the farm gate were also imputed from the wholesale price of fertilizer reported for Addis Ababa and Asmara in 1967 by Benedict and Cogswell.[1] Because it

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[1]H.M. Benedict and S.A. Cogswell, Potential Fertilizer Demand in Ethiopia, Report No. 1 (Menlo Park, California: Stanford Research Institute, 1968).

does not differ from the price for 1970 quoted to the author by ABs Company, the 1967 price was used.

Methodology and Tools of Analysis

Three different analytical tools were employed in this study. First, variance analysis was used to test the statistical significance of the increase in yield due to application of fertilizer at specified rates. Using the new multiple range test, those groups where a significant difference was found were further tested to determine the highest yielding treatment or treatments. Finally, partial budget analysis was used for the economic evaluation. Net returns for owner operated farms, two-thirds crop-share lease farms, and fifty-fifty crop-share lease farms were calculated.

Shortcomings of the Study

The major weakness of this study can be attributed to the data. Due to lack of skilled research personnel in developing countries like Ethiopia, the yields, as well as the market data, are susceptible to error. Especially in experiments such as the fertilizer demonstration programme, where the major aim was to cover as much area as possible with limited funds, there was a good chance the yield data would contain observation errors. Of the many possible weaknesses the most obvious are:

1. Treatments are the same on all the cereal crops and in all regions and furthermore, only one level of application was used.

2. The time covered is very short. In some of the areas it is only one year's observation.

Nevertheless, this study is the first of its kind and could be used as a base for further, more detailed and refined studies.

CHAPTER II

THEORETICAL ANALYSIS OF THE EFFECT OF NEW INPUTS IN TRADITIONAL AGRICULTURE

The economic theory relevant for this study deals with the shift in the production function due to technological change. But before discussing the theoretical aspects of new technology, it is helpful to look at a traditional farm, noting the factors of production employed and the level of technology being used.

Traditional Agriculture

Definition

Professor T.W. Schultz defines traditional agriculture in this way: "Farming based wholly upon the kinds of factors of production that have been used by farmers for generations can be called traditional agriculture."[1] In traditional agriculture production involves the conventional factor inputs of land, labor, and capital. Of the three factors of production, land is constant whether it is employed in modern or in traditional farming. The big difference between modern and traditional farms depends upon the amount and kind of capital employed and the managerial capacity and skill of labor used. In traditional agriculture the capital employed in farming is mainly comprised of small farm tools, draft animals, and seeds. These factor inputs are combined and managed in the manner passed down for many generations. To quote

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[1]Theodore W. Schultz, Transforming Traditional Agriculture (New Haven: Yale University Press, 1969), pp. 3-4.

Schultz again:

> The agricultural factors that farmers employ have been used by them and their forefathers for a long time and none of these factors meanwhile has been altered significantly as a consequence of learning from experience. Nor have any new agricultural factors been introduced.[1]

The Allocative Efficiency of Resources in Traditional Agriculture

Defining allocative efficiency in terms of profit maximization, T.W. Schultz has hypothesized that there are comparatively few significant inefficiencies in the allocation of factors of production in traditional agriculture. This hypothesis has been verified by empirical studies. The major empirical studies supporting this hypothesis have been the cross-sectional production function analyses of Chennareddy,[2] Hopper,[3] Massel and Johnson,[4] Sahota,[5] Welsch,[6] and others.

The basic conclusion from Schultz's hypothesis is that traditional agriculture has reached an optimum equilibrium point of

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[1] *Ibid*., p. 30.

[2] V. Chennareddy, "Production Efficiency in South Indian Agriculture," *Journal of Economics*, XLIX (1967), pp. 816-820.

[3] W.D. Hopper, "Allocation Efficiency in a Traditional Indian Agriculture," *Journal of Farm Economics*, XLVII (1965), pp. 611-624.

[4] B.F. Massell and R.W.M. Johnson, "Economics of Smallholder Farming in Rhodesia: A Cross-Section Analysis of Two Areas," *Food Research Institute Studies in Agricultural Economics, Trade, and Development*, Supplement to VII (1968).

[5] G.S. Sahota, "Efficiency of Resource Allocation in Indian Agriculture," *Journal of Agricultural Economics*, L (1968), pp. 584-605.

[6] D.E. Welsch, "Response to Economic Incentive by Abakaliki Rice Farmers in Eastern Nigeria," *Journal of Farm Economics*, XLVII (1965), pp. 900-914.

production within the existing level of technology and the available factor inputs known to farmers. The economic logic underlying the particular economic equilibrium of traditional agriculture is closely related to that of the classical long-run stationary state. It is a type of equilibrium which an economy, or a sector of an economy, reaches when it has exhausted all of the economic opportunities inherent in the state of the productive arts at its disposal. Thus if farmers have been responding to the relevant economic incentive, enough time has elapsed for them to have arrived at a relatively efficient allocation of the agricultural factors of production at their disposal. They will also have equalized their marginal satisfactions from additional savings and the marginal value productivities of additional investment to increase the stocks of agricultural factors of production. Thus in traditional agriculture there are no unexploited opportunities that could be used by traditional farmers to increase agricultural productivity.

This analysis leads to the following conclusion. The reshuffling of traditional agricultural production factors offers very few possibilities for significant increase in agricultural productivity. Schultz argues that greater growth prospects are to be found in new techniques, new inputs, and new market opportunities.

J.W. Mellor has this to say in support of this argument:

> The only remaining means of increasing agricultural production within the context of a traditional agriculture is through large injections of capital. This may take two forms--that of programs for increasing the land area through land reclamation and large-scale irrigation on the one hand, and programs of increasing yields through large-scale application of inorganic fertilizers on the other.[1]

---

[1]John W. Mellor, The Economics of Agricultural Development (New York: Cornell University Press, 1966), p. 216.

Mellor also points out that in "Phase II," as he calls it—the agricultural growth stage following traditional agriculture where technological change is achieved through the employment of non-capital intensive innovations—the emphasis is on increasing yields per acre of crops.[1] This can be achieved through the use of innovations such as inorganic fertilizer, improved seeds, chemicals, and improved farm tools. Of these new inputs, inorganic fertilizer use on the Ethiopian farm is the subject of this thesis.

Traditional Agriculture Production Model and Shift in Production Process

After this brief look into the production behavior of traditional agriculture, we can now consider the theory of production and technological change. The traditional farmer, as pointed out earlier, employs the conventional factor inputs of land, labor, and capital to produce an agricultural commodity. The basic physical relationship between inputs and output in production is known as the production function. A production function may be expressed in several forms: an arithmetic table, geometrically as a graph, and as an algebraic equation. The quantity of output is determined by the quantity of factor inputs.. Thus we can say, quantity Y depends on factor inputs $X_1, X_2, X_3 \ldots X_n$, which can be written in functional form as:

$$Y = f(X_1, X_2, X_3 \ldots X_n), \qquad (2.1)$$

where Y is the amount of yield of a given agricultural commodity, and

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[1] *Ibid.*

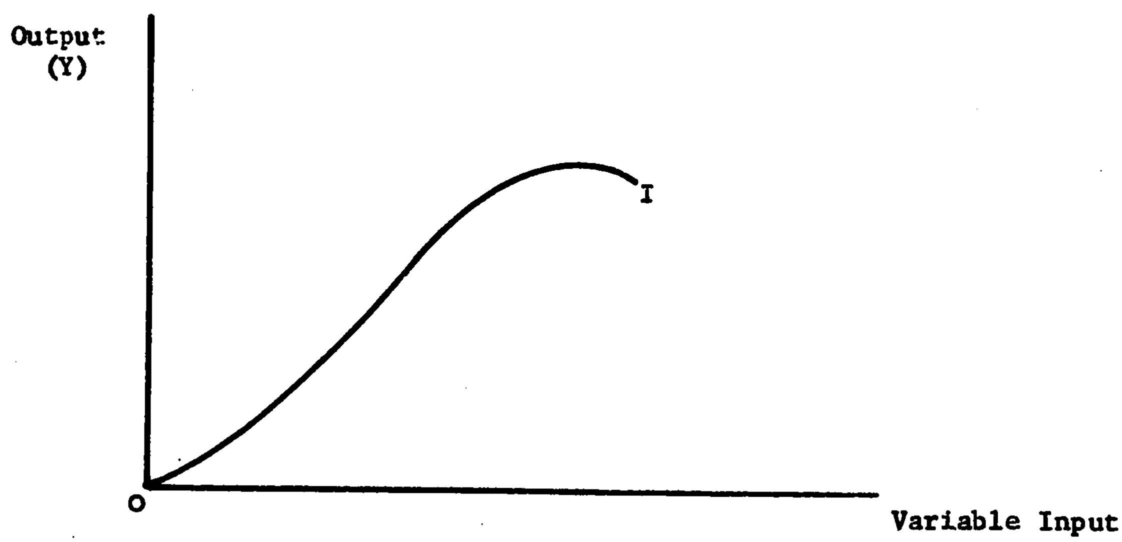
the X's are the inputs required to produce Y. The X's include both those factor inputs over which man has control and those over which he has no control in the production of Y. If we limit our factor inputs to land, labor, and capital, equation 2.1 can be written as:

$$Y = f(L, N, K), \qquad (2.2)$$

where L represents land size, N is the number of man-years or man-hours, and K represents capital in traditional agriculture. We can demonstrate the above functional relationship in a two dimensional diagram, taking only one of these inputs as variable input and assuming the other two inputs remain fixed in the short run.

Figure 2.1

PHYSICAL PRODUCTION FUNCTION

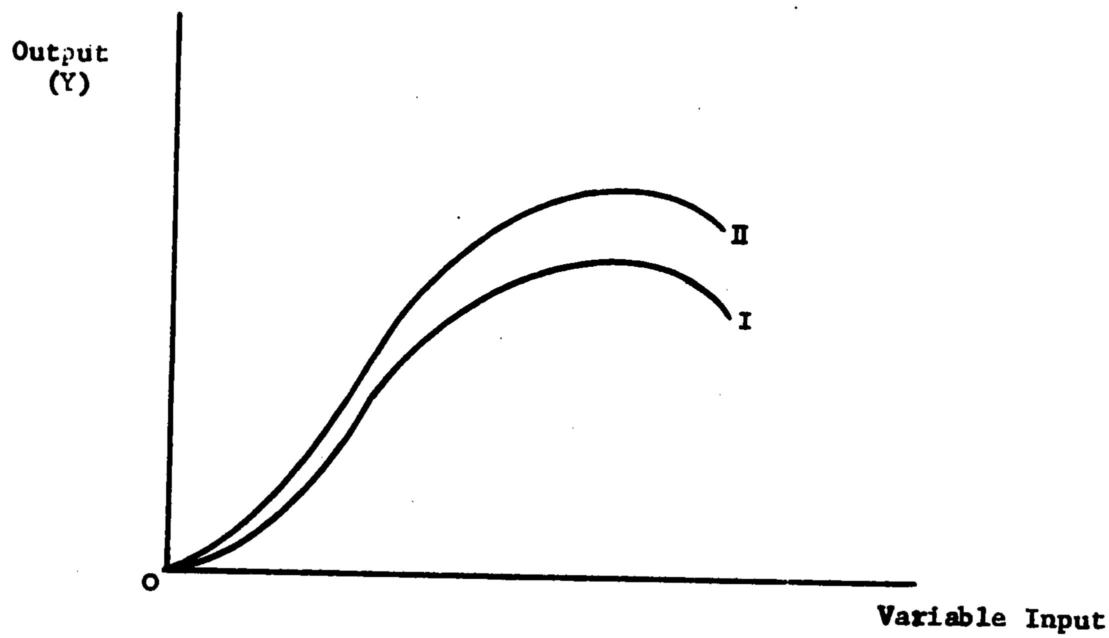


What will be the effect of injecting fertilizer into the traditional agricultural production process? Other factors of production remaining constant, the addition of fertilizer will increase the productivity of land, labor, and traditional capital inputs. Thus in

Figure 2.2, the production function represented by curve I will be lifted upward to the position of curve II, following the use of fertilizer. The shifting of the production up and to the right is the common expository device for depicting technological change.

Figure 2.2

HYPOTHETICAL DIAGRAM DEPICTING A SHIFT IN THE PRODUCTION FUNCTION

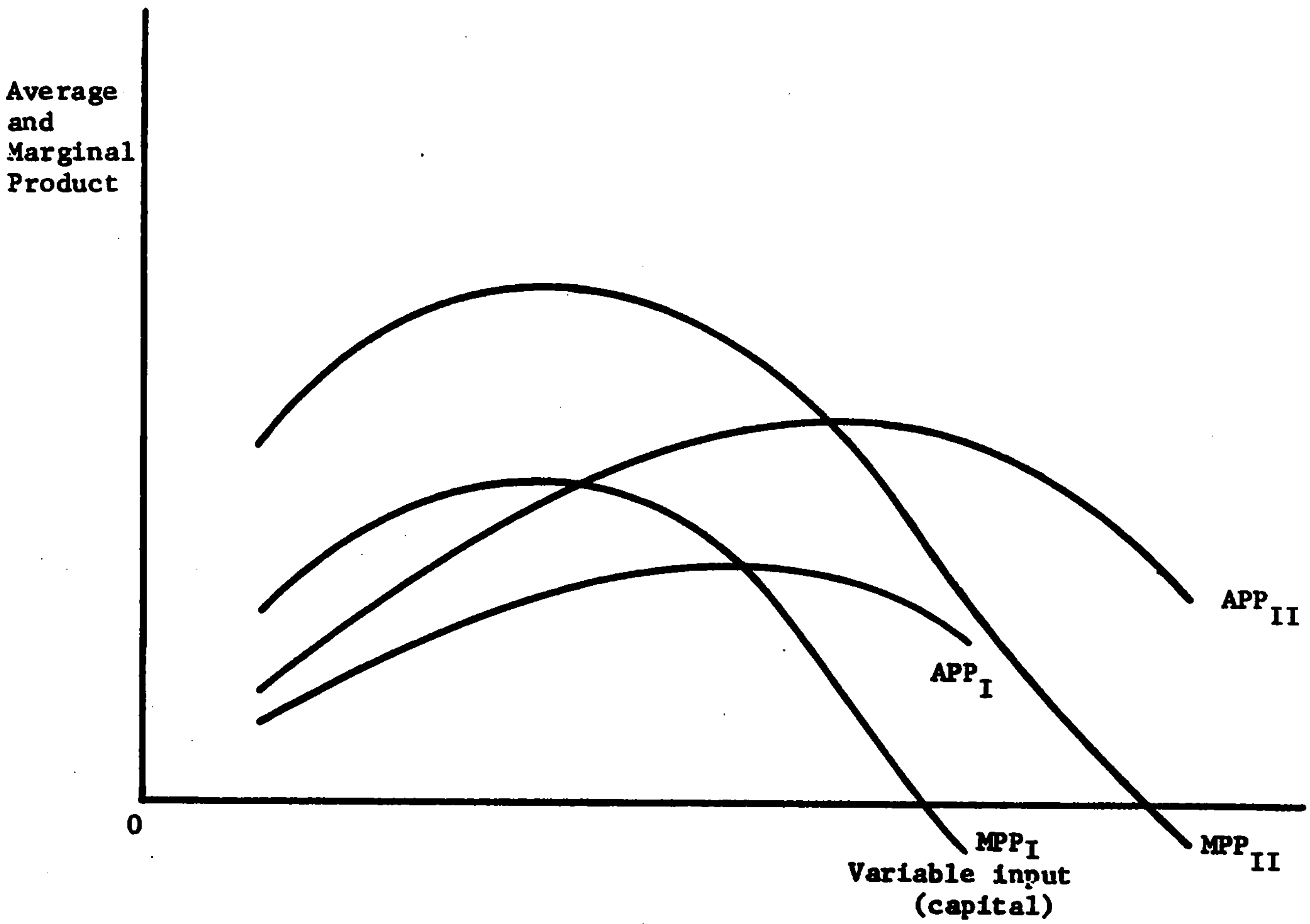


The addition of fertilizer into the production process requires an additional capital input. Fertilizer might be regarded as an item of working capital which embodies technological progress. That is, , fertilizer is an "input of technical change" (in Mellor's terminology) which is highly complementary to the traditional farm inputs.

In Figure 2.2 we have seen the effect of fertilizer on the total productivity of the variable input, either land, labor, or traditional capital. The impact of fertilizer on average and marginal prouuctivity of the variable input. For instance, the traditional capital forms can be depicted as in Figure 2.3. As is shown in the diagram, the use of modern capital inputs such as fertilizer, markedly raises the average and marginal productivities of the existing inputs used in traditional agriculture.

Figure 2.3

HYPOTHETICAL DIAGRAM SHOWING INCREASE IN PRODUCTIVITY OF CAPITAL



APP_I and MPP_I are the average physical products and marginal physical products of capital before the use of fertilizer, while APP_{II} and MPP_{II} represent the average physical product and marginal physical product of capital after the use of fertilizer.

Theory of Technological Change

In the preceding section, the effect of a new input (fertilizer) in traditional agriculture was demonstrated. In this section the phenomenon of technological change is examined more rigorously.

Taking the traditional production relationship as illustrated in equation 2.2, we add another variable "t." This variable is defined as technical change, or new technology. The new production function can be written as:

$$Y = f(L, N, K{:}t). \qquad (23\ )$$

The application of new technology can have a profound influence on total resource productivity, as well as on resource substitution ratios. Shifts in the production function are defined as neutral if the marginal rate of substitution of resources used in the production process remains unchanged, simply increasing or decreasing the output attainable from given inputs. In this kind of technical change, the production function takes the following form:

$$Y = A\ (t)\ f\ (L, N, K), \qquad (2.4)$$

where the multiplicative factor A (t) measures the accumulated effect of the shift in the production function. Other technical changes are known by the resources they save or use. Usually fertilizer is classified as land-saving technology, but in the case of traditional agriculture the productivity of land, labor, and capital increases. This phenomenon is shown for land and labor in Figure 2.2 and for capital in Figure 2.3. This implies that the shift in the production function for traditional agriculture due to application of fertilizer is a neutral type of technical change.

Heady[1] classifies farm innovations as either mechanical or biological. Mechanical innovations are those which substitute capital for labor, but do not change the physical outcome of the plants or animals to which they may apply. On the other hand, biological innovations have a physiological effect by increasing the total output of a given land base. Included in the latter are innovations such as hybrid corn, fertilizer, improved rations, and similar techniques which result in greater output. "The effect of biological innovations is one of increasing both total output and total cost."[2] For mechanical innovations, on the other hand, the question is one of decreased versus increased costs.

Fertilizer as pointed out above, is a biological innovation which causes both total cost and total output to increase. The manner in which net returns are affected by such a technological improvement depends upon various factors. For example, returns are dependent on the price elasticity of demand for the specific product and the effect of the innovation on the total output on the total cost of production, and on the nature of the supply function of the factor input.

It is beyond the scope of this thesis to go into an analysis of the price elasticity of demand and the nature of the supply function of factor inputs. This thesis is limited to the effect of the innovation on:

1. the value of the total output,
2. the total cost of production, and

---

[1]Earl O. Heady, Economics of Agricultural Production and Resource Use (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1952), pp. 818-819.

[2]*Ibid*.

3. the net returns, assuming constant prices for both output and fertilizer inputs.

Factors Affecting the Adoption of New Techniques

Before a farmer accepts a new technology, he must answer two questions. One, is the added income realized from the new technology greater than the added cost incurred? And two, how much should the return over the cost on this investment be in order to compensate for the possible risk and uncertainties involved in the new technology?

In subsistence agriculture, where almost all farm inputs are produced on the farm and where most of the produce is also consumed on the farm, the major decision parameter is the volume produced. The farmer has to produce enough volume to satisfy the subsistence requirement of his family. Oncehe starts to employ purchased farm inputs in his production process, he must think in terms of cost-return analysis. That is, will the added income compensate for the added cost of the new input or technology?

This question is easily answered, provided there are sufficient observations of crop and livestock yields following the use of the new input, as well as data on product prices and costs of the new input. The difficult question is: How much return over investment should a farmer expect from the new investment before he accepts the venture? The acceptability of a new venture is not only an economic question, but it also involves social, psychological, and institutional factors. However, some authorities have attempted to give a measure which can be used to evaluate the acceptability of an innovation by subsistence farmers.

A.T. Mosher cites several experts who estimate that, to appeal to farmers initially, the increased yield necessary from fertilizer ranges from 40 to 100 percent.[1]

The use of percentage increase as a basis for measuring the benefit of fertilizer is very misleading. Benedict and Cogswell illustrate the weakness of this technique with the following example:

> . . . if a grower doubled his yield through use of $50 worth of fertilizer, yet the actual increase was only two quintals per hectare, worth an additional $40, his return/cost ratio would be only 0.8 and he would not use fertilizer again. However, if he increased his yield by only 20 percent from 25 to 30 quintals per hectare, the production increase of $100 in return for a $50 fertilizer cost would result in a marginally attractive return/cost ratio of 2.0.[2]

Instead of percentage increase, Benedict and Cogswell suggest a benefit-cost ratio of 2.0 as a minimum acceptable marginal return.

However, the decision parameter goes beyond the return farmers get from the new input. Their level of subsistence production and their desire to improve living conditions, both regionally and nationally, also have impact. Professor Miracle[3] presents a very interesting analysis of this topic. He notes two basic phenomena: the minimum physiological level of living (MPL)—that is, the minimum level of consumption necessary to maintain life—and the minimum desired level of consumption

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[1]A.T. Mosher, Getting Agriculture Moving (New York: Frederick A. Praeger, 1966), p. 78.

[2]Benedict and Cogswell, op.cit., p. 14.

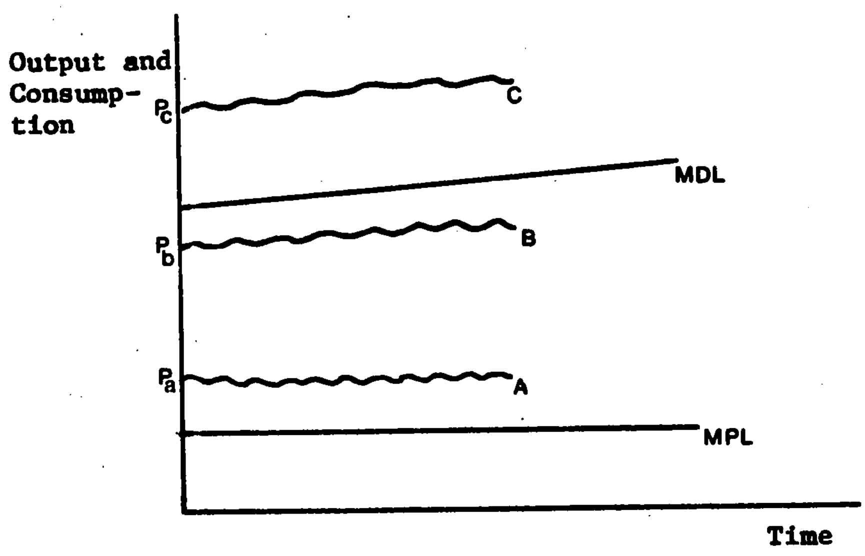
[3]Marvin P. Miracle, "'Subsistence Agriculture': Analytical Problems and Alternative Concepts," American Journal of Agricultural Economics, L (1968), pp. 292-310.

(MDL)--that is, the minimum level of living he feels that he is expected to attain. The minimum physiological level of living is fixed for any group in a given environment, but the minimum desired level is elastic and largely culturally determined.

Let us assume that three farmers, A, B, and C, live in the same cultural and environmental situation. Figure 2.4 depicts their respective production positions with respect to minimum physiological level and minimum desired level.

Figure 2.4

A HYPOTHETICAL DIAGRAM SHOWING THE PRODUCTION POSITION OF THREE FARMERS WITH RESPECT TO MDL AND MPL



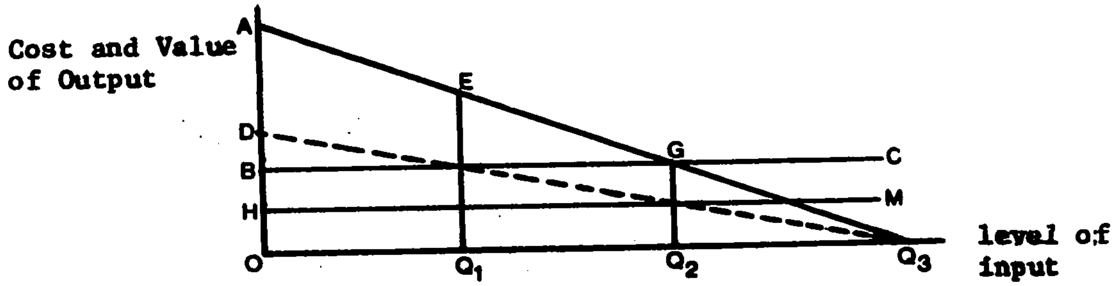
Suppose the three farmers sell the same percentage of production, but A's production level is very close to MPL, B's is very close to MDL, and C's is above MDL. The producer nearest the minimum physiological level of living will be unlikely to accept an opportunity to try a new technique or input because a small loss is required to take him below his MPL. The probability of acceptance of a new technique is stronger for B than for C, even though both have little chance of falling below MPL. This occurs because farmer B has not yet reached his MDL and his desire to attain it constitutes a stronger incentive than farmer C's desire to add to the margin above his MDL that he already enjoys.

The wide acceptability of a new factor input is also dependent upon the availability of the input, credit, and markets for the additional output. Moreover, for farmers, particularly tenant farmers, acceptance of a new input depends on how costs and returns are shared with the landlord. A crop-sharing tenant does not realize the full benefit of his added efforts. If he is considering using a new technique that promises to increase production, he takes into account only the value of his share of the harvest. If he has to pay the full cost of the new technique, his incentive to adopt it is much lower than if he is either an owner operator or a cash renter. An alternative to cash rent is sharing the cost of the new technique in proportion to the income share.

Assuming that the farmer is maximizing profits with no allowance for risk and uncertainty, he will employ the new input to the point where marginal value product equals price of the input or its marginal factor cost. The profit maximizing point for the three types of farmers introduced in Chapter I can be demonstrated graphically (Figure 2.5). For ease of demonstration, let us assume a 50-50 share arrangement where the prices of the product and of the factor input remain constant. There is a dimishing marginal return from the new factor input.

Figure 2.5

OPTIMUM VARIABLE RESOURCE EMPLOYMENT LEVEL



The line AQ_3 represents the marginal value product (MVP) of the firm. The firm's marginal factor cost (MFC) for the new input is depicted by BC. An owner operator's profit is maximum at the Q_2 level of input, where MVP is equal to the MFC of the firm. For the type of crop-sharing tenant we have assumed, the MVP that accrues to him is represented by DQ_3, but the MFC is the same. His profit share is maximum if he employs only Q_1 of the new input. It is at this point that half of the MVP equals the MFC of the firm. On the other hand, if the landlord shares half of the cost of the new input, then the tenant's share of MFC is OH. In this case the profit maximization level of input for the tenant will be at the Q_2 level of input. At this point his marginal factor cost, $\frac{MFC}{2}$, is equal to his marginal value product, $\frac{MVP}{2}$. Hence, the new input utilization of an owner operator farm and of a crop-share lease arrangement, where cost is shared proportionally to the income share, is the same.

But one should not conclude from this analysis that the owner operator and the crop-share tenant will have equal inventive to accept a new technique. The absolute value of the income gained is an important consideration. Suppose adding $60.00 worth of fertilizer to a hectare of land increases the total revenue by $120.00. The net revenue in the case of the owner operator farm is $60.00. For the 50-50 crop-sharer, the additional costs will be $30.00, so that he will net $30.00. Percentage or proportion-wise, profits are the same, but in absolute terms it is only half of what the farmer would have been awarded had he been an owner operator.

In summary, the traditional farmer's acceptance of a new technique is the product of many factors: the amount of net return he receives from implementing new techniques, his level of production in comparison to the minimum physiological level and the minimum desired level of output, the availability of the new factor, and the share and absolute amount of the reward he realizes from accepting the new input.

CHAPTER III

ANALYTICAL TOOLS USED

Three different tools of analysis are used in this thesis: variance analysis, new multiple range test, and partial budgeting. This chapter provides a brief introduction to these tools.

Variance Analysis

Analysis of variance is the process of partitioning the sum of squares into components. One of the objectives of the process is to test the hypothesis that a number of population means are equal. Li says this about the analysis of variance:

> If treatments are qualitative, that is, they involve different kinds of fertilizers rather than different quantities of the same fertilizer, the method of regression cannot be used and one must rely on the analysis of variance where the treatment may be either qualitative or quantitative.[1]

Computations

The mechanics of computing the required information from given data are discussed in many statistics books. The following computational procedure summarizes what most books cover about one-way classification analysis of variance.

In variance analysis the data to be analyzed should be grouped into different samples, and each sample should be observed separately. Suppose the problem involves K treatment samples, each consisting of n observations. Let X_{ij} denote the ith observation on the jth treatment, where i = 1, 2, ..., n, and j = 1, 2, ..., k. Let their respective means

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[1]Jerome C.R. Li, Statistical Inference (Ann Arbor, Michigan: Edwards Brothers, Inc., 1964), pp. 279-280.

be denoted by $\bar{X}_1$, $\bar{X}_2$, ..., $\bar{X}_k$, and the totals of n observations by T_1, T_2, ..., T_k. The total of the K sample totals is called the grand total, which will be denoted by G, and the mean of the kn observations is called the general mean, which is denoted by $\bar{\bar{X}}$. From the above defined relationships, we can compute the required values for the F test, the important statistical test in variance analysis.

The above distribution can be clarified by a tabular demonstration.

Table 3.1

SETUP OF YIELD OBSERVATIONS FROM DIFFERENT TREATMENTS

Sample No.	Treatment 1	2 ... j ... k	Combination
1	X_{11}	$X_{12}...X_{1j}...X_{1k}$	
2	X_{21}	$X_{22}...X_{2j}...X_{2k}$	
.	.		
.	.		
.	.		
i	X_{i1}	$X_{i2}...X_{ij}...X_{ik}$	
.	.		
.	.		
.	.		
n	X_{n1}	$X_{n2}...X_{nj}...X_{nk}$	
Total	T_1	$T_2...T_j...T_k$	G
Mean	$\bar{X}_1$	$\bar{X}_2...\bar{X}_j...\bar{X}_k$	$\bar{\bar{X}}$

The sum of squares $\sum^{kn} (X_{ij} - \bar{\bar{X}})^2$ is called the total sum of squares (SS). It is the sum of the squares of the composite sample kn. The total sum of squares is composed of two sums of squares:

$$\sum^{kn} (X_{ij} - \bar{\bar{X}})^2 = \sum^{kn} (\bar{X}_j - \bar{\bar{X}})^2 + \sum^{kn} (X_{ij} - \bar{X}_j)^2. \qquad (3.1)$$

The first term of the right side of equation 3.1 is called the among-sample sum of squares, and the last term is called the within-sample sum of squares. The among-sample SS measures the variation among the K sample means. It is equal to zero only if all the k sample means are equal. The within-sample SS measures the variation of observations within the sample. It is equal to zero if all the observations within each K sample are the same. The total SS is equal to zero only if all the kn observations are the same.

The among-sample SS is also known as the treatment sum of squares. The within-sample SS is known by other names, such as, pooled sum of squares, residual sum of squares, or error sum of squares. The error sum of squares is generally obtained by subtracting the treatment sum of squares from the total SS:

Error SS = total SS - treatment SS. (3.2)

Using equation 3.1 or 3.2, the numerical values of the components of the total sum of squares used in testing a hypothesis are calculated. The calculated F value is the instrument of measurement used in statistical testing. The F value is obtained by dividing the treatment mean square by the error mean square. The calculated F value is compared with the tabular F value.

The numerical results of an analysis of variance are usually presented in an analysis of variance table.

Table 3.2a

COMPUTING PROCEDURE OF ANALYSIS OF VARIANCE
FOR SAMPLE OF EQUAL SIZES

Preliminary Calculation

Type of Total	Total of Squares	No. of Items Squared	No. of Observations per Squared Item
Observation	$\sum^{kn} X_{ij}^2$	kn	1
Sample	$\sum_{j=i}^{k} T_j^2$	k	n
Grand	G^2	1	kn

Table 3.2b

ANALYSIS OF VARIANCE

Source of Variation	Sum of Square	Degrees of Freedom	Mean Square*	F*
Among treatment	$\frac{\sum_{j=i}^{k} T_j^2}{n} - \frac{G^2}{kn}$	$k - 1$	$ns_{\bar{X}}^2$	$\frac{ns_{\bar{X}}^2}{s_p^2}$
Within treatment	$\sum^{kn} X_{ij}^2 - \frac{\sum_{j=i}^{k} T_j^2}{n}$	$kn - k$	s_p^2	
Total	$\sum^{kn} X_{ij}^2 - \frac{G^2}{kn}$	$kn - 1$		

* $s_{\bar{X}}^2 = \frac{\sum^{k} (\bar{X}j - \bar{\bar{X}})^2}{k - 1}$, and $s_p^2 = \frac{\sum^{kn} (X_{ij} - \bar{X}_j)^2}{k(n - 1)}$

Test of Hypothesis

The F value estimated above is used to test the null hypothesis that the k population means are equal. The comparison between the F value calculated above and the tabular F value for a desired significant level (α) with $V_1 = k$, and $V_2 = k(n - 1)$ degrees of freedom, is used to either accept or reject the hypothesis. If the calculated F value (F_s) is less than the tabular F value (F_α), then the null hypothesis is accepted. Otherwise the null hypothesis is rejected, and the alternative hypothesis is accepted. In other words, if F_s is less than the F_α value with V_1 and V_2 degrees of freedom, it suggests that the treatment means are not significantly different from each other at α significance level. In our analysis, for those crops in a region where F_s is greater than F_α (V_1, V_2) d.f., fertilizer application has significantly increased yields.

The New Multiple Range Test

In the previous section, variance analysis and the F test were used to test for homogeneity of the treatment means. This procedure tests the homogeneity hypothesis; that is, it determines whether or not the k population means concerned are equal. After testing and discovering the existence of significant differences among the treatment means, an important question arises regarding which of the treatments gave a high significant yield increase over the check and which did not. The new multiple range test thus complements variance analysis:

> An F test alone generally falls short of satisfying all of the practical requirements involved. When it rejects the homogeneity hypothesis, it gives no decision as to which

of the differences among the treatment means may be considered significant and which may not.[1]

The new multiple range test was used to single out the treatments which gave the highest significant yield increase. There are two good reasons for doing this. First, this test helps to select only those treatments which are significantly different from the check yield. And second, because the national objective is to increase total agricultural production, the problem is not only to estimate the most profitable level of fertilizer use for farmers, but also to increase the total agricultural product for the country. This involves a constrained production maximization problem that consists of maximizing national agricultural production subject to increasing the incomes of farmers. These are not contradictory objectives because one is necessary for the other. It should be recognized, however, that if we concentrate only on the return-cost ratio a farmer achieves from applying fertilizer, it is possible for the lowest yielding treatment to have the highest return-cost ratio.

The new multiple range test is one of the many methods of testing the significant difference among the means of different treatments. According to Duncan,[2] this method combines the simplicity and speed of application of tests proposed by Newman and Keuls with most of the statistical power advantages of the multiple comparisons test previously proposed by Duncan himself.

The data necessary to perform this test are:

1. the individual treatment means,

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[1]David B. Duncan, "Multiple Range and Multiple F Tests," Biometrics, XI (1955), pp. 1-42.

[2]*Ibid.*, p. 2.

2. the standard error of each mean, and

3. the degrees of freedom on which this standard error is based.

All three inputs required for this test have been calculated in the previous section on variance analysis.

Applying the new multiple range test involved performing the following steps:

1. The significant studentized ranges for α significance levels are obtained from the Studentized Ranges Table for k treatments and V_2 degrees of freedom, where V_2 is the number of degrees of freedom of the error mean square in the analysis of variance, and k is the number of means to be compared in a group.

2. Each significant studentized range found in step 1 is then multiplied by the standard error. This result is called the shortest significant range.

3. The means of the k treatments are arranged according to their magnitudes, starting with the smallest at the extreme left and ending with the highest mean at the extreme right.

4. The difference between the means is tested in the following way:

a. The smallest mean is subtracted from the largest mean, then the second smallest from the largest, etc., ending with the second largest mean being subtracted from the largest mean.

b. This step is similar to step a, except that it starts with the smallest mean being subtracted from the second largest mean, etc.

c. The subsequent steps follow steps a and b, starting each time with the next smallest mean and finally ending with the second smallest mean minus the smallest. In general, there are 1/2 k(k-1) comparisons to be made for k treatment means.

5. The difference between each pair of means is compared with the corresponding shortest significant range as calculated in step 2. Two means are significantly different if the difference between the two is greater than the corresponding shortest significant range between them. Otherwise, they are declared not significant. However, there is the exception that no difference between two means can be declared significant if the two means concerned are both contained in a larger subset with a nonsignificant range.

6. If the difference between two compared means is found to be not significant, these two means and the intervening ones are grouped together, and the group is underscored with a line for convenience. It is not necessary to test for significant differences between any two means within such a group. Consequently, the number of comparisons to be made is less than 1/2k (k-1) for k means to be tested.

Partial Budgeting

In the first two sections of this chapter, the tools for physical fertilizer response analysis were discussed. As pointed out in the introduction, knowledge of the physical yield increase alone is not sufficient for farmers to adopt fertilizer use. They are more concerned about the extra costs and receipts so that they can estimate the increase in net return. Partial budgeting is a useful tool with which to examine these questions.

Partial budgeting is an instrument used to estimate the effect on farm profit of changes in the farm business which do not affect the basic organization of the farm. When a partial budget is being constructed, only those costs and returns which would be altered as a result of the change need be considered. Therefore the following questions must be answered:

1. What extra costs will be incurred as a result of the change?

2. What revenue will be lost?

3. What costs will be reduced?

4. What extra revenue will be gained?

However, not all changes will affect all of these factors. In appraising the addition of fertilizer (input-output) only, increased costs and increased receipts are important.

In using a partial budget to estimate net income change from fertilizer used, the important information needed is:

1. The physical increase in yield or output that can be realized from the change.

2. The farm price expected in the future.

3. The physical amount and the kind of fertilizer used.

4. The cost of the fertilizer at the farm.

In partial budgeting the effect of any undertaking can be grouped into two parts: the benefits or advantages, and the costs or disadvantages. Table 3.3 shows the general layout of a partial budget form.

Table 3.3

THE PARTIAL BUDGET FORM

Costs		Benefits	
1. Added Costs		3. Added Returns	
Variable	$ ______	Fixed	$ ______
Fixed	$ ______	Variable	$ ______
2. Reduced Returns	$ ______	4. Reduced Costs	$ ______
Total Costs	$ ______	Total Benefits	$ ______
Expected change in net income (total benefits - total costs)=$ ______			

The farmer or farm adviser can use this result to help assess whether or not the new venture should be undertaken. The result of partial budgeting analysis will answer the first question in the decision making process. Will the venture be profitable or not?

Other considerations which cannot be so easily measured will be discussed later. With this background concerning the tools of analysis used, we will now pass on to the actual analysis of the effect of fertilizer on Ethiopian farm income.

CHAPTER IV

YIELD DATA AND STATISTICAL ANALYSIS RESULTS

Yield Data

As pointed out in the introduction the yield data were collected from three years of demonstration results. The fertilizer trial demonstrations were done mainly on three of the major cereal crops grown in the country; namely, teff,* wheat, and barley. A few trials were also done on corn, sorghum, and oil crops. Because the observations on oil crops were so minimal that is was impossible to make any relevant statistical conclusion from them, they are not included in this study.

Demonstration Design and Fertilizer Application Rates

In all three seasons and in all areas the same experimental design and fertilizer application rates were used. Each demonstration trial included five treatments. The amount of nutrient applied and the nutrient combinations of the five treatments were as follows. In each trial site, a hectare of land was divided into five subplots, and the amounts of nutrients indicated in Table 4.1 were applied to these subplots on a random selection basis.

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*Teff (*Eragrostis abyssinian*) is a kind of cereal grain with very small seeds (2.5 to 3 million seeds per kg.) measuring about 1 to 1.5 millimeters in diameter. It is the most important crop for domestic consumption in Ethiopia.

Table 4.1

TREATMENTS FOR DIFFERENT CROPS
IN TERMS OF THE PURE NUTRIENT (KG/HA)

Crop	Check	N	P	NP	NPK
Small grains & oilseeds	0-0-0	40-0-0	0-46 -0	40-46-0	40-46-37.5
Corn	0-0-0	60-0-0	0-69-0	60-69-0	60-69-37.5

Source: Imperial Ethiopian Government, Ministry of Agriculture, Extension Service, Fertilizer Demonstrations 1969-70, FAO Fertilizer Program Report (Addis Ababa: n.d.), p. 4.

Collection of Yield Data

Each farmer whose area was selected for the demonstration worked under the close supervision of an extension agent. The agent assisted him in laying out the plots, applying the fertilizer, and collecting the yield data. The agent, in turn, received guidance from an FAO fertilizer expert and an extension supervisor.

The following procedure was used for collecting yield samples. For small grains and oilseeds, a frame measuring two meters square was randomly dropped five times in each subplot. The crop inside the frame was then cut, threshed, and weighed. For sorghum and potatoes a triangular frame with an area of ten square meters was used twice at random for each of the subplots. The crop from this area was also harvested and weighed. For row-planted crops such as corn, harvest samples were selected by taking ten meters from each of the three center rows in every subplot. All the sample weights were converted to a yield per hectare equivalent.

As pointed out above, an extension agent was needed to supervise the work. Therefore, the demonstration trials were conducted in regions where extension agents were available to work with the cooperating farmers. Extension agents are usually posted in areas where there are roads for motor vehicles so that they can be readily contacted by their supervisors and others who are involved in agriculture. Because of the lack of a good road network in Ethiopia, only those areas that are close to main highways which connect the provincial capitals with the national capital meet the transportation requirement. Consequently, study areas are concentrated around cities on main highways.

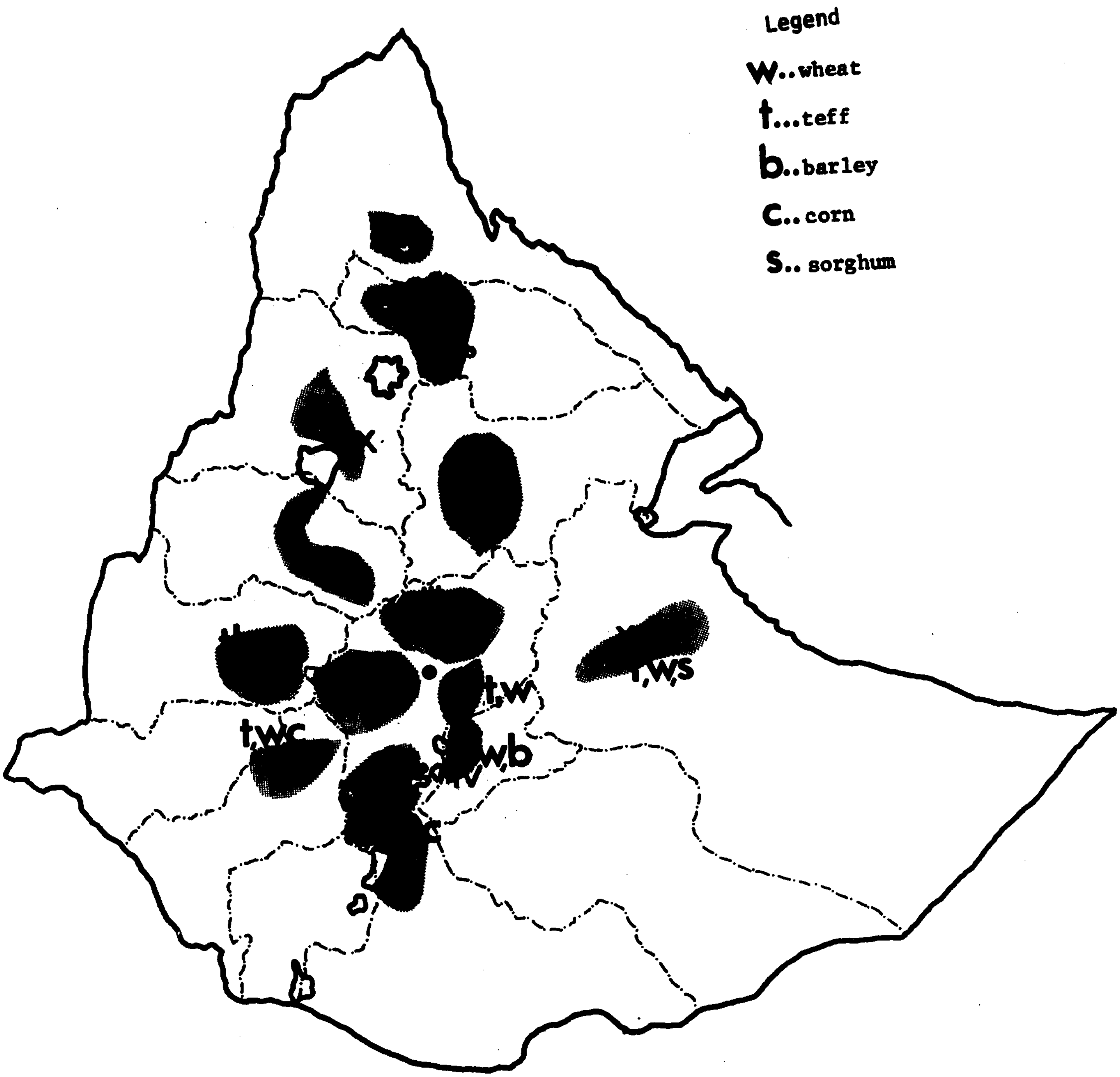
Because of the heterogeneity of many factors, it is more logical to emphasize the profit or loss involved due to the application of fertilizer on smaller sectors than to talk in terms of an average for the whole country. Thirteen regions were selected based on the pattern of the scatter of the fertilizer trials, market conditions, and some physical similarities among the areas.

The physical factors taken into consideration were general altitude and precipitation. The term *general* is used here to indicate that, because of the rugged terrain, the country has altitudes which vary considerably within a small area. The author by no means thinks that this is the best means of classifying the country into different regions for a fertilizer trial study. But in view of the lack of well-classified soil, climate, altitude, and other physical statistics that affect yield, this method was considered the best approach.

One factor used to classify the area into different regions was

Figure 4.1

STUDY REGIONS



the market shed; i.e., the centers where the product was marketed and the inputs were purchased. This factor is relatively clear and easily identified. It is also a very important factor because net farm income is affected by the market price of the product and the cost of fertilizer in a region.

The regions covered in this study are shown in Figure 4.1. They coincide with those established by Miller and his associates[1] as potential areas for increasing the production of grains, pulses, and other crops (Figure 4.2)

To obtain a reliable statistical result, there should be a reasonable number of observations on a given crop in a given area. In this study, crops considered for statistical analysis had been observed at least ten times in the three years. In each region, one, two, or all of the five crops were grown. Of the thirteen regions, only region XIII did not satisfy the above requirements.

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[1]Miller *et al.*, *op cit.*, p. 87.

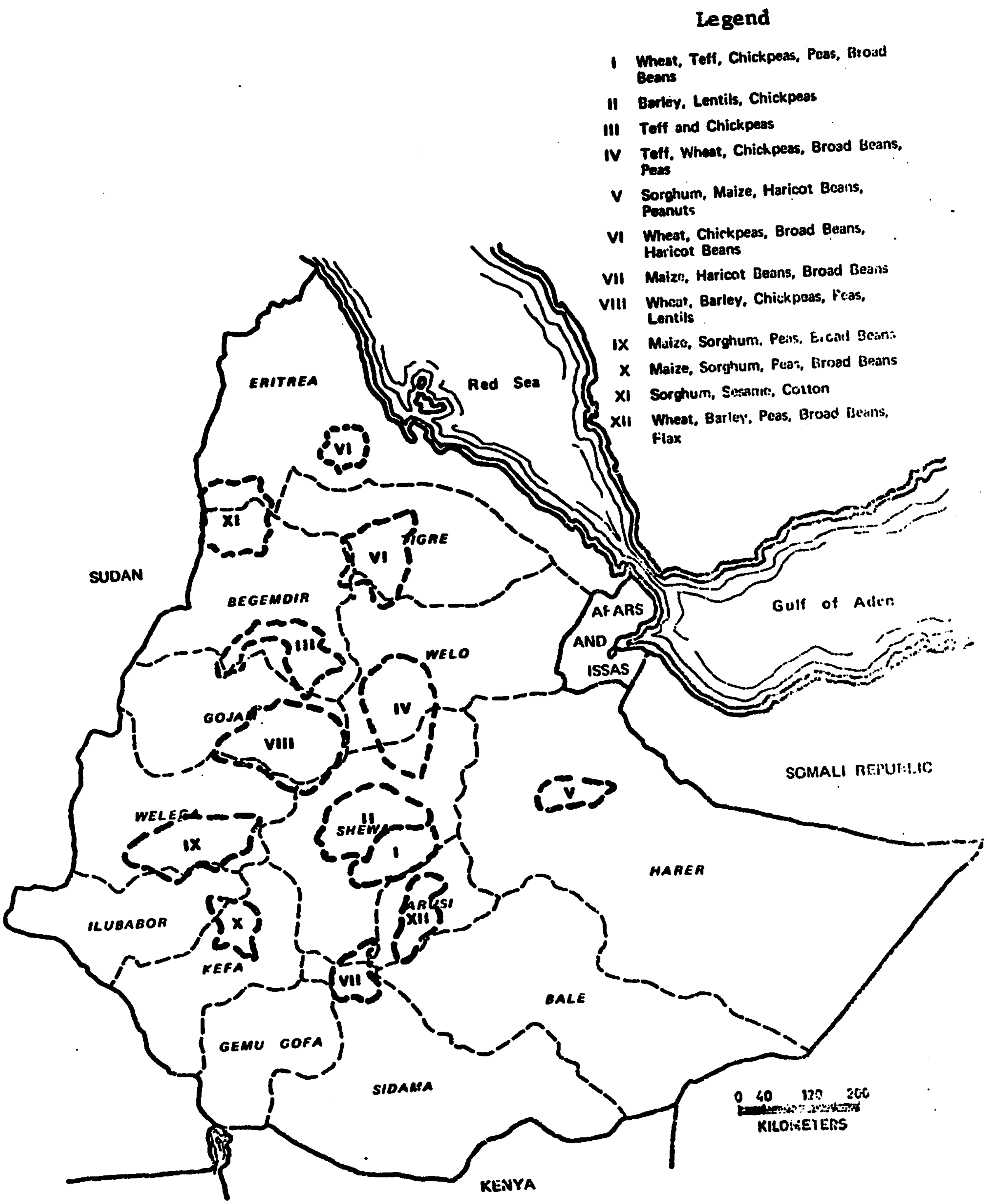

Figure 4.2
POTENTIAL AREAS FOR INCREASING PER HECTARE PRODUCTION OF GRAINS, PULSES, AND OTHER CROPS

Source: Clarence J. Miller et al., Production of Grains and Pulses in Ethiopia, Report No. 10 (Menlo Park, California: Stanford Research Institute, 1969), p. 87.

Results of Statistical Analysis

The objective of this section is to see whether or not fertilizer treatments gave statistically significant increases in yield. The null hypothesis to be treated is that the five treatment yield means are equal. Algebraically, the above hypothesis is expressed as:

$$H_0: \bar{X}_1 = \bar{X}_2 = \bar{X}_3 = \bar{X}_4 = \bar{X}_5. \tag{4.1}$$

The alternative hypothesis is that the five treatment means are not all the same:

$$H_1: \bar{X}_1 \neq \overline{X_2} \neq \bar{X}_3 \neq \bar{S}_4 \neq \bar{X}_5. \tag{4.2}$$

The assumptions used in this test are: (1) each region is homogeneous and (2) each treatment observation is made on randomly selected plots. For hypothesis testing, the 1 percent level of significance has been used.

Results of Variance Analysis

A total of twenty-eight variance analyses were made. These were: teff in eleven regions, wheat in nine regions, barley in five regions, corn in two regions, and sorghum in one region. Of these twenty-eight analyses, three were found to be homogeneous. In other words, there was no significant difference between their means at the 1 percent significance level. Hence, for these three analyses no further tests were required. The remaining twenty-five, however, had to be subjected to further analysis.

The data used for the variance analysis are tabulated in Appendix B. The results of the F test follow.

Teff--The null hypothesis was rejected for the eleven regions where there was enough data for analysis: This means that in all of these eleven regions, the application of fertilizer gave a significant yield increase at the 1 percent level of significance (Table 4.2a).

Wheat--For all but one of the nine regions, the application of fertilizer gave a significant yield increase for wheat. The region that did not show any significant increase was the Tigre region (X), where the observations were for only one area, the Michew Post. Not only were the observations few, but the check yield was much higher than the estimated national yield or the mean yield obtained from other regions in this study. Because of the high check yield, increase in yield due to fertilizer was very small. The reasons for this high check yield are not known (Table 4.2b).

Barley--Of the five regions included only Western Shca (II), Northern and North-Eastern Shoa (III), and Northern Sidanno-Southern Shoa (V) showed significant yield increases. The remaining two regions, Arusi (IV) and Wolega (VII), did not show any significant effect from fertilizer use (Table 4.2c).

Corn and Sorghum--There were significant yield increases in the two regions with fertilizer trials on corn (Table 4.2d) and the one region with trials on sorghum (Table 4.2e).

Table 4.2a

ANALYSIS OF VARIANCE BY REGION FOR TEFF

Region	Source of Variation	Degree of Freedom (d.f.)	Sum of Squares (SS)	Mean Square (MS)	F
I	Among treatment	4	4057.12	1014	29.0
	Within treatment	265	9524.76	35	
	Total	269	13581.88		
II	Among treatment	4	2346.52	586.63	39.95
	Within treatment	370	5432.98	14.68	
	Total	374	7779.50		
III	Among treatment	4	1058.84	264.71	8.50
	Within treatment	130	4050.62	31.16	
	Total	134	5109.46		
V	Among treatment	4	3269.99	817.50	24.19
	Within treatment	360	12165.76	33.79	
	Total	364	15435.75		
VI	Among treatment	4	4929.34	1232.33	35.33
	Within treatment	440	15345.43	34.88	
	Total	444	20274.77		
VII	Among treatment	4	1269.53	317.38	5.98
	Within treatment	145	7701.76	53.12	
	Total	149	8971299		
VIII	Among treatment	4	2105.45	526.36	14.80
	Within treatment	260	9246.56	35.56	
	Total	264	11352.01		
IX	Among treatment	4	1414.27	353.57	21.32
	Within treatment	305	5057.30	16.58	
	Total	309	6471.57		
X	Among treatment	4	1376.91	344.23	18.27
	Within treatment	265	4992.55	18.84	
	Total	269	6369.46		
XI	Among treatment	4	5351.82	1337.95	19.10
	Within treatment	305	21367.75	70.06	
	Total	309	26719.57		
XII	Among treatment	4	964.61	241.15	4.87
	Within treatment	45	2230.58	49.57	
		49	3195.19		

Table 4.2b

ANALYSIS OF VARIANCE BY REGION FOR WHEAT

Region	Source of Variation	Degree of Freedom (d.f.)	Sum of Squares (SS)	Mean Square (MS)	F
I	Among treatment	4	1665.97	416.49	16.33
	Within treatment	155	3954.06	25.51	
	Total	159	5620.03		
II	Among treatment	4	3945.96	986.49	27.44
	Within treatment	465	16720.01	35.96	
	Total	469	20665.97		
III	Among treatment	4	970.60	241.65	11.27
	Within treatment	195	4198.91	21.53	
	Total	199	5169.51		
IV	Among treatment	4	2096.15	524.04	10.54
	Within treatment	200	9939.67	49.70	
	Total	204	12035.82		
V	Among treatment	4	8304.92	2076.23	44.10
	Within treatment	435	20480.56	47.08	
	Total	439	28785.48		
VI	Among treatment	4	956.61	239.15	5.39
	Within treatment	85	3771.65	44.37	
	Total	89	4728.26		
X*	Among treatment	4	290.90	72.72	1.17
	Within treatment	45	2792.38	62.05	
	Total	49	3083.28		
XI	Among treatment	4	1133.05	283.26	7.21
	Within treatment	105	4127.23	39.31	
	Total	109	5260.29		
XII	Among treatment	4	2308.40	577.10	5.69
	Within treatment	130	13186.13	101.43	
	Total	134	15494.53		

*Are not significantly different from each other.

Table 4.2c

ANALYSIS OF VARIANCE BY REGION FOR BARLEY

Region	Source of Variation	Degree of Freedom (d.f.)	Sum of Squares (SS)	Mean Square (MS)	F
II	Among treatment	4	813.50	203.38	4.39
	Within treatment	90	4168.98	46.32	
	Total	94	4982.48		
III	Among treatment	4	2290.73	572.68	23.80
	Within treatment	190	4571.44	24.06	
	Total	194	6862.16		
IV*	Among treatment	4	739.51	184.88	1.91
	Within treatment	80	7747.36	96.84	
	Total	84	8486.87		
V	Among treatment	4	581.88	145.47	17.05
	Within treatment	55	469.47	8.53	
	Total	59	1051.15		
VII*	Among treatment	4	164.73	41.18	1.97
	Within treatment	70	1461.11	20.87	
	Total	74	1625.84		

*Are not significantly different from each other.

Table 4.2d

ANALYSIS OF VARIANCE BY REGION FOR CORN

Region	Source of Variation	Degree of Freedom (d.f.)	Sum of Squares (SS)	Mean Square (MS)	F
V	Among treatment	4	2075.46	518.87	4.38
	Within treatment	70	8291.97	118.46	
	Total	74	10367.43		
VI	Among treatment	4	12420.28	3105.07	17.25
	Within treatment	85	15300.21	180.00	
	Total	89	27720.49		

Table 4.2e

ANALYSIS OF VARIANCE BY REGION FOR SORGHUM

Region	Source of Variation	Degree of Feeedom (d.f.)	Sum of Squares (SS)	Mean Square (MS)	F
XII	Among treatment	4	19274.42	4818.42	34.25
	Within treatment	230	32356.05	140.68	
	Total	234	51630.47		

Results of the New Multiple Range Test

The objectives and analytic techniques of the new multiple range test were discussed in Chapter III. This section contains the results obtained when the analyses found to have significant different means by variance analysis were subjected to new multiple range analysis.

The raw data used in the analysis are the means presented in Table 4.3, and the shortest significant ranges (SSR) are presented in the last four columns of Table 4.4. The remainder of Table 4.4 presents both the relevant values calculated in the variance analysis and the middle step values used to arrive at the SSR.

The results of the analysis are presented in Table 4.5. Each line of Table 4.5 represents the analysis for one of the twenty-five statistically significant fertilizer trials. The crop and the region for which a given line or analysis number stands can be found by referring to Table 4.4. In this analysis the means are arranged in order of magnitude starting with the smallest in the lefthand corner and ending with the largest in the righthand corner. The means are not arranged as they were in Table 4.3. In this analysis the existence of significant yield differences is indicated by underscoring the values having no significant difference, as has been done in Table 4.5. Two or more values underscored by the same line indicates that, in that region for that crop, there is no significant difference between any of the treatments underscored, using a 1 percent significance level.

In all twenty-five analyses the highest yield resulted from NP and NPK treatments, and there was no significant difference between the two in all of the regions and on all crops covered in this study.

Table 4.3

MEAN YIELD BY REGION AND ANALYSIS NUMBER

Analysis No.	Region	Number of Observations	Mean Yield in Quintals per Hectare: Check	N	P	NP	NPK	Crop
1	I	54	7.92	10.29	12.25	17.24	17.85	Teff
2	II	75	6.77	8.61	9.79	12.93	13.27	Teff
3	III	27	7.42	9.62	8.00	12.46	14.84	Teff
4	V	73	6.87	8.02	11.54	13.83	14.26	Teff
5	VI	89	6.22	8.77	10.81	14.23	15.14	Teff
6	VII	30	8.95	12.14	13.95	16.08	17.10	Teff
7	VIII	53	7.03	10.90	11.84	14.50	14.40	Teff
8	IX	62	5.66	8.40	7.79	10.53	11.77	Teff
9	X	54	6.40	9.95	10.73	12.39	12.69	Teff
10	XI	62	15.60	24.29	20.50	25.24	27.40	Teff
11	XII	10	5.03	11.53	9.05	15.01	17.53	Teff
12	I	32	8.34	11.44	11.60	16.32	16.87	Wheat
13	II	94	8.62	11.71	11.13	15.64	16.34	Wheat
14	III	40	7.02	8.75	9.33	12.02	13.05	Wheat
15	IV	41	11.26	12.28	15.91	18.56	19.14	Wheat
16	V	88	11.22	13.04	18.10	21.34	22.04	Wheat
17	VI	18	6.48	9.48	11.08	13.06	15.92	Wheat
18	XI	22	9.86	16.22	11.03	16.55	17.81	Wheat
19	XII	27	10.41	18.37	15.03	20.93	21.61	Wheat
20	II	19	13.68	18.53	16.95	22.27	20.26	Barley
21	III	39	8.15	12.10	12.70	17.46	16.95	Barley
22	V	12	10.92	13.29	13.88	17.50	19.63	Barley
23	V	15	17.13	22.37	26.43	27.79	32.76	Corn
24	VI	18	23.09	27.15	36.52	48.96	53.10	Corn
25	XII	47	19.63	35.41	28.95	40.46	45.59	Sorghum

Table 4.4

PRELIMINARY CALCULATIONS FOR NEW MULTIPLE RANGE ANALYSIS

Region	Crop	Analysis No.*	Error Mean Sq. (MS)	Estimated Error $\left(\sqrt{\frac{MS}{n}}\right)$	d.f. of Error Mean $[V_1^2 = K(n-1)]$	Sig. Stud. Ranges for 1% Sig. Level g:** 2	3	4	5	SSR*** g:** 2	3	4	5
I	Teff	1	35.94	0.186	265	3.64	3.80	3.90	3.98	2.97	3.10	3.18	3.25
II	Teff	2	14.68	0.442	370	3.64	3.80	3.90	3.98	1.61	1.68	1.72	1.76
III	Teff	3	31.16	1.074	130	3.64	3.80	3.90	3.98	3.91	4.08	4.19	4.27
V	Teff	4	33.79	0.680	360	3.64	3.80	3.90	3.98	2.48	2.58	2.65	2.71
VI	Teff	5	34.88	0.626	440	3.64	3.80	3.90	3.98	2.28	2.38	2.44	2.49
VII	Teff	6	53.11	1.331	145	3.64	3.80	3.90	3.98	4.85	5.06	5.19	5.30
VIII	Teff	7	35.56	0.819	260	3.64	3.80	3.90	3.98	2.98	3.11	3.19	3.26
IX	Teff	8	16.58	0.517	305	3.64	3.80	3.90	3.98	1.88	1.96	2.02	2.06
X	Teff	9	18.84	0.591	265	3.64	3.80	3.90	3.98	2.15	2.2	2.30	2.35
XI	Teff	10	70.06	1.063	305	3.64	3.80	3.90	3.98	3.87	4.04	4.15	4.23
XII	Teff	11	49.57	2.226	45	3.82	3.99	4.10	4.17	8.50	8.77	9.13	9.28
I	Wheat	12	25.51	0.893	115	3.64	3.80	3,90	3.98	3.25	3.39	3.48	3.55
II	Wheat	13	35.96	0.619	465	3.64	3.80	3.90	3.98	2.25	2.35	2.41	2.46
III	Wheat	14	21.53	0.734	195	3.64	3.80	3.90	3.98	2.67	2.79	2.86	2.92
IV	Wheat	15	49.70	1.101	200	3.64	3.80	3.90	3.98	4.01	4.18	4.29	4.38
V	Wheat	16	47.08	0.731	435	3.64	3.80	3.90	3.98	2.66	2.78	2.85	2.91
VI	Wheat	17	44.37	1.570	85	3.71	3.85	3.98	4.06	5.82	6.06	6.25	6.37
XI	Wheat	18	39.31	1.337	105	3.71	3.85	3.98	4.06	4.96	5.16	5.32	5.43
XII	Wheat	19	101.43	1.938	130	3.64	3.80	3.90	3.98	7.05	7.36	7.56	7.71

(continued ...)

Table 4.4 (continued)

Region	Crop	Analysis No.*	Error Mean Sq. (MS)	Estimated Error $\left(\sqrt{\frac{MS}{n}}\right)$	d.f. of Error Mean $[V_i^2 = K(n-1)]$	Sig. Stud. Ranges for 1% Sig. Level				SSR***			
						g:** 2	3	4	5	g:** 2	3	4	5
II	Barley	20	46.32	1.561	90	3.71	3.86	3.98	4.06	5.79	6.03	6.21	6.34
III	Barley	21	24.06	0.785	190	3.64	3.80	3.90	3.98	2.86	2.98	3.06	3.12
V	Barley	22	8.33	0.843	55	3.76	3.92	4.03	4.12	3.17	3.30	3.40	3.47
V	Corn	23	118.46	2.810	70	3.76	3.42	4.03	4.12	10.57	11.02	11.32	11.58
VI	Corn	24	180.00	3.162	85	3.71	3.86	3.98	4.06	11.73	12.21	12.58	12.84
XII	Sorghum	25	140.68	1.730	230	3.64	3.80	3.90	3.98	6.42	6.68	6.89	7.03

* To avoid lengthly descriptive references, from now on the analysis number is used to refer to the corresponding region and crop as shown on this page.

** g is the number of means to be compared.

*** SSR - Shortest Significant Range.

Table 4.5

RESULTS OF THE NEW MULTIPLE RANGE TEST

Analysis No.	Treatment Means				
1	7.92	10.29	12.25	17.24	17.85
2	6.77	8.61	9.79	12.93	13.27
3	7.42	8	9.62	12.46	14.84
4	6.87	8.02	11.54	13.83	14.36
5	6.22	8.77	10.81	14.23	15.14
6	8.95	12.14	13.95	16.08	17.1
7	7.03	10.09	11.84	14.4	14.5
8	5.66	7.79	8.4	10.53	11.77
9	6.4	9.95	10.73	12.39	12.69
10	15.6	20.5	24.29	25.24	27.4
11	5.03	9.05	11.53	15.01	17.53
12	8.34	11.44	11.6	16.32	16.87
13	8.62	11.13	11.71	15.64	16.34
14	7.02	8.75	9.33	12.02	13.05
15	11.26	12.28	15.91	18.56	19.14
16	11.22	13.04	18.1	21.34	22.04
17	6.48	9,48	11.08	13.06	15.92
18	9.86	11.03	16.22	16.55	17.81
19	10.41	15.03	18.37	20.93	21.61
20	13.68	16.95	18.53	20.26	22.27
21	8.15	12.1	12.7	16.95	17.46
22	10.92	13.29	13.88	17.5	19.63
23	17.13	22.37	26.43	27.79	32.76
24	23.09	27.15	36.52	48.96	53.1
25	19.63	28.95	35.41	40.46	45.49

In analyses 1, 2, 4, 5, 8, 12, 13, 14, 16, 21, and 24, both of these treatments clearly showed highly significant differences from the others. In the remaining fourteen analyses, even though the NP and NPK are still superior, there is an overlap with the other treatments. In analyses 6, 11, 19, 20, and 23, all four treatment yields are not significantly different from each other, but N and P treatment yields in analyses 6, 11, and 20; N treatment in 19; and N, P, and NP treatment in 23 did not give significant yield increases over the check. In analyses 7, 9, 15, and 17, P alone, and in 10, 18, and 25, N alone, gave yield increases which are not significantly lower then NP and NPK yields. While NP and NPK yields are not significantly different in analyses 3 and 22, it is the N and NP treatment yields in 3 and the P and NP treatment yields in 22 that are not significantly different. However, yields from NPK are significantly higher than those from N in analysis 3 and P in analysis 22.

The result of the new multiple range test can be summarized as such: NP and NPK treatments gave the highest yield increases over the check in all twelve regions and for all five crops examined in this study. Also, there was no significant yield increase over NP from the addition of potassium (K) in all of the regions and crops.

In this chapter one of the objectives set forth in the introduction has been accomplished. The effect of the given levels of the four nutrient treatments N, P, and NPK on the five major crops grown in the country has been analyzed. In the first stage, by using one-way variance analysis, the existence of significant differences between the check nd the fertilizer treatments was tested. Of the twenty-eight sites analyzed, only three failed to show any significant increase.

The remaining twenty-five were further tested using the new multiple range test for a 1 percent significance level to determine which treatment or treatments gave the highest statistically significant yields.

But although the highest yielding treatments have been determined, the economic question, "does it pay?," has not yet been answered. The next chapter deals with this question.

CHAPTER V

COST-RETURN ANALYSIS

In Chapter IV the analysis was devoted to testing the significance of yield increases due to application of fertilizer and determining the treatment or treatments which gave the highest significant increases in yield. Only physical yields were analyzed. If the main objective of this study was to examine only physical yield increase, the research would be concluded. However, the main objective of this study is to examine the profitability of adding fertilizer under different existing tenure arrangements.

In that fertilizer application involves additional cost, the problem under investigation is this. Will the added revenue more than cover the added cost? When a farmer plans to apply a new input, he must calculate the added cost associated as well as the return he will get from it. Moreover, in adopting a new technique, the farmer's decision is governed not only by the net return he receives, but also by the risk and uncertainty he anticipates. The risk aversion or risk taking ability of the farmer is in itself a complex factor, as was discussed in Chapter III.

There are different methods of analyzing the cost and return a farmer experiences when he employs a new input in his production process. As pointed out in Chapter III, one of the most commonly used analytical tools in farm management decision making is the partial budget. In this study, partial budgeting was used to analyze a farmer's net return as a result of applying the fertilizer treatment that gave the highest yield for a given crop in a region. Fertilizer profitability is examined under the three tenure arrangements which were described in Chapter I.

Information Needed for Partial Budgeting

The information required for partial budgeting analysis of fertilizer application can be grouped into two major classes: (1) information required to calculate the extra or marginal costs incurred and (2) information required to calculate the added revenue or return. To estimate the added revenue the two types of information needed are (1) the yield increase and (2) the price farmers receive for the product. In the previous chapter the increased yield from the highest yielding applications and the other treatments was calculated. However, further information is needed on the price farmers receive for the products they sell.

In partial budgeting analysis one of the biggest problems is determining what price will be a good proxy for future price. Farm managers use varying degrees of conscious judgment in estimating future prices. Whereas some proceed largely on intuition, others devote serious and extended thought to the matter. Hedges points out eight techniques farm managers use to estimate future prices:

> Assume that present prices will continue or repeat; choose the expected price from a list of past prices or other possibilities by some random methods; assume that some past price will repeat, or that an opposite price reaction will occur; use an average of past prices ...; extend past price trend with or without modification; base the future price on some economic data series; use an informal analysis, involving various of the above methods; or accept and use estimates prepared by price analysts or economic outlook workers.[1]

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[1]Trimble R. Hedges, Farm Management Decisions (Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1963), p. 193.

In Ethiopia, the problem of price prediction involves not only which method of estimation to select, but also which present price to use in calculating the future price. No official data on the prices farmers receive for their products are available. The only price data available for use are the wholesale price of grains in some of the main markets. To arrive at the estimated price farmers receive in their local markets, the following procedure was used. In each region a five-year average wholesale price for the market or markets where data was available was calculated (Tables 5.1a and 5.1b). From this average price the estimated assembler's and wholesaler's gross profits, plus the cost of transportation between assembling and wholesale markets, were deducted in order to arrive at a local market price for a given crop. (For the location of regional market centers, see Figure 5.1).

Table 5.1a

AVERAGE YEARLY WHOLESALE PRICE OF THE FIVE MAJOR CROPS IN THE ADDIS ABABA MARKET (1966-70)

Crop	1966	1967	1968	1969	1970	Average of Five Years
	$Eth/Quintal					
Brown Teff*	29.63	25.55	25.95	28.11	37.28	29.30
Wheat	22.41	22.35	23.10	23.23	30.91	24.00
Barley	15.80	15.56	14.40	15.17	22.52	16.69
Corn	18.55	13.54	12.42	13.56	21.17	15.85
Sorghum	24.94	19.96	15.26	20.45	28.67	21.86

Source: Ethiopian Grain Corporation, Monthly Average Prices of Cereals, Oilseeds and Pulses, unpublished data.

*According to the Grain Corporation's classification, brown teff is considered a mixed color teff and is known by the common name of Sergenia. It receives approximately the average price for teff.

Table 5.1b

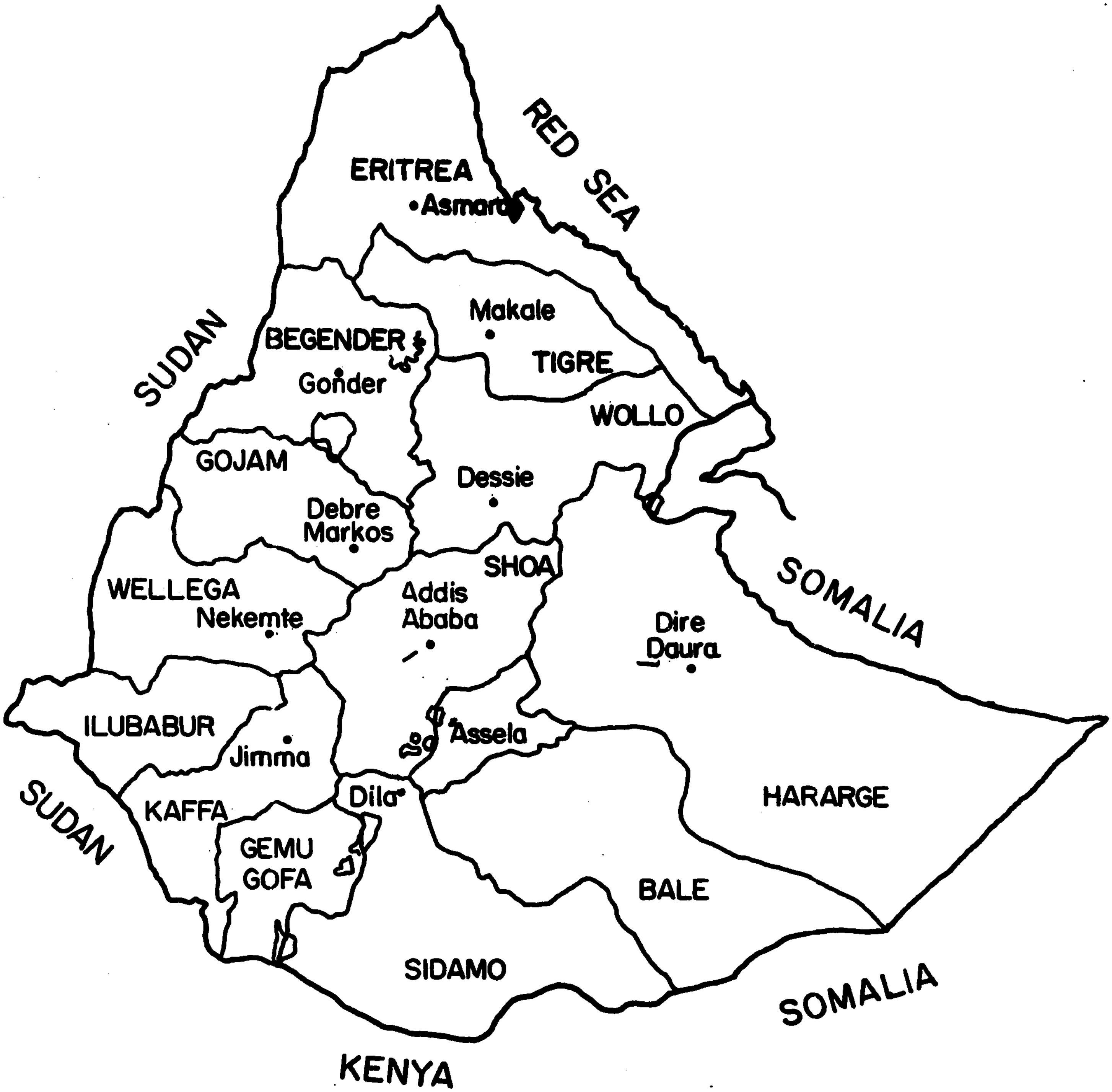
FIVE-YEAR AVERAGE WHOLESALE PRICE FOR REGIONS OTHER THAN THE ADDIS ABABA MARKET (1966-70)

Region	Market	Crops Studied in the Region				
		Brown Teff	Wheat	Barley	Corn	Sorghum
		($Eth/Quintal				
IV	Nazerth	-	23.36	-	-	-
V	Dilla	33.37	25.95	14.94	17.60	-
VI	Jimma	30.74	30.95	-	16.81	-
VII	Gimbi	35.68	-	-	-	-
VIII	Debre Markos & Bahar Dar	25.38	-	-	-	-
IX	Gonder	24.53	-	-	-	-
X	Makale	29.35	-	-	-	-
XI	Dessie	28.83	25.10	-	-	-
XII	Dire Dawa	29.30	25.54	-	-	20.52

Source: Ethiopian Grain Corporation, Monthly Average Prices of Cereals, Oilseeds and Pulses, unpublished data.

Figure 5.1

REGIONAL MARKET CENTERS



Assembling Margin

It is through local rural markets that most of the marketable surplus grains and pulses enter the marketing system. Because each farmer produces a small surplus in excess of his family's needs, there are large numbers of local assembly markets. Assemblers procure supplies either directly from producers or from other assemblers, then sell in bulk quantities to wholesalers in large urban markets and retail to consumers in the area. The bulk of the product, however, goes to the wholesalers.

Thodey[1] estimated the cost of assembling, the cost of transportation, and the assemblers' net margin in 1969. Assuming the distance on an accessible truck road to be 50 km. from assembling point to wholesale market, he estimated the following costs per quintal of grain:

	($Eth)
Assemblers' net margin	0.050 - 2.00
Costs:	
Buying agent's pay	0.10 - 2.00
Sack sewing	0.05
Handling cost (labor)	0.10
Selling brokers in terminal markets	0.10
Transportation	1.00
Truck loading	0.10
Total Cost	1.45 - 1.60
Assemblers' gross margin	1.95 - 3.60

[1]Alan R. Thodey, Marketing of Grains and Pulses in Ethiopia, Report No. 16 (Menlo Park, California: Stanford Research Institute, 1969), p. 136-37.

Wholesalers' Margin

Wholesalers operate merchandising and storage facilities in large urban centers and sell in bulk quantities. Costs involved in the wholesale business are small per unit of volume compared to assembling costs. In most cases the costs involved are: storage, rents, wages, license fees, interest on capital invested on inventories, and handling costs. Thodey[1] estimated the wholesalers' gross margin at $Eth 1.10 per quintal. Since these wholesalers are dealing with large volumes of merchandise, this appears to be a reasonable estimate.

Total Gross Margin

The sum of the two gross margins ranges between $Eth 3.05 and $Eth 4.70. This margin is the same for all crops, regardless of their value, because costs and margins are estimated on volume or weight, rather than on value.

To impute the price farmers receive at local markets, the upper limit of $Eth 4.70 gross margin was used. The upper limit was chosen because the information was gathered mainly from the merchants who likely underestimated their margin. The imputed prices appear in Table 5.2.

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[1] Ibid.

Table 5.2

IMPUTED LOCAL PRICE FARMERS RECEIVE BY REGION

Region	Grain				
	Brown Teff	Wheat	Barley	Corn	Sorghum
	($Eth/Quintal)				
I	24.60	19.30	11.99	11.15	17.16
II	24.60	19.30	11.99	11.15	17.16
III	24.60	19.30	-	11.15	17.16
IV	-	18.66	10.24	-	-
V	28.67	21.25	-	12.90	-
VI	26.04	26.25	-	12.11	-
VII	30.98	-	-	-	-
VIII	20.68	-	-	-	-
IX	19.83	-	-	-	-
X	24.65	-	-	-	-
XI	24.13	20.40	-	-	-
XII	24.60	20.84	-	-	15.82

Added Costs

There are two types of added cost: (1) added fixed costs, where the change requires the purchase or building of additional assets, and (2) added variable costs. The application of fertilizer does not require the acquisition of additional capital assets unless the farmer needs a fertilizer spreader. However, in this study no extra equipment is needed because the fertilizer is broadcast by hand. Therefore, the major cost to the farmer is the cost of the fertilizer.

It is very difficult to account for additional labor required in harvesting, weeding, and other activities related to increasing yield. However, in subsistence agriculture, labor is usually an underutilized fixed asset, which implies that the additional hours of work required will not require additional cash outlay. For example, Heady says:

> . . . the subsistence or low-income farm with a given stock of labor, ordinarily that of the operator plus some provided by the housewife and/or other family members. Here labor can be considered as fixed if outside employment opportunities are unimportant.[1]

The most important cost in this study then, is the cost of fertilizer. Unlike the product market, the fertilizer market in Ethiopia is limited to a few big cities. With only big plantations using it, the demand for fertilizer has been very small. As a result, the few existing importing companies handle the sale of fertilizer through their main headquarters in Addis Ababa or Asmara. Because of the limited fertilizer market, there is no available data on the cost of

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[1]Heady, op cit., p. 84.

fertilizer in different regions. The only available information is the wholesale price of fertilizer in Addis Ababa and Asmara. These two cities are currently the centers of distribution. The wholesale prices of different fertilizers for 1967 in these two cities are presented in Table 5.3

Table 5.3

FERTILIZER PRICES, $ETH PER TON, 1967

Fertilizer	Port	Asmara	Addis Ababa
AS	183	197	243
ASN	195	209	255
Urea	288	302	348
TSP	288	302	348
K_2SO_4	246	260	306
15-15-15	283	297	343
13-13-20	283	297	343
20-20-0	273	287	333

Source: H.M. Benedict and S.A. Cogswell, Potential Fertilizer Demand In Ethiopia, Report No. 1 (Menlo Park, California: Stanford Research Institute, 1968), p. 41.

To impute the cost of fertilizer at the farm gate, the following steps were used. First, for the twelve regions, by calculating the cost of transportation from both Addis Ababa and Asmara and adding this to the initial fertilizer price in each city, the cheaper source was determined. On the basis of this data, the northern provinces of Tigre, Wallo, and Gonder fell into the Asmara Zone; the remaining nine fell into the Addis Ababa Zone. Second, the cost of transportation from the closest supply center to the regional center was estimated. To calculate this cost, the distance between the supply center and each regional center was multiplied by the average freight rate charged per ton kilometer.* Third, assuming fertilizer wholesalers make the same amount of gross margin as grain wholesalers, $Eth 1.10 per 100 kg. of fertilizer was taken as the wholesalers margin. Then the wholesale fertilizer price at the center of each region (except for Regions I, II, and III, which are adjacent to Addis Ababa) was calculated as the sum of wholesale price at the main source plus transportation cost to the center of each region, plus the wholesalers' gross margin. At this stage the wholesale price of fertilizer for all regional centers is known.

The fourth step is based on the following assumptions: that the average distance from the regional center to the farmer's local town is 50 km.; that transportation between the local town and the regional center is available; and that the farmer goes to the regional center to purchase fertilizer only. Based on these assumptions, the costs of hauling and handling the amount of fertilizer required to fertilize one hectare from the regional center to the farm gate were estimated. The sum of these costs, added to the wholesale price at Asmara or Addis Ababa, gives the estimated fertilizer cost at the farm gate. An interest cost at a rate of 8 percent for eight months on the farmer's capital invested in fertilizer was added to that cost.

However, the capital invested in fertilizer may not be the farmer's only expense. Other added costs must be considered such as the costs of marketing the additional yield. Assuming that all the

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*The per ton kilometer freight rate for different classes of roads from 1953-66 as estimated by the Imperial Highway Authority and reported by Thodey, op cit., pp. 86-87, was used.

increased yield is sold to the nearest local market, a nominal cost of $Eth 0.50 per quintal was added for sacks, handling, and other costs. This is the same as the cost of hauling and handling fertilizer from the closest town to the farmer's home.

Estimated Net Return from Fertilizer Use for the Owner Operated Farm

Partial budgeting was the analytical tool used in calculating the net return or loss a farmer realizes through fertilizer application. Partial budget calculations were done for each crop in each area. However, to reduce space requirements and monotony to readers, aggregated added costs and returns are shown in tabular form for all areas and crops in Table 5.4

The net return or loss realized from applying the specified quantity and combination of nutrient is the difference between total added return and total added cost. Table 5.4 illustrates the net return or loss for the highest yielding treatments, NP and NPK. The last two columns of this table give the net returns or losses realized for each region and crop for NP and NPK treatments.

Table 5.4

NET RETURN OR LOSS FROM FERTILIZER USE FOR OWNER OPERATED FARMS

Analysis No.	Increased Yield (qu/Ha)		Price of Product ($Eth/qu)	Total Added Return ($Eth/Ha)		Total Added Cost ($Eth/Ha)		Added Net Return or Loss ($Eth/Ha)	
	NP	NPK		NP	NPK	NP	NPK	NP	NPK
1	9.32	9.93	24.6	229.27	224.28	79.36	104.62	149.91	139.67
2	6.16	6.5	24.6	151.54	159.9	77.78	102.90	73.76	57.00
3	5.04	7.42	24.6	123.98	182.53	77.22	103.36	46.76	79.17
4	6.96	7.39	28.67	199.54	211.87	85.84	114.36	113.70	97.50
5	8.01	8.92	26.04	208.58	232.28	86.30	114.97	122.28	117.31
6	7.13	8.15	30 98	220.89	252.49	85.65	114.32	135.24	138.18
7	7.47	7.37	20.68	154.48	152.41	85.55	113.54	68.94	38.88
8	4.87	6.11	19.83	96.57	121.16	78.75	104.10	17.81	17.05
9	5.99	6.29	24.65	147.65	155.05	75.63	99.02	72.02	56.02
10	9.64	11.8	24.13	232.61	284.73	83.44	110.17	149.17	174.56
11	9.98	12.5	24.60	245.51	307.5	89.33	119.05	156.18	188.45
12	7.98	8.53	19.30	154.01	164.63	78.21	103.51	75.8	61.12
13	7.02	7.72	19.30	135.49	149	77.20	102.66	58.29	46.33
14	5	6.03	19.30	96.5	116.38	78.35	103.59	18.15	12.79
15	7.3	7.88	18.66	136.22	147.04	84.83	112.40	51.39	34.64
16	10.12	10.82	21.25	215.05	229.93	85.65	115.39	129.4	114.54
17	6.58	9.44	26.25	172.73	247.8	85.63	114.49	87.09	133.30
18	6.69	7.95	20.40	136.48	162.18	83.88	109.87	52.60	52.31
19	10.52	11.2	20.84	219.24	233.41	89.64	118.08	129.60	115.33
20	8.59	6.58	19.99	171.71	131.53	79.35	104.05	92.35	27.48
21	9.31	8.8	19.99	186.11	175.91	77.99	104.00	108.12	71.90
22	6.58	8.71	10.24	67.38	89.19	87.69	118.49	-20.31	-29.29
23	10.66	15.63	12.90	137.51	201.63	138.02	168.40	-0.51	33.23
24	25.87	30.01	12.11	313.29	363.42	135.44	166.22	177.85	197.20
25	20.83	25.96	15.82	329.53	410.69	134.24	163.99	195.29	246.69

The net return is positive for all crops and regions where data were available for analysis, except for barley in Region V (Northern Sidamo and Southern Shoa). The net return for the two treatments ranged from a net loss of $Eth 29.29 per hectare for barley in Region V to a net gain of $Eth 246.69 per hectare for sorghum in Region XII.

Of the twenty-four analyses with a positive net return, fifteen were from NP, eight from NPK, and only one from N.* From this result we can conclude that, except for barley in Region V, it pays owner operators to apply the fertilizer treatment giving the highest yield increase for a particular crop in a particular region. This relationship holds only as long as the prices of grain and fertilizer are similar to the values used in this study.

Other Factors Affecting the Adoption of Fertilizer Use on Ethiopian Farms

In Chapter II we discussed at least two major limiting factors, in addition to net returns, which have impact on the adoption of new techniques in traditional agriculture. They are (1) how much allowance is needed for risk and uncertainty for the wide acceptance of a new technique and (2) what incentives do tenant farmers have to use the new inputs.

In Chapter II we discussed the difficulty in setting an empirical value for the contingency allowance. Different authorities have set different values. The author agrees with Professor Miracle's reasoning: i.e., there are different psychological, social, and economic factors which affect the individual's risk taking ability. Hence, the decision as to whether or not an individual thinks the profit margin is attractive

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*The net income shown in Table 5.4 includes only from NP and NPK treatments, but for those sites where N and/or P treatments has given yields close to the highest yielding treatments, the net return is calculated.

enough for him to take the risk is left to him. Another important factor is the rental arrangement under which the farmer operates. In countries such as Ethiopia, where a high percentage of the farmers are tenants, it is unrealistic to base any economic recommendation on owner operated farm results only. The effect of fertilizer use on tenant operated farms should be also examined.

Common Tenure Arrangements in Ethiopia

The common tenure arrangement practiced in Ethiopia is the crop-share lease. The proportion of the produce which accrues to the landlord differs widely from area to area, depending upon the remoteness of the area, the transportation availability, the population concentration and the fertility of the soil within an area. However, in most of the highland regions, the most commonly used share arrangements are: one-third of the produce for the landlord if all of the cost of production except land is covered by the tenant, or one-half of the produce to the landlord if half of the seed cost is covered by him. In addition to the one-third or one-half share, the landlord collects 10 percent of the total product under the disguised name of *asrat* (tithe). In these arrangements the landlord gets 43.3 percent of the crop increase in the first case, 60 percent in the second.

Chapter II covered the theoretical aspect of cost-share lease arrangements with respect to the level of input utilization required to optimize profits. Here we will examine the net return or loss tenant farmers experience through application of fertilizer under the two tenure arrangements. In the two-thirds crop-share arrangement, the tenant covers 100 percent of the added cost of fertilizer and 56.7 percent of the marketing cost of the additional produce. In the second case he covers 50 percent of the fertilizer cost and only 40 percent of the marketing cost of the additional product since 60 percent of the increased yield goes to the landlord.

The revenue and costs accruing to tenants under the two crop-share lease arrangements can be demonstrated in algebraic form:

$$TC_1 = C_F + 0.567\ XC_MY_A, \tag{5.1}$$

$$TR_1 = 0.567 \times TAR, \tag{5.2}$$

$$TC_2 = 0.5 \times C_f + 0.4 \times C_MY_A, \tag{5.3}$$

$$TR_2 = 0.4 \times TAR, \tag{5.4}$$

$$NR_1 = TR_1 - TC_1, \tag{5.5}$$

$$NR_2 = TR_2 - TC_2, \tag{5.6}$$

where C_f, Y_A, C_M, TAR, CT, TR, and NR stand for cost of fertilizer including interest on capital, added yield, marketing cost, total added return, cost to the tenant, tenant's share of revenue, and net return, respectively. The subscript 1 stands for two-third crop-share arrangement, whereas the subscript 2 stands for one-half crop-share arrangement.

The amount of cost the farmer incurs and the revenue he receives from applying the specified amount of NP or NPK in different regions and for different crops under the two lease arrangements are shown in Table 5.5. For ease in comparing the three types of farmers' net income from fertilizer application, the net returns for the owner operated farm and the two types of crop-share lease are presented in Table 5.6.

Table 5.5

TENANT'S SHARE OF COST AND RETURN UNDER TWO-THIRDS AND ONE-HALF CROP-SHARE LEASES FOR THE TWO HIGHEST YIELDING FERTILIZER TREATMENTS

Analysis No.	Crop-Share Arrangement 1				Crop-Share Arrangement 2			
	Cost		Total Revenue		Cost		Total Revenue	
	NP	NPK	NP	NPK	NP	NPK	NP	NPK
	($Eth/Ha)				($Eth/Ha)			
1	76.72	101.80	129.99	139.77	39.21	51.81	91.71	97.71
2	76.03	101.06	85.93	91.48	38.58	51.13	60.62	63.96
3	75.79	101.26	71.15	104.51	38.36	51.31	49.59	73.01
4	83.87	112.27	113.14	121.23	42.57	56.81	79.82	84.75
5	84.03	112.44	118.26	132.90	42.75	57.04	83.43	92.91
6	83.63	112.20	125.24	144.46	42.47	56.75	88.36	101
7	83.43	111.45	87.59	87.20	42.4	56.4	61.79	60.96
8	77.37	102.37	54.76	69.32	39.13	51.75	38.63	48.46
9	73.93	97.24	83.71	88.72	37.51	49.2	59.06	62.02
10	80.71	106.82	131.89	162.91	41.24	54.5	93.04	113.89
11	87.07	116.64	139.20	175.93	44.27	59.1	98.2	123
12	76.22	101.32	87.32	94.19	38.75	51.37	61.6	65.85
13	75.78	100.96	76.83	85.25	38.35	51.03	54.2	59.6
14	76.28	101.36	54.70	66.59	38.81	51.4	38.6	46.55
15	81.96	109.33	77.23	84.13	41.91	55.66	54.49	58.82
16	83.78	112.71	121.93	131.55	42.5	57.22	86.02	91.97
17	83.74	112.24	97.94	141.78	42.48	56.85	69.09	99.12
18	80.90	106.69	77.39	92.79	41.41	54.38	54.59	64.87
19	87.20	116.21	124.31	133.55	44.39	58.71	87.7	93.36
20	76.72	101.56	97.36	75.26	39.21	51.59	68.68	52.61
21	76.12	101.54	105.53	100.64	38.67	51.57	74.44	70.36
22	84.67	114.05	38.20	51.38	43.31	58.46	26.95	35.68
23	130.69	159.90	77.97	115.36	67.72	82.7	55.00	80.65
24	129.53	158.86	177.63	207.93	66.68	81.81	125.32	145.37
25	131.60	161.18	186.85	234.98	66.65	81.5	131.81	164.28

Table 5.6

NET RETURN TO A FARMER FROM FERTILIZER APPLICATION
UNDER THREE DIFFERENT TENURE SYSTEMS

Analysis No.	Net Returns for Owner Operated Farm ($Eth/Ha)		Net Returns for Two-Thirds Crop-Share Lease* ($Eth/Ha)		Net Returns for One-Half Crop-Share Lease** ($Eth/Ha)	
	NP	NPK	NP	NPK	NP	NPK
1	149.91	139.67	53.28	37.97	52.49	45.9
2	73.76	57.00	9.89	-9.57	22.03	12.84
3	46.76	79.17	-4.64	3.25	11.23	21.7
4	113.71	997.50	29.27	8.96	37.24	27.94
5	122.28	117.31	34.24	20.46	40.69	35.87
6	146.24	138.18	41.61	32.26	45.89	44.25
7	68.94	38.88	4.16	-24.25	19.39	4.57
8	17.81	17.05	-22.62	-33.05	-0.51	-3.28
9	72.02	56.02	9.79	-8.52	21.55	12.82
10	149.17	174.56	51.18	56.08	51.81	59.4
11	156.18	188.45	52.14	59.30	53.94	63.9
12	75.80	61.12	11.10	-7.13	22.85	14.48
13	58.29	46.33	1.04	-15.71	15.85	8.57
14	18.15	12.79	-21.58	-34.77	-0.21	-4.85
15	51.39	34.64	-4.73	-25.20	12.58	3.16
16	129.40	114.54	38.15	18.84	43.52	34.75
17	87.09	133.30	14.20	29.53	26.61	42.27
18	52.60	52.31	-3.51	-13.90	13.18	10.5
19	129.60	115.33	37.11	17.33	43.31	34.65
20	92.35	27.48	20.64	-26.30	29.47	1.03
21	108.12	71.90	29.40	-0.89	35.78	18.8
22	-20.31	-29.29	-46.47	-63.02	-16.36	-22.78
23	-0.51	33.23	-52.72	-44.54	-12.71	-2.05
24	177.85	197.20	48.10	49.07	58.64	63.56
25	195.29	246.69	55.25	73.80	65.16	82.78

* The values are calculated using equations 5.1, 5.2, and 5.5.
** The values are calculated using equations 5.3, 5.4, and 5.6.

Net Returns for Tenants Under Two-Thirds and One-Half Crop-Share Lease Arrangements

The simplest comparison of net returns farmers receive from applying fertilizer under the three existing tenure arrangements can be made by referring to the figures given in Table 5.6. Examination of the owner operator's net return situation (shown in the first two columns of Table 5.6) shows that the net return for the two highest yielding treatments (NP and NPK) is positive for all regions and crops included in the study, except for barley in Region V. Not only are the net returns positive, but the increased returns are highly significant.

However, for the tenant operated farms the results are different. The net returns for a two-thirds crop-share tenant and a one-half crop-share tenant are shown in Table 5.6 in columns 3 and 4 and columns 5 and 6 respectively for NP and NPK treatments. The values in these columns are very low when compared with those in the first two columns for owner operated farms.

For a two-thirds crop-share lease, the NP treatments result in a net loss to tenant farmer: teff in Regions III and IX ($Eth 4.64 and 22.62, respectively), barley in Region V ($Eth 46.47), and corn in Region V ($Eth 52.72). The NPK treatments show a higher number of net losses. Of the twenty-five sets of analyses done, thirteen resulted in a net loss. These net losses occured with teff in Regions II, VIII, IX, and X ($Eth 9.57, 24.25, 33.05, and 8.52, respectively), wheat in Regions I, II, III, IV, and XI ($Eth 7.13, 15.71, 34.77, 25.20, and 13.90, respectively), barley in Regions II, III, and V ($Eth 26.30, 0.89, and 63.02, respectively), and corn in Region V ($Eth 44.54).

For a two-thirds sharecropper, fertilizer application either results in a loss or the increased income is so low that it is unlikely to cover the risk allowance the farmer takes. Therefore, in general, we can conclude that, except in areas such as Region XII (sorghum) and Region VI (corn) where the net return is high, the fertilizer venture under existing costs of fertilizer and prices of grain will not appeal to most tenant farmers who have to cover the entire cost of fertilizer.

For the one-half crop-share tenant, where the landlord contributes to the cost of fertilizer in the same proportion as he shares the gross return, the tenant's net return appears to be positive and somewhat higher than under the two-thirds crop-share arrangement. The net losses for NP treatments are fifty-one cents for teff in Region IX and twenty-one cents for wheat in Region III. Much heavier losses did occur for barley and corn in Region V ($Eth 16.35 and $Eth 12.71, respectively). However, for NPK the number of cases with negative returns and the magnitude of those returns are less. For teff in Region IX a loss of $Eth 3.28 occurred, while a loss of $Eth 4.85 occurred in Region III for wheat. In Region V $Eth 22.68 and $Eth 2.05 were lost on barley and corn respectively.

A lease arrangement where the landlord has to share the cost has two advantages in addition to the minimization of loss to the tenant farmers. First of all, the landlord is in a better position to finance fertilization either from his own savings or by getting a loan. Secondly, the risk is divided between the landlord and the tenant. Obviously these advantages do not exist under a tenure arrangement where the tenant has to bear both the cost and the risk of the investment.

However, neither lease arrangement is as desirable in terms of returns to the tenant as is the owner operated farm. Except for the barley crop in Region V, this study has shown that it is profitable for the owner operator to apply fertilizer of the kind and in the quantity specified in all regions and on all crops.

CHAPTER VI

SUMMARY OF ECONOMIC APPRAISAL OF FERTILIZER USE IN ETHIOPIA

Summary

In this study two objectives were set out: (1) to test whether or not the amount and kinds of nutrient applied in the fertilizer demonstration trials resulted in any statistically significant yield increases and (2) to examine the net return individual farmers can expect from fertilizer application under different tenure systems. To accomplish these objectives, the areas where fertilizer trial studies were done were divided into thirteen regions based on common physical factors and market influence (Figure 4.1). Not enough observations were made on any one of the crops for statistical analysis in one region (Region XIII). In the remaining twelve regions, however, there were enough observations on one, two, or three of the five major grain crops grown in the country. In total there were twenty-eight different sets of observations for analysis in the twelve regions. Each of the twenty-eight sets of data were analysed by using one-way variance analysis, and of the twenty-eight, only three did not show any significant response to fertilizer use at a 1 percent significance level. These were wheat in Region X and barley in regions IV and VII.

The physical yield increases were highly significant for the remainder of the analyses. Teff, a crop which is widely grown in the country, showed significant yield increases for all eleven regions for which data were available. Wheat yields also showed significant increases in eight of the nine regions where data were available for analysis.

Barley did not show a highly significant increase; that is, of the five regions where analysis was done for barley, the yield increase was significant in only three regions. Corn in the two regions and sorghum in the one region where enough data was available for analysis showed very high yield increases.

Following this, the twenty-five analyses giving significant yield increases were further analyzed using the new multiple range test to determine which of the treatments gave the highest significant yield increase. The results of this analysis revealed that the highest yield on all of the crops in different regions was from NP and NPK. Also, it was found that there was no significant difference in yield from the use of K over NP. However, on wheat, the use of nitrogen alone in Region IV and the use of phosphorus alone in Region XI gave a yield very close to that of the NP and NPK treatments.

After the physical yield increase and the highest yielding fertilizer treatment were determined, the partial budget technique was used to appraise the net return from the application of the highest yielding fertilizers under three different tenure systems. The tenure systems considered were: the owner operated farm; the two-thirds crop-share lease farm, where the tenant has to cover all the added costs of fertilizer; and the one-half crop-share lease where the tenant pays only 50 percent of the added cost of fertilizer and the landlord pays the balance.

The net returns for owner operated farms, except for barley in Region V, were positive. The amount ranged from a loss of $Eth 29.29 per hectare for barley in Region V to a net gain of $Eth 246.69 per hectare for sorghum in Region XII. The specific amount of net income for each crop and region can be obtained from Table 5.4. In general, the net return resulting from fertilizer use on the owner operated farm was high enough to appeal to most farmers.

However, the net return received by a two-thirds crop-share tenant did not appear very attractive to farmers in most regions. Of the twenty-five analyses done for the twelve regions, the NP treatments resulted in seven net losses, the NPK treatment in thirteen. Not only did many of the regions show a loss for the tenant, but most of the regions showed a very low net income increase. The net income for a two-thirds crop-share tenant was attractive only for sorghum in Region XII, corn in Region VI, and teff in Regions I, XI and XII.

The net income for a tenant farmer who only pays half of the cost of the fertilizer, although not as high as that for the owner operated farm, was far higher for most crops in different regions than the net return of a two-thirds crop-share tenant, who pays all the added cost. However, even in the one-half cost-share arrangement, there were four analyses where the net income was negative for the NP treatments and four negative net incomes for the NPK treatments. But these losses were very small compared to the two-thirds crop-share lease arrangement. For further details the reader can refer to Table 5.6.

Conclusions

The results of this study provide a useful guide for making certain conclusions about current and future fertilizer use on Ethiopian farms. The following are this author's conclusions.

The high physical yield response of almost all crops in the regions included in this study is an excellent indication that fertilizer application can significantly increase the agricultural productivity of the country. And there are at least two good reasons for higher yield increases in the future. For one thing the current fertilizer trials only applied one level of nutrient or combination of nutrients on all small grains and a different constant quantity on corn and sorghum in all regions. Therefore, further research on the response of different crops in different soils and climates can provide answers to the optimum quantities and combinations of nutrients that will give the highest yield increases. Secondly, the introduction of new seeds, improved cultural practices, better farm tools, and farmer education will further increase yields. Many studies conducted on the complementarity of new inputs support the hypothesis that the yield increase from the combined use of inputs such as fertilizer, improved seeds, pesticides and insecticides, and irrigation is greater than the sum of the individual input increases.

Mosher has this to say on the subject:

> Because of the intimate way in which different farm practices interact in affecting yield, it frequently is desirable to introduce several changes of technology simultaneously ... farmers increased maize yields 600% (from 800 to nearly 5,000 kilograms per hectare) by (1) using a new variety, (2) using recommended amounts and kinds of fertilizer, (3) changing the depth of planting the seeds, and (4) controlling insect pests. In most cases, only a whole package of new techniques can achieve such dramatic results.[1]

While we can make positive forecasts about the increase in physical yields, the increase of net farm income, in addition to the physical yield increase, is a function of input costs and the prices of

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[1]Mosher, op. cit., pp. 77-78.

commodities. We can surmise that input costs will probably decrease. As more farmers use fertilizer and the demand increases, there will likely be more suppliers, and because of bulk handling, the costs can be reduced. However, the major factor affecting future net income is the price farmers can expect for their products. In fact, one of the prime elements discouraging farmers from undertaking a new venture is the unpredictability of grain prices.

In Ethiopia the merchants alone determine the price paid to farmers. With no government controls over price, the merchants can reduce the prices of products to any amount they wish when they can expect large supplies. This situation was demonstrated recently in one of the biggest market centers in Ethiopia. The increase in sorghum production in the small area of Setit Humera during 1966 and 1967 resulted in a 44 percent price reduction for sorghum in the Asmara market, where sorghum from this area is marketed. According to the Institute of Agricultural Research:

> The sorghum production of the region has helped the dramatic reduction of sorghum prices in Asmara—from about E$25/quintal last year to around E$14 currently.[1]

Unfortunately, this drastic drop in price, concurrent with the increased supply, drains the net returns farmers receive. Hence, it discourages farmers from increasing their yields.

One of the other basic factors discouraging farmers from undertaking new ventures is the tenure problem. This study has revealed

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[1]Institute of Agricultural Research," Report of the Survey Mission on the Agricultural Development of Setit Humera" (unpublished study, Addis Ababa, Ethiopia, December 1967), p. 34.

that in some regions a crop-share tenant who covers all the added cost has a relatively small incentive to use fertilizer because of a very low net return or even a loss to him. On the other hand, a tenant who shares the cost of fertilizer with the landlord has a lower net return than an owner operator, but he has the advantage of sharing the risk of loss of capital invested. Also because the landlord is in a better financial position, he can obtain the necessary capital for investment in fertilizer and other new inputs. For the tenant to equal the landlords' contribution however, credit must be available at reasonable rates. If farmers have no access to such credit, they must borrow from merchants, local money lenders, or their landlords, often at very high rates of interest which greatly reduce the profitability of using fertilizer.

The above stated problems are the major factors in determining the success or failure of programs planned to increase the agricultural productivity of a country. The government can take steps to rectify the failu es, thereby achieving the goal of increasing agricultural productivity. This goal must be realized in order to meet growing domestic demands and to increase the exportable agricultural product.

Recommendations

The following recommendations are submitted as a result of this study. They suggest means of increasing the success of the current fertilizer demonstration program and ways to supplement the nation's economy through increased agricultural productivity.

1. To alleviate the credit problem--The government, through a development bank established through loans obtained from friendly countries and/or international organizations, should make credit available to

participating farmers at low interest rates during the first few years of a fertilizer program. In other words, loans can be made to a certain number of farmers for one or two years. During that time these farmers should be able to save enough from the additional income generated through the application of the new input to buy it from their own savings. In this way the fund can be rotated among different farmers in a region until the fertilizer program becomes self-financing.

In addition, the government loan scheme should include risk allowance. This is accomplished by providing for flexible repayments, thus allowing for crop years with low returns due to yield or price fluctuations. In a fertilizer program the risk involved is the loss of capital invested in the fertilizer. If farmers are given this flexibility, they will be more willing to take on the venture of fertilizer application.

2. To reduce the cost of fertilizers—Ethiopia can adopt some of the methods used in other less developed countries. Some of the methods used in such countries are: subsidizing fertilizer prices, removing import duty and surcharges, subsidizing cost of transportation, and subsidizing the domestic fertilizer industries.

3. To reduce price fluctuations for products—The net farm income of a farmer is affected more by the fluctuation of product prices than by yield variations. Thus the government should have some control over prices paid to farmers. There should at least be a floor price set by the government for different agricultural products.

4. To manage increased supplies of agricultural products—If supply increases at a greater rate than demand for a product, it is inevitable that the price paid for the product will be substantially

reduced unless the government becomes involved in buying and storing the surplus. However, to tie up scarce capital resources in agricultural support programs in a country like Ethiopia is unwise. The best feasible solution would be to divert the agricultural resources into the production of export crops. All agricultural research stations in the country should be encouraged to devote a larger amount of time and effort toward achieving this goal.

5. To improve the land tenure situation--One of the most important policies for the government to consider is the improvement of the land tenure situation in Ethiopia. More and better incentive can be given to farmers through:

(a) Land reform, whereby the farm operator becomes the owner of the land. This is the most desirable alternative for establishing a healthy socio-economic situation in Ethiopia.

(b) Cash rent, whereby the amount of rent paid to landlor s is controlled or set through government policy.

(c) If the above two recommendations cannot be implemented in the short run, the landlords should share the cost of additional input in proportion to the revenue they receive. It has been shown that both landlords and tenants gain in most cases (See Table 5.6).

In policy making one should be careful not to assume that the problem will be solved with the accomplishment of only parts of the above recommendations. The author believes that all of them must be utilized in order to realize their full benefits. He also feels that the benefits of one recommendation can be negated by the effects of unemployed recommendations if one is done without the other.

The author recommends the following areas for further research:

1. Fertilizer response studies should be done on different crops and in different regions to determine the optimum amount and kinds of nutrients to be used on different crops in an area. This means that fertilizer trials using different rates of fertilization should be implemented.

2. The effects of new seeds should also be studied with and without different levels and combinations of various nutrients. The objective of this research would be to introduce a "package" of new and complementary inputs to the farmer, rather than to introduce each input separately.

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APPENDICES

APPENDIX A

POSTS, CROPS, AND NUMBERS OF OBSERVATIONS BY STUDY REGIONS

APPENDIX A

POSTS, CROPS, AND NUMBERS OF OBSERVATIONS BY STUDY REGIONS

Region	Post	Crop and Number of Observations				
		Teff	Wheat	Barley	Corn	Sorghum
I	Akaka	5	11	0	0	0
	Debre Zeit	8	14	0	0	0
	Mojo	24	7	0	0	0
	Nazerth	17	0	0	0	0
II	Ambo	6	20	0	0	0
	Ghion	18	10	0	0	0
	Ginchi	9	16	0	0	0
	Ghedo	0	6	8	0	0
	Holeta	9	12	11	0	0
	Ijaj	7	0	0	0	0
	Sebeta	5	15	0	0	0
	Tulubolo	12	15	0	0	0
	Wolkite	9	0	0	0	0
III	Chancho	0	10	12	0	0
	Debre Birhan	0	6	22	0	0
	Debre Sina	0	0	5	0	0
	Fiche	9	0	0	0	0
	Gebre Gurach	10	0	0	0	0
	Goha Tsion	8	15	0	0	0
	Molale	0	9	0	0	0
IV	Asela	0	8	0	0	0
	Backaji	0	0	6	0	0
	Degelo	0	0	5	0	0
	Dera	0	5	6	0	0
	Gonde	0	7	0	0	0
	Huruta	0	15	0	0	0
	Sagure	0	6	0	0	0
V	Alaba Kulito	12	0	0	0	0
	Buta Jira	6	0	0	0	0
	Negele	0	6	0	0	0
	Shashamene	0	15	0	6	0
	Abela	0	0	0	9	0
	Areka	14		0	0	0
	Awassa	8	0	0	0	0
	Boditi	5	18	7	0	0
	Dilla	12	0	0	0	0
	Hager Selam	0	0	5	0	0
	Humba	7	0	0	0	0
	Tora	0	23	0	0	0
	Walamo Sodo	9	26	0	0	0

APPENDIX A (continued)

Region	Post	Crop and Number of Observations				
		Teff	Wheat	Barley	Corn	Sorghum
VI	Agaro	6	5	0	6	0
	Asendabo	14	0	0	12	0
	Dedo	13	8	0	0	0
	Jimmea	21	5	0	0	0
	Kumbi	7	0	0	0	0
	Seka	15	0	0	0	0
	Sokoru	13	0	0	0	0
VII	Arjo	0	0	8	0	0
	Gimbi	8	0	0	0	0
	Lekemti	6	0	0	0	0
	Shambo	0	0	7	0	0
	Sire	16	0	0	0	0
VIII	Bahirdar	11	0	0	0	0
	Bure	5	0	0	0	0
	Dangla	6	0	0	0	0
	Debre Markos	5	0	0	0	0
	Dejen	14	0	0	0	0
	Dembecha	12	0	0	0	0
IX	Addis Zemen	12	0	0	0	0
	Chilga	20	0	0	0	0
	Gonder	14	0	0	0	0
	Kola Diba	16	0	0	0	0
X	Abey Adi	6	0	0	0	0
	Adwa	16	0	0	0	0
	Axum	9	0	0	0	0
	Inda Selase	11	0	0	0	0
	Michew	0	10	0	0	0
	Wokro	12	0	0	0	0
XI	Dessie	13	0	0	0	0
	Haik	26	0	0	0	0
	Combolcha	23	12	0	0	0
	Woldia	18	10	0	0	0
XII	Alemaya	0	0	0	0	8
	Asebe Teferi	0	8	0	0	5
	Babile	0	0	0	0	10
	Chilenco	0	6	0	0	0
	Combolcha	0	0	0	0	6
	Deder	0	6	0	0	0
	Hirna	5	0	0	0	7
	Whoter	5	0	0	0	0

APPENDIX A (continued)

Region	Post	Crop and Number of Observations				
		Teff	Wheat	Barley	Corn	Sorghum
XII	Kersa	0	7	0	0	11
Total 12	81	607	372	102	33	47

APPENDIX B

YIELD DATA

YIELD DATA

TEFF YIELD Q./HA.

REGION I

Check	N	P	NP	NPK
4	5	9.3	6.5	8
5.5	2.5	6	9.8	9
6.8	7.6	7.8	7.8	10
2.5	4	6.5	7.5	9.5
7	10	10	12	13
4.5	9.5	6	13.5	22.5
10	11.5	9.5	14.5	17.5
7	11.5	12.3	15.6	18.9
10.5	12	16.5	18.9	22.7
9.5	17	10	15.5	18
6	11.5	15	11.5	12.5
8	9	12.5	22	22
18	18.5	18	23	21.5
8	13.3	14	24.5	14
4	8	13	15	26
8.3	10.5	14	27	23.6
3.5	14	6	10.5	21
10.5	13	18	29.5	21.5
3	6.3	7	13.5	11.5
4.5	11.5	15.3	27.5	21.5
6.5	13.3	16.5	27.5	35.8
4.5	4.5	13.5	16.5	18.3
6.5	8	7.5	23	22.5
5	6	14	15.5	17.5
9.5	10.5	17	19.5	21.5
1.5	3	4.8	7.5	6
9	11.5	12.3	22.9	21.8
8.5	10	10.3	16.8	14.5
11	12.1	15.3	19.5	17
8	9.3	11.6	22.5	19.5
10	8.3	16.3	19	18.8
17	21	22.5	27.3	25.5
10	11	11.5	19.5	18.8
6.5	7.3	10	16.8	15
8.3	8.5	8.3	15	17
5.5	7.3	9.1	15.5	15
1.5	4.5	4.7	9.8	8.5
13.5	15	16	18	18.5
18	21	21.5	27	29.5
7	7.5	11	15	10
10	13	15	15	23
5.5	8	12.5	15	13.5
4	8	6.5	16	16.5
4.5	8.5	16.5	11.5	12
23	14.5	24.5	34	26.5
13	17.5	15	23.5	27
22	23.5	29.5	38	39
4.5	7.5	9	13	14
5	9.5	10	11	13.5
12	19	20	21	23
3	5	5.5	10	9
10	12	11.5	12	13.5
2	2.5	4	7	6
1	1.2	1.5	4.5	4

REGION II

Check	N	P	NP	NPK
11	15	13	13	15
9	10	10	12	13
5	6.5	7.5	9	8
1	2	2.5	3.5	5
6	7	7.5	9	11.5
8.5	8.5	10	13	13.5
5	6	17.5	19	15
18	20	15	9	10
9	9	11	6.5	7
5	2	3.5	10	13
9	10	11	10	22
7.5	6	9	13	14
9	10	11	10	13
6	9.5	11	14	13
7.5	6.5	12.5	9	9.5
3	4	5	8	6.5
5	1	12.5	19.5	13
2.8	2.8	7	6	8
10	11.2	11.5	16.5	12.5
7.5	8.5	14	17	14
6.5	7	9	11	9
6	1.4	10.5	18.8	14
2	2.8	7.5	12.5	10
5.5	1.3	11	19	14
18	18	20	24	25
8	7.8	11.5	16.5	15
8	10	12	15	19
7	10	10	15	13

Region	Check	N	P	NP	NPK
REGION II Continued	3	4	6	11	12
	5	7	10	14	15
	6	7	8	16	16
	6	5	7	11	11
	4	5	5	12	11
	5	11	9.5	11	10.5
	5	12.5	16.5	12.3	12
	8.5	15.3	15	14	13.5
	6	13.5	8.5	14.5	11
	7.3	10.3	11.3	13.1	12.8
	9.5	15	12.5	13.5	13.3
	7	10	8.5	14	14.5
	8.3	16	12.8	17	18
	7	8	7.5	9	11
	3	3	5	6	7
	3.5	6	5.5	11	10
	11	12	14	17	18.5
	4	6	5	6	7
	4	6	7.5	9	17
	10	17.5	12.5	20	21
	11	12	13.5	17	19.5
	7.5	12.5	9	14.5	17.5
	9.5	12.4	10	11.5	17.5
	9.5	14.5	11	19.5	18
	8.5	9	12.5	10	11
	8.5	14.5	9.5	15	16.9
	6.5	9	9.5	12.5	11
	6.5	7.5	6.6	8.5	7.9
	3	7	4	9.6	10
	6.8	9.5	8.5	9.8	7.8
	5.5	9.8	5.8	11.2	11.3
	7.8	11.5	6.3	9.8	8.3
	7.3	9.8	9.3	13	12.8
	3.6	6.9	4.6	13.9	13.1
	2.3	6.5	5	16	16
	3.3	6	2	6.3	6.5
	3.5	4.3	3.8	8	9
	8.8	9	8.8	9	9
	11	13	15	18	19
	6	6	12.5	15	16
	4	5	13	16	18
	4	4	11	13	14
	5	6.5	12.5	16.5	18
	11	11	13	16	17
	10	12	12	17	18
	5	6.5	12.5	14	18
	4	6	12	19	19.5
REGION III	10	14.4	7.5	13.8	13.8
	7.5	11.9	6.9	15.8	13.1
	6.9	10	3.8	12.5	12.5
	6.9	9.4	12.5	17.5	19.4
	8.1	20.6	6.9	11.2	13.1
	6.3	8.1	10.6	8.8	13.1
	2.5	7.8	4.4	14	17.5
	1.5	5.5	4	6.5	6.7
	1.6	2	2.3	4.3	4
	6	10	8	17	20
	25	20	27	17	38
	20	21	17	14	10
	6	8	10	11	10
	10	6	1	11	17
	13	10	12	13	24
	12	10	10	21	16
	11	15	16	10	14
	10	13	2	16	17
	3	7	1	5	9
	6	9	10	19	21
	5	6	7	6	9.5
	3	3	2	6	9
	4	4	4	7	8
	5	8	10	18	22
	4	7	6	17	20
	1	7	7	14	14
	5	6	7	8	9
REGION V	12	15	18	18.3	15
	6	7	9.2	9.2	10
	7	9	10	17	15
	9	10	20	14	15
	8	8.3	10	12	13
	15.2	10	15.5	16	20
	28	30	33	32	35
	7	9	10	11	13
	9	10	16	18	16
	10	13	20	21	22.5
	12	14	19	21	20
	10	12.5	19	20	21.5
	12.5	14	19.5	28	24.5
	14	15	27.5	38	38

REGION V Continued

Check	N	P	NP	NPK
3	4.8	18.8	19.5	21
13.8	19.5	22.8	20	26.8
2.5	4.3	4.5	7.5	7
12.5	17.8	24.8	24.5	27.5
5.5	4.5	6.5	9	9.5
4	8	7	16	15
4	5	15	19	16
3.5	3	4	12	11
3	2.5	3.5	9	9.5
3	4	8	11	13
3	4	11	10	12
13	15	17	20	20
7	8	16	11	8
3	7.5	9	9.5	9
3	9	19	17	9
3	4	8	11	10
2.5	1	10.5	9.5	7.5
3.5	3	12	8	8
18	17	17.5	21	23
20	15	25	25.8	23
6	7.5	7	8	9
7	10	15	11	11.2
5	8	9	10	11
7	9	9.5	10	11
4	9	10	10	11
4	9	10	10	11
6.5	8	15.5	18.5	21
7	9.5	13.5	15	21.5
5.5	6	7	9.5	10
6	7	9	10	12.5
7.5	9.5	10	12	22
3.4	3.5	4.3	6.5	8.5
3	3.5	4.2	6.4	8.5
2.5	3.5	4.3	8.5	6.5
3	3.4	4.3	6.5	8.5
3.4	3	4.5	6.5	8.5
3.5	4	5	7	9
11	4.5	5	10.5	11.5
3.5	4	5	7	6
3	1.5	3.5	6	7.5
3	4	4.5	7	8.5
3.5	3.5	9	11	3.5
3	3.5	4.3	6.5	8.5
4	12	12	12	12.5
2.5	4.2	7.5	13.5	14.5
8	6.5	12	14.5	15.5
4.2	4	7	12	12
4.5	3.8	6.5	12.5	14
4.5	4	7	15.5	16
4.5	4.4	5.5	13.5	14.5
7.5	7	14.3	16.8	15.6
5.6	6.5	7.3	13	11.5
8	11	12.8	14	16.5
8	10.5	11	14.5	14
9	8.6	11	12	15
7.6	7.8	10.8	15.3	13.8
5	4	10.6	10.8	11
10.5	14	17	18.5	18.5
6.5	9	10	14	15.5

REGION VI

Check	N	P	NP	NPK
4.9	6	8.5	9	10.1
8	11	10	15	11
9.5	11	18	20	22.5
4.5	10	8.9	13	16
7	25	35	40	30
6	20	17	21	40
6	6.5	7	8	9.5
6.5	7	7.5	10	11
4	5	8	9.9	10
4.7	6	5	8.9	9.5
4.5	6	6.9	8.3	11
4	5.5	6.9	7.5	8.3
2.5	2.6	7.5	9	9.5
3.5	3	8.9	10	11
2.6	2.7	6.5	9.2	9.1
3	3	7.9	11	10.5
3.5	3.2	9	11	12.5
7.5	9	9	10.5	10
3.8	3.6	8	11	12.5
3.4	3.5	9.1	10	11
15	21	18	21.5	23
7	9.5	8.5	15	17.5
7.5	10.5	9.5	16.5	17
6.5	9.5	21	28	29
7.5	16.5	14.5	19	19.5
6.5	14.5	11	13	14
8	11	21	27	28
11	16	17	19	21
11	14	16	18	19

REGION VI Continued

Check	N	P	NP	NPK
8	17.5	15	19	19.5
12	21	18	21	23
7.5	11	9.5	16	17.5
8	12	15	17.5	18.5
10	20	22	30	30
3	5	8	20	25
15	15	20	30	32
4	5	6	20	20
8	20	16	40	30
8	8	9	30	30
3	6	6.2	20	20
10	22	30	40	40
8	9	10	12	17
6	5	12	7	12
6	8	8.5	10	12
3	7	8	9	10
3	7.5	8	10	10
10	15	20	23	24
5	7	10	20	22
9	9	15	20	20
4	8	16	18	18
8	6	14	15	15
3.5	4	14	16	18
5	7.5	7.5	9.4	11
6	5	12	7.5	12
7	8.5	9.5	10.5	10.5
9.5	9.5	9.5	11.5	11
6.5	9	9.5	10.5	7.5
8.5	10.5	11	11	10
4	6	5	10.5	10.5
7.5	10	7.5	12	12
11.5	15	13	13	17
7.5	6.5	7.5	8.8	9
4.5	3	10	10	9
5	9	6	7	5
3.8	3.8	7.6	8.8	10.1
6.5	9	7	7	6.5
3.8	6.3	7.6	10.6	8.8
6.7	11.5	10	8.8	12.5
5.1	7.2	10	4.3	9.9
3.2	4.3	4.6	6.9	10
8.3	7.5	16	14	8.8
7.5	7.5	6.5	8.8	12.4
5	10	4.1	5	15
3.6	3.8	3.8	11.6	10
6	5	9	7	5
2	3.8	3.8	10	12
2	2	11	8	11
3.5	3.5	7	12.5	11.5
4.5	4	4.5	15	16
3	3.5	10	9.5	11
9.5	9.5	10	11.5	12.5
4	6	5	10	9
8	10	8	12	15
12	11.5	12	16.5	14.5
3.5	9	7	8.5	11
3.6	3.7	9	11	11.5
3.8	4	9.5	12.5	11.5
8	11.5	11	12	11
3	3.5	8.9	10	10.2

REGION VII

Check	N	P	NP	NPK
12	14	15.2	19.2	18.2
5	7.5	10	15	16
7	9	10	11.3	13.2
4.5	10.5	9	11.5	11.5
5	9	9.8	9.9	10.5
6.7	10	10.6	14.8	16
4.2	8	8.5	10.3	12.4
3	4	6.5	8	14
11	16	20	12	15
10	20	22	20	22.5
15	16	20	20	15
7.5	13.5	13	14	16
15.5	16.5	17.5	25	20
5	6.6	9	10	8.5
17.5	22.5	35	42.5	47.5
10	12.5	12.5	15	17.5
17.5	22.5	45	45	45
7.5	7.5	7.5	11.3	11.3
7.5	12.5	12	15	17.5
7.5	17.5	15	17.5	22.5
15	17.5	17.5	22.5	23
7.5	7.5	7.5	15	17.5
7.5	7.5	10	20	20
12	16	13.5	11.5	14
4.5	6	5	10	12.5
7	7	10	8	8
8.5	8.5	10.5	10.5	8.5
8.5	8.5	10.5	10.5	8.5
10	15	12.5	12	14
9	15	13.5	15	17

Region	Check	N	P	NP	NPK
REGION VIII	13	16	17	19	20
	10	12	15	16	15
	3	5	10	11	14
	7	8	9	11	12
	8	11	13	15	16
	8	12	17	18	19
	6	8	9	11	12
	7	10	11	12	13
	9	11	14	17	18
	6	9	12	13	15
	9	12	15	17	18
	8.5	14	11	19	20
	7.5	21	12	24	31
	5.5	12	11.5	20	22
	9.5	15	12.5	19.5	21
	7.5	14	12	21	23.5
	6	9	12	11	14
	6	9	9	14	10
	5	8	9	15	10.5
	6	8	10	13	13
	5	8	9	10.5	11
	6	8	8	10	9
	10	28	25	30	30.2
	9	25	26	28	29
	8	9	8.5	8	9.5
	9	10	9.5	9.5	8.5
	9.5	9	8.5	12	10
	4	4	6	8	8
	1	1	2	6	5
	5	6	5	9	8
	1	1	2	5	5
	2	3	2	5	5
	1	3	2	6	6
	3	2	3	5	4
	6	10.2	10	19	19
	7	8	9	15	16
	6	8	9	12	11.4
	6	7	7	10.9	10.8
	8	9	10.9	15	15
	6	8	8	13	12
	8	9	9	10.5	10.5
	6	7.2	10	12.4	10.4
	7.2	7.2	10	10	8.4
	4	6.4	10.4	10	8
	3.6	4.4	6	7.2	7.6
	4.8	5.6	6	8.8	8
	4.8	6	7.6	11.2	10
	9	15	16	17	17
	13	16	31	25	24
	14	17	32	25	23
	11	14	28	27	22
	15	17	21	25	22
	12	15	29	26	23
REGION IX	5	10	9	3	8
	6	10	6.5	7	8
	1	8	2	6.5	7.5
	1	3.5	1.5	6.5	5.5
	5	10	5.5	10	5
	6.5	8	12.5	6	7
	5	10	7	8.5	10
	2.5	7.5	5	7.6	10
	1.6	3.5	1.8	7.5	10
	7.5	10	8	10.8	20
	7.5	10.8	10	10.8	20
	4.5	10.5	10.5	20	20
	12.5	12.5	15.3	12.2	15
	13	15	18	19.5	20
	9.5	9.5	14.5	13.5	15
	8	9.8	14	12	14
	8	9.8	15	13	14.6
	12.8	13.3	16.3	15	18.0
	12.5	13.3	16.4	16	19.1
	7.5	9.8	15.6	14	16
	2.5	2	5	8	8.5
	1.5	1.5	4.5	5.5	5
	2.5	3.5	5	8	9
	3	5	8	10	12
	6	2	8	10	12
	3.5	3.5	5.5	8.5	8.5
	7	1.5	7.5	10.5	11
	2.8	3.5	4.5	8.5	8
	6	3	9	11	14
	2	1.5	2.5	4	3.5
	2	3.3	3.5	8	13
	2	1.5	3	6	6
	3	6	4	7	8
	3	5	4	5.6	6
	3	7	4	7	6
	9	25	14	25	26

REGION IX Continued

Check	N	P	NP	NPK
4	9	5	7	8
3	6	12	12	12
6	10	6	10	15
10	15	9	15	14
9	13	7	13	11
13	15	13	13	15
6	10	4	10	12
6	10	6	10	12
10	12	12	14	15
9	12	11	14	19
4	6	5	9	10
3	6	3	8	7
7	9	7	15	12
3.5	6	4.5	14	14
4.5	7.5	6.5	8.5	8.5
3	8	4	10.5	9.5
2	3	4	7	5
4.5	8	5.5	11	9.5
7	13	10	10	17
6	11	8	13	15
6	10	8.5	12	13
7.5	10	9	10	10
7	10	8	11	11
4	10	5	9	11
5	9	7.5	11	12
5.5	12.5	6	14	12

REGION X

Check	N	P	NP	NPK
5	7.5	6.5	7	5.5
10.5	12	12.5	9.5	11
7.5	10	12.5	10.5	9.5
3.7	5.5	4.6	10	11.5
8	6.5	10	15	10
4.9	7	7.5	7.5	8.1
5	8.5	8	7	7
6	3.5	7.5	4	4
6.5	10.5	10	11	11
7.5	9	10	12	11
10	14.5	13	14	13
7.5	8.5	8.5	8.5	7
9.5	7.5	12	12	13.5
5	7	7.5	17.5	7
6	25	27.5	25	29
2.5	11.3	12.5	13.8	12.5
1.3	5.5	12.5	22.5	22.8
1.3	8.8	13.8	10	12.5
6.3	15	15	18.8	25
6	8	8.5	7	9
1.3	4.5	15	16.5	17
1.5	7.8	13.8	13.1	12.5
3	5	4	14	11
9	12	10	12.5	13
3.5	4	5	6.5	8
6.5	8.5	7.5	10	11
4	6	6	7.5	10
5.5	12	8	11	13.5
8.5	20	21.5	23	21
6	12	13.5	15	14.5
8	10	11	12	11
5	6	6	9	10
8.5	15	12	16	13
8.5	10	9	13	15
8.5	9	18	10	15
12	18	15	18	16
10	16	17	18	18
12	15	14	16	18
8	15	15	16	18
10	16	15	15	18
9	15	14	18	18
10	12	11	15	16
5	8	9	11	12
3.5	5	4	6	5.5
5.5	8	9	10	8.5
10	11	11.5	13.5	14
5	7.5	7.5	8.5	10
2.5	8	7.5	11	12
5	8	8.5	9	10
5	7	7.5	12	13
11.5	16	15	18	20
5.5	8	6.5	9.5	10
4	5	5.5	6	6
4	6	6.5	7	7

	Check	N	P	NP	NPK
REGION XI	9.8	15.1	10.7	16.9	19.6
	20.4	24	20.4	21.1	24
	10.7	12.3	11.6	14.2	15.1
	18.7	24.9	16.9	22.2	25.3
	12.9	22.2	14.2	20.4	24.9
	11.6	24.4	14.8	20	22.2
	16.9	24.9	16.9	22.2	24.9
	13.5	22.5	14.2	17.5	19.5
	13.8	28.3	21	23.5	26.6
	13	29.5	20.2	24	27
	14	24	15.5	20	25
	13	19	16	19	18.5
	23	29	22	28	30
	18	34	27	39.6	35.7
	28	45	47.6	48	50
	18	25	21	32	34.5
	25	39	40	49.5	50
	15.9	28	29.8	36	37.5
	23.6	29.5	24.7	31.5	30
	15	24	25.6	28	30
	15	27	29.8	29.7	31
	19	29	30	34	36
	20	38.8	39.5	40	39
	31.8	40	46	49	50
	15	25	27.8	31.8	38.9
	28	40	38.5	48.9	50
	21.1	40	31.7	46	49.9
	15	39	26.5	42	45
	14.5	24.1	26.7	31	32.9
	10	11.5	12.6	17.8	18.5
	16	23	21.8	27	30
	15	18	17	26	28
	13	20	19	25	26
	15	22	18	27.5	28.9
	8	15	11	20.5	21
	11	19.7	15.2	24	27
	8	11.4	10	15	13
	13	21	25	29	35
	7	10	9	9.6	21.9
	12	18	16	17	21
	14	19	16	14	19
	15	21	18	22	23
	16	19	18	18	21
	12	19	16	17	21
	15	18.5	14	17.5	18
	11.5	17	11.5	15	13.5
	8	10	9	14.5	15.3
	11	17	12	15	15.3
	20	27.5	20	21	30
	18	27	20	21	26
	19	30	20	25	27
	11	28	18	20	20
	18	29.5	18.5	20	21
	14	22	15	18	20
	16	21	17.5	17	18.5
	14.5	19.5	19	19.5	17
	20	28.5	24	32	34
	9.5	21	9	13.3	15.5
	19.5	23	20	20	21
	12	20	18	30	25
	20	28.5	24	32	34.5
	11	23	12	19.5	24
REGION XII	10.3	11.3	12	12.6	16
	10.5	18	15.5	23.5	24.3
	6	20.5	10.5	26.5	32.5
	6	18	12.5	21	26.5
	6	20.5	15.5	26.5	30.5
	2	6	5	8	9.5
	2.5	5	4	9	10
	2	6	5	8	9
	2	5	4.5	7	8
	3	5	6	8	9

WHEAT YIELD Q./Ha.

	CHECK	N	P	NP	NPK
REGION I	1.3	3.1	2.4	3.5	3.1
	7	9.4	9	15.5	8
	5.5	8	7.5	12	10.5
	9.7	13	12.8	20.5	21
	10	16.5	10.5	25.5	25
	9.6	13.6	15.5	21	21.7
	7	11	11	19.5	19.6
	6	9.5	10.1	19.5	19.7
	8.5	14.2	16	21.9	22
	6.9	9.8	9.5	19	19.5
	9	13.5	14.5	21.5	22
	13.7	17	14.9	18.7	23.7
	16.7	17.8	17.6	19.7	24.5
	11.4	14.3	13.6	16.7	19.5
	4	13.4	15.5	12.4	13.7
	12.5	17	11.5	21	19.5
	14.5	16	17.5	23.5	17.5
	11.4	18.5	10.2	14.7	18.4
	5	8	8.5	8.5	14
	3.5	4.5	4	8.5	10
	7.5	8.5	7	13	15
	11	13.5	19.5	22	22
	9.5	5.5	9	5.5	8
	4	4.5	4.5	6	7
	7	10	9.5	15.5	17
	3.5	6.5	6.5	18.5	9.5
	6	7.5	10	12	9
	19.5	21.5	20.5	25.5	22.5
	8.5	12.3	15.5	16	21
	3.3	5.5	8.8	10.6	17.3
	9	15	17	19.3	21.5
	4.8	7.8	11.3	15.3	17
REGION II	10	12	15	16	16
	17	18	18	25	26
	18	23	19	27	25
	10	13	13	24	23
	4	5	5	6	6
	12	15	14	23	24
	16	17	23	30	27.5
	15.5	19	15.5	19	19
	1	2	2	2	4
	9	12	10	10	12
	10	14	13	16	18
	5	6	8	10	12
	14	22	16	18	15
	12	24	22	26	25
	4	6	4	5	3
	7.5	9	11	13	15.5
	11	9	10	17	19.5
	5.5	6	7.5	12	12.5
	6.5	7	7.5	11	12
	4.5	5	7	11	10.5
	10	14	9	19	18
	12.5	9	11.5	13.5	12
	6.7	8.1	10	14	12
	8.7	9.4	11	17	16
	11.5	12.5	9	13.5	12
	8	9	11.5	13.5	12.5
	11.3	13.5	12.5	13	11.8
	4.5	5.5	6	7.5	7
	9	3	13.5	11	10
	9	10	10	20	20
	10	12	10	25	30
	8	15	8	24	25
	15	24	25	40	43
	4	6	5	8	10
	15	20	18	22	24
	10	12	20	20	25
	8	18	10	24	24
	10	15	10	22	28
	14	18	20	24	28
	12	20	18	25	28
	6	8	8	18	19
	1.3	2.8	2.5	1.3	1.5
	2	2.5	1.5	3.5	3.8
	1.2	1	1.5	3.5	4.5
	2.5	3.5	2.5	7	5
	8	10	9	20	18
	12	10	10	12	22
	11	25	18	25	21
	15	10	17	27	26
	12	10	18	12	12
	11	23	19	21	29
	13	20	18	24	33
	13.5	23.3	16	24	23
	5	6	8.5	9.8	8.8
	12.5	13.5	17	21.3	21.5

Region	Check	N	P	NP	NPK
REGION II Continued	6.8	9.8	11	13.8	14
	11.3	14.8	12	16.3	15
	10	15	14	14.3	13.7
	10	15	14	14.3	13.8
	4.3	7.1	10.1	18.1	21.1
	12.5	18	16.5	22.5	18.5
	7.5	14.3	11.3	12	12
	12	14.8	19.5	14.3	12
	7	12.8	11	13.3	14.5
	4	15	4.8	7	8
	10	13	17.5	19	18.5
	9.3	13	7.5	13.3	21.3
	4.2	8.8	11.4	15.4	17
	8.6	14.1	10	18.9	25.6
	8.5	19.5	11.5	17.7	22.6
	5	7	10	11	10
	4	5	5	10	7.3
	11	12	14	20	16
	10	12	15	20	21
	7.5	8	10.5	18.5	21
	7.3	7.5	8	8.3	10
	7.5	13	8.5	14	16
	9	15	12	17.5	16
	5	12	9	15.3	18.5
	15	16	17	17	16
	10.5	12.8	12.3	15	18
	6	4.5	6	12	12.5
	3.5	13.5	8.5	11.5	11
	5	7.5	8	10.3	10
	7.5	11	8.3	10.5	12.5
	6	10.3	6.8	10.3	10.3
	11	13	11.5	17.5	16.5
	3	5.8	4.5	8.3	8.5
	10	16.5	11	14	15.5
	1.3	3.3	2.8	6.3	6.5
	1.5	4.5	4	14	14
	6	8	7.5	12.3	12.5
	1.8	4.3	3.8	13	13.3
	4	7	5	7	5.3
REGION III	9	13	10	13	15
	8.5	12	13	18.5	19.5
	9	11.5	10	11	12.5
	8.5	8.5	12.5	10	12
	8	11	12.5	15	17
	8.5	8.5	12.5	9	12
	10	12	14	11	18
	7	6	10.5	6.5	11
	10	12	15	10	18
	3.8	5	5.5	5	7
	6	6.3	6.8	10	8
	7	6.4	8	9.5	8.5
	6	8.5	7	9	10
	5	10	7	12	13
	6.5	8.3	7	9.3	10.5
	4.5	6	7	6	8.5
	5	4	8	10	10
	5	6	8	20	21
	10	10	18	20	20
	10	15	25	35	35
	8	10	10	18	20
	9	2	3	10	10
	2	3	5.5	10	15
	4	5	7	7	9
	8	8	8	13	11
	6	7	7	9	9
	3	8	6	9	10
	12	17	14	21	22
	3	9	6	14	15
	10	17	14	21	14
	6	11	13	16	17
	4.3	4.9	3.1	6.3	7.8
	13	13	13	12.5	12.6
	8.2	11.3	8.7	11.4	11.1
	7.5	8.7	9.2	8.9	12
	4.3	4.3	2.5	5.6	6.3
	6.9	8.5	7.6	8.9	10.1
	4.2	4.8	2.7	5.6	6.5
	10	14	13.4	10.9	10.8
	4.1	3.5	2.1	5	6.1
REGION IV	7.6	8.8	12.5	12.9	17.3
	7.3	5.3	16	13	16.3
	12	16	17	16	16
	12.9	12.5	22.7	25.1	27.7
	8	7.6	8.4	14.5	14.3
	8.5	12.5	18	21	22
	11.5	7.5	12	16	17
	11	12	11	13.2	13
	11.5	12	13.5	13.5	16.5

REGION IV Continued

Check	N	P	NP	NPK
2.5	3.8	5	5	6
9.5	12	13	15.5	16
9	9.5	12.5	16.3	18.3
8.5	7	10	15	12.5
6.7	7.9	9.1	10.6	11.9
7.4	6.9	7.9	10.5	16.1
6.8	7.2	7.6	7.8	9.2
10	16	20.5	23	21.5
15.5	16	17.5	19.5	20.5
12	6.5	17.5	18	19
5	6.5	14.5	15	15
15.5	18.5	22.5	32	27.5
15.3	21.3	25.6	34.1	38.6
17	15.2	22.5	32.5	32.7
12.3	13.5	22.1	25.8	20.1
16.5	24	26.8	31.3	34
30	31.5	39	35.5	31.5
34	30.5	33.5	34.3	28.5
5.2	6	4.7	5	6.4
12.7	12.2	17.1	20.1	17.9
12.4	16.3	13.2	17.9	17.2
12	12.5	15	16	14.5
10.6	15	19	18.1	19.1
7.4	10	7.6	10.1	16
10	13.6	12.6	18.1	20.5
7.6	11.1	13	19.5	15.1
5.7	6.2	12.8	16.2	17.2
9.1	10.5	19.7	23.7	21.6
8.5	6.6	12.4	21.8	23.3
15.7	18.4	29.2	27.7	29.9
8.5	9.5	9.5	14	12.5
12.5	7.5	8.5	6	14.5

REGION V

Check	N	P	NP	NPK
12	12.5	24	35.9	39
14	12.2	28	32.5	35
11.5	11.8	32	31.7	34
14	12	26.7	23	28.5
14	17.3	31.5	34	37.5
14.5	18	27	31.5	33
13	12.4	19.7	18.9	19.2
12.2	17.7	28.5	31.7	33.5
26	20	34.5	38.5	39.5
7.5	7.5	20	18	23.5
10.2	12.2	20.7	23.5	26
9.7	10.7	28.5	30.5	30
8.7	12.5	20.5	19.7	27.5
11.5	14.7	29	32.5	31.7
8	8.7	19.5	28	27.7
6.5	8.5	21.5	23	26
12	21	30	34	38
15	21	25	22.5	18
14	11	26	30.5	28
16.3	22.3	40.3	30	43
13.3	11	31.8	26.8	28
17.5	9	23.3	28	34
13.5	10	17.5	18	20.1
9	10	11	28.5	26.5
6.5	8.5	13.5	14	21
15	16	19	24	32
12.5	16	20.5	18.5	19.2
9	14	16.5	19	22
13	15.5	20.5	23.5	29
18.5	31.5	27.5	32	32.5
16	18.5	21.5	23	19
19	27.5	31.5	32	34
9.5	12	10.5	22.5	17.5
7.5	15	18	21.5	19.5
8	10	11	13.5	15
14	16.5	26	31	20.5
12.5	15	22.5	23.5	29
6	9	11	18	20.5
5.5	8	8.5	10	10.5
9	3	8	14	8.5
7.5	12.5	9	16	15.3
7	6.5	9.5	11.5	10
6	5	6	11	12
5	8.5	7	6.5	9.5
9	10	12	14	12
8.5	2	6	8.9	8.2
10.5	15	13	17	16.5
7	8	9.5	11.5	11
8	9	14	16	21.5
11	13	18	21	21.5
16	11	22	35	32
5	4.5	7	9.5	14.5
7.3	8.6	9.8	15.3	14.3
6.5	5.5	13	17	19.5
4	9	.8	10.5	16
10.5	9	14	17	18

Region	Check	N	P	NP	NPK
REGION V Continued	12	14	15.6	16	18
	5	4.5	9	15	15.5
	8	8	9	16	16
	5	6	10	16	15
	4.5	5	10	15	14
	15	15	15.5	18	18
	12.9	17.3	17.6	23.3	19.8
	18.3	22.5	22.3	31.5	19.5
	12.3	15.4	16.6	22.3	17.8
	11	14	14.5	19	13.9
	10.8	15	14.8	24	12
	8.3	11	11.2	15	14.5
	16	20	21	21	27.5
	12.5	18	21	21	22
	6	6.5	7.5	10	15
	13	19	17	22	26
	8.5	9	12	11	19
	5.5	8.8	8.8	11	14.5
	5	11	10.1	12	13
	15.3	20.3	22.5	21	22.2
	18	22.5	24	31	23
	20	21	21.5	28	27.5
	9	12.5	16	17.5	16.5
	10.5	11.5	16.5	16.5	14.5
	8.6	12	13.5	20	25
	22	23.5	23	30.5	30.5
	21	24	29	27	26
	11	10	13	18.5	21.5
	15	20	22	24	23.3
	12	12	16	19	14
	13.5	12	21.5	25	22
	8	9.5	10.5	12	14
REGION VI	10	17.5	30	30	37.5
	10	10	17.5	20	17.5
	10	10	15	12.5	20
	10	12.5	20	20	25
	12.5	15	20	17.5	20
	5.5	9	7	12.5	14.5
	17.5	19.5	21	23	29.5
	5	8	8	10	15
	5	8	5.5	10	15
	5	10	8.5	11	15
	5	8	7	10	15
	3.5	6	6.5	10	11.5
	8	7.5	13	19.5	15
	1	5.5	3.5	5	18
	1	5.5	3.5	5	6
	1	6	4.2	6.5	6
	1	6.2	4.5	6.5	7
	1.5	6.5	4.7	6	7
					7
REGION X	17	18	17	19.5	22.5
	13	13.8	20	15.8	17.5
	21	26	24	29	31.5
	26	35	27	36	31
	16.5	21.5	20	27.5	28
	23	24	28	32	[illegible]
	19	21	19	22	[illegible]
	9.5	7	8	15	[illegible]
	7	11	10	10	[illegible]
	10	12	12	13	12.5
REGION XI	10.5	16.8	11.5	20.8	25
	12	17.8	12.5	14	21
	19.5	18	11.5	20	20.5
	11	18	11.3	20	14
	5	15.3	8	16.5	18.5
	4	14.8	6.8	15.5	17.5
	8	19.5	15	16.5	17.5
	4	8	4.5	6.9	7
	31	36.5	32.5	33	36.8
	7	15.3	8	18.5	19.5
	9	18	11	12	17
	7	15	8	11.5	11
	8.5	19.5	10	15	15.5
	15	14.5	14.5	29	30
	9	14	10	17	18
	2	7	3	10	11
	4.4	11	3	4	3.5
	13.5	15	16	17	19
	8.5	19.5	13	15	15.5
	9	15	10.5	20.3	21
	11	18.5	13	17	18
	8	10	9	14.5	15

REGION XII

Check	N	P	NP	NPK
10	19	16	19.5	17
4.5	18	14	13	10
12	16	14	13	15.5
6.5	12.8	6.8	12.5	16.9
4	10	6	10	8
2.3	3.5	4.8	6.5	5
6	9.5	7.3	8.3	14
14	19	18	15	17.5
15	30.5	18.5	33	32
21	45	34.5	50	46.5
7.5	10.5	9.5	15.5	19.5
10	19.5	10.5	23.5	20.5
12	24.5	18	30	31.5
5.5	11.5	10.5	13.5	15.5
7.8	16	8.3	21.1	15.8
5.5	8.8	5.8	11.8	9.3
5.1	6.3	4.9	15	13
7	12	8	11	13
3.5	5	5	11	7
8	17.5	11.5	16	15.1
20	29	22	31	29
15	19	30	35	40
15	25	20	35	40
15	20	24	23	23
7	15	14	20	25
20	35	27	30	47
22	38	37	42	43

BARLEY YIELD Q./Ha.

REGION II

Check	P	P	NP	NPK
15	11	14	27	26
20	28	25	29	25
13	20	14	24	13
15	19	17	23	28
29	31	28	32	22
20	23	27	29	26
28	27	30	34	29
19	29	21.8	27	23
8.5	12.5	11.3	13.3	17.3
7	9.5	8.5	14.5	16
5.3	13.8	14.3	9.6	9
2.3	5.6	4.1	13.1	8.1
13	18	21.3	22.3	21.8
9	19.3	12.5	19	19
11.3	18.3	18.3	23	23.5
9	17.5	11.5	20.3	18.8
12.5	17.5	15	21	18.5
14	20	18.5	27	26
9	12	10	15	16

REGION III

Check	P	P	NP	NPK
10	12	14	11	13
9	12.5	10	10	12.5
10	20	22	20	21
10	20	22	24	23
12	11	15	20	19
7.5	15	8.5	19	15
7.5	14	7.5	19	15
9	12.5	10	10	12.5
10.4	18	17	17.5	19.5
10	11	12	19	20
11	22	15	20	19
7	18	8.5	17	15
5.5	9	8.5	14	12.5
9	18.1	15	20	21.8
3.5	6.5	5	10	7
6.5	10	11	12.4	13.5
6.5	9	12	23	23.5
9	16	10.5	22	24
6.5	6	11	19	21.5
5.6	8	7.5	17	16.5
7	12	15	23	22
9	10	15.5	19	17
6	7	12	8.5	8.5
12	14	20	24	21
7	7	9	14.5	15.5
8.5	12	13	17	16
6	7	8	14	12
7	10	12	12.5	13
5	8	12	25	19.5
5	4.5	10	12	15
7	8.5	9	17.5	18
2	3	3	11	13
4	5	8	13	16
4	7	8	14	15
11	15	15	17.5	17.5
11.5	16.5	10	18.5	17.5
4	4	14	15	15
18.5	26.5	26.1	31	22
18	26.5	26	30	22.8

	Check	N	P	NP	NPK
REGION IV	21.5	35.5	36.3	37	32.5
	18.5	17.5	27.5	35.5	33
	22.5	30.5	33	44.5	39
	22.5	34.5	22.5	32.5	35.5
	24.5	34	24	34.5	36
	29.5	26.5	23	30	26
	11.9	16.8	25	28	24.5
	12.5	14.5	21	30	23.5
	6	8	9	7.5	13
	27	27.5	29	34	25.5
	3.5	4.5	7	11	6.5
	15.3	18.3	14	15.6	22.8
	11.5	10	17	10.2	9.7
	20.5	21	23.5	17.5	18
	19	18.5	19.5	19.3	26.5
	6	4.5	7.5	12.5	10.5
	5.8	5.3	8.2	18.8	15
REGION V	10	14.5	17.5	18.5	20
	10	16	18	16.5	22
	8	10.5	12	13.5	19.5
	10	11	17	21	19
	9.5	12.5	16	18	20
	8.5	11	13	16.5	18
	7	8.5	12	14	16
	16	18	16	22	25
	16	18	13	21	23
	13	14	10	16	18
	13	13.5	12	18	20
	10	12	10	13	15
REGION VII	12.5	15	12.5	17.5	15
	12.5	15	12.5	15	15
	16	12.5	16	18.3	10.5
	15	13	17.5	17	25
	14	13.2	16.5	15	12.2
	11.5	12	10.5	15	17.5
	29	26.5	25.8	22	23.5
	10	11	12	12	17
	9	19	10.5	23.5	19.5
	15.5	16.5	17	22	19.5
	5.5	9.5	6.5	8	8.5
	17	18	17.5	21.5	22
	15.5	17.5	17	19	18.5
	11	14.5	12.5	17	18.5
	10.5	12.5	12	14.5	16

CORN YIELD Q./Ha.

Region	Check	N	P	NP	NPK
REGION V	20.2	29	27.3	32.8	42.4
	19.3	24.8	54.8	48.1	61.3
	19.7	22.3	37.4	26.1	28.6
	18.1	18.5	23.5	25.2	26.5
	19.8	33.6	24.4	41	50.8
	14.2	24.8	27.1	40	66.6
	20	33.3	33.3	26.2	26.2
	13.1	20	33.3	26.2	26.2
	26.2	20	26.2	26.2	20
	20	26.2	26.2	20	26.2
	20	40	26.2	26.2	33.3
	6.6	16.6	13.5	13.5	20
	6.6	3.3	3.3	13.3	13.3
	16.6	16.6	20	30	30
	16.6	6.6	19.9	20	20
REGION VI	13.8	20	47.5	66.3	75
	55	16.3	32.5	82.5	83.3
	22.5	35	71.3	75	95
	25	20	43.3	55	78.8
	29.7	39.7	40	56.4	56.3
	22.2	48.8	40	53.3	48.8
	24	27	32.3	36.5	39
	13	27.6	27.9	30	32
	19.5	28	30	38.5	46
	29	35	45	52	56.5
	25	35	35	39	45
	24.5	29	34.5	37.5	39
	24	29.3	38.8	37.5	44.5
	13.3	8.7	26.4	35.5	37.5
	14	16	8.9	34.2	29.7
	14	19.1	31.1	49.9	61.5
	21.0	25.8	36.4	53.3	37.7
	25.8	28.4	36.4	48.8	50.2

SORGHUM YIELD Q./Ha.

Region	Check	N	P	NP	NPK
REGION XII	12.5	17.5	20	23	31.5
	16.5	21	24	24.5	35.2
	13	25	30	32	35
	22	28.8	30	38	45
	31	35	37.5	55	60
	18.5	19.8	23.5	39	31.3
	15	38	35	60	55
	35	38.5	37.3	45	53
	30	45	42.4	36	30.5
	28.8	64.1	30	41.8	59.6
	30.5	67	39.6	37	42.8
	29.5	37.5	37.5	55.5	43.5
	35	45.5	44	36.3	37
	32	50	52	57	60
	32	41	32	20	61
	32	41	32	50	51
	20	46	37	41	48
	20	31	42	43	50
	17	34	22	40	41
	24	52	31	61	67
	30	54	34	62	73
	29	53	30	70	73
	24	51	30	62	71
	5.8	9.5	9.7	18.5	30.7
	2	5	3.5	8.5	10
	16.8	29.8	22	48.5	39.8
	15.5	24.5	23	38	43.5
	13.5	20	15	23.5	30
	18.5	46	24	44.5	49.5
	26.5	40	39	43.8	45.7
	30	35	34.5	38.8	46.5
	20	36	34	38	56.5
	9	35	30	36	43
	10	36	34.5	38.7	46.5
	9.7	31.2	21.5	32	40.5
	12.5	30	20	36	46
	10	22.5	19.5	25	28.5
	12.5	26	15	30	35
	6	25	13	29	29.5
	11	26.5	15.5	28	27
	9.5	23.5	15	30	31
	16	39.5	40.5	50	49.5
	12	28	18.5	32.5	33
	23	48.5	44.5	62.5	63.5
	19	37.5	31.5	51.5	52.5
	17	33.5	30.5	39.5	40
	19.5	40	33.5	50	48.5