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Agronomic and Economic Evaluation of Urea Placement and Sulfur-Coated Urea for Irrigated Paddy in Farmers' Fields in Eastern India

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Abstract

In six states of eastern India, 162 fertilizer trials were conducted in farmers' fields to compare the response of wetland paddy to three different fertilizer practices: deep-placed, hand-placed urea supergranules (USG); basally broadcast, sulfur-coated urea (SCU); and split-broadcast prilled urea.

Results of the analysis indicated that the agronomic efficiencies of USG and SCU are equivalent and that both are greater than the efficiency of prilled urea. It was determined that the N required to obtain an increase of 1 mt of paddy yield was approximately 25%-45% less with USG or SCU than with prilled urea. Also, grain yield increases from an application of 50 kg of N/ha in the form of USG and SCU were 25%-60% higher than grain yield increases obtained from prilled urea.

In approximately 40% of the experiments, the response to USG and SCU was statistically greater than the response to prilled urea. In 55% of the experiments response to all materials was equivalent, and in about 5% of the experiments response to prilled urea was better than response to USG and SCU.

At the economic optimum, the average agronomic efficiencies from the 162 experiments were equal to 15.9, 21.0, and 21.8 kg of paddy/kg of N applied in the form of prilled urea, USG, and SCU, respectively. The paddy value:cost of fertilizer ratio was equivalent at the optimum when USG was assumed to cost 10% more than prilled urea and have an application requirement of 15 days/ha, and SCU was assumed to cost 50% more than prilled urea and have an application requirement of 2 days/ha. The average value:cost ratios were equal to 2.7, 2.8, and 2.6 for prilled urea, USG, and SCU, respectively.

Assuming an annual cost for a USG applicator of Rs 400/year and average yield gains as determined in this study, at the price relationships used, a farmer would need to use the applicator on 10 ha/year to recover his investment. If the wage rate doubles, the use requirement would be reduced to 5.2 ha/year.

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Symbols, Acronyms, and Abbreviations

Fertilizers

K_2O	potash, expressed as potassium oxide
KCl	potassium chloride
N	nitrogen
P_2O_5	phosphate, expressed as phosphorus pentoxide
SCU	sulfur-coated urea
SSP	single superphosphate
USG	urea supergranules

Organizations

HFC	Hindustan Fertilizer Corporation Limited
IFDC	International Fertilizer Development Center
IRRI	International Rice Research Institute
TVA	Tennessee Valley Authority

Measuring Units

cm	centimeter
ha	hectare
kg	kilogram
m	meter

Miscellaneous

CV	coefficient of variation
MC	marginal cost
MR	marginal revenue
MRM	multifertilizer response model
Rs	Indian rupee
VCR	value:cost ratio

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Summary

In six states of eastern India, 162 fertilizer trials were conducted in farmers' fields to compare the response of wetland paddy to three different fertilizer practices: deep-point, hand-placed urea supergranules (USG); basally broadcast, sulfur-coated urea (SCU); and split-broadcast prilled urea. Response curves were estimated for each N management practice for individual trials and for groupings by states and seasons. The mean values of the linear regression coefficients from the 162 trials were 22.7 for urea, 32.0 for USG, and 33.7 for SCU. For data pooled on a state basis by season, the linear regression coefficients for urea ranged from 9 to 30 and for USG and SCU from 17 to 45. N sources, which include their unique time and method of application within the trials, were statistically compared by testing for differences among their linear regression coefficients. USG and SCU were superior to urea in about 40% of the trials and equivalent to urea in 55%. USG and SCU gave equivalent responses in 71% of the trials.

There were wide variations in paddy responses to N and among N sources in the various trials. Site-specific variables that were measured included rainfall, soil pH, and topsoil texture. Correlation analysis between the linear response coefficient or differences in the coefficients between any two sources and the site variables showed only very weak relationships. There is a need for documentation of other soil, climatic, and management site characteristics. Some that might be useful are water percolation rates, adequacy of water supply and nutrients other than nitrogen, land form and hydrology, and pest incidence.

Economic analyses were made on the basis of maximizing net returns from the use of N by considering the estimated response curves, paddy price, and cost of N. Price assumptions were these: paddy at Rs 0.80/kg, urea-N at Rs 4.65/kg, USG-N at Rs 5.915/kg, and SCU-N at Rs 6.67/kg. N costs include estimated labor cost for its application, which varies among N sources. Optimum rates of N (rate that maximizes estimated net returns to N) are generally in the following decreasing order: Urea>USG>SCU. The arithmetical means of optimum rates from all trials were 91, 85, and 80 kg of N/ha for urea, USG, and SCU, respectively. The mean paddy yield increases for those rates of N were 1,575, 1,932, and 1,863 kg of paddy/ha for the three fertilizers. Mean net returns at the optimum N rates were generally higher from USG than from urea and SCU. The means of the average grain produced per kilogram of N at the optimum rate were 16, 21, and 22 kg/kg for urea, USG, and SCU. In general, the highest value:cost ratios were attained from USG use.

On the average the agronomic efficiencies of USG and SCU are similar and both are greater than that of urea. Because the N from SCU costs more than the N from USG, the economic optimum rate of N, the corresponding yield increase, the net return, and the value:cost ratio at the optimum N rate are lower for SCU than for USG. But, all of these criteria except value:cost ratio are greater for SCU than for urea. In terms of greater agronomic efficiency, higher net returns, and higher value:cost ratios, deep-point placement of USG appears to hold more promise than the present practice of split-broadcast applications of urea.

It was determined that the N required to obtain 1 mt of paddy yield increase was approximately 25%-45% less with USG or SCU than with prilled urea. Also, grain yield increases from application of 50 kg/ha of N in the form of USG and SCU were 25%-60% higher than grain yield increases obtained with urea.

Considering the average wet season results, SCU and deep placement would be expected to give similar net returns (about Rs 200 greater than split broadcast urea) when wage rate is Rs 6/day, SCU-N cost is 30% more than urea, and deep-placement material cost is 10% more than urea and requires 8 days of labor.

Reducing the labor requirement to 2 days, as possible with a simple application machine, would provide an additional Rs 41/ha, which could be considered as available to recover the investment and maintenance costs estimated to be Rs 400/year. Use of the applicator for 5 ha at 2 crops/year would recover the cost of owning the machine. At a wage rate of Rs 12/day, 2.6 ha/crop season would cover investment and maintenance costs.

Under the average conditions of these trials, the marginal net return to labor for hand placement would appear to be attractive. The marginal net return to a simple fertilizer applicator is estimated to be attractive only to farmers using the machine on more than about 12 ha/year. The profitability would increase or the required level of use for a given return would decrease with increasing wage rates.

Introduction

Development of new and/or improved fertilizers and fertilization practices for crop production has been and continues to be a major undertaking of the International Fertilizer Development Center (IFDC). Included in the development process is evaluation from technological, agronomic, economic, and socioeconomic viewpoints.

Considerable progress has been made in understanding and improving the agronomic efficiency of nitrogen (N) fertilization for wetland rice production. Urea accounts for the major portion of fertilizer N used for rice production.[1] It is widely recognized, however, that only about one bag in three of the urea applied for wetland rice production is utilized by the rice crop. As early as the 1960s it was demonstrated that placement of N fertilizer into the paddy soil resulted in increased agronomic efficiency (De Datta et al., 1968; IAEA, 1970). More recently it has been shown that ammonia volatilization accounts for significant losses of applied N when urea is broadcast on paddy soils (Vlek and Craswell, 1979; Fillery, 1981). Losses are particularly great when crop demand for N is low, pH is high, temperature is high, and air movement is rapid (removing ammonia from the soil or water surface). Even when attempts are made to incorporate the urea into the paddy soil during puddling, a portion of urea remains on or near the soil surface or in the floodwater and thus is subject to loss.

Most urea is in the form of prills, and because urea is hygroscopic, prills are difficult to handle under humid conditions. Significant efforts to develop fertilizer applicators that place prilled urea into paddy soil have started only recently. However, large particles of urea, such as urea supergranules (USG) or urea briquettes, have been developed to facilitate hand placement into paddy soils. It now has been demonstrated through many trials conducted on experiment stations that the deep-point placement of urea by hand into paddy soil increases the agronomic efficiency of urea for wetland rice (De Datta and Gomez, 1981; Parish et al., 1980; Yamada et al., 1979). Although wide variations exist among trials, on the average results show that at optimum application rates only about two-thirds as much N is needed from point-placed urea (USG) as is needed from split-broadcast prilled urea. Hand placement of the fertilizer, however, has the disadvantage of a relatively great labor requirement. Thus, the potential advantage of increased agronomic efficiency from urea deep placed into paddy soil clearly indicates the urgent need to develop applicators that are suitable for farmers' use. From the agronomic viewpoint, applicators designed to use prills, granules, supergranules, or solutions appear to be suitable.

The use of a slowly soluble urea product may also result in low losses of ammonia by reducing the concentrations of urea in solution. Sulfur-coated urea (SCU) was developed by the Tennessee Valley Authority (TVA) during the 1960s. It has been widely tested in experiment station trials (De Datta and Gomez, 1981; Yamada et al., 1979) and more recently in trials on farmers' fields in the Philippines (Martinez et al., 1982). In general, results show that about the same rice yields can be obtained with about two-thirds as much N from SCU or deep-placed urea as from split-broadcast applied urea. The disadvantage of SCU is the higher costs of production and distribution, compared with costs for urea; its great advantage is its suitability for a single broadcast application.

Comparisons of economics of use represent an important aspect in evaluation of products and practices, particularly when large differences exist in the input cost (price of product and/or cost of performing a given practice). However, to date only cursory estimates of the relative economics of use of these materials and practices have been made.

This report presents the results and analysis of 162 trials that were conducted in farmers' fields in eastern India during the 1977-80 period.

Objective

The overall objective of this study was to evaluate both the application of deep-point, hand-placed USG and the application of basally broadcast SCU application for rice production. These practices were compared with the standard fertilization practice of using urea in split-broadcast applications. Specifically, rice yield response and the relative economics of use are analyzed.

1. In this report "urea" refers to "prilled urea."

Data Used and Description of Trials

During 1977 through 1980, 162 trials were conducted in farmers' fields in the following states of eastern India: Assam, Bihar, Madhya Pradesh, Orissa, Uttar Pradesh, and West Bengal. Trials were arranged and supervised by the Hindustan Fertilizer Corporation (HFC). Table 1 summarizes information on the trials that were conducted. The experimental design was a randomized block with three replications. Plot size was 50 m^2.

Experiments conducted during the wet seasons had a control plot and three levels of N application for each source of N. These levels were equal to 40, 80, and 120 kg/ha for the 1977 season and equal to 36, 72, and 108 kg/ha for the remaining seasons. Experiments conducted during the dry season in Assam and Orissa had a control plot and four levels of N as follows: 36, 72, 108, and 144 kg/ha. The dry-season experiments in West Bengal had a control plot and three levels of N as follows: 72, 108, 144 kg/ha.

In addition to N fertilizers, all plots, including the control plot, received 20 kg/ha of P_2O_5 in the form of single superphosphate (SSP) and 20 kg/ha of K_2O in the form of potassium chloride (KCl). Prilled urea was broadcast: one-third basal (incorporated), one-third at tillering, and one-third at the panicle initiation stage. Each supergranule of urea was placed by hand 10 cm deep at such a point that it fertilized four hills of rice. The SCU was broadcast and incorporated immediately before the rice was transplanted.

In the economic evaluation of the trials, the following prices were used: paddy, Rs 0.80/kg; urea, Rs 4.35/kg of N; USG, Rs 4.79/kg of N; and SCU, Rs 6.52/kg of N. Prices for paddy and urea are farm-level prices; on an N basis, the USG price is 10% greater and the SCU price is 50% greater than that of urea.

The cost of application of the different products was estimated on the basis of a labor cost of Rs 6/day and

Table 1.
Summary of Experimental Data Provided by HFC

Year	State	Season	Number of Experiments	Number of Replications	Treatments
					(kg of N/ha)
1977	Assam	Wet[a]	2	3	0-40-80-120
1978	Assam	Wet	6	3	0-36-72-108
1978	Assam	Dry[b]	7	3	0-36-72-108-144
1979	Assam	Wet	8	3	0-36-72-108
1980	Assam	Wet	5	3	0-36-72-108
1977	Bihar	Wet	10	3	0-40-80-120
1978	Bihar	Wet	6	3	0-36-72-108
1979	Bihar	Wet	10	3	0-36-72-108
1980	Bihar	Wet	11	3	0-36-72-108
1977	Madhya Pradesh	Wet	4	3	0-40-80-120
1978	Madhya Pradesh	Wet	7	3	0-36-72-108
1977	Orissa	Wet	10	3	0-40-80-120
1978	Orissa	Wet	11	3	0-36-72-108
1978	Orissa	Dry	8	3	0-36-72-108-144
1979	Orissa	Wet	12	3	0-36-72-108
1980	Orissa	Wet	5	3	0-36-72-108
1977	Uttar Pradesh	Wet	8	3	0-40-80-120
1977	West Bengal	Wet	5	3	0-40-80-120
1978	West Bengal	Wet	5	3	0-36-72-108
1978	West Bengal	Dry	9	3	0-72-108-144
1979	West Bengal	Wet	9	3	0-36-72-108
1980	West Bengal	Wet	4	3	0-36-72-108

a. Wet or kharif.
b. Dry or rabi.

labor requirements of 4 days/ha for urea, 15 days/ha for USG, and 2 days/ha for SCU.[2] These labor requirements correspond with those for an application of 80 kg of N/ha and are equivalent to an application cost of Rs 0.30/kg for urea, Rs 1.125/kg for USG, and Rs 0.15/kg for SCU. This gives a total application cost on an N basis for urea, USG, and SCU of Rs 4.65/kg, Rs 5.915/kg, and Rs 6.67/kg, respectively. For the sensitivity analysis, labor requirements ranging from 2 to 16 days/ha for hand placement of USG and price premiums ranging from 30% to 55% for SCU were used as described in the text and appropriate tables.

Methodology for Analysis

To accomplish the objective of this study, several statistical procedures and the estimation of various economic coefficients were necessary. Specifically, the following determinations were made:

1. Regression coefficients and related statistics for functions that define paddy response to N fertilizers.
2. Optimum application rates for each N fertilizer to obtain maximum net returns.
3. Increase in paddy yields due to N use at optimum rates.
4. Increase in net returns due to optimum use of N.
5. Average paddy yield produced per unit of N applied (at optimum rate).
6. Ratio between the value of paddy yield increase and fertilizer cost for N applied at optimum rates.

The statistical analysis and the economic determinations were made for individual trials and for trials grouped on a regional basis for wet and dry seasons. The analysis was conducted in a way that permits direct comparisons among the products tested. The following paragraphs describe briefly the statistical analysis used and the procedure for estimation of economic coefficients.

The statistical model used for the analysis of the 162 trials is described in detail by Pesek (1964) and Tejeda et al. (1980). The model used is usually referred to as Multifertilizer Response Model (MRM), and it can be expressed as follows:

$$Y = a + b_1N_1 - b_{11}N_1^2 + b_2N_2 - b_{22}N_2^2 + b_3N_3 - b_{33}N_3^2 \qquad (1)$$

where:

Y = paddy yield in kilogram per hectare
a = intercept, yield with no applied N
b_1, b_2, b_3 = linear regression coefficients for urea, USG, and SCU, respectively
b_{11}, b_{22}, b_{33} = quadratic regression coefficients for urea, USG, and SCU, respectively
N_1, N_2, N_3 = linear form for N rates applied as urea, USG, and SCU, respectively
N_1^2, N_2^2, N_3^2 = quadratic form for N rates applied as urea, USG, and SCU, respectively.

Crop yields (Y) and rates of nitrogen applied (N_1, N_2, and N_3) are recorded in the field. The statistical parameters (a's and b's) are estimated utilizing regression analysis.

The structural form of this model represents a curvilinear relationship between yield and N applied. The positive sign expected for the linear term and the negative sign expected for the quadratic term imply that paddy yield increases at a decreasing rate as the amount of N applied increases until a maximum is reached; then yield decreases.

The analysis of the 162 experiments was started by fitting the MRM to each experiment. Then, in cases of models with regression coefficients that did not have the expected signs, the models were reestimated, and only the linear regression coefficients were included. For example, if for a particular experiment the linear and quadratic coefficients for urea were both positive, all parameters of the MRM were reestimated excluding the quadratic effect for urea response.

After a satisfactory MRM for each experiment had been fitted, statistical comparisons of the linear coefficients were made. To evaluate and compare the agronomic response of paddy to urea, USG, and SCU, the following hypotheses were tested:

H_1: $b_1 - b_2 = 0$
H_2: $b_1 - b_3 = 0$
H_3: $b_2 - b_3 = 0$

To test these hypotheses in a given MRM, two conditions were required as follows:

1. At least one of the linear coefficients had to be statistically significant at 10% level.
2. Similar relationship with independent variable (Y) had to exist between the two sources of N being tested. In other words, if the MRM was of the form

$$Y = a + b_1N_1 + b_2N_2 - b_{22}N_2^2 + b_3N_3 - b_{33}N_3^2$$

only H_3: $b_2 - b_3 = 0$ could be tested. The remaining two hypotheses, H_1 and H_2, were not tested. In a table presented later, this will be classified as "not comparable."

2. For convenience the product terms are generally used in this report, but those terms imply the materials used in the manner described above.

The analysis performed for individual experiments was also made on a regional basis by season, pooling experiments together. The MRM is similar to the one explained earlier, but a class variable was added to account for differences in sites where experiments were conducted.

After the MRMs had been fitted to each experiment and to regional data, they were used to determine optimum N application rates from each source. Optimum N application rate is defined as the N rate that would result in maximum estimated net returns to the farmer from the use of fertilizer N. The optimum rate is determined by the response curve and by the N:paddy price ratio. It occurs at a point where the slope of the response curve is equal to the price ratio. In mathematical terms, and generalizing for more than one source of N, it can be expressed as follows:

Slope of MRM with respect to a source of N:

$$\frac{\partial Y}{\partial N_i} = b_i - 2b_{ii}N_i.$$

Price ratio = P_{N_i}/P_Y

where P_{N_i} = price of N_i (Rs/kg)
P_Y = price of paddy (Rs/kg).

This is applied to the MRM fitted in terms of kg of paddy/ha and kg of N/ha. Therefore, the optimum N_i application rate (N_i^*) is defined by

$$b_i - 2b_{ii}N_i^* = \frac{P_{N_i}}{P_Y} \quad \text{or} \quad N_i^* = \frac{b_i - (P_{N_i}/P_Y)}{2b_{ii}} \qquad (2)$$

The first part of equation (2) can be expressed as

$$P_Y(b_i - 2b_{ii}N_i^*) = P_{N_i},$$

which implies that, at the profit-maximizing point, the incremental value of paddy produced is exactly equal to the incremental cost of the fertilizer used. This is commonly referred to as the point where Marginal Revenue (MR) equals Marginal Cost (MC).

It is generally agreed that small farmers with scarce capital resources are not willing to risk the possibility that some factor will limit the response to applied N in a given season and thus decrease their returns as a result of overestimating the rate of needed nutrient to obtain MR = MC. Also, farmers usually have other opportunities for using some of their capital. Some of these ventures offer a greater return on their investment than the last increment of fertilizer when attempts are made to maximize returns from the use of fertilizer. In an attempt to account for this kind of reasoning, the economic analysis of the data was performed at points in the response curve where MR = MC and where MR = 2MC. At the point where MR = 2MC, Rs 1 spent on fertilizer generates Rs 2 in paddy production.

The MRM as represented in equation (1) defines the total paddy production at different N rates. It also defines the paddy production at zero N rate, at which rate Y = a. To determine the increase in paddy yield due to N* use, or Y*, the intercept term is subtracted from the MRM. Therefore, the MRM to measure increase in yields due to N use at optimum rates can be expressed as follows:

$$Y - a = Y^* = b_1N_1^* - b_{11}(N_1^*)^2 + b_2N_2^* - b_{22}(N_2^*)^2 + b_3N_3^* - b_{33}(N_3^*)^2. \qquad (3)$$

The increase in paddy yield due to optimum N use is obtained by replacing the value obtained for N_i^* in equation (2) into equation (3).

Net returns due to optimum use of a source of N are defined as the difference between the value in yield increase ($Y^* \times P_Y$) and the cost of N used ($N^* \times P_{N_i}$). This can be represented as follows:

$$NR_i = (Y^* \times P_Y) - (N_i^* \times P_{N_i}). \qquad (4)$$

Average paddy yield increase (AY) at the optimum N rate is equal to the ratio of yield increase (Y^*) and the amount of N applied (N^*) or

$$AY_i = Y_i^*/N_i^*. \qquad (5)$$

Value:cost ratios are obtained by dividing the value of the paddy yield increase by the cost of N used to obtain the yield increase or

$$VCR_i = \frac{Y^* \times P_Y}{N_i^* \times P_{N_i}}$$

The above-mentioned statistical and economic coefficients were estimated for urea, USG, and SCU for each of the 162 experiments and for groups of experiments on a regional and seasonal basis.

The economic analysis, as explained here, requires a curvilinear response to each of the fertilizer sources. This is a necessary condition for the existence of a maximization point. As will be shown later, this relationship did not exist for all 162 experiments. In some MRMs there was only a linear response for one or more of the fertilizer sources. In cases where no quadratic response was found or where the optimum application rate exceeded the maximum applied rate of a particular experiment, the optimum application rate was set to be equal to the maximum applied rate (i.e., 108, 120, or 144), if the linear regression coefficient was greater

than the nitrogen price:paddy price ratio (P_N/P_Y); otherwise, the optimum application rate was considered to be zero.

Results

Individual Experiments

Appendix Table 1 shows the estimated values and statistics for the coefficients of the MRM. It includes the intercept term, the regression coefficients with their respective significance levels, the R^2 values, and the coefficients of variation for each of the 162 experiments.

The intercept term represents paddy yields that can be obtained at different locations without N application. The terms b_1, b_2, and b_3 represent the linear regression coefficient for urea, USG, and SCU, respectively, while b_{11}, b_{22}, and b_{33} represent the quadratic regression coefficient for the same fertilizers, respectively. The R^2 values measure the percentage of variation in paddy yields accounted for by the MRM. The coefficient of variation (CV) measures the amount of variation in a given experiment.

Values for the intercept term show that wide variations for yield existed among locations. The value for the intercept ranged from 536 kg/ha (EX = 51) to 6,690 kg/ha (EX = 23).[3]

In a quadratic model, the linear regression coefficients b_1, b_2, and b_3 measure the agronomic efficiency of the first unit of applied urea, USG, and SCU, respectively. They represent the units of paddy produced by the first unit of N applied. Appendix Table 1 shows that, in general, the b_2 and b_3 values were greater than the b_1 values. The b_1 values ranged from -1.05 (EX = 7) to 70.96 (EX = 57), b_2 values from -2.62 (EX = 7) to 76.98 (EX = 74), and b_3 values from -4.17 (EX = 122) to 89.76 (EX = 69). In only 2 of the 162 experiments did one or more of the linear regression coefficients have a negative sign. The average values obtained from the 162 experiments were equal to 22.72 for urea, 32.01 for USG, and 33.69 for SCU. As far as statistical significance levels are concerned, 135 b_1 values, 148 b_2 values, and 152 b_3 values were significant at the 10% level or better. In only 7 of the 162 MRMs fitted was there no significant response to at least one of the N fertilizers. The R^2 values ranged from 10.2% (EX = 7) to 98.9% (EX = 46). Of the 162 experiments, 98 (60%) had an R^2 value of 80% or more. The CV values ranged from 2.1% (EX = 23) to 39.6% (EX = 50), and 143 of the 162 experiments (88%) had CVs of less than 15%.

3. EX refers to experiment numbers.

A statistical test was made for each experiment to determine if differences in linear regression coefficients, hence the agronomic efficiencies at low N rates of urea, USG, and SCU, were significant ($P \leq 10$). Table 2 presents a summary of the results of these comparisons. It can be seen that in 38.2% of the experiments the agronomic efficiency of USG was greater than that of urea. Also, in 41.7% of the experiments the agronomic efficiency of SCU was greater than that of urea. Urea had greater agronomic efficiency than USG and SCU in 7.3% and 3.5% of the experiments, respectively. In approximately 55% of the experiments the agronomic efficiencies of USG and SCU were not significantly different from that for urea.

Table 2.
Summary of Statistical Comparisons of Agronomic Efficiency for Urea, USG, and SCU from 162 Experiments

Type of Comparison		Number of Observations	Percent
No significant response to N		7	
USG versus urea			
USG larger than urea	($b_2 > b_1$)	47	38.2
USG smaller than urea	($b_2 < b_1$)	9	7.3
USG not different from urea	($b_2 = b_1$)	67	54.5
		123	100.0
SCU versus urea			
SCU larger than urea	($b_3 > b_1$)	48	41.7
SCU smaller than urea	($b_3 < b_1$)	4	3.5
SCU not different from urea	($b_3 = b_1$)	63	54.8
		115	100.0
USG versus SCU			
USG larger than SCU	($b_2 > b_3$)	16	12.3
USG smaller than SCU	($b_2 < b_3$)	22	16.9
USG not different from SCU	($b_2 = b_3$)	92	70.8
		130	100.0
USG not comparable with urea		32	
SCU not comparable with urea		40	
USG not comparable with SCU		25	

Comparisons of agronomic efficiencies of USG and SCU show that in 12.3% of the experiments the agronomic efficiency of USG was greater, while in 16.9% of the experiments the agronomic efficiency of SCU was greater. In 70.8% of the experiments the agronomic efficiencies for USG and SCU were essentially equal.

Comparisons were not possible in all 162 experiments for two reasons: in 7 experiments there was no significant response to any one of the fertilizers, and in 50 other MRMs different relationships between fertilizers and independent variables existed. The numbers of models where comparisons were not possible appear in Table 2.

Appendix Table 2 presents results of the economic evaluation of individual experiments. This table shows the optimum application rates, the paddy yield increases, net returns, agronomic efficiencies, and value:cost ratios at optimum rates (MR = MC). Analysis of results for individual experiments shows that optimum application rates for urea, USG, and SCU vary widely within a given state and season.

The arithmetic means for all experiments grouped on a state and season basis and for the total are shown in Table 3. Mean optimum application rates were generally higher for urea and USG than for SCU. The overall arithmetic mean optimum application rates for urea, USG, and SCU were equal to 91, 85, and 80 kg/ha, respectively. The coefficients of variation for the three means were equal to 40.8%, 40.5%, and 40.8%, respectively.

Table 3.
Mean Values for Optimum Application Rates, Yield Increases, Net Returns, Agronomic Efficiencies, and Value:Cost Ratios by Region and Season[a]

		Optimum Application Rates			Yield Increase			Net Returns			Agronomic Efficiencies			Value:Cost Ratios		
State	Season	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU
		(kg/ha)						(Rs/ha)			(kg/kg)					
							Analysis at MR = MC									
Assam	Dry	82	61	52	1,375	1,389	1,140	721	750	564	11.2	16.4	13.5	1.92	2.22	1.62
Assam	Wet	59	57	54	836	1,035	1,243	395	493	631	10.2	13.3	18.9	1.76	1.80	2.27
Bihar	Wet	85	89	80	1,698	2,174	2,014	964	1,217	1,080	18.9	23.9	24.9	3.23	3.24	2.99
Madhya Pradesh	Wet	106	86	92	1,822	2,237	2,515	966	1,282	1,400	17.2	26.1	27.9	2.96	3.53	3.35
Orissa	Dry	125	126	107	1,873	2,236	1,655	917	1,039	611	15.8	17.6	15.2	2.72	2.38	1.82
Orissa	Wet	90	83	84	1,416	1,936	1,965	713	1,056	1,009	14.5	21.7	21.9	2.49	2.94	2.62
Uttar Pradesh	Wet	117	118	110	2,715	2,943	2,837	1,629	1,660	1,538	23.2	25.1	26.4	3.99	3.39	3.17
West Bengal	Dry	140	126	110	2,654	2,922	2,450	1,471	1,594	1,239	19.0	23.2	22.2	3.27	3.14	2.67
West Bengal	Wet	86	73	72	1,337	1,526	1,431	669	789	667	15.6	19.9	19.2	2.69	2.69	2.30
Overall Mean		91	85	80	1,575	1,932	1,863	832	1,042	954	15.9	21.0	21.8	2.73	2.83	2.61
							Analysis at MR =2 MC									
Assam	Dry	55	43	31	1,120	1,198	876	641	706	498	9.1	15.9	11.9	1.57	2.15	1.43
Assam	Wet	30	27	29	560	708	944	307	407	558	7.9	12.2	19.2	1.36	1.65	2.30
Bihar	Wet	68	74	56	1,550	2,016	1,723	924	1,175	1,002	20.2	26.0	27.4	3.47	3.51	3.29
Madhya Pradesh	Wet	85	71	80	1,660	2,075	2,366	931	1,239	1,359	17.5	29.2	30.6	3.01	3.94	3.67
Orissa	Dry	84	83	32	1,509	1,730	760	817	891	396	16.1	17.8	11.7	2.76	2.41	1.40
Orissa	Wet	61	68	63	1,174	1,766	1,683	656	1,010	929	14.3	23.5	23.8	2.46	3.18	2.86
Uttar Pradesh	Wet	106	101	82	2,620	2,746	2,478	1,604	1,603	1,433	24.3	26.7	26.4	4.18	3.61	3.17
West Bengal	Dry	114	103	66	2,421	2,663	1,845	1,405	1,523	1,034	18.8	25.9	24.0	3.24	3.50	2.88
West Bengal	Wet	60	55	42	1,103	1,328	1,041	604	736	557	17.5	22.2	21.4	3.01	3.00	2.57
Overall Mean		66	65	53	1,357	1,716	1,519	779	985	859	16.1	22.5	23.2	2.77	3.04	2.78

a. Means calculated from results of 162 individual experiments, including those for which optimum application rates were equal to 0.

The optimum application rates were used to estimate increase in paddy yields due to N use at the economic optimum. As in the case of application rates, a wide variation in yield increases was observed within a given state and season and for the different N sources in a given experiment. Yield increases due to N use ranged from 0 to 4,521 kg/ha for urea, from 0 to 4,644 kg/ha for USG, and from 0 to 4,388 kg/ha for SCU. The mean paddy yield increases at the economic optimum for the three sources tested were equal to 1,575 kg/ha for urea, 1,932 kg/ha for USG, and 1,863 kg/ha for SCU. These means had coefficients of variation equal to 59.6%, 52.1%, and 51.4%, respectively.

Net returns to farmers estimated at optimum economic rates were higher, in general, for USG than for urea and SCU. Net returns ranged from 0 to Rs 3,115/ha for urea, from 0 to Rs 3,012/ha for USG, and from 0 to Rs 2,710/ha for SCU. The overall means from the 162 experiments were equal to Rs 832/ha, Rs 1,042/ha, and Rs 954/ha, with coefficients of variations equal to 76.2%, 62.7%, and 65.3%, for urea, USG, and SCU, respectively.

The agronomic efficiency for the three N sources being studied is defined here as the average amount of paddy (in kilograms) produced by unit of fertilizer used (in kilograms). SCU and USG have, in general, higher agronomic efficiencies than urea. Values ranged from 0 to 41.9 for urea, from 0 to 42.3 for USG, and from 0 to 49.0 for SCU. The overall means from the 162 experiments were equal to 15.9 kg of paddy/kg for urea, 21.0 kg/kg for USG, and 21.8 kg/kg for SCU. The coefficients of variation were equal to 48.6%, 40.6%, and 43.8%, respectively.

The value:cost ratios (VCR), estimated at the economic optimum, for urea, USG, and SCU are in general higher for USG than for urea or SCU. VCR values ranged from 0 to 7.20 for urea, from 0 to 5.71 for USG, and from 0 to 5.88 for SCU. Overall means for VCR were equal to 2.73, 2.83, and 2.61, with coefficients of variations equal to 48.6%, 40.6%, and 43.8% for urea, USG, and SCU, respectively.

Table 3 also presents the arithmetic means for all experiments grouped on a state and season basis and for the total for the mean optimum application rates, yield increases, net returns, agronomic efficiencies and VCR values, estimated at MR = 2 MC. Comparison of these figures with those obtained at MR = MC indicates that, in general, for all three N sources the optimum application rates, yield increases, and net returns are lower. On the other hand, the agronomic efficiencies and the VCR values are generally higher. Since the overall means include experiments for which optimum rates were equal to zero, in some cases the agronomic efficiencies and the VCRs are lower. It is important to note that the relative position of urea, USG, and SCU, with respect to each other, remains the same.

Results for individual experiments show a wide variation within states and seasons. In some cases no response was observed to one, two, or all of the fertilizers, while in other cases the MRM was adequate to account for yield variations. The experiments were conducted in farmers' fields that often were spread over large areas. An attempt was made to explain variations in results. Data on soil texture, soil pH, and rainfall were available for approximately 100 of the 162 trials. These data were correlated with values for linear regression coefficients for urea, USG, and SCU, and with differences between these coefficients. It was found that the linear regression coefficients for urea were positively and significantly ($P \leq 0.05$) related to soil pH. The correlation coefficient for this relationship was equal to 0.21. All other correlation coefficients that were estimated had values under 0.10 and were not significant at $P \leq 0.20$.

Pooled Data

Table 4 presents the regression coefficients, levels of significance, R^2 values, and coefficients of variation for the MRM fitted to the data pooled on a state basis by season. As in the case of the analysis of MRM for single experiments, the b_2 and b_3 values are higher than the b_1 values with only one exception for the Orissa dry season, where all are equal. Values for b_1 ranged from 9.37 in Assam to 29.69 in Uttar Pradesh, b_2 values ranged from 19.63 in Assam to 44.59 in Madhya Pradesh, and b_3 values ranged from 17.16 in Assam to 45.19 in Madhya Pradesh. All linear regression coefficients and most b_{22} and b_{33} values were significant at $P \leq 0.01$ while only three b_{11} values were significant at $P \leq 0.01$. The R^2 values were high, ranging from 96.8% to 99.1%. The CVs ranged from 10% to 20.6%. Figures 1 through 9 are graphic representations of the MRM, for urea, USG, and SCU, in each region during the wet or dry season. These graphs were prepared from the MRM presented in Table 4. It can be seen that in all cases curves representing paddy response to USG and SCU are above those for urea.

As in the case of the MRM fitted to single experiments, the linear regression coefficients for urea, USG, and SCU were compared. Results of the statistical analysis indicate that in all cases b_2 and b_3 were statistically equal to or greater than b_1 at the $P \leq 10$. Of seven possible comparisons, b_2 was greater than b_1 in five cases, and b_3 was also greater than b_1 in five cases. Only during the dry season in Orissa and wet season in Uttar Pradesh were

Table 4.
Regression Coefficients, Levels of Significance, R^2 Values, and Coefficients of Variance (CV) for the Quadratic Multifertilizer Response Models Fitted to Experiments in Each State for Wet and Dry Seasons

State	Season	Number of Trials	Regression Coefficients: Urea b_1	Urea b_{11}	USG b_2	USG b_{22}	SCU b_3	SCU b_{33}	R^2 (%)	CV[a] (%)
Assam	Dry	7	9.3666**	-	23.8274**	-.11134**	17.1560**	-.06916+	96.8	20.6
Assam	Wet	21	10.6275**	-.02167	19.6330**	-.09462**	29.2285**	-.18239**	98.6	13.1
Bihar	Wet	37	28.4781**	-.11959**	34.7349**	-.13583**	40.3570**	-.20656**	97.7	16.8
Madhya Pradesh	Wet	11	24.2199**	-.06952*	44.5897**	-.22363**	45.1891**	-.21436**	98.2	14.3
Orissa	Dry	8	20.9052**	-.06211**	22.6962**	-.04835**	20.4768**	-.05645**	99.1	10.2
Orissa	Wet	38	16 6427**	-.03425*	30.8987**	-.12518**	29.9008**	-.11090**	98.5	12.8
Uttar Pradesh	Wet	8	29.6875**	-.06146	31.9320**	-.06346*	33.1930**	-.08550**	98.3	14.0
West Bengal	Dry	9	18.4610**	-	32.2902**	-.08266**	33.6391**	-.11551**	98.8	11.6
West Bengal	Wet	23	22.4727**	-.09730**	29.7322**	-.15254**	29.1535**	-.15060**	99.1	10.0

** $P \leq .01$; * $P \leq .05$; + $P \leq .10$.
a. Coefficient of variation.

responses approximately equal for all three N management practices. Comparisons of b_2 and b_3 revealed that in only two cases was b_3 greater than b_2.

Table 5 presents results of the economic evaluation of pooled data grouped by states and seasons. This table shows the optimum application rates, yield increases, net returns, agronomic efficiencies, and value:cost ratios estimated at MR = MC and at MR = 2 MC. With MR = MC the optimum application rates range from 86 to 144 for urea, from 64 to 144 for USG, and from 57 to 120 for SCU. In general, urea application rates were higher than rates for USG, and USG rates were higher than rates for SCU. In addition, the increases in paddy yields and in net returns due to USG use are generally higher than those due to urea or SCU use. Estimated net returns are graphically presented in Figures 10 through 18.

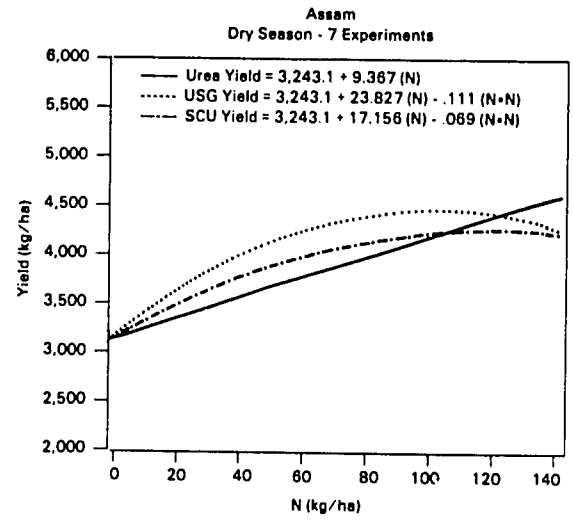
The agronomic efficiencies of USG and SCU are similar to but greater than that for urea in most of the groups. The agronomic efficiency coefficients range from 8.2 to 22.4 for urea, from 13.5 to 26.0 for USG, and from 12.7 to 26.8 for SCU. The VCRs were, in general, higher for USG and urea than for SCU. They ranged from 1.41 to 3.85 for urea, from 1.83 to 3.52 for USG, and from 1.53 to 3.21 for SCU.

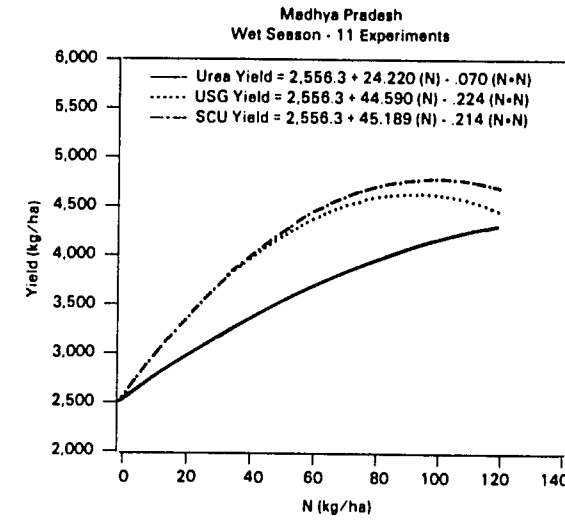
Comparisons of estimates made by assuming that MR = 2 MC with those made by assuming that MR = MC indicate that for the three N management practices being studied the optimum application rates, yields, and net returns are lower; the agronomic efficiencies and VCRs, however, are higher when MR = 2 MC. The relative positions of the three products remain the same, as should be the case.

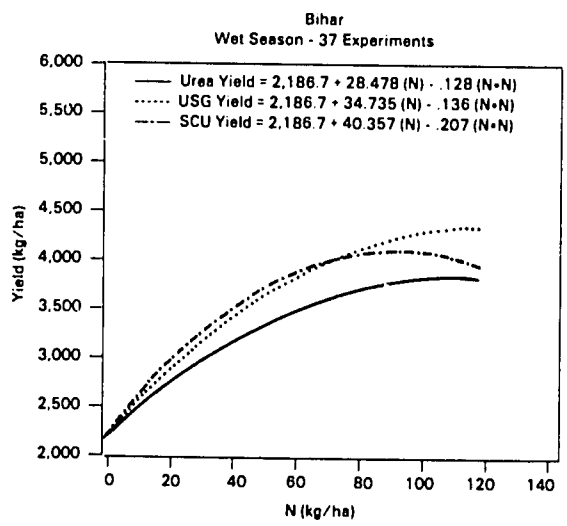
In comparing the mean values of groups of individual experiments with values estimated from pooled data, it can be noted that differences exist among the absolute values. In general, these differences occur when there is a small number (<10) of trials in a group. However the relative positions of the three fertilizers remain the same.

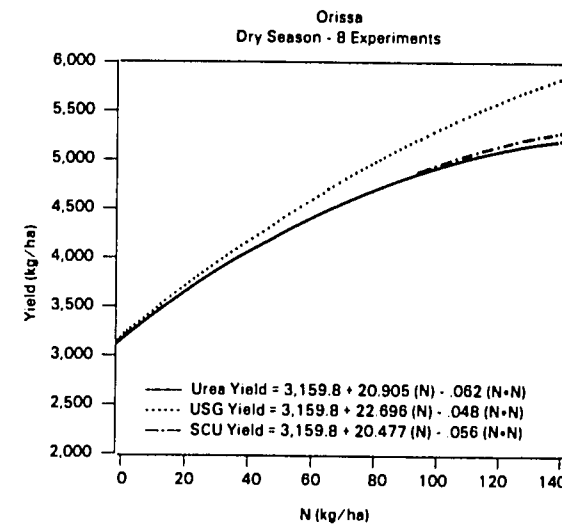
To further evaluate the performance of urea, USG, and SCU, it was necessary to estimate the quantities of N required to produce a given quantity of paddy and the quantities of paddy produced by applying a given rate of N. The estimated quantities obtained from response functions of pooled data are shown in Tables 6 and 7.

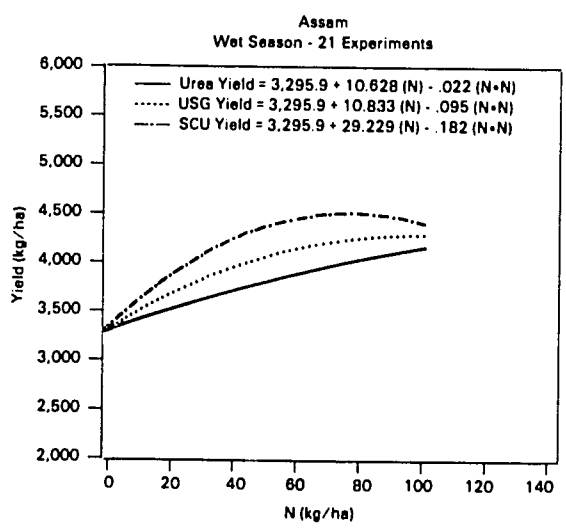
Table 6 shows that N requirements to obtain a 1-mt increase in paddy yield are generally 25%-45% lower with USG and SCU than with urea. Table 7 shows the predicted paddy yield increase from application of 50 kg of N. In general, grain yield increases from use of USG or SCU were 25%-60% higher than grain yield increases obtained using urea. If this relative performance could be realized by farmers on a regional or national basis, the effect on both paddy production and N consumption would be enormous. Suppose, for example, that 10% of the N used for paddy production in India, or approximately 90,000 mt, were deep placed. Further, assume that, on

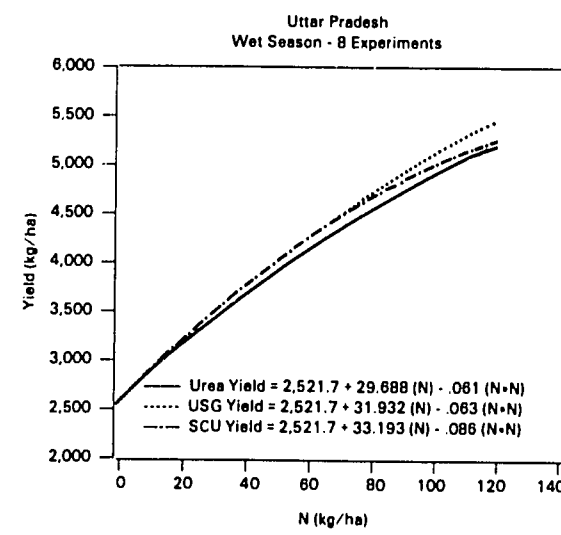




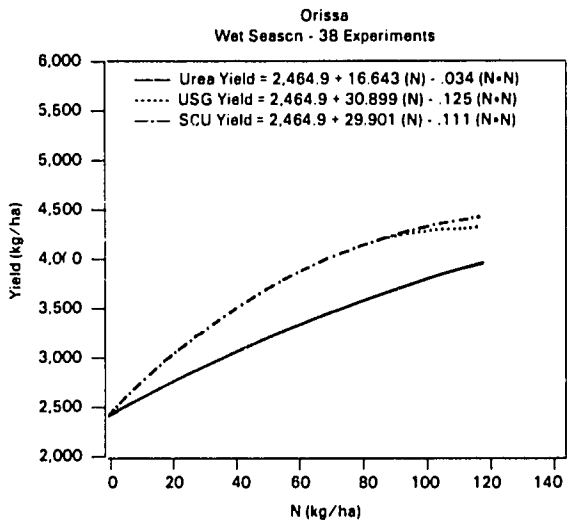


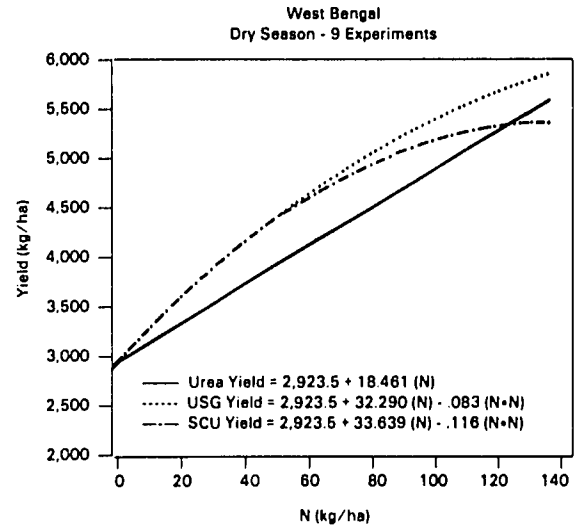


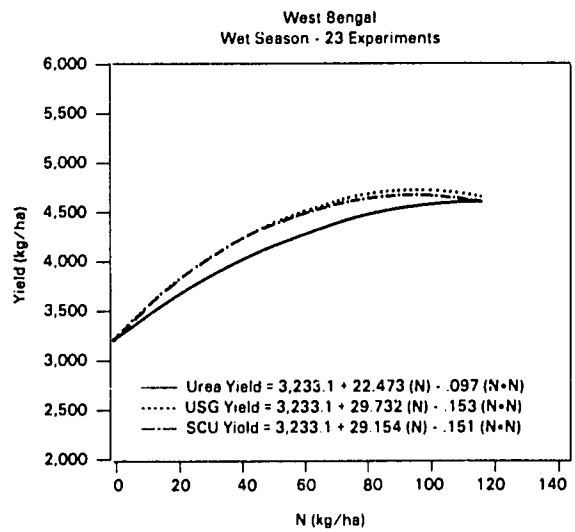




Figures 1-9. Graphic Representation of MRM for Urea, USG, and SCU for Each State and Season.







Figures 1-9. Graphic Representation of MRM for Urea, USG, and SCU for Each State and Season. (Continued)

Table 5.
Optimum Application Rates, Yield Increase, Net Returns, Agronomic Efficiencies, and Value:Cost Ratios by Region and Season Analysis[a]

State	Season	Optimum Application Rates			Yield Increase			Net Returns			Agronomic Efficiencies			Value:Cost Ratios		
		Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU
		(kg/ha)						(Rs/ha)			(kg/kg)					
Analysis at MR = MC																
Assam	Dry	144	74	64	1,349	1,156	815	409	487	225	9.4	15.6	12.7	1.61	2.11	1.53
Assam	Wet	109	64	57	900	870	1,078	211	315	480	8.2	13.5	18.8	1.41	1.83	2.25
Bihar	Wet	94	101	77	1,619	2,117	1,883	856	1,099	991	17.1	21.1	24.3	2.95	2.85	2.92
Madhya Pradesh	Wet	120	83	86	1,898	2,158	2,304	961	1,235	1,269	15.8	26.0	26.8	2.72	3.52	3.21
Orissa	Dry	122	144	108	1,626	2,273	1,562	735	967	526	13.4	15.8	14.4	2.30	2.13	1.73
Orissa	Wet	120	91	97	1,508	1,706	1,857	648	827	838	12.6	18.8	19.1	2.16	2.54	2.29
Uttar Pradesh	Wet	120	120	120	2,684	2,925	2,752	1,589	1,625	1,401	22.4	24.4	22.9	3.85	3.30	2.75
West Bengal	Dry	144	144	109	2,658	2,929	2,289	1,457	1,491	1,104	18.5	20.3	21.0	3.18	2.75	2.52
West Bengal	Wet	86	73	69	1,215	1,355	1,292	572	652	574	14.1	18.6	18.7	2.43	2.51	2.25
Analysis at MR =2 MC																
Assam	Dry	0	41	3	0	786	59	0	388	24	0	19.3	16.9	0	2.61	2.03
Assam	Wet	0	26	34	0	439	792	0	200	403	0	17.2	23.0	0	2.33	2.75
Bihar	Wet	70	73	57	1,408	1,816	1,631	800	1,019	923	20.1	24.8	28.5	3.45	3.35	3.42
Madhya Pradesh	Wet	90	67	67	1,612	1,975	2,061	872	1,187	1,204	17.9	29.7	30.9	3.08	4.02	3.71
Orissa	Dry	75	82	34	1,217	1,544	631	626	748	278	16.3	18.7	18.6	2.80	2.53	2.23
Orissa	Wet	74	61	60	1,043	1,378	1,387	491	739	713	14.1	22.5	23.2	2.43	3.04	2.79
Uttar Pradesh	Wet	120	120	96	2,684	2,925	2,395	1,589	1,643	1,275	22.4	24.4	24.9	3.85	3.62	2.99
West Bengal	Dry	144	105	73	2,658	2,482	1,839	1,464	1,362	984	18.5	23.5	25.2	3.18	3.18	3.02
West Bengal	Wet	56	49	41	953	1,087	947	503	581	482	17.0	22.3	22.9	2.93	3.01	2.75

a. Values derived from pooled data within states by seasons.

Table 6.
Estimated N Requirements for a 1-mt Yield Increase[a]

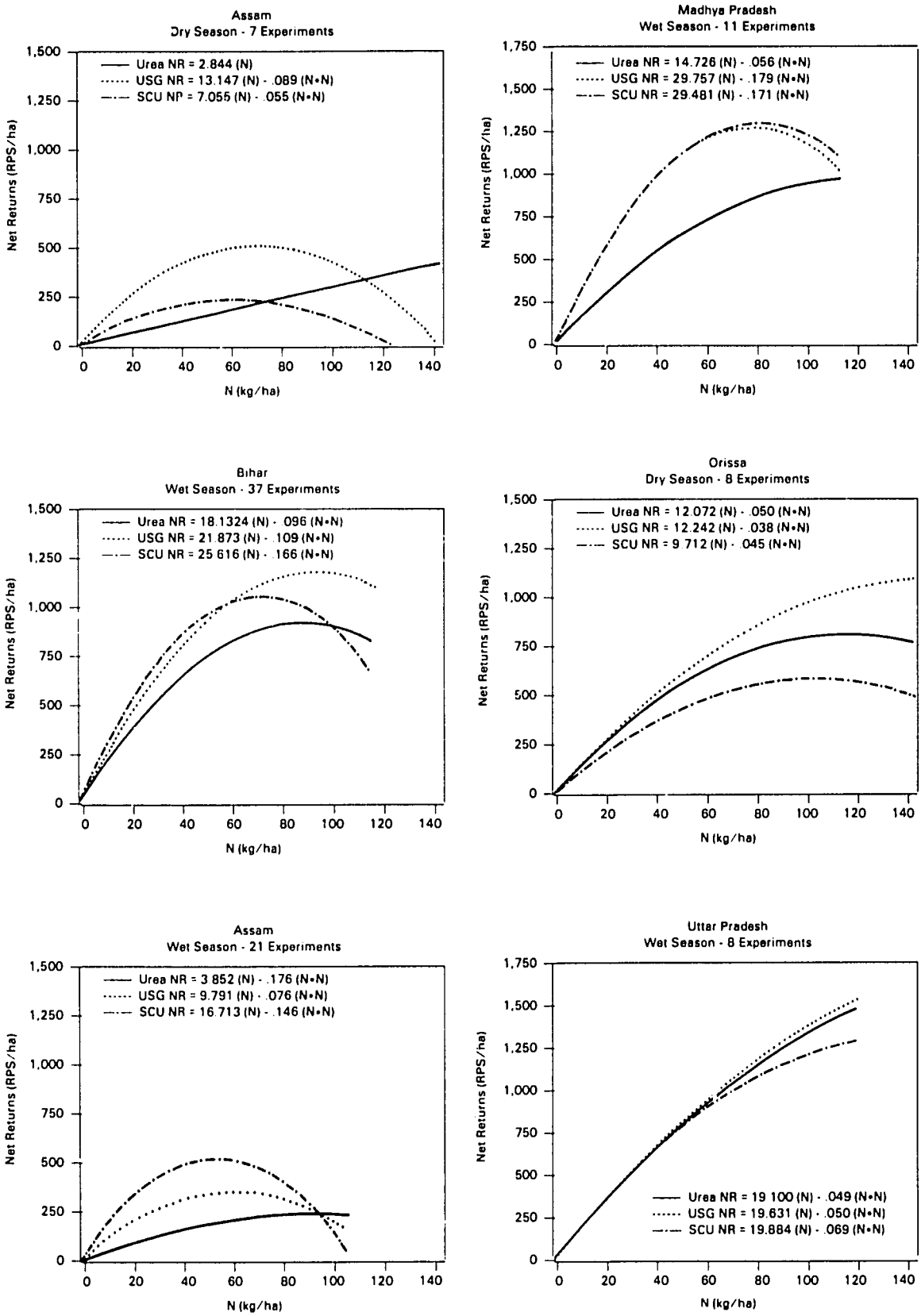
State	Season	N Required for 1-mt Yield Increase			Reduction in Nitrogen Requirement, as Compared With Urea	
		Urea	USG	SCU	USG	SCU
		(kg/ha)			(%)	
Assam	Dry	107	57	93	47	13
Assam	Wet	128	91	49	29	62
Bihar	Wet	43	33	29	24	33
Madhya Pradesh	Wet	48	26	25	46	48
Orissa	Dry	58	49	58	16	0
Orissa	Wet	70	40	39	43	44
Uttar Pradesh	Wet	36	34	33	6	8
West Bengal	Dry	54	34	34	37	37
West Bengal	Wet	60	43	45	28	25

a. Values are derived from MRM for pooled data.

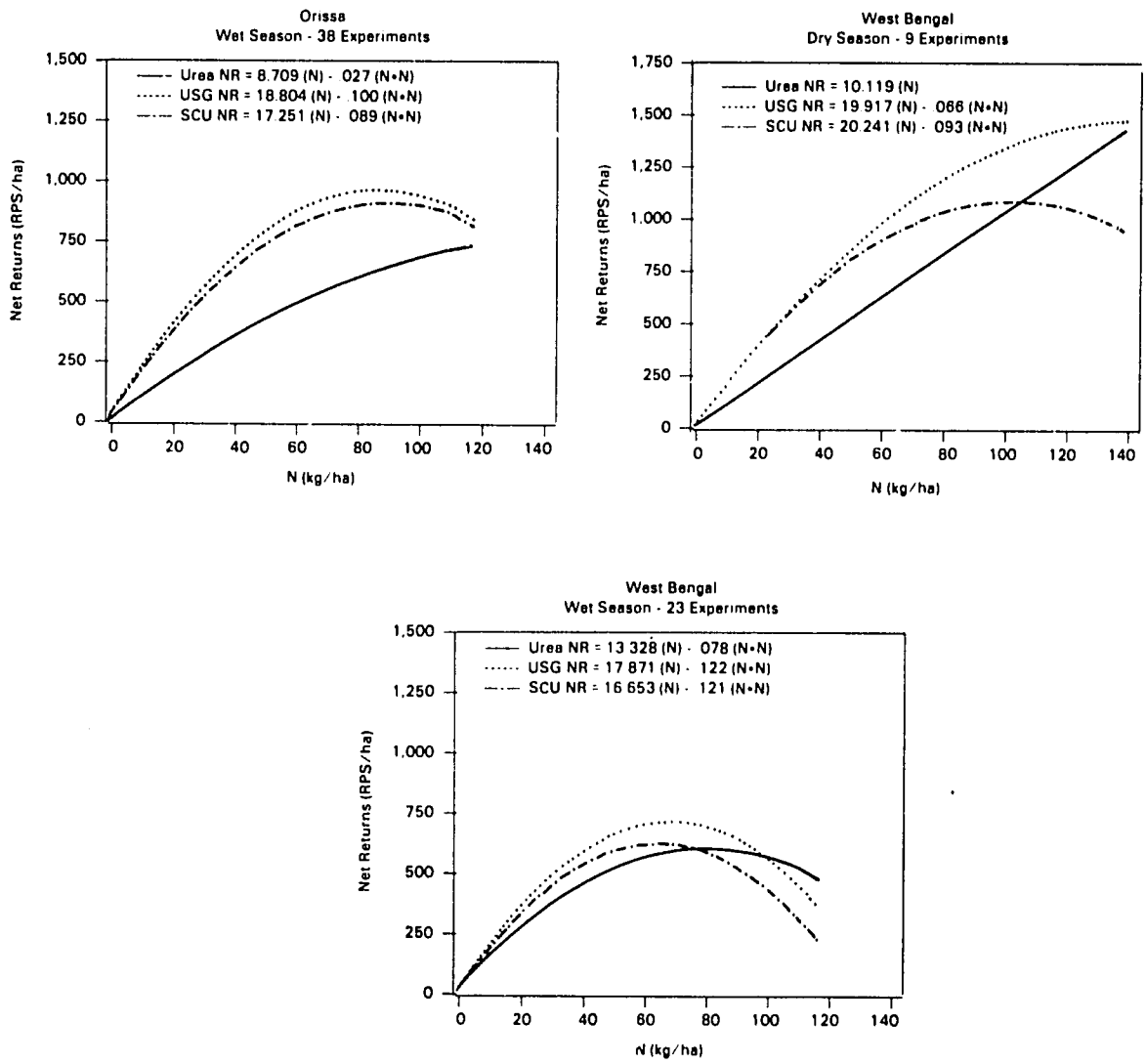
Table 7.
Estimated Paddy Yield Increase From 50 kg of N/ha[a]

State	Season	Paddy Yield Increase From 50 kg of N/ha			Yield Increase Compared With Urea	
		Urea	USG	SCU	USG	SCU
		(kg/ha)			(%)	
Assam	Dry	468	914	685	95	46
Assam	Wet	476	744	1,006	56	111
Bihar	Wet	1,124	1,397	1,500	24	33
Madhya Pradesh	Wet	1,036	1,670	1,724	61	66
Orissa	Dry	890	1,015	884	14	-1
Orissa	Wet	747	1,194	1,218	60	63
Uttar Pradesh	Wet	1,332	1,439	1,445	8	8
West Bengal	Dry	923	1,407	1,392	52	51
West Bengal	Wet	881	1,104	1,080	25	23

a. Values are derived from MRM for pooled data.



Figures 10-18. Graphic Representation of Net Return Curves for Urea, USG, and SCU for Each State and Season.



Figures 10-18. Graphic Representation of Net Return Curves for Urea, USG, and SCU for Each State and Season. (Continued)

the average, this would result in a 25% reduction in N requirement for equivalent paddy production. This action would save 22,500 mt of N, which at a cost of $500/mt of N represents a total saving of $11,250,000. Conversely, if 90,000 mt of N were deep placed, the total paddy production would be increased by 360,000 mt, assuming that 1 mt of N in the form of urea yields 16 mt of paddy and that 1 mt of N in the form of USG yields 20 mt of paddy, or a 25% increase in agronomic efficiency.

Sensitivity Analysis

Presently, neither the equipment for deep placement of N nor SCU is available to farmers. There are some deep placement machines being developed and used in China, and research work on applicators is being continued at the International Rice Research Institute (IRRI). Also two commercial companies, one in the United States and the other in Canada, are producing SCU in small amounts.

For this study, estimates of labor requirements and cost of products were made from experiences in small plot experiments and demonstration-scale production. These estimates may change as more information is gained. Labor requirements for USG application would be reduced when application equipment is introduced. Production costs of SCU could be reduced when a more efficient production process is developed. Also, SCU production cost is highly dependent on amount of sulfur coating used and the sulfur price.

The varying labor requirements for deep-point placement of USG affect optimum application rates and net returns (Table 8). Varying the labor requirements from 2 to 16 days increases the cost of application from Rs 4.94 to Rs 5.99/kg, or approximately 20%. This increase in application cost reduces the optimum application rates by

Table 8.
Optimum Application Rates and Net Returns at Different Labor Requirements for Deep Placement of USG, by Region and Season

	Applied N[a]	Assam		Bihar	Madhya Pradesh	Orissa		Uttar Pradesh	West Bengal		Average	
Labor	Cost	Dry	Wet	Wet	Wet	Dry	Wet	Wet	Dry	Wet	Dry	Wet
(Days/ha)	(Rs/kg)											
						Optimum Application Rates (kg/ha)						
2	4.94	80	71	105	86	144	96	120	144	77	123	93
4	5.09	79	70	104	85	144	95	120	144	76	122	92
6	5.24	78	69	104	85	144	94	120	144	76	122	91
8	5.39	77	68	103	84	144	94	120	144	75	122	91
10	5.54	76	67	102	84	144	93	120	144	75	121	90
12	5.69	75	66	102	84	144	92	120	144	74	121	90
14	5.84	74	65	101	83	144	91	120	144	73	121	89
16	5.99	74	64	100	83	144	91	120	144	73	121	89
						Net Returns (Rs/ha)						
2	4.94	561	381	1,200	1,318	1,107	918	1,747	1,632	725	1,100	1,048
4	5.09	550	371	1,184	1,305	1,085	903	1,729	1,610	714	1,082	1,034
6	5.24	538	360	1,168	1,292	1,064	889	1,711	1,588	702	1,063	1,020
8	5.39	526	350	1,153	1,279	1,042	875	1,693	1,567	691	1,045	1,007
10	5.54	515	340	1,137	1,267	1,021	861	1,675	1,545	680	1,027	993
12	5.69	503	330	1,122	1,254	999	847	1,657	1,524	669	1,009	980
14	5.84	492	320	1,107	1,242	977	834	1,639	1,502	658	990	967
16	5.99	481	311	1,092	1,229	956	820	1,621	1,480	647	972	953

a. Includes cost of labor for application.

Table 9.
Optimum Application Rates and Net Returns at Different Costs of SCU, by Region and Season

Premium Over Cost	Applied N[a] Cost	Assam		Bihar	Madhya Pradesh	Orissa		Uttar Pradesh	West Bengal		Average	
		Dry	Wet	Wet	Wet	Dry	Wet	Wet	Dry	Wet	Dry	Wet
(%)	(Rs/kg)											
		Optimum Application Rates (kg/ha)										
30	5.8050	72	60	80	89	118	102	120	114	73	101	87
35	6.0200	70	60	79	88	116	101	120	113	72	100	87
40	6.2400	68	59	79	87	113	100	120	111	71	97	85
45	6.4575	66	58	78	87	111	98	120	110	70	96	85
50	6.6750	64	57	77	86	108	97	120	109	69	94	84
55	6.8925	62	57	77	85	106	96	120	108	68	92	84
		Optimum Application Rates (kg/ha)										
30	5.8050	284	531	1,059	1,345	624	924	1,499	1,200	635	702	999
35	6.0200	269	518	1,041	1,326	599	902	1,473	1,176	620	681	980
40	6.2400	254	505	1,024	1,306	574	880	1,447	1,151	604	660	961
45	6.4575	239	492	1,007	1,288	550	859	1,421	1,127	589	639	943
50	6.6750	225	479	990	1,269	526	837	1,395	1,103	574	618	924
55	6.8925	211	467	973	1,250	502	816	1,369	1,080	559	598	906

a. Includes cost of labor for application.

up to 6 kg of N/ha and reduces net returns by Rs 5 to Rs 11/ha for each additional day of labor at the different locations included in the study.

Latest estimates indicate that possible improvements in sulfur-coating processes and the possible increase in natural gas prices may permit large-scale production of SCU for as little as 30% premium over urea.[4] The different premiums for SCU cost over urea have an effect on optimum application rates and on net returns (Table 9). Lowering SCU premium over urea from 55% to 30% decreases the cost of application from Rs 6.9 to Rs 5.8/kg of N. This decrease in SCU cost increases the optimum application rates by up to 12 kg of N/ha and thus increases net returns by up to Rs 130/ha at the different locations studied.

Recent information from large-plot demonstrations in Burma indicates that, with little experience, farmers could deep point place USG by hand at the rate of 0.125 ha/day.[5] The effects of the possibly lower labor requirement and potentially lower cost of SCU on average optimum N application rates and net returns are illustrated in Table 10. For USG the prices correspond to 15, 8, and 2 days for application, and for SCU the prices correspond to a 50% and 30% premium over urea. This table shows that prices within the range used have little influence on the optimum application rates for the findings and assumptions used in this study. However, net returns increase by Rs 48 and Rs 63/ha for USG in the wet and dry season, respectively, with an applied N cost decreasing from Rs 5.92 to Rs 5.39/kg of N. Similarly, for SCU the net returns increase by Rs 75 and Rs 84/ha in the wet and dry seasons, respectively, when applied N cost decreases from Rs 6.68 to Rs 5.80/kg of N. During the dry season SCU gave lower net returns than urea at both price levels. Also the advantage of deep placement of USG as compared to split broadcast urea was less during the dry season. However, results from wet and dry season trials are not directly comparable since number of trials, area represented, and year when trials were conducted were different.

To gain some insight into the possible advantages of a deep-placement applicator, average results for the wet season, as presented in Table 8, are used. It was assumed

4. Private communications with TVA officials.
5. Private communications with staff of Agricultural Research Institute.

Table 10.
Optimum N Application Rates and Net Returns for Two Possible Prices for USG and SCU and for Urea at Actual N Price

Season	Applied N Prices[a] (Rs/kg)					
	Urea	*USG*	*USG*	*USG*	*SCU*	*SCU*
	4.65	**5.92**	**5.39**	**4.94**	**6.68**	**5.80**
	Optimum Rate (kg/ha)					
Wet	108	89	91	93	84	87
Dry	137	121	122	123	94	101
	Net Returns (Rs/ha)					
Wet	806	959	1,007	1,048	924	999
Dry	867	982	1,045	1,100	618	702

a. These prices include labor for application at a rate of Rs 6/day. The urea price of Rs 4.65/kg includes 4 days of labor/ha; USG at Rs 5.92/kg, 15 days; USG at Rs 5.39/kg, 8 days; and USG at Rs 4.94/kg, 2 days. SCU at Rs 6.68/kg and Rs 5.80/kg is calculated for 50% and 30% premium (N basis) over urea.

assumed that yield gains are similar for hand and machine placement as compared to split broadcast application and that labor required is 2 days/ha for machine and 8 days/ha for hand placement. The results presented in Table 10 indicate an advantage in net returns of Rs 201/ha and Rs 242/ha for deep placement of USG as compared with split broadcast urea with 8 and 2 days/ha of labor requirement, respectively, at a wage rate of Rs 6/day. Then, Rs 41 (242-201)/ha/crop season may be considered as available to cover the cost of investment in the applicator.

Assuming that an applicator would cost Rs 800, with full depreciation over 3 years, annual maintenance cost of 10% of investment, and opportunity cost of capital at 12%/year, the annual cost of the applicator would be approximately Rs 400/year. With the average yield gains found in this study and the price relationships that were used, at two crops per year, the farmer would need to use an applicator for 5 ha/crop season. At a wage rate of Rs 12/day the use requirement would be reduced to 2.6 ha/crop season. This reasoning considers return on machine investment and operating cost only in comparison to hand placement. If hand placement is not an alternative, then the total Rs 242/ha/crop season may be considered to cover applicator costs, and the use requirement is reduced to about 0.8 ha/crop season. The net benefit for machine placement over split broadcast application would remain at approximately Rs 242/ha/crop season with varying wage rates, since similar labor requirements have been assumed for each method. However, the net benefit per hectare derived from machine placement as compared to hand placement increases as wage rates increase. Net returns to hand placement decrease faster than net returns to split broadcast and machine application with increasing wage rates. Under the situation that is described above, the net benefit of hand placement as compared with split broadcast application disappears when wage rates approach Rs 33/day.

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Appendix

Appendix Table 1. Regression Coefficients, Levels of Significance, R^2 Values, and Coefficients of Variation (CV) for the Quadratic Multifertilizer Response Models Fitted to 162 Experiments

Experiment Number	Year	Intercept	Regression Coefficients: Urea b_1	Urea b_{11}	USG b_2	USG b_{22}	SCU b_3	SCU b_{33}	R^2 (%)	CV (%)
					State = Assam, Season = Dry					
3	1978	2,103.31	18.8088**		42.5763**	-0.15233*	30.3392**	-0.19722**	72.1	17.9
4	1978	3,398.58	16.7662**		36.3891*	-0.18719+	45.9094**	-0.18777+	44.9	18.8
5	1978	5,676.51	44.9276*	-0.17338	40.4455*	-0.19977	40.6441*	-0.11924	45.2	14.0
6	1978	4,315.34	10.1604**		44.2955**	-0.17299**	8.1728**		73.1	10.2
7	1978	2,032.74	-1.6562		-2.6229+		-2.5735		10.2	19.0
8	1978	2,567.91	5.9828	-0.03573	11.9219+	-0.07771	16.0037*	-0.12310	28.5	12.4
9	1978	1,836.05	8.0625	-0.04376	9.1143	-0.05765	14.4810*	-0.07135	30.8	15.2
					State = Assam, Season = Wet					
1	1977	3,247.50	11.6220**		13.5149**		11.3839**		56.6	11.3
2	1977	1,865.25	2.1651**		1.3842+		5.9339*	-0.03949	29.8	6.3
10	1978	3,049.03	7.3582**	-0.02584	14.3675**	-0.07805**	10.1438**	-0.06033**	82.9	2.7
11	1978	4,930.29	17.8404**		42.3789**	-0.14262*	64.4403**	-0.30249**	93.2	4.6
12	1978	1,804.55	5.4647	-0.00246	9.1075	-0.00145	13.3107+	-0.03292	64.6	11.5
13	1978	1,162.27	22.4302**	-0.05869+	16.2826**	-0.06580*	47.4278**	-0.31637**	95.6	5.8
14	1978	3,118.55	13.1684	-0.12335	7.4253	-0.07495	3.8004		10.7	15.0
15	1978	3,525.00	27.8216**	-0.05063	41.9542**	-0.19101*	31.5668**	-0.07601	85.2	7.0
16	1979	4,539.31	15.0082**		56.3271**	-0.45606**	73.3788**	-0.62812**	46.7	13.2
17	1979	3,497.88	9.9580	-0.08301	5.1443*		30.6793**	-0.17939*	68.7	8.2
18	1979	5,128.98	11.5907	-0.06221	5.7360	-0.03951	7.2583	-0.05584	27.2	5.6
19	1979	2,024.24	32.5890*	-0.20084+	25.6933*	-0.04990	79.4701**	-0.62725**	70.4	15.0
20	1979	4,586.21	2.2460	-0.00334	2.6906**		7.0024*	-0.04043+	47.7	2.3
21	1979	5,262.19	23.9825	-0.19462	34.2310	-0.24918	12.6988		12.2	19.2
22	1979	2,506.06	10.2915	-0.01907	36.8997**	-0.27222**	58.1960**	-0.50370**	66.2	11.7
23	1979	6,689.59	5.4943**		6.7279*	-0.00604	32.8391**	-0.28382**	80.5	2.1
24	1980	1,979.87	11.5359**		12.1093*	-0.01248**	32.4114**	-0.21093**	69.6	10.4
25	1980	2,195.45	18.8384+	-0.08932	43.2780**	-0.28574**	35.4173**	-0.21954+	64.4	11.8
26	1980	1,593.03	36.3007**	-0.23249*	41.4908**	-0.20582+	54.1614**	-0.36556**	66.6	15.6
27	1980	1,892.73	3.8198	-0.00175	11.8997**	-0.03559	25.5937**	-0.14037**	95.0	4.0
28	1980	3,506.98	17.3969*	-0.06758	26.3903**	-0.14433**	24.7894**	-0.14847**	39.3	10.1

(Continued)

Appendix Table 1. Regression Coefficients, Levels of Significance, R^2 Values, and Coefficients of Variation (CV) for the Quadratic Multifertilizer Response Models Fitted to 162 Experiments (Continued)

Experiment Number	Year	Intercept	Regression Coefficients: Urea b_1	Urea b_{11}	USG b_2	USG b_{22}	SCU b_3	SCU b_{33}	R^2	CV (%)
					State = Bihar, Season = Wet					
29	1977	1,406.06	14.1746+	-0.07247	17.4422**	-0.08398+	11.1483*	-0.06041	57.5	12.3
30	1977	3,361.82	41.7656**	-0.17360*	58.5594**	-0.17218+	34.2129**	-0.07865	86.6	9.6
31	1977	785.76	10.2927	-0.03666	32.3892**	-0.06978	35.1742**	-0.18239**	90.4	15.4
32	1977	4,329.70	65.1180**	-0.23086**	33.8285**	-0.08152	70.9777**	-0.45542**	96.2	4.0
33	1977	1,756.67	19.8509**	-0.04693	60.3114**	-0.27884**	46.8377**	-0.21173**	96.7	5.6
34	1977	5,052.71	33.4645**	-0.15515*	19.2328**		21.0698*	-0.06589	73.9	6.5
35	1977	2,486.97	41.1451**	-0.31059**	27.8776*	-0.15324+	27.3864**	-0.16420+	47.1	13.6
36	1977	897.25	11.8627**		22.2776**	-0.02348	18.1636**	-0.12260**	91.9	11.9
37	1977	2,625.76	22.6216*	-0.01660	22.3585*	-0.10432	27.2927**	-0.13666+	76.2	10.3
38	1977	3,150.00	38.4211**	-0.23465**	45.3070**	-0.23794**	78.7719**	-0.44408**	94.4	5.3
39	1978	837.99	15.9267*	-0.08941	24.6800*		31.7040**	-0.15947**	90.9	13.2
40	1978	2,232.12	31.5918**	-0.17122**	34.0820**	-0.22713**	28.5265**	-0.17568**	75.9	7.6
41	1978	2,636.52	29.7780	-0.16498	54.8000+	-0.36905	56.8614+	-0.42347	20.8	30.6
42	1978	3,070.00	39.6540**	-0.21131**	48.0458**	-0.21023**	64.8928**	-0.32949**	96.2	4.1
43	1978	1,797.58	20.9126**	-0.04841	65.1329**	-0.31320**	52.4477**	-0.24889**	97.3	5.3
44	1978	1,795.76	33.4636**	-0.13461	45.9831**	-0.13853	25.9490**	-0.03714	85.5	12.1
45	1979	1,951.52	10.6016	-0.03827	34.2615**	-0.17026+	71.2985**	-0.42746**	93.6	8.6
46	1979	2,539.09	34.0971**	-0.08858**	36.7287**	-0.10158**	50.4957**	-0.20757**	98.9	2.5
47	1979	1,241.31	15.8249*	-0.08874	24.6405**		33.0885**	-0.17842**	90.7	11.0
48	1979	2,745.15	35.8189*	-0.23335+	34.8735*	-0.18312	29.7200+	-0.14867	49.1	13.5
49	1979	1,500.00	29.5224**	-0.13402**	21.5302**	-0.05225	22.1881**	-0.05293	94.5	5.6
50	1979	1,536.37	30.8014	-0.24567	40.4535	-0.26138	21.9374**		31.1	39.6
51	1979	535.59	64.0753**	-0.36132+	59.3053**	-0.34181*	65.9881**	-0.36233*	70.2	22.5
52	1979	1,239.50	19.2917**		14.8604**		32.1449**	-0.11070**	94.1	7.4
53	1979	1,128.48	13.0192**	-0.06014*	9.4471**	-0.03456	11.4646**	-0.03835	82.5	7.2
54	1979	1,449.55	26.7562**	-0.06771	30.7693**	-0.16186*	39.5242**	-0.17249*	82.7	11.8
55	1980	2,269.41	4.3192**		16.2169**	-0.07051**	30.5151**	-0.15552**	96.0	3.6
56	1980	2,060.00	24.9123**	-0.06335	33.0994**	-0.13808**	29.2105**	-0.09178+	90.2	6.9
57	1980	4,134.55	70.9569**	-0.26941**	37.1850**	-0.09749	80.5281**	-0.57913**	95.9	4.3
58	1980	1,922.42	28.3320**	-0.12933**	27.6059**	-0.15735**	31.5874**	-0.19078**	88.4	5.7
59	1980	2,895.76	45.2959**	-0.21041	69.3067**	-0.29475**	64.8671**	-0.24750**	98.7	2.9
60	1980	1,890.91	20.8200**	-0.02012	32.8571**	-0.04584+	24.8161**	-0.06615*	98.6	3.3

(Continued)

Appendix Table 1. Regression Coefficients, Levels of Significance, R^2 Values, and Coefficients of Variation (CV) for the Quadratic Multifertilizer Response Models Fitted to 162 Experiments (Continued)

Experiment Number	Year	Intercept	Regression Coefficients: Urea b_1	Urea b_{11}	USG b_2	USG b_{22}	SCU b_3	SCU b_{33}	R^2	CV (%)
					State = Bihar, Season = Wet (Continued)					
61	1980	2,540.30	34.0355**	-0.14451+	59.2353**	-0.32686**	70.6096**	-0.41972**	90.0	7.2
62	1980	1,948.48	18.6869**	-0.00234	30.8214**	-0.03483	23.6820**	-0.05987*	98.5	3.4
63	1980	1,626.02	20.7391	-0.10564	37.7011	-0.24317	29.9509	-0.21411	18.4	36.5
64	1980	2,008.95	36.7743**	-0.19386*	50.4853**	-0.36348**	52.3752**	-0.29564**	83.7	9.4
65	1980	2,897.58	35.8931**	-0.19624**	36.0345**	-0.16361**	47.6768**	-0.25580**	88.4	5.8
					State = Madhya Pradesh, Season = Wet					
66	1977	2,150.00	20.6930**	-0.12039**	31.5351**	-0.18553**	46.2719**	-0.27325**	92.8	5.2
67	1977	2,720.30	23.3162*	-0.05982	37.7548**	-0.18306*	34.5881**	-0.15390+	71.2	10.5
68	1977	2,736.01	6.4951		20.9040	-0.11590	40.4391+	-0.23476	22.9	29.0
69	1977	2,560.91	34.7994+	-0.10972	67.0889**	-0.37573*	89.7556**	-0.62573**	55.7	19.5
70	1978	2,249.39	29.9942*	-0.13089	45.3037**	-0.18389	26.9874+	-0.00053	76.1	13.9
71	1978	3,934.24	26.1295**	-0.07312	54.2119**	-0.25309**	41.9019**	-0.17498**	93.0	4.6
72	1978	1,760.45	23.0830**	-0.05873*	35.8730**	-0.15667**	48.3462**	-0.22361**	98.3	3.4
73	1978	3,804.88	12.4816**		18.2752**		23.5295**	-0.02947	90.0	4.8
74	1978	2,537.42	28.8681**	-0.00966	76.9821**	-0.48183**	41.0732**	-0.07213	92.0	7.4
75	1978	1,121.39	18.0811*	-0.03018	22.5099**		23.1448**		84.9	14.3
76	1978	2,910.61	28.0216+	-0.04320	57.1305**	-0.29701*	47.8956**	-0.18939	71.3	13.2
					State = Orissa, Season = Dry					
87	1978	3,492.40	49.9174**	-0.31755**	18.5028	-0.00144	17.1091	-0.03505	56.7	13.9
88	1978	2,485.79	13.3031**	-0.01604	11.0266**		11.5636**		80.6	7.8
89	1978	2,748.03	40.9451**	-0.15170**	49.6017**	-0.19095**	44.4571**	-0.16896**	90.9	6.2
90	1978	1,075.50	9.4965*	-0.00960	17.6207**	-0.05159+	12.2527**	-0.03864	77.9	12.5
91	1978	3,930.23	17.5619**	-0.01756	32.4346**	-0.06377+	29.1073**	-0.13430**	92.1	5.0
92	1978	4,282.48	14.4083**	-0.04516	22.0254**	-0.08739**	11.6795*	-0.02674	72.5	5.1
93	1978	3,592.92	14.9235**		18.1431**	-0.01407	21.7196**	-0.04485	87.1	5.9
94	1978	3,434.88	16.6369*	-0.00404	20.1477**	-0.02553	24.2468**	-0.05423	82.7	7.6

(Continued)

Appendix Table 1. Regression Coefficients, Levels of Significance, R^2 Values, and Coefficients of Variation (CV) for the Quadratic Multifertilizer Response Models Fitted to 162 Experiments (Continued)

Experiment Number	Year	Intercept	Regression Coefficients: Urea b_1	Urea b_{11}	USG b_2	USG b_{22}	SCU b_3	SCU b_{33}	R^2	CV (%)
			State = Orissa, Season = Wet							
77	1977	4,628.79	21.6256**	-0.08408*	35.7703**	-0.17125**	30.9677*	-0.14505	84.6	4.4
78	1977	1,580.61	30.3254**	-0.09003**	26.5315**	-0.06646**	35.6280**	-0.12040**	97.8	4.0
79	1977	2,145.98	6.1740*		35.2646**	-0.18213**	37.0541**	-0.18147**	78.3	11.6
80	1977	1,869.70	9.8066	-0.01869	45.6838**	-0.28185**	39.0171**	-0.24018**	74.2	12.5
81	1977	2,490.61	15.1280+	-0.09957	14.6894	-0.11799	9.6675	-0.01350	37.7	13.3
82	1977	2,575.15	23.7831**	-0.06220	41.0901**	-0.16681**	37.4147**	-0.14334**	92.5	5.8
83	1977	3,385.15	14.5901*	-0.04181	19.2656**	-0.08610+	24.1822**	-0.07152	82.5	5.9
84	1977	1,775.41	21.6564**		22.6087**		25.1883**	-0.01084	98.0	4.1
85	1977	1,684.17	23.4315**		24.4077**		24.0982**		97.7	4.6
86	1977	1,423.30	29.3035**	-0.03038	40.4220**	-0.10549**	28.3456**		97.0	5.9
96	1978	2,209.08	11.9553**		29.5359**	-0.09075**	22.7571**	-0.07139**	97.3	3.4
97	1978	2,035.83	13.3565**		23.4358**		20.9623**		90.6	7.9
98	1978	1,813.30	12.9766**		46.4532**	-0.23203**	43.3343**	-0.18005*	87.1	10.5
99	1978	1,456.54	5.5206*	-0.01790	4.5915**		5.7594*	-0.00747	74.6	5.8
100	1978	1,978.40	29.5561**		72.1837**	-0.27716**	58.8430**	-0.21685**	98.7	3.7
101	1978	2,835.76	26.6166**	-0.15938**	47.0893**	-0.19606**	43.8193**	-0.22490**	94.1	5.3
102	1978	3,293.03	41.2715**	-0.24846**	40.2773**	-0.21029*	51.2374**	-0.36827**	74.4	7.5
103	1978	2,064.85	20.6504*	-0.09567	41.6348**	-0.24891**	18.3209*	-0.03936	76.8	10.0
104	1978	2,335.76	19.0874*	-0.13163+	21.7092**	-0.14652*	25.9879**	-0.17874	45.8	10.0
105	1978	2,551.73	21.1310**	-0.08317+	25.4049**	-0.02889	17.7968**		92.5	5.6
106	1978	2,024.74	8.5812**		31.6138**	-0.19194**	28.9091**	-0.18287**	88.7	5.4
107	1979	3,391.52	21.4788**	-0.07347	21.9369**	-0.08728	28.4866**	-0.15117*	73.0	6.7
109	1979	2,287.88	24.1051**	-0.06879	52.7113**	-0.26779**	65.1870**	-0.31110**	91.4	8.3
110	1979	3,248.18	44.5149**	-0.21358**	58.2576**	-0.32945**	53.2040**	-0.27815**	96.6	3.1
111	1979	1,809.55	41.3322**	-0.19387**	51.1202**	-0.28139**	58.7177**	-0.33960**	91.5	6.8
112	1979	2,923.33	23.9550**		27.0370**		26.1376**		97.1	3.7
113	1979	2,504.12	27.7293	-0.22063	31.4428+	-0.11585	16.6176**		44.9	21.6
118	1979	3,411.52	4.7586	-0.00159	25.7576**	-0.14169+	37.5899**	-0.17635*	84.1	7.3
119	1979	2,467.61	6.3644**		37.1980**	-0.20977**	57.3881**	-0.27055**	95.9	5.9
120	1979	2,288.02	24.6400**		22.6096**		27.7143**	-0.03228	98.7	2.8

(Continued)

Appendix Table 1. Regression Coefficients, Levels of Significance, R^2 Values, and Coefficients of Variation (CV) for the Quadratic Multifertilizer Response Models Fitted to 162 Experiments (Continued)

Experiment Number	Year	Intercept	Regression Coefficients: Urea b_1	Urea b_{11}	USG b_2	USG b_{22}	SCU b_3	SCU b_{33}	R^2	CV (%)
					State = Orissa, Season = Wet (Continued)					
121	1979	2,520.30	7.1886	-0.01496	29.2451**	-0.18607**	38.6505**	-0.24509**	83.9	6.9
122	1979	4,016.67	8.6452	-0.09368	10.5214	-0.15067	-4.1667		29.1	11.6
123	1979	1,004.55	12.6285+	-0.01126	39.2123**	-0.21770**	31.3663**	-0.20010**	83.0	12.6
124	1980	2,269.31	23.4275**	-0.07337	26.6488**	-0.03344	20.0082**		91.8	6.6
125	1980	2,110.33	12.6416**		29.9851**	-0.15520*	33.2965**	-0.20062**	72.0	10.0
126	1980	2,136.09	12.0836**		28.4486**	-0.05318	31.2361**	-0.03585	90.9	8.7
127	1980	2,636.36	24.9265**	-0.11391*	28.3231**	-0.06044	38.7959**	-0.17428**	93.5	5.1
128	1980	2,872.58	9.1217	-0.00313	28.5491**	-0.16334*	29.5262**	-0.12767+	75.1	8.4
					State = Uttar Pradesh, Season = Wet					
129	1977	1,910.61	38.9175**	-0.15308*	57.2376**	-0.22205**	38.7464**	-0.10385	89.6	9.8
130	1977	1,837.27	55.5666**	-0.16865**	54.6061**	-0.13258**	47.1455**	-0.08817+	97.5	5.4
131	1977	3,446.46	17.0022**		16.7642**		44.4619**	-0.27854**	65.2	10.4
132	1977	2,845.92	39.5383**	-0.06789	33.9813**	-0.06953	22.0319**		94.1	6.2
133	1977	2,713.33	22.7976**		32.1429**		26.5595**		93.6	6.7
134	1977	3,368.30	18.6829	-0.05565	25.0426	-0.06771	12.7206*		38.7	17.9
135	1977	1,766.67	44.9430**	-0.17664**	36.1184**	-0.13344*	79.8553**	-0.38783**	93.3	8.6
136	1977	1,754.08	19.1348**		23.4266**	-0.05909**	22.7205**	-0.04933**	98.9	2.5
					State = West Bengal, Season = Dry					
143	1978	2,486.76	20.1077**		32.7487**	-0.07626**	33.1658**	-0.12522**	96.5	3.9
144	1978	3,419.42	29.7496**		30.3179**		45.4250**	-0.12028*	93.4	5.7
145	1978	3,647.92	38.8254**	-0.15067*	34.8499**	-0.11598	33.2402**	-0.13120+	67.0	10.1
146	1978	2,870.83	28.3931**	-0.07726	37.6141**	-0.13307*	31.7358**	-0.11278*	78.2	9.0
147	1978	2,970.64	18.1267**		18.8291**		16.1727**		95.8	3.7
148	1978	2,457.66	8.7622**		43.1123**	-0.16727**	41.3284**	-0.18237**	93.6	6.3
149	1978	2,404.71	17.4179**		26.1841	-0.07221	25.6081	-0.09855	31.9	26.6
150	1978	2,703.10	23.9067**	-0.00681	53.1753**	-0.18121**	51.8102**	-0.19935**	89.0	8.0
151	1978	2,700.36	19.9429**	-0.03770	37.2229**	-0.14313**	36.4635**	-0.12354**	93.2	5.0

(Continued)

Appendix Table 1. Regression Coefficients, Levels of Significance, R^2 Values, and Coefficients of Variation (CV) for the Quadratic Multifertilizer Response Models Fitted to 162 Experiments (Continued)

Experiment Number	Year	Intercept	Regression Coefficients: Urea b_1	Urea b_{11}	USG b_2	USG b_{22}	SCU b_3	SCU b_{33}	R^2	CV (%)
137	1977	2,730.61	18.5578**	-0.02435	18.1894**	-0.03883	20.7376**	-0.05955+	92.9	4.5
138	1977	2,989.51	22.9653**	-0.07102	19.3505**		18.0004**	-0.02322	89.2	5.9
139	1977	3,310.62	7.9171	-0.02391	5.3505*		12.3820	-0.06338	26.8	9.6
140	1977	3,146.06	28.6089**	-0.17981*	27.5167**	-0.22093**	27.9729**	-0.20361*	46.0	11.2
141	1977	3,617.27	16.9745*	-0.01810	45.2552**	-0.27315**	45.4219**	-0.28981**	83.4	5.6
152	1978	3,396.97	29.7568**	-0.13287**	37.8903**	-0.21287**	36.1408**	-0.20326**	90.6	3.9
153	1978	1,756.11	14.2130**		30.3289**	-0.05778	28.1896**	-0.07254	79.1	14.0
154	1978	3,160.26	13.1937**	-0.04611	26.8390**	-0.2661*	19.6133**		95.7	10.3
155	1978	2,923.64	26.5648**	-0.19798*	22.9926*	-0.20326*	27.0082**	-0.21978**	45.8	9.9
156	1978	2,605.45	16.1873	-0.04411	40.9242**	-0.30618**	26.9963*	-0.13886	57.0	11.1
158	1979	3,375.76	61.6751**	-0.44122**	53.0932**	-0.37638**	56.6458**	-0.40061**	93.0	3.6
159	1979	4,083.33	40.2680**	-0.17422	36.7788**	-0.19425**	36.5643**	-0.16393**	92.5	3.7
160	1979	3,799.09	24.1653*	-0.11132	27.1039*	-0.17779+	29.9597**	-0.19864*	48.0	8.7
161	1979	4,741.52	48.8862**	-0.26637**	39.9145**	-0.18217**	34.8146**	-0.16044**	94.8	2.7
162	1979	3,961.67	31.9883**	-0.21781**	52.5219**	-0.39440**	25.5824**	-0.12853+	72.3	6.2
163	1979	4,256.67	22.2953	-0.19155	8.7622	-0.02464	7.8314	-0.01530	17.5	11.4
164	1979	3,209.09	12.7813+	-0.03064	21.9187**	-0.02861	21.5289**	-0.07870	85.7	6.1
165	1979	3,368.48	18.5260**	-0.03875	25.5046**	-0.12214*	35.0855**	-0.20878**	83.2	5.2
166	1979	3,491.21	18.0768**	-0.07326	42.2191**	-0.30176**	34.6704**	-0.22122**	81.4	4.9
167	1980	2,591.52	16.6007**	-0.10122+	35.2166**	-0.20058**	37.6777**	-0.26217**	83.7	6.5
168	1980	1,900.61	23.5876*	-0.11142	33.5779**	-0.16990*	37.3547**	-0.21742*	68.2	12.2
169	1980	2,294.24	25.5179**	-0.08916	35.1280**	-0.15982+	49.8844**	-0.21235*	86.3	9.3
170	1980	2,641.76	14.0686**	-0.01589	23.3279**	-0.06733*	13.4314**		95.7	3.3

** $P \leq .01$; * $P \leq .05$; + $P \leq .10$.

Appendix Table 2. Optimum Application Rates, Yield Increase, Net Returns, Agronomic Efficiencies, and Value:Cost Ratios for 162 Experiments and Means by Region and Season (Analysis at MR = MC)

Experiment Number	Optimum Application Rates			Yield Increase			Net Returns			Agronomic Efficiencies			Value:Cost Ratios		
	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU
	- - (kg/ha) - -			- - - (kg/ha) - - -			- - - (Rs/ha) - - -			- - - (kg/kg) - -					
							State = Assam, Season = Dry								
3	144	115	56	2,708	2,885	1,079	1,497	1,625	491	18.8	25.0	19.3	3.24	3.38	2.32
4	144	77	100	2,414	1,695	2,714	1,262	898	1,504	16.8	21.9	27.1	2.88	2.96	3.25
5	113	83	135	2,862	1,979	3,318	1,765	1,094	1,751	25.4	23.9	24.5	4.36	3.24	2.94
6	144	107	0	1,463	2,757	0	501	1,574	0	10.2	25.8	0.0	1.75	3.50	0.00
7	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.00	0.00	0.00
8	0	29	31	0	281	379	0	53	95	0.0	9.7	12.2	0.00	1.31	1.46
9	26	15	43	178	123	491	23	10	106	6.9	8.3	11.4	1.19	1.12	1.37
							State = Assam, Season = Wet								
1	120	120	120	1,395	1,622	1,366	558	588	292	11.6	13.5	11.4	2.00	1.83	1.37
2	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.00	0.00	0.00
10	30	45	15	197	486	138	18	125	11	6.6	10.9	9.2	1.13	1.47	1.11
11	108	108	93	1,927	2,913	3,375	1,039	1,692	2,081	17.8	27.0	36.4	3.07	3.65	4.36
12	0	108	76	0	967	818	0	135	150	0.0	9.0	10.8	0.00	1.21	1.30
13	108	68	62	1,738	800	1,723	888	240	966	16.1	11.8	27.9	2.77	1.60	3.34
14	30	0	0	283	0	0	88	0	0	9.5	0.0	0.0	1.63	0.00	0.00
15	108	90	108	2,414	2,232	2,523	1,429	1,251	1,298	22.4	24.7	23.4	3.85	3.34	2.80
16	108	54	52	1,621	1,709	2,115	795	1,050	1,347	15.0	31.9	40.9	2.58	4.31	4.90
17	25	0	62	197	0	1,215	41	0	557	7.9	0.0	19.5	1.36	0.00	2.34
18	46	0	0	404	0	0	107	0	0	8.7	0.0	0.0	1.50	0.00	0.00
19	67	108	57	1,280	2,193	2,489	714	1,115	1,613	19.2	20.3	43.9	3.30	2.75	5.27
20	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.00	0.00	0.00
21	47	54	108	695	1,121	1,371	339	578	377	14.9	20.8	12.7	2.56	2.81	1.52
22	108	54	49	889	1,200	1,646	209	640	987	8.2	22.1	33.3	1.42	3.00	3.99
23	0	0	43	0	0	889	0	0	423	0.0	0.0	20.6	0.00	0.00	2.47
24	108	108	57	1,246	1,162	1,163	495	291	550	11.5	10.8	20.4	1.98	1.46	2.44
25	73	63	62	899	1,591	1,349	380	901	668	12.3	25.3	21.9	2.12	3.43	2.62
26	66	83	63	1,381	2,025	1,959	800	1,130	1,149	21.1	24.4	31.2	3.62	3.31	3.75
27	0	62	61	0	611	1,043	0	114	424	0.0	9.6	17.0	0.00	1.30	2.03
28	86	66	55	995	1,112	918	397	500	365	11.6	16.9	16.6	2.00	2.28	1.99

(Continued)

Appendix Table 2. Optimum Application Rates, Yield Increase, Net Returns, Agronomic Efficiencies, and Value:Cost Ratios for 162 Experiments and Means by Region and Season (Analysis at MR = MC) (Continued)

Experiment Number	Optimum Application Rates			Yield Increase			Net Returns			Agronomic Efficiencies			Value:Cost Ratios		
	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU
	- - (kg/ha) - -			- - - (kg/ha) - - -			- - - (Rs/ha) - - -			- - - (kg/kg) - -					
							State = Bihar, Season = Wet								
29	58	60	23	577	743	227	193	240	26	10.0	12.4	9.7	1.72	1.68	1.17
30	104	120	120	2,463	4,548	2,973	1,489	2,928	1,578	23.8	37.9	24.8	4.09	5.13	2.97
31	61	120	74	492	2,882	1,601	109	1,596	790	8.1	24.0	21.8	1.39	3.25	2.61
32	120	120	69	4,490	2,886	2,727	3,034	1,599	1,723	37.4	24.0	39.7	6.44	3.25	4.76
33	120	95	91	1,706	3,212	2,508	807	2,009	1,400	14.2	33.9	27.6	2.45	4.58	3.31
34	89	120	97	1,750	2,308	1,421	986	1,137	492	19.6	19.2	14.7	3.38	2.60	1.76
35	57	67	58	1,335	1,179	1,036	804	548	442	23.5	17.6	17.9	4.04	2.39	2.14
36	120	120	40	1,424	2,335	531	581	1,158	158	11.9	19.5	13.3	2.04	2.63	1.59
37	120	72	69	2,476	1,067	1,235	1,422	429	526	20.6	14.9	17.8	3.55	2.01	2.14
38	69	80	79	1,537	2,099	3,454	906	1,208	2,234	22.1	26.4	43.6	3.81	3.56	5.22
39	57	108	73	615	2,665	1,467	229	1,494	685	10.9	24.7	20.0	1.87	3.34	2.40
40	75	59	57	1,408	1,218	1,059	776	627	464	18.7	20.7	18.4	3.22	2.80	2.21
41	73	64	57	1,293	1,997	1,868	696	1,218	1,112	17.8	31.1	32.6	3.06	4.21	3.91
42	80	97	86	1,820	2,680	3,142	1,084	1,572	1,941	22.7	27.7	36.6	3.91	3.75	4.39
43	108	92	89	1,694	3,343	2,693	853	2,129	1,563	15.7	36.3	30.4	2.70	4.90	3.65
44	103	108	108	2,017	3,350	2,369	1,136	2,041	1,175	19.6	31.0	21.9	3.38	4.20	2.63
45	63	79	74	513	1,643	2,932	120	848	1,855	8.2	20.8	39.8	1.41	2.82	4.78
46	108	108	102	2,649	2,782	2,987	1,617	1,587	1,712	24.5	25.8	29.4	4.22	3.48	3.53
47	56	108	69	610	2,661	1,437	226	1,490	687	10.8	24.6	20.7	1.86	3.33	2.48
48	64	75	72	1,338	1,586	1,368	772	825	615	20.8	21.1	19.0	3.58	2.86	2.28
49	88	108	108	1,563	1,716	1,779	839	734	703	17.7	15.9	16.5	3.04	2.15	1.98
50	51	63	108	931	1,513	2,369	508	836	1,175	18.3	23.9	21.9	3.15	3.24	2.63
51	81	76	80	2,817	2,532	2,956	1,879	1,577	1,835	34.9	33.3	37.2	6.01	4.51	4.46
52	108	108	108	2,083	1,605	2,177	1,165	645	1,024	19.3	14.9	20.2	3.32	2.01	2.43
53	60	30	41	564	250	404	173	24	51	9.4	8.4	9.9	1.62	1.14	1.19
54	108	72	90	2,100	1,378	2,163	1,178	675	1,128	19.4	19.1	23.9	3.35	2.58	2.87
55	0	63	71	0	739	1,385	0	221	633	0.0	11.8	19.4	0.00	1.60	2.33
56	108	93	108	1,952	1,885	2,084	1,059	957	947	18.1	20.2	19.3	3.11	2.74	2.31
57	108	108	62	4,521	2,879	2,769	3,115	1,664	1,800	41.9	26.7	44.4	7.20	3.61	5.33
58	87	64	61	1,486	1,124	1,216	784	519	567	17.1	17.5	20.0	2.94	2.37	2.39
59	94	105	108	2,398	4,028	4,119	1,482	2,601	2,575	25.6	38.4	38.1	4.40	5.19	4.57

(Continued)

Appendix Table 2. Optimum Application Rates, Yield Increase, Net Returns, Agronomic Efficiencies, and Value:Cost Ratios for 162 Experiments and Means by Region and Season (Analysis at MR = MC) (Continued)

Experiment Number	Optimum Application Rates			Yield Increase			Net Returns			Agronomic Efficiencies			Value:Cost Ratios		
	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU
	- - (kg/ha) - -			- - - (kg/ha) - - -			- - - (Rs/ha) - - -			- - - (kg/kg) - -					
					State = Bihar, Season = Wet (Continued										
60	108	108	108	2,014	3,014	1,909	1,109	1,772	807	18.6	27.9	17.7	3.21	3.77	2.12
61	98	79	74	1,946	2,642	2,928	1,102	1,644	1,848	19.9	33.3	39.5	3.43	4.51	4.73
62	108	108	108	1,991	2,922	1,859	1,091	1,699	767	18.4	27.1	17.2	3.17	3.66	2.06
63	71	62	50	938	1,405	966	422	755	436	13.3	22.5	19.1	2.28	3.05	2.30
64	80	59	74	1,700	1,715	2,261	989	1,022	1,312	21.3	28.9	30.4	3.66	3.91	3.64
65	77	88	77	1,598	1,901	2,154	922	1,003	1,210	20.9	21.7	28.0	3.59	2.94	3.36
					State = Madhya Pradesh, Season = Wet										
66	62	65	69	819	1,266	1,895	368	628	1,053	13.3	19.5	27.3	2.28	2.63	3.27
67	120	83	85	1,937	1,872	1,830	991	1,007	896	16.1	22.6	21.5	2.78	3.05	2.57
68	120	58	68	779	825	1,667	66	315	878	6.5	14.1	24.4	1.12	1.91	2.93
69	120	79	65	2,596	2,958	3,191	1,519	1,897	2,119	21.6	37.2	49.0	3.72	5.04	5.88
70	92	103	108	1,654	2,716	2,908	894	1,563	1,606	17.9	26.3	26.9	3.08	3.56	3.23
71	108	92	96	1,969	2,849	2,409	1,073	1,732	1,288	18.2	30.8	25.1	3.14	4.17	3.01
72	108	91	89	1,808	1,966	2,536	944	1,035	1,432	16.7	21.6	28.3	2.88	2.93	3.40
73	108	108	108	1,348	1,974	2,197	576	940	1,038	12.5	18.3	20.3	2.15	2.47	2.44
74	108	72	108	3,005	3,047	3,595	1,902	2,010	2,155	27.8	42.2	33.3	4.79	5.71	3.99
75	108	108	108	1,601	2,431	2,500	778	1,306	1,279	14.8	22.5	23.1	2.55	3.04	2.78
76	108	84	104	2,522	2,701	2,936	1,515	1,666	1,652	23.3	32.3	28.1	4.02	4.36	3.37
					State = Orissa, Season = Dry										
87	69	144	125	1,935	2,634	1,592	1,225	1,256	439	27.9	18.3	12.7	4.79	2.47	1.53
88	144	144	144	1,583	1,588	1,665	597	419	372	11.0	11.0	11.6	1.89	1.49	1.39
89	116	111	107	2,707	3,150	2,822	1,627	1,866	1,544	23.4	28.5	26.4	4.02	3.85	3.17
90	144	99	51	1,168	1,240	522	265	406	79	8.1	12.5	10.3	1.40	1.69	1.23
91	144	144	77	2,165	3,348	1,448	1,062	1,827	642	15.0	23.3	18.7	2.59	3.14	2.25

(Continued)

Appendix Table 2. Optimum Application Rates, Yield Increase, Net Returns, Agronomic Efficiencies, and Value:Cost Ratios for 162 Experiments and Means by Region and Season (Analysis at MR = MC) (Continued)

Experiment Number	Optimum Application Rates			Yield Increase			Net Returns			Agronomic Efficiencies			Value:Cost Ratios		
	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU
	(kg/ha)			(kg/ha)			(Rs/ha)			(kg/kg)					
						State = Orissa, Season = Dry (Continued)									
92	95	84	62	962	1,231	625	327	490	84	10.1	14.7	10.0	1.74	1.99	1.20
93	144	144	144	2,149	2,321	2,198	1,050	1,005	798	14.9	16.1	15.3	2.57	2.18	1.83
94	144	144	144	2,312	2,372	2,367	1,180	1,046	933	16.1	16.5	16.4	2.76	2.23	1.97
						State = Orissa, Season = Wet									
77	94	83	78	1,290	1,788	1,533	595	940	706	13.7	21.6	19.7	2.36	2.92	2.36
78	120	120	113	2,343	2,227	2,491	1,316	1,072	1,237	19.5	18.6	22.0	3.36	2.51	2.64
79	120	77	79	741	1,632	1,796	35	853	909	6.2	21.3	22.7	1.06	2.88	2.72
80	107	68	64	834	1,803	1,512	171	1,040	784	7.8	26.5	23.7	1.34	3.59	2.84
81	47	31	49	490	341	444	174	90	26	10.5	11.0	9.0	1.80	1.49	1.08
82	120	101	101	1,958	2,449	2,320	1,009	1,361	1,180	16.3	24.2	22.9	2.81	3.28	2.74
83	105	69	111	1,071	919	1,801	369	327	702	10.2	13.3	16.3	1.76	1.80	1.95
84	120	120	120	2,599	2,713	2,866	1,521	1,461	1,493	21.7	22.6	23.9	3.73	3.06	2.87
85	120	120	120	2,812	2,929	2,892	1,691	1,633	1,513	23.4	24.4	24.1	4.03	3.30	2.89
86	120	120	120	3,079	3,332	3,401	1,905	1,955	1,921	25.7	27.8	28.3	4.41	3.75	3.40
96	108	108	101	1,291	2,131	1,570	531	1,066	583	12.0	19.7	15.5	2.06	2.67	1.86
97	108	108	108	1,443	2,531	2,264	652	1,386	1,091	13.4	23.4	21.0	2.30	3.17	2.51
98	108	84	97	1,401	2,266	2,511	619	1,315	1,361	13.0	26.9	25.8	2.23	3.64	3.10
99	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.00	0.00	0.00
100	108	108	108	3,192	4,563	3,826	2,051	3,012	2,340	29.6	42.3	35.4	5.08	5.71	4.25
101	65	101	79	1,058	2,758	2,057	543	1,607	1,120	16.2	27.2	26.1	2.79	3.68	3.13
102	71	78	58	1,680	1,864	1,735	1,012	1,028	999	23.5	23.8	29.8	4.05	3.22	3.57
103	78	69	108	1,026	1,686	1,520	460	942	495	13.2	24.5	14.1	2.28	3.32	1.69
104	50	49	49	628	711	847	268	280	349	12.4	14.6	17.2	2.14	1.97	2.06
105	92	108	108	1,241	2,407	1,922	564	1,287	817	13.5	22.3	17.8	2.32	3.01	2.13
106	108	63	56	927	1,231	1,047	239	611	463	8.6	19.5	18.6	1.48	2.64	2.23
107	107	83	67	1,455	1,222	1,227	668	485	537	13.6	14.7	18.4	2.35	1.98	2.21
109	108	85	91	1,801	2,543	3,359	939	1,534	2,078	16.7	30.1	36.8	2.87	4.06	4.41

(Continued)

Appendix Table 2. Optimum Application Rates, Yield Increase, Net Returns, Agronomic Efficiencies, and Value:Cost Ratios for 162 Experiments and Means by Region and Season (Analysis at MR = MC) (Continued)

Experiment Number	Optimum Application Rates			Yield Increase			Net Returns			Agronomic Efficiencies			Value:Cost Ratios		
	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU
	- - (kg/ha) - -			- - - (kg/ha) - - -			- - - (Rs/ha) - - -			- - - (kg/kg) - -					
					State = Orissa, Season = Wet (Continued										
110	91	77	81	2,280	2,534	2,482	1,403	1,571	1,447	25.2	32.8	30.8	4.33	4.44	3.69
111	92	78	74	2,159	2,273	2,487	1,302	1,359	1,495	23.6	29.3	33.5	4.06	3.96	4.02
112	108	108	108	2,587	2,920	2,823	1,568	1,697	1,538	24.0	27.0	26.1	4.12	3.66	3.13
113	50	104	108	833	2,015	1,795	435	998	715	16.8	19.4	16.6	2.89	2.63	1.99
118	0	65	83	0	1,074	1,905	0	476	970	0.0	16.6	23.0	0.00	2.24	2.75
119	108	71	91	687	1,584	2,979	48	847	1,779	6.4	22.3	32.9	1.09	3.02	3.94
120	108	108	108	2,661	2,442	2,617	1,627	1,315	1,373	24.6	22.6	24.2	4.24	3.06	2.91
121	46	59	62	299	1,076	1,453	25	513	750	6.5	18.3	23.5	1.12	2.48	2.82
122	15	10	0	109	93	0	17	13	0	7.2	9.0	0.0	1.24	1.21	0.00
123	108	73	58	1,233	1,703	1,142	484	930	530	11.4	23.3	19.9	1.96	3.15	2.38
124	108	108	108	1,674	2,488	2,161	837	1,352	1,008	15.5	23.0	20.0	2.67	3.12	2.40
125	108	73	62	1,365	1,360	1,295	590	658	621	12.6	18.7	20.8	2.17	2.53	2.50
126	108	108	108	1,305	2,452	2,955	542	1,323	1,644	12.1	22.7	27.4	2.08	3.07	3.28
127	84	108	87	1,290	2,354	2,059	641	1,244	1,065	15.4	21.8	23.6	2.64	2.95	2.83
128	108	65	83	949	1,164	1,571	257	548	703	8.8	18.0	18.9	1.51	2.43	2.27
					State = Uttar Pradesh, Season = Wet										
129	108	112	120	2,418	3,627	3,154	1,432	2,238	1,723	22.4	32.3	26.3	3.85	4.37	3.15
130	120	120	120	4,239	4,644	4,388	2,834	3,005	2,710	35.3	38.7	36.6	6.08	5.23	4.39
131	120	120	65	2,040	2,012	1,712	1,074	900	937	17.0	16.8	26.4	2.93	2.27	3.17
132	120	120	120	3,767	3,077	2,644	2,456	1,751	1,315	31.4	25.6	22.0	5.40	3.47	2.64
133	120	120	120	2,736	3,857	3,187	1,631	2,376	1,749	22.8	32.1	26.6	3.92	4.35	3.19
134	116	120	120	1,416	2,030	1,526	595	914	421	12.2	16.9	12.7	2.11	2.29	1.53
135	111	108	92	2,811	2,342	4,066	1,734	1,237	2,638	25.4	21.8	44.1	4.37	2.94	5.29
136	120	120	120	2,296	1,960	2,016	1,279	858	813	19.1	16.3	16.8	3.29	2.21	2.02

(Continued)

Appendix Table 2. Optimum Application Rates, Yield Increase, Net Returns, Agronomic Efficiencies, and Value:Cost Ratios for 162 Experiments and Means by Region and Season (Analysis at MR = MC) (Continued)

Experiment Number	Optimum Application Rates			Yield Increase			Net Returns			Agronomic Efficiencies			Value:Cost Ratios		
	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU
	(kg/ha)			(kg/ha)			(Rs/ha)			(kg/kg)					
State = West Bengal, Season = Dry															
143	144	144	99	2,896	3,135	2,057	1,647	1,656	985	20.1	21.8	20.8	3.46	2.94	2.49
144	144	144	144	4,284	4,366	4,047	2,758	2,641	2,277	29.7	30.3	28.1	5.12	4.10	3.37
145	110	118	95	2,445	2,500	1,973	1,447	1,300	945	22.3	21.1	20.8	3.84	2.86	2.49
146	144	114	104	2,486	2,555	2,079	1,320	1,373	971	17.3	22.5	20.0	2.97	3.04	2.40
147	144	144	144	2,610	2,711	2,329	1,419	1,317	903	18.1	18.8	16.2	3.12	2.55	1.94
148	144	107	90	1,262	2,696	2,246	340	1,525	1,194	8.8	25.3	24.8	1.51	3.42	2.98
149	144	130	88	2,508	2,184	1,487	1,337	978	605	17.4	16.8	17.0	3.00	2.27	2.04
150	144	126	109	3,301	3,826	3,279	1,972	2,313	1,896	22.9	30.3	30.1	3.94	4.10	3.61
151	144	104	114	2,090	2,325	2,550	1,002	1,243	1,281	14.5	22.3	22.4	2.50	3.02	2.69
State = West Bengal, Season = Wet															
137	120	120	104	1,876	1,624	1,514	943	589	516	15.6	13.5	14.5	2.69	1.83	1.74
138	120	120	120	1,733	2,322	1,826	828	1,148	660	14.4	19.4	15.2	2.48	2.62	1.82
139	44	0	32	302	0	331	37	0	52	6.9	0.0	10.4	1.18	0.00	1.24
140	63	46	48	1,091	795	875	578	367	379	17.2	17.5	18.2	2.96	2.36	2.18
141	120	69	64	1,776	1,824	1,720	863	1,050	949	14.8	26.3	26.9	2.55	3.56	3.22
152	90	72	68	1,602	1,622	1,521	863	874	761	17.8	22.6	22.2	3.06	3.06	2.67
153	108	108	108	1,535	2,602	2,198	726	1,442	1,038	14.2	24.1	20.4	2.45	3.26	2.44
154	80	108	108	761	2,588	2,118	236	1,432	974	9.5	24.0	19.6	1.63	3.24	2.35
155	52	38	42	848	583	751	435	239	317	16.2	15.2	17.7	2.79	2.05	2.12
156	108	55	67	1,234	1,323	1,187	485	734	501	11.4	24.2	17.7	1.97	3.27	2.12
158	63	61	60	2,136	1,836	1,959	1,415	1,110	1,165	33.7	30.2	32.5	5.81	4.09	3.90
159	99	76	86	2,278	1,670	1,933	1,363	889	972	23.0	22.1	22.5	3.96	2.99	2.69
160	82	55	54	1,236	956	1,042	605	437	471	15.0	17.2	19.1	2.58	2.33	2.30
161	81	89	83	2,211	2,111	1,780	1,393	1,161	874	27.3	23.7	21.6	4.71	3.20	2.59
162	60	57	67	1,136	1,714	1,138	629	1,033	463	18.9	30.0	17.0	3.25	4.05	2.03
163	43	28	0	625	204	0	284	15	0	14.1	8.1	0.0	2.42	1.09	0.00
164	108	108	84	1,023	2,033	1,252	316	988	442	9.5	18.8	14.9	1.63	2.55	1.79

(Continued)

Appendix Table 2. Optimum Application Rates, Yield Increase, Net Returns, Agronomic Efficiencies, and Value:Cost Ratios for 162 Experiments and Means by Region and Season (Analysis at MR = MC) (Continued)

Experiment Number	Optimum Application Rates			Yield Increase			Net Returns			Agronomic Efficiencies			Value:Cost Ratios		
	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU	Urea	USG	SCU
	(kg/ha)			(kg/ha)			(Rs/ha)			(kg/kg)					
State = West Bengal, Season = Wet (Continued)															
165	108	74	64	1,549	1,220	1,391	737	537	685	14.3	16.4	21.7	2.47	2.22	2.60
166	84	58	60	1,000	1,431	1,280	411	804	627	11.9	24.8	21.5	2.05	3.36	2.58
167	53	69	56	597	1,478	1,287	230	772	657	11.2	21.3	23.0	1.93	2.88	2.76
168	80	77	67	1,173	1,579	1,525	567	807	775	14.7	20.5	22.8	2.53	2.77	2.74
169	108	87	98	1,716	1,845	2,848	871	963	1,626	15.9	21.3	29.1	2.73	2.88	3.49
170	108	108	108	1,334	1,734	1,451	565	748	440	12.4	16.1	13.4	2.13	2.17	1.61