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ABSTRACT

China is the first and only country in the world where hybrid rice is commercially grown. This paper describes the economics of hybrid rice and hybrid seed production based on 1982 data obtained by interviewing farmers in Fujian and Hunan Provinces, China.

Production data were from six farmers from each province who grow hybrid rice and six who plant conventional rice. Hybrid rice yields were 16% higher than conventional rice yields. Profitability of hybrid rice production alone and comparative profitability between hybrid and conventional rice production were analyzed. Findings showed that relative profitability of hybrid and conventional rice production was largely dependent on paddy price.

Hybrid seed production data were collected from two producers of male-sterile seed and four hybrid seed producers in Fujian. In Hunan, four male-sterile seed producer and four hybrid seed producers were interviewed. Seed production yields were high. In Fujian, average yield was 614 kg male-sterile seed and 1962 kg hybrid seed/ha. In Hunan, average yields were 1256 kg male-sterile seed and 1352 kg hybrid seed/ha. The present 1:10 seed-to-paddy price scheme in China lets seed producers earn substantially higher incomes than hybrid rice growers.

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THE ECONOMICS OF HYBRID RICE PRODUCTION IN CHINA

Hybrid rice technology is an important achievement of Chinese agricultural research. Successful research and technology dissemination have made China the only country in the world where hybrid rice is commercially grown. Since 1976, the area planted to hybrid rice in China has expanded to more than 5.3 million ha which is about 17% of the country's rice area.

The Chinese Academy of Agricultural Sciences (CAAS) and IRRI cooperated in April 1983 to examine the econonomics of hybrid seed and rice production in China. This report of that study is divided into four parts. The first section is an evaluation of the technical advantage of hybrid rice over conventional rice. In the second and third sections, the economics of hybrid rice cultivation and of hybrid seed production are examined. In the last section, the challenges to furthering the spread of hybrid rice technology are discussed.

Study areas and sample farmers

The areas included Minho and Changlo Counties and Fuzhou city suburb in Fujian Province, and Liling County in Hunan Province. Twelve conventional rice growers, 12 hybrid rice growers, 8 hybrid seed producers, and 6 male-sterile-line seed producers were interviewed. We use these terms in the discussion although all farmers grew conventional rice in the first season and some planted both types in the second season.

Before starting the analysis, two aspects of the sample must be described. The sample was small and not drawn randomly. It may not represent the total farmer population within a province, and within-sample comparison of farmers planting different crops may be unreliable.

The only available provincial production parameters are average 1982 yields of the four types of rice (Table 1). The yields on the sample farms far exceeded the provincial averages in all categories but Fujian male-sterile seed production. Although those data seem to deny the representativeness of the sample, it is impossible to determine the causes of discrepancy with available information.

Within-sample comparability is equally important. If conventional and hybrid rice farmers in a province are from the same group, as defined by factors that affect farming ability such as education, assets, and access to inputs, then we can compare the relative profitability of conventional and hybrid rice farming within each provincial sample. The basic characteristics of the sample farmers are in Table 2.

Table 1. Comparison of sample and provincial yield levels, Fujian and Hunan, China, 1982.

	Yield (kg/ha)			
	Fujian		Hunan	
	Sample	Provincial	Sample	Provincial
Conventional rice	7208	4132	5801	4185
Hybrid rice	8374	4815	7044	5070
Male-sterile seed	614	572	1256	1050
Hybrid seed	1962	810	1352	900

Table 2. Average characteristics of sample rice producers, Fujian, and Hunan, China, 1982.

Characteristic	Fujian farmers[a]		Hunan farmers	
	Hybrid	Conventional	Hybrid	Conventional
Sample size	6	6	6	6
Age of household head	39.3	46.2	44.7	43.0
Years of schooling of household head	8.5	5.8	6.8	5.4
Household size	6.7	5.3	5.3	5.8
Nonrice income per capita ($/year)	153	321	194	61
Assets ($)	n.d.	n.d.	29	12
Rice area (ha)	0.127	0.159	0.293	0.338
Rice yield (kg/ha)				
Early season[b]	6912	7106	8103	6292
Late season	8374	7208	7044	5801

[a]n.d. = no data. [b]All farmers planted conventional rice during the early season, therefore yields are for conventional rice.

In Fujian, hybrid rice farmers are younger and better educated, but have larger households and considerably less outside income. Both groups plant conventional varieties in the early season and harvest roughly equal yields, suggesting that their technical skills are similar. However, the much higher nonrice family income of conventional growers raises questions about comparability.

In Hunan, hybrid farmers have significantly better education, more outside income and farm assets, and nearly a 30% yield advantage in early season conventional rice as compared with farmers who grow late season conventional rice. It is likely that the two groups are not comparable. Hybrid growers were more skilled farmers with superior assets.

Measuring the contribution of hybrid rice to increased production

China has a large man-arable land ratio. The most important obligation of China's agricultural sector is to increase food production to feed its more than one billion people. Several provinces and districts have lauded the advantages of hybrid rice, leading to high expectations about its role in increased food production.

Gross and net yields

There is no doubt that hybrid rice yields more per ha than conventional rice. However, hybrid rice seed production requires more land than conventional seed production. Therefore, net yield advantage of hybrid rice over conventional rice is less than it first appears. Hybrid rice requires specialized two-stage seed production: multiplication of male-sterile seeds and production of hybrid seeds. Land used for seed production could alternatively be used for production of conventional rice. A realistic estimate of yield advantage must include land used for seed production.

The distinction between gross and net yields applies to both hybrid and conventional rice. The gross yield of conventional rice is the amount of paddy harvested per unit area. The net yield is the gross yield less the amount of seed used in production. The gross yield of hybrid rice is also the amount of paddy harvested per unit area, but the computation of the net yield is more complicated.

To evaluate the technical advantage of hybrid rice it is important to separate gross and net yields. Such differentiation strengthens the basis of comparability and provides a better estimate of the actual production increase attributable to hybrid rice.

Methodology for computing the net yield

The net yield per ha of hybrid rice is the gross yield less the resources used to produce the hybrid seed. Land is needed to produce hybrid seed. From the land, a certain amount of hybrid seed and paddy from the restorer line are harvested. However, had the land not been used to produce seed, conventional rice could have been planted and harvested. Moreover, to produce the male-sterile seeds needed for hybrid seed production, land, which would have produced conventional rice, also is needed. The relationship of the net to gross yield of hybrid rice and the related variables in hybrid seed production and male-sterile seed multiplication are expressed as:

$$Y_{HR} = Y_H - \alpha\,[(Y_C - S_C) - (Y_R - S_R) - Y_{HS}(1 - k_{HS})] - \beta\,[(Y_C - S_C) - (Y_M - S_M) - Y_{MS}(1 - k_{MS})], \quad (1)$$

where Y_{HR} is the net yield/ha of hybrid rice,

Y_H is the gross yield/ha of hybrid rice,

Y_C is the gross yield/ha of conventional rice,

S_C is the amount of seed used/ha of conventional rice,

Y_R is the yield of restorer line/ha of hybrid seed production,

S_R is the amount of restorer seed used/ha of hybrid seed production,

Y_{HS} is the yield of hybrid seed/ha;

k_{HS} is the proportion of acceptable hybrid seed,

Y_M is the yield of the maintainer line/ha of male-sterile seed multiplication,

S_M is the amount of maintainer seed used/ha of male-sterile seed multiplication,

Y_{MS} is the yield of male-sterile seed/ha, and

k_{MS} is the proportion of acceptable male-sterile seed.

The α in equation 1 is the allocation factor of the foregone conventional rice production in the hybrid seed production field and the β is the allocation factor in the male-sterile seed production field. They are expressed as:

$$\alpha = \frac{dS_H}{K_{HS} \cdot Y_{HS}}, \text{ and} \quad (2)$$

$$\beta = \alpha \cdot \frac{dS_{HS}}{k_{MS}(Y_{MS} - S_{MS})}, \quad (3)$$

where d is the allowance factor for seed,

S_H is the amount of hybrid seed used/ha of hybrid rice production,

S_{HS} is the amount of male-sterile seed used/ha of hybrid seed production, and

S_{MS} is the amount of male-sterile seed used/ha of male-sterile seed multiplication.

Computational results and sensitivity analysis

We used average yield and seed use figures from the sample farmers (Table 3) to compute the net yield of hybrid rice for Fujian and Hunan. The net yield of hybrid rice for Fujian was 8374 kg/ha, about 98 kg/ha less than the gross yield. The difference was almost the same for Hunan.

To further define the relationship between net and gross yields of hybrid rice, we conducted a sensitivity analysis by changing the yields of hybrid and male-sterile seed, and percentage of acceptable male-sterile seed. Results of the analysis are in Tables 4, 5, and 6. Changing male-sterile seed yield and the percentage of acceptable seed had negligible influence on the difference between gross and net yields (Tables 5 and 6). Changing hybrid seed yield caused a larger difference between gross and net yields, especially at lower yield levels (Table 4).

After computing net yield/ha of hybrid rice, Y_{HR}, the actual yield increase, ΔY, of a shift from planting conventional to hybrid rice is calculated as:

$$\Delta Y = Y_{HR} - (Y_C - S_C) \quad (4)$$
$$\Delta Y = Y_H + \Delta Y_H - Y_C + S_C$$
$$\Delta Y = Y_H - Y_C + \Delta Y_H + S_C,$$

where ΔY_H is the difference between net and gross yields of hybrid rice (Note that ΔY_H is negative.).

Table 3. Basic data[a] used in computing the net yield of hybrid rice, Fujian and Hunan, China, 1982.

Variables[b]	Fujian		Hunan	
	Sample av	Provincial av	Sample av	Provincial av
Y_H	8374	4815	7044	5070
S_H	24	24	23	23
Y_C	7208	4132	5801	4185
S_C	135	149	53	53
Y_R	1595	659	1860	1237
S_R	11	11	8	8
Y_{HS}	1961	810	1354	900
S_{HS}	21	21	30	30
Y_M	959	894[c]	3305	2764[c]
S_M	6	6	8	8
Y_{MS}	614	572	1256	1051
S_{MS}	23	23	30	30
d	1.1	1.1	1.1	1.1
k_{HS} (%)[d]	90	90	90	90
k_{MS} (%)[d]	50	50	50	50

[a]Data for Y_H to S_{MS} are all in kg/ha. [b]See text for variable definitions. [c]Extrapolated based on the ratio of male and female parents' average yield from the sample. [d]According to report of Hunan Province seed company, 98% of hybrid seed and 33.5% of male-sterile seed were acceptable in 1982. Note: Averages of the samples seed used are used in the provincial calculation.

Table 4. Effect of variation in hybrid seed yield on net yield of hybrid rice, Fujian and Hunan, China, 1982.

Yield (kg/ha)							
Fujian				Hunan			
Hybrid seed	Gross	Net	Difference	Hybrid seed	Gross	Net	Difference
375	8374	7891	-483	375	7044	6710	-334
750	8374	8123	-251	750	7044	6872	-172
1125	8374	8205	-169	1125	7044	6928	-116
1500	8374	8246	-128	1354	7044	6947	-97
1875	8374	8271	-103	1500	7044	6956	-88
1961	8374	8276	-98	1875	7044	6974	-70
2250	8374	8288	-86	2250	7044	6986	-58
2625	8374	8300	-74	2625	7044	6994	-50
3000	8374	8309	-65	3000	7044	7000	-44

From (4), it can be deduced that the actual yield increase, ΔY, is a function of the difference between the net and the gross yields of hybrid rice and the amount of seed used to grow conventional rice. When the absolute value of ΔY_H is greater than S_C, then actual yield increase, ΔY, is smaller than gross yield difference between hybrid and conventional rice. When the absolute value of ΔY_H is smaller than S_C, then ΔY is bigger than gross yield difference between hybrid and conventional rice. When the absolute value of ΔY_H is equal to S_C, then actual yield difference exactly equals gross yield difference.

For example, Table 4 shows that when the yield of hybrid seed is less than 1500 kg/ha, ΔY_H is bigger than S_C. The actual yield increase is smaller than the gross yield difference between hybrid and conventional rice. With 750 kg seed/ha, actual yield difference is 113-120 kg/ha less than gross yield difference; and when seed yield is 375 kg/ha, the difference is 281-345 kg/ha less. When hybrid seed yield exceeds 1500 kg/ha, actual yield increase is minimally larger than the gross yield difference between hybrid and conventional rice. Therefore, in ordinary calculation, when the hybrid seed yield exceeds 1500 kg/ha, the gross yield difference can be used to represent the actual yield difference.

Table 5. Effect of variation in male-sterile seed yield on net yield of hybrid rice, Fujian and Hunan, China, 1982.

Yield (kg/ha)							
Fujian				Hunan			
Male-sterile seed	Gross	Net	Difference	Male-sterile seed	Gross	Net	Difference
375	8374	8271	-103	375	7044	6939	-105
614	8374	8276	-98	750	7044	6945	-99
750	8374	8277	-97	1125	7044	6947	-97
1125	8374	8279	-95	1256	7044	6947	-97
1500	8374	8280	-94	1500	7044	6947	-97
1875	8374	8281	-93	1875	7044	6948	-96
2250	8374	8281	-93	2250	7044	6949	-95
2625	8374			2625	7044	6949	-95
3000	8374			3000	7044	6949	-95

Table 6. Effect of variation in percentage of acceptable male-sterile seed on net yield of hybrid rice, Fujian and Hunan, China, 1982.

Acceptable male-sterile seed (%)	Yield (kg/ha)					
	Fujian			Hunan		
	Gross	Net	Difference	Gross	Net	Difference
50	8374	8276	-98	7044	6947	-97
60	8374	8277	-97	7044	6947	-97
70	8374	8278	-96	7044	6948	-96
80	8374	8279	-95	7044	6948	-96
90	8374	8279	-95	7044	6949	-95

Profitability of hybrid rice production

Three issues are discussed in this section:

- costs and returns of hybrid rice production in Fujian and Hunan Provinces,
- the comparative profitability of hybrid rice and conventional rice cultivation in Fujian, and
- the calculation of the minimum yield advantage necessary for hybrid rice production to be an economical technology.

The data are from six conventional and six hybrid rice growers in each province.

Costs and returns of hybrid rice production

Average yields and inputs used to produce late season rice are given in Table 7. The direct cost of growing hybrid rice in Fujian and Hunan are about equal but, given equal prices, hybrid rice production seems more profitable in

Table 7. Average levels of output and inputs[a] in rice production, Fujian and Hunan, China, 1982 late season crop.

	Fujian		Hunan	
	Hybrid	Conventional	Hybrid	Conventional
Yield (kg/ha)				
Paddy	8374	7208	7044	5801
Straw	6563	5663	7148	5370
Input				
Labor (labor days/ha)	227	256	238	223
Nonlabor inputs ($/ha)	422	266	396	288
Indirect cost ($/ha)	70	60	70	70

[a]For a detailed accounting of inputs used in rice production, see Appendix 1.

Table 8. Average net returns[a] of hybrid rice production at different paddy and straw (Ps) prices, Fujian and Hunan, China, 1982 late season crop.

Paddy price ($/kg)	Net returns ($/ha)			
	Fujian		Hunan	
	Ps=0	Ps=$0.02/kg	Ps=0	Ps=$0.02/kg
0.116	231	364	98	243
0.172	696	829	490	643
0.202	950	1083	703	848
0.253	1373	1506	1059	1203
0.116/0.172[b]	464	596	294	439

[a]Assume wage is $1.01/day for ordinary operations and $1.26/day for plowing/harrowing, transplanting, and harvesting. [b]Assume 50% of output price at $0.116/kg and the remaining 50% at $0.172/kg.

Table 9. Total benefit-cost ratio[a] of hybrid rice production at different paddy and straw (Ps) prices, Fujian and Hunan, China, 1982 late season crop.

Paddy price ($/kg)	Fujian		Hunan	
	Ps=0	Ps=$0.02/kg	Ps=0	Ps=$0.02/kg
0.116	1.31	1.49	1.14	1.34
0.172	1.94	2.12	1.68	1.88
0.202	2.28	2.46	1.98	2.18
0.253	2.85	3.03	2.47	2.67
0.116/0.172[b]	1.63	1.80	1.41	1.61

[a]Computed as total revenue divided by total cost. Assume wage is $1.01/day for ordinary operations and $1.26/day for plowing/harrowing, transplanting, and harvesting. [b]Assume 50% of output price at $0.116/kg and the remaining 50% at $0.172/kg.

Fujian, where yields are higher (Table 7, Appendix 1). However, to calculate the profitability of hybrid rice production, wages and paddy prices must be considered.

The most common wages were $1.01/day for ordinary work and $1.26/day for heavy and seasonally concentrated operations, which include plowing and harrowing, transplanting, and harvesting. There were three official paddy prices. The quota price was $0.116/kg. The above-quota price was $0.172/kg and the negotiated price was $0.202/kg in Hunan and $0.253/kg in Fujian.

Gross benefits from rice production include the value of paddy and the value of rice straw. If the straw is sold, the value is the amount sold multiplied by the price. When the straw is not sold, but is used on the farm, gross benefit is more difficult to calculate. In Fujian, most of our sample farmers sold their late season straw to a paper factory at $0.02/kg. In Hunan, however, about a third of the harvested straw is used as cattle feed and the rest is plowed into the field. It is difficult to impute a price because farmers valued their straw at a sale price of $0.02/kg but could not sell it. To set lower and upper limits, we computed two sets of profitability figures. One set assumes no value for straw and the other imputes a price of $0.02/kg (Table 8).

If straw has no value, the average net returns for hybrid rice production in Fujian range from $231 to $1373/ha, depending on paddy price. If straw is $0.02/kg, the net returns range from $364 to $1506/ha. The average yield for the Hunan sample is lower than for the Fujian sample, but production costs are about equal. The Hunan sample farmers earn lower net returns, ranging from $98 to $1059/ha for paddy alone and from $243 to $1203/ha with straw priced at $0.02/kg. If profitability is returns per unit cost, Fujian hybrid rice growers earn a higher return per dollar spent than Hunan growers (Table 9). Fujian growers earn an average $1.31-$3.03 for each dollar spent, depending on paddy price. Returns in Hunan are $1.14-$2.67.

Another way of determining the profitability of production, and one that may be important to the farmer who uses family labor, is to compute returns to labor (Table 10). Returns to labor were $2.12-$9.37/labor day in Fujian and $1.48-$6.12/labor day in Hunan.

Comparative profitability of hybrid and conventional rice cultivation

Data in Table 7 show that hybrid rice growers in Fujian and Hunan spend more on nonlabor inputs than conventional farmers. Labor input is about equal for both groups. Net returns and returns to labor for hybrid rice and conventional rice growers are in Tables 11 and 12.

In the Hunan sample hybrid rice production is more profitable than conventional rice production, both in net returns and returns to labor. However, it is not valid to attribute the advantage to varietal differences alone, because the respondents did not possess comparable technical skills. In early season, when both groups grew conventional rice, hybrid growers had a greater yield advantage than in late season (Table 2).

Because farmer groups within the Hunan sample were not comparable, the Fujian data, which were more technically homogeneous, will be used to compare relative profitability of hybrid and conventional rice production. Even then, the Fujian sample represents very good rather than average farmers. The comparison therefore shows

Table 10. Returns to labor in hybrid rice production at different paddy and straw (Ps) prices, Fujian and Hunan, China, 1982 late season crop.

Paddy price ($/kg)	Returns to labor ($/labor day)			
	Fujian		Hunan	
	Ps=0	Ps=$0.02/kg	Ps=0	Ps=$0.02/kg
0.116	2.12	2.70	1.48	2.09
0.172	4.16	4.75	3.13	3.73
0.202	5.28	5.86	4.02	4.63
0.253	7.14	7.73	5.52	6.12
0.116/0.172[a]	3.14	3.72	2.30	2.91

[a]Assume 50% of output price at $0.116/kg and the remaining 50% at $0.172/kg.

relative profitability for the most technically advanced situation.

In Fujian, at the quota price of $0.116/kg, the profitability of hybrid and conventional rice is about equal. In fact, conventional rice farmers had a slight advantage at lower labor costs when straw value was not included. At above-quota paddy prices, hybrid rice was more profitable. If 50% of the paddy was sold at $0.116/kg and 50% at $0.172/kg, net returns ranged from $40-%54/ha when straw value was included. This implies a 6-11% higher return than that earned by conventional rice growers.

When profitability is viewed in terms of returns to labor (Table 12), hybrid rice growers have a slight edge over conventional rice growers, even at quota price. However, when profitability is viewed as the return per unit cost (Table 13), conventional rice production is more profitable than hybrid rice production at all prices.

Another comparison considers the percentage of total revenue spent for nonlabor inputs (Table 14). At the quota price, if straw is not sold, nonlabor inputs represent 50% of the revenue of hybrid rice growers and 40% of the revenue of conventional growers. Nonlabor costs are consistently higher for hybrid producers, but differences are greater at lower paddy prices. Farmers with cash constraints may be less inclined to adopt hybrid rice technology.

Table 11. Average net return of rice production at different wages, paddy and straw (Ps) prices, Fujian and Hunan, 1982 late season crop.

Paddy price ($/kg)	Returns ($/ha)[a]					
	Ps=0			Ps=$0.02/kg		
	0.76/1.01[b]	1.01/1.26[b]	1.26/1.52[b]	0.76/1.01[b]	1.01/1.26[b]	1.26/1.52[b]
			Fujian			
0.116	289	231	174	421	364	306
	299	235	170	414	349	285
	(-10)	(-4)	(4)	(7)	(15)	(21)
0.172	754	696	639	886	829	772
	700	635	571	814	750	685
	(54)	(61)	(68)	(72)	(79)	(87)
0.202	1008	950	893	1140	1083	1025
	918	854	789	1033	968	903
	(90)	(96)	(104)	(107)	(115)	(122)
0.253	1430	1373	1316	1563	1506	1448
	1282	1218	1153	1397	1332	1268
	(148)	(155)	(163)	(166)	(174)	(180)
0.116/0.172[c]	521	464	406	654	596	539
	500	435	370	614	549	485
	(21)	(29)	(36)	(40)	(47)	(54)
			Hunan[d]			
0.116	159	98	38	303	243	183
	132	76	19	240	184	128
0.172	550	490	430	694	634	574
	454	398	342	563	506	450
0.202	763	703	643	908	848	788
	630	574	517	738	682	626
0.253	1119	1059	999	1264	1203	1143
	923	867	810	1031	975	919
0.116/0.172[c]	354	294	234	499	439	378
	293	237	180	401	345	289

[a]For each paddy price, figures in the first row represent the net returns of hybrid rice growers, those in the second row represent net returns of conventional rice growers, and those in parentheses are the difference. [b]In $/day. The first figure is for ordinary operations, the second is for heavy or seasonally concentrated activities which include plowing or harrowing, transplanting, and harvesting. [c]Assume 50% of output price at $0.116/kg and the remaining 50% at $0.172/kg. [d]It is not valid to compare hybrid and conventional rice in Hunan from our sample because the two groups are not homogeneous.

Table 12. Returns to labor in rice production at different paddy and straw (Ps) prices, Fujian and Hunan, 1982 late season crop.

Paddy price ($/kg)	Returns to labor ($/labor day)							
	Fujian				Hunan			
	Hybrid		Conventional		Hybrid		Conventional	
	Ps=0	Ps≠0[b]	Ps=0	Ps≠0[b]	Ps=0	Ps≠0[b]	Ps=0	Ps≠0[b]
0.116	2.12	2.70	2.00	2.44	1.48	2.09	1.42	1.90
0.172	4.16	4.75	3.56	4.01	3.13	3.73	2.86	3.35
0.202	5.28	5.86	4.41	4.87	4.02	4.63	3.65	4.14
0.253	7.14	7.73	5.84	6.29	5.52	6.12	4.96	5.45
0.116/0.172[c]	3.14	3.72	2.78	3.23	2.30	2.91	2.14	2.63

[a]Figures for returns to labor for Hunan are computed for information. It is not valid to compare hybrid rice and conventional rice from these results because the two groups are not homogeneous. [b]Ps ≠ $0.02/kg. [c]Assume 50% of output price at $0.116/kg and the remaining 50% at $0.172/kg.

Table 13. Total benefit-cost ratio[a] of rice production at different paddy and straw (Ps) prices, Fujian, China, 1982 late season crop.

Paddy price ($/kg)	Hybrid		Conventional	
	Ps=0	Ps=$0.02/kg	Ps=0	Ps=$0.02/kg
0.116	1.31	1.49	1.39	1.58
0.172	1.94	2.12	2.05	2.24
0.202	2.28	2.46	2.42	2.61
0.253	2.85	3.03	3.02	3.21
0.116/0.172[b]	1.63	1.80	1.72	1.91

[a]Computed as total revenue divided by total cost. Assume wage is $1.01/day for ordinary operations and $.126/day for plowing/harrowing, transplanting, and harvesting. [b]Assume 50% of output price at $0.116/kg and the remaining 50% at $0.172/kg.

If we assume that our sample farmer's cultural practices represent those of their respective groups, hybrid rice has only a small economic advantage over conventional rice at low paddy price. At above-quota prices, the profitability is only slightly greater. However, this does not hold for all situations in which hybrid rice might be grown. Some scientists have argued that the advantage of hybrid rice would be more evident under less favorable environmental conditions. Unfortunately, our data do not allow us to examine that issue.

Minimum required yield advantage

For a new technology to be considered economically equal to an existing one, yields must be high enough to have a marginal benefit-cost ratio (MBCR) of 1. However, because of the risks involved in agricultural production, many agricultural economists believe a new technology would be widely adopted by farmers only if it has a MBCR of at least 2.

Almost all riceland in China is irrigated and farmers get higher prices for above-quota sales. Those factors make the production risk lower for Chinese farmers than that faced by farmers in a market economy. Consequently, a new technology may not need a MBCR of 2 to be acceptable to farmers. A MBCR of 1.2 to 1.5 may be adequate.

Table 14. Nonlabor cost as a proportion of total revenue at different paddy and straw (Ps) prices, Fujian, China, 1982 late season crop.

Paddy price ($/kg)	Nonlabor cost (%)			
	Hybrid		Conventional	
	Ps=0	Ps=$0.02/kg	Ps=0	Ps=$0.02/kg
0.116	50	44	39	34
0.172	34	31	26	24
0.202	29	27	22	21
0.253	23	22	18	17
0.116/0.172[a]	41	37	31	28

[a]Assume 50% of output price at $0.116/kg and the remaining 50% at $0.172/kg.

Using the differences in production cost from our Fujian sample, Table 15 gives the minimum yield advantage that hybrid rice cultivation must achieve for the MBCR to equal 1.2 to 1.5 for different paddy prices and wages. If the increased production will be sold at the above-quota price, hybrid rice must yield 968-1215 kg/ha more than conventional rice to be economically attractive to farmers. The difference between the average yields of our sample hybrid and conventional rice farmers in Fujian for the late 1982 crop was 1166 kg/ha, which satisfied the minimum yield requirement for a new technology to be economically viable in China.

Also to be considered in evaluating yield advantage are alternative crops. In Fujian, hybrid rice has a longer growth duration than late season conventional rice. Farmers who plant certain third crops after rice could not plant hybrid rice as the second rice crop. In our sample, five of six conventional rice farmers planted a third crop of wheat or vegetables. Only two of six hybrid farmers grew a third crop. Without a short duration hybrid, the yield advantage of hybrid rice must be higher than shown in Table 15 if the foregone income from the third crop is considered.

Our analysis shows that the economic advantage of hybrid rice over conventional rice is extremely sensitive to paddy price. Technically, our Fujian data show that hybrid rice has a 16% gross yield and 17% net yield advantage. Economically, if 50% of production is sold at $0.116/kg and 50% at $0.172/kg, hybrid rice growers earn 6-11% higher net return/ha than conventional rice growers.Those data can be used to evaluate efforts to encourage further adoption of hybrid rice technology.

In China, three criteria are used to evaluate a new technology:

- significant yield increase - at least a 10% yield advantage;
- some degree of assured economic profitability; and
- availability of appropriate resources for its dissemination.

Because hybrid rice cultivation fulfills all those conditions, China is encouraging the further spread of hybrid rice technology.

Table 15. Minimum yield advantage for hybrid rice to have a marginal benefit-cost ratio (MBCR) of 1.2 and 1.5 over conventional rice, for different wage levels, Fujian, China, 1982 late season crop.

Paddy price ($/kg)	Yield advantage (kg/ha)					
	MBCR = 1.2			MBCR = 1.5		
	0.76/1.01[a]	1.01/1.26[a]	1.26/1.52[a]	0.76/1.01[a]	1.01/1.26[a]	1.26/1.52[a]
0.116	1508	1433	1358	1890	1793	1703
0.172	1020	968	923	1275	1215	1148
0.202	870	825	780	1080	1035	975
0.253	698	660	623	870	825	780
0.116/0.172[b]	1215	1115	1095	1523	1448	1373

[a]In $/day. The first figure is for ordinary operations, the second is for heavy or seasonally concentrated activities which include plowing or harrowing, transplanting, and harvesting. [b]Assume 50% of output price at $0.116/kg and the remaining 50% at $0.172/kg.

Male-sterile and hybrid seed production

Before discussing the economics of male-sterile and hybrid rice seed production, it is useful to review the production process. Because rice is a self-pollinating plant, hybridization requires a cytoplasmic male-sterile line. The line is maintained by crossing male-sterile plants with a maintainer male parent, which reproduces the sterility characteristic. Hybrid seed production requires the male-sterile line to be crossed with a male parent, called a restorer, which produces a fertile seed. Producing male-sterile or hybrid seed thus requires cross pollination of a self-pollinating plant. The difficulty of achieving cross-pollination largely accounts for the difference between conventional and hybrid seed production.

To ensure that the male parent is the one desired, seed fields must be isolated from other pollen sources. Fields can be isolated by time so that plots flower when other rice is not flowering, or can be physically isolated. Our sample farmers relied on physical isolation. In Hunan, male-sterile seed producers use a 50-m separation from other rice fields. They often plant the male parent plant in the 50-m belt around the seed fields. In Fujian, one producer built a 3.5-m-high wall around the seed fields, and another used seed plots that were 50-60 m higher than other fields. Fujian hybrid seed producers largely relied on natural isolation provided by hills or rivers surrounding the fields. Hunan hybrid seed producers used a 50-m separation or natural barriers such as hills or rivers to isolate fields.

Synchronizing the flowering of male and female parents is difficult because varieties are different. To solve this problem, most male-sterile seed growers planted male parents twice. The first sowing of the male parent was done simultaneously with the female parent, or when it had 1½ leaves. The second sowing of male parent was when the female parent had 2½ leaves or when the first sown male parent had 1 leaf. Hybrid seed producers sowed male seed either 2 or 3 times at 4- to 7-d intervals. Male seed was planted much later than the female seed – the only respondent reporting female-male planting date gaps gave a 32-d interval. Transplanting was also done at different times, ranging from 3 times at 3-d intervals to twice at a 6- to 7-d interval.

Growth rate can also be influenced to achieve synchronization. Respondents used different fertilizer applications and irrigation to regulate growth, and applied a growth stimulant. One farmer cut male plant leaves to retard growth.

Even if synchronized flowering is achieved, artificial assistance may be necessary to ensure good seed set. In addition to clipping flag leaves, which increases panicle exposure to pollen, all but two respondents reported using two men to drag a rope through the fields to encourage pollen transfer. This usually is done 5-6 times a day during flowering, beginning at 0900 or later and ending by 1400 h. Where a rope was hard to drag, several respondents used a pole.

The economics of seed production

The sample of seed producers in the survey was small and, in terms of output, did not represent all seed producers in the province. Four hybrid seed producers were interviewed in Fujian and Hunan. Four male-sterile seed producers in Hunan and two in Fujian were interviewed. Average yields, material inputs, and labor use for male-sterile and hybrid seed producers are in Table 16 and Appendix 2.

Labor use was greatest for male-sterile seed production, followed by hybrid seed production and hybrid rice production (Tables 7 and 16). In Fujian, hybrid rice cultivation requires 227 labor d/ha and seed production needs 374 d. In Hunan, hybrid rice needs 238 d and seed 360 d/ha. Nonlabor cost of hybrid seed production about equals that of hybrid rice cultivation – $417/ha in Fujian and $394/ha in Hunan. For male-sterile seed production, the nonlabor cost in Fujian is lower than hybrid rice cultivation – $316/ha compared to $422/ha; in Hunan, nonlabor cost of male-sterile seed production is $507/ha versus $396/ha for hybrid rice production.

Given these differences, the question remains whether the returns to producing seed are above or below those of producing hybrid rice. We compared seed producers with the hybrid rice producers who harvested highest yields, and assumed that skill levels and access to inputs were similar.

Table 16. Average yield and inputs used[a] in seed production, Fujian and Hunan, China, 1982.

	Fujian		Hunan	
	Male-sterile	Hybrid	Male-sterile	Hybrid
Yield (kg/ha)				
Seed	614	1962	1256	1352
Maintainer/restorer	957	1578	3304	1860
Straw	3375	4170	5025	6960
Input				
Labor (labor day/ha)				
ordinary	298	314	322	234
heavy	78	59	92	72
Nonlabor ($/ha)	316	417	507	394
Indirect cost ($/ha)	85	85	70	70

[a]For a detailed account of the inputs use in seed production, see Appendix 2.

From Table 17 it is clear that in both Hunan and Fujian, hybrid seed cultivation has a much higher return than male-sterile seed cultivation. In the sample, this is because of higher hybrid seed yields and prices. Labor use also is greater for male-sterile than for hybrid seed. Returns per labor day of hybrid rice production were $5.26 in Fujian and $4.14 in Hunan, using average straw values (Table 12). Hybrid seed production in both provinces yields at least 140% more per labor day than does rice crop production. However, in Fujian, returns to male-sterile seed production are 43% below those of rice cultivation, in contrast to Hunan where returns are 41% above rice production. These data substantiate Fujian farmers' contention that male-sterile seed production is not very profitable.

Appropriate pricing policy for male-sterile and hybrid seed is an issue of great interest. Lower seed prices will encourage seed use, but the price must also be high enough to encourage its production. The survey data allow some potentially useful observations on profit levels yielded by various seed prices. For this analysis labor is valued at $1.01/d for ordinary operations and $1.26/d for heavy tasks. Results are in Tables 18 and 19. The price needed for a particular level of profit is higher in Fujian in all cases because Fujian hybrid rice farmers in our sample realized an average $763 return/ha. The Hunan sample realized only $562/ha. Only within-province comparisons are appropriate.

An evaluation of present provincial average yields and prices in each category is instructive. According to provincial statistics, average Hunan male-sterile seed yield is 1050 kg/ha. In our sample the price was $2.02/kg. At those levels, the return for male-sterile seed production is well over 50% above the normal return. Hybrid seed yield is is 900 kg/ha, and the average price is $2.68/kg, so for hybrid seed the profit level is also well over 50% above normal. In Hunan, at present average yields, male-sterile seed could be priced at $1.20/kg, and hybrid seed at

Table 17. Returns to seed production, Fujian and Hunan, China, 1982.

	Fujian		Hunan	
	Male-sterile	Hybrid	Male-sterile	Hybrid
Total income ($/ha)[a]	1594	5409	3139	3986
Nonlabor cost ($/ha)	401	502	577	464
Net income ($/ha)	1193	4907	2562	3522
Total labor (days/ha)[b]	395	388	437	325
Net income per labor day ($/day)	3.02	12.65	5.86	10.84

[a]Seed prices are reported values, male-sterile seed is $2.29/kg in Fujian and $2.02/kg in Hunan; hybrid seed is $2.58/kg in Fujian and $2.68/kg in Hunan. Maintainer/restorer output is valued at $0.17/kg. For straw, all the harvested straw of Fujian hybrid seed producers are valued at $0.02/kg because they are sold to paper factory; for the others, only 1/3 of the harvested amount is valued because the rest is plowed into the field. [b]Labor days are adjusted so that 1 d of heavy labor is equal to 1.25 d of ordinary labor.

Table 18. Male-sterile seed prices needed to yield indicated returns for different yield levels,[a] Fujian and Hunan.

Returns level[b]	Price needed ($/kg)				
	450 kg/ha	600 kg/ha	750 kg/ha	900 kg/ha	1050 kg/ha
Hunan					
Equal	3.06	2.29	1.84	1.53	1.31
15% greater	3.31	2.48	1.99	1.66	1.42
30% greater	3.57	2.68	2.14	1.79	1.53
50% greater	3.91	2.93	2.34	1.95	1.68
Hunan					
Equal	2.17	1.64	1.30	1.09	0.93
15% greater	2.36	1.78	1.41	1.18	1.01
30% greater	2.56	1.91	1.54	1.27	1.09
50% greater	2.80	2.10	1.68	1.40	1.20

[a]We assume that within a province all seed producers use the same technology and differences in output are the result of cross pollination problems or other random factors. Further, we assume that yields of maintainer lines and straw are independent of those factors. [b]Compared to hybrid rice cultivation.

Table 19. Hybrid seed prices needed to yield indicated returns for different yield levels,[a] Fujian and Hunan.

Returns level[b]	Price needed ($/kg)			
	675 kg/ha	788 kg/ha	900 kg/ha	1012 kg/ha
Fujian				
Equal	1.93	1.66	1.44	1.28
15% greater	2.10	1.80	1.58	1.39
30% greater	2.26	1.94	1.70	1.52
50% greater	2.49	2.14	1.87	1.66
Hunan				
Equal	1.46	1.25	1.10	0.98
15% greater	1.59	1.36	1.19	1.06
30% greater	1.72	1.46	1.28	1.14
50% greater	1.88	1.62	1.41	1.25

[a]We assume that within a province all seed producers use the same technology and differences in output are the result of cross pollination problems or other random factors. Further, we assume that yields of restorer lines and straw are independent of those factors. [b]Compared to hybrid rice cultivation.

$1.41/kg and still return seed producers' profits 50% above normal. Based on provincial average yield, male-sterile seed in Hunan should be priced at $1.09/kg and hybrid seed at $1.28/kg for seed producers to earn a 30% higher net return than hybrid rice cultivators.

Fujian yields of male-sterile seed average 572 kg/ha, at a price of $2.29/kg. At this level the return just equals the profits of hybrid rice cultivators. Hybrid seed yield is 810 kg/ha with an average price of $2.58/kg. At this level, profit also is well over 50% above normal. To enable seed producers to have profits 30% above normal, male-sterile seed should be priced at $2.68/kg, and hybrid seed at $1.94/kg.

In China, farmers can pay for hybrid seed with cash or paddy. The seed:rice exchange rate had been 1:10 since hybrid rice was introduced. As seed production techniques have improved, seed yield has increased threefold. It is felt that the 1:10 exchange rate may be inappropriate. To test the validity of that contention, we computed the exchange rate that will allow a 30% profit incentive for seed producers under average output conditions (Table 20). Appropriate exchange rates for Hunan are about 1:6 for male-sterile seed and 1:7 for hybrid seed. Fujian rates are much higher because yields are lower and Fujian rice farmers earn higher profits. In Fujian, appropriate ratios are 1:15 for male-sterile seed and 1:11 for hybrid seed.

Increasing hybrid rice productivity

To increase hybrid rice productivity and encourage its further expansion, the following issues need serious consideration.

Speed the development of new hybrid combinations

One common response during our two-province investigation was, "Present available hybrid rice combinations are not suitable for all farming environments." Lack of suitable hybrids is a major obstacle to the further spread of hybrid rice. For example, in Xiangpei District, Hunan Province, the available hybrid combinations have longer growth duration than the growing season allows. In Fujian, available hybrids have longer growth duration than conventional rice. If hybrid rice is planted as the late crop, then a third crop of wheat is impossible. In Lungchi District of Fujian, the early hybrid crop is not resistant to rice blast and the late hybrid crop is not resistant to bacterial leaf blight. Under those conditions, many farmers believe available hybrids are less suitable than local conventional varieties. Therefore, to expand the area planted to hybrid rice and increase the economic profitability of hybrid rice production, breeding for new hybrid combinations with early maturity, high yields, and disease resistance must be increased. Breeding for hybrids suited to the early season should be emphasized.

Table 20. Seed:rice exchange rates yielding profits at 30% above best-practice hybrid producers at 1982 provincial average yield.[a]

Paddy price ($/kg)	Male-sterile seed		Hybrid seed	
	Fujian	Hunan	Fujian	Hunan
0.116	1:14.3	1:5.21	1:10.8	1:5.91
0.172	1:15.4	1:6.35	1:11.8	1:7.29
0.253	1:16.16	1:7.12	1:12.4	1:8.20

[a]Yields used: Male-sterile: Fujian = 600 kg/ha, Hunan = 1050 kg/ha; Hybrid seed: Fujian = 788 kg/ha, Hunan = 900 kg/ha. Wage rate: Ordinary = $1.01/day, heavy = $1.26/day. Cost conditions: those of the sample.

Improve cultivation techniques

Cultivation methods must be improved to increase the economic profitability of hybrid rice production. Some hybrid rice scientists claim that hybrid rice yields more than conventional rice with the same level of inputs. Experiments should be done under farmer field conditions to verify that claim. If hybrids do yield more, then extension programs disseminating that information could minimize unnecessary expenses and improve the economic profitability of hybrid rice cultivation.

Coordinate the interest between the seed producers and rice cultivators

We learned that some hybrid combinations give very high seed yields, but low rice yields. Most seed producers would like to grow combinations with high seed yield because they are more profitable. However, rice producers are not interested in planting those varieties. To improve the technical and economic efficiency of hybrid rice cultivation, seed producers must be encouraged to grow seed that hybrid rice growers wish to plant.

Summary and conclusions

In this evaluation of the economics of hybrid rice and seed production in two Chinese provinces, the following observations were most important.

1. The difference between gross and net yields of hybrid rice was about 98 kg/ha for the sample. Sensitivity analysis showed that male-sterile seed yield and percentage of acceptable male-sterile seed exert negligible influence on the difference between gross and net yields. The effect of variations in hybrid seed yield was slightly more pronounced at low seed yields, but became less significant as yield increased. This implied that land devoted to seed production becomes a less significant factor as seed yield increases.

2. The average yield of the sample hybrid rice farmers was 8374 kg/ha in Fujian and 7044 kg/ha in Hunan. The average net returns for hybrid rice production ranged from $231 to $1506/ha in Fujian, depending on paddy and straw prices, and $98 to $1203/ha for Hunan. The total benefit-cost ratio ranged from 1.31-3.03 in Fujian and 1.14-2.67 in Hunan. Returns to labor ranged from $2.12-$9.73/d in Fujian and $1.48-$6.12 in Hunan.

3. A comparison of the average net returns of hybrid rice and conventional rice growers in Fujian showed that relative profitability depended largely on paddy price. At quota prices, average net returns were about equal. The economic advantage of hybrid rice, in terms of average net returns, was only clear at above-quota prices. When profitability was viewed in terms of returns to labor, hybrid rice growers had a slight edge over conventional rice growers at all prices. However, when profitability was viewed as the returns obtained per unit cost, conventional rice growers had more favorable returns at all prices. Nonlabor input cost as a proportion of total revenue was higher for hybrid rice growers. From this it may be deduced that farmers with cash constraints might be less inclined to adopt hybrid rice technology.

4. The average net return of male-sterile seed production of the sample farmers was $794/ha in Fujian and $2121/ha in Hunan; for hybrid seed it was $4515/ha in Fujian and $3194/ha in Hunan. Except for the Fujian male-sterile seed producers, the other groups of seed producers in both provinces were earning profits 50% higher than those earned by hybrid rice growers. If the provincial average yield, instead of the sample average, was used, the seed:paddy exchange rate could be lowered from the present 1:10 to 1:6 for male-sterile seed and 1:7 for hybrid seed in Hunan and still allow seed producers to earn 30% higher profits than hybrid rice growers.

5. A major obstacle to the further spread of hybrid rice in China is the absence of short-duration hybrid combinations.

Appendix 1. Labor and inputs use in rice production, Fujian and Hunan, China, 1982 late season crop.

Item	Fujian				Hunan			
	Hybrid		Conventional		Hybrid		Conventional	
	Quantity	Value ($)	Quantity	Value ($)	Quantity	Value ($)	Quantity	Value ($)
I. Labor (labor days/ha)								
Clearing and repairing dikes	10.58		8.40		9.56		13.05	
Plowing and harrowing	15.17		16.89		13.20		15.08	
Seed selection and preparation	2.61		2.91		4.80		11.25	
Seedbed preparation and care	13.67		29.68		11.59		9.68	
Planting	42.81		30.88		41.10		49.56	
Organic fertilizer application	10.42		11.79		11.31		9.06	
Chemical fertilizer application	4.71		10.11		5.92		5.40	
Water control	10.05[a]		10.05[b]		6.98		5.48	
Disease and insect control	13.14		21.47		23.68		13.58	
Weed control	23.16		29.87		13.89		20.62	
Rat and bird control	1.54		0.32		6.60		–	
Procurement of inputs	3.82		2.89		7.03		6.69	
Harvest and postharvest	75.58		80.59		82.50		63.47	
Total labor								
(hours/ha)	1818.08		2046.80		1905.28		1783.36	
(labor days/ha)	227.26		255.85		238.16		222.92	
II. Nonlabor inputs (in per ha main field basis)								
A. Seedbed component								
Seeds (kg)	25.28	75.30	172.42	43.56	22.42	53.26	52.05	11.59
Organic fertilizer (kg)	2160.00	8.03	1425.00	5.61	6442.5	23.33	2662.50	7.42
Chemical fertilizer (kg)	18.98	3.33	29.62	4.24	93.60	10.68	120.52	10.68
Pesticides (kg)	0.75	2.27	0.60	1.82	1.50	6.14	2.02	1.89
Animal labor (days)	2.1	3.71	0.45	0.80	13.95	24.70	16.65	29.47
Tractor service	–	–	–	0.09	–	–	–	–
B. Main field component								
Organic fertilizer (kg)	10837.50	85.91	9060.00	39.85	16770.00	67.50	8122.50	39.09
Chemical fertilizer (kg)								
15-0-0-0	680.78	52.27	440.02	37.80	403.05	34.62	527.02	45.23
0-13-0	397.50	30.08	157.65	11.97	410.25	24.85	458.25	27.80
46-0-0	147.68	33.56	125.10	28.41	186.38	42.35	145.12	32.95
0-0-60	140.48	18.41	93.75	12.35	150.00	30.30	71.48	9.39
0-24-27	0.90	1.89	73.50	5.23	1.28	1.89	0.90	1.09
Pesticides (kg)	90.45	30.61	44.55	17.35	48.52	31.29	38.48	17.35
Irrigation fee ($)		21.14		18.94		7.05		3.41
Tractor service fee ($)		13.03		9.32		15.76		3.79
Animal labor (days)	15.75	27.88	15.75	27.88	11.10	19.62	16.05	28.41
Others		14.70		0.83		2.58		18.33
Total nonlabor input cost ($/ha)		422.12		266.05		395.92		288.09
III. Indirect cost ($/ha)[c]		69.55		60.08		69.5[d]		69.55[d]

[a]Three of the sample reported the time spent in water control for their plots. For others water control was a communal activity and they could not report the time spent. This is the average for the 3 sample farmers. [b]Water control for the sample is a communal activity and they could not report the time spent. So simply assume to be equal to those spent by the hybrid rice growers. [c]This is an imputed cost which includes depreciation and maintenance/repair costs of machineries and small tools and administrative costs of brigade and production team. [d]Data are not available to make imputation. Therefore, we assumed data to be equal to the Fujian hybrid rice growers' costs.

Appendix 2. Labor and inputs use in seed production, Fujian and Hunan, China, 1982.

Item	Fujian				Hunan			
	Male-sterile		Hybrid		Male-sterile		Hybrid	
	Quantity	Value ($)	Quantity	Value ($)	Quantity	Value ($)	Quantity	Value ($)
I. Labor (labor days/ha)								
Cleaning and repairing dikes	4.69		8.51		19.14		3.08	
Plowing and harrowing	4.20		13.88		22.67		8.04	
Seed selection and preparation	1.46		8.38		3.02		3.30	
Seedbed preparation and care	8.48		8.18		12.62		12.71	
Planting	61.03		41.87		44.96		60.00	
Organic fertilizer application	12.60		40.14		37.63		10.29	
Chemical fertilizer application	4.91		15.13		11.04		4.31	
Water control	18.56		6.90		6.19[b]		15.00[b]	
Disease and insect control	4.59		29.29		10.33		12.19	
Weed control	44.25		26.83		34.20		7.50	
Rat and bird control	11.62		0.68		–		14.06	
Special activities[a]	159.02		97.71		135.47		93.81[b]	
Procurement of inputs	1.89		4.91		3.43		1.78	
Harvest and postharvest	38.72		80.42		73.63		60.47	
Total labor								
(hours/ha)	3008.16		2982.64		3314.40		2452.32	
(labor days/ha)	376.02		372.83		414.33		306.54	
II. Nonlabor inputs (in per ha mainfield basis)								
A. Seedbed component								
Seeds (kg)								
Female parent	22.58	67.27	20.70	61.67	30.00	71.21	30.22	71.74
Male parent	5.70	1.44	11.18	2.80	7.50	1.67	7.58	1.67
Organic fertilizer (kg)	1215.00	2.42	555.00	2.73	3000.00	15.15	5205.00	16.14
Chemical fertilizer (kg)	17.40	2.65	44.70	5.61	151.35	14.02	119.78	14.17
Pesticides (kg)	0.68	0.15	1.05	3.26	0.98	1.89	4.95	3.03
Others ($)		1.06		1.74		55.76		2.35
B. Main field component								
Organic fertilizer (kg)	3000.00	75.76	84862.50	96.89	42510.00	120.15	15187.50	80.83
Chemical fertilizer (kg)								
46-0-0	168.75	37.42	155.55	35.38	205.88	46.82	186.98	42.50
0-13-0	225.00	14.24	303.60	21.44	421.20	25.53	187.50	11.36
15-0-0	375.00	31.44	620.55	53.26	352.65	30.30	581.25	57.20
0-0-60	30.00	3.94	144.38	18.94	150.45	20.53	170.62	23.26
0-0-50	56.25	10.00	–	–	–	–	–	–
Pesticides (kg)	34.88	17.20	72.08	24.47	10.58	25.76	50.18	15.38
Irrigation fee ($)		7.65		15.61		12.12		11.36
Tractor service fee ($)		13.03		13.03		4.55		3.79
Animal labor (days)		27.88		27.88	18.30	32.35	15.00	26.52
Others ($)		2.27		31.97		29.32		13.26
Total nonlabor inputs cost ($/ha)		315.82		416.68		507.13		394.56
III. Indirect cost ($/ha)		85.00		85.00		69.55		69.55

[a]Special seed-production-related activities, which include supplementary pollination, clipping of flag leaves, application of growth stimulant, and roguing. [b]Av of two farmers only. Information on the other sample is missing.

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