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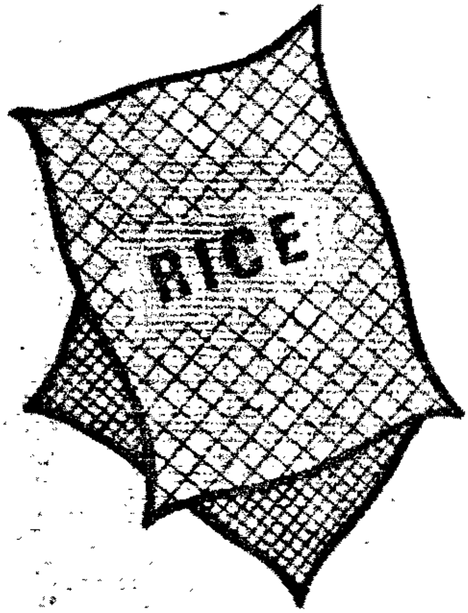

SEMINAR on Rice policies in Latin America

PAPERS PRESENTED

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EL VALOR NUTRICIONAL DEL ARROZ EN COMPARACION CON EL DE OTROS CEREALES EN LA DIETA HUMANA DE AMERICA LATINA

Ricardo Bressani, Ph.D.
Jefe de la División de Ciencias Agrícolas y de Alimentos del Instituto de Nutrición de Centro América y Panamá (INCAP)

INTRODUCCION

Entre los cultivos alimenticios, los cereales se consideran como los de mayor rendimiento, y por este motivo han sido y seguirán siendo fuente primordial de alimento para la población mundial. Los cereales constituyen la fuente principal de calorías para una gran mayoría, y suministran dos terceras partes y aún más del consumo total de proteínas, así como cantidades significativas de vitaminas y otros nutrientes. A medida que aumente la población del mundo, la dependencia en los cereales para satisfacer las necesidades nutricionales del hombre también aumentará, ya que su capacidad de rendimiento de calorias por unidad de área cultivada, es una de las más elevadas.

Los cereales generalmente tienen un bajo contenido de proteína, y aun cuando ésta sea de mejor calidad, como es la del arroz, no pueden por sí solos suplir la proteína en la concentración y de la calidad que requieren los niños pequenos una vez dejan de recibir cantidades adecuadas de leche.

En los países en vías de desarrollo los atoles a base de cereales se ofrecen casi universalmente a los niños. Sin embargo, la ineficacia de éstos en suplir proteínas de alta calidad y en cantidades adecuadas, explica de hecho la necesidad de suplementar con proteína las dietas a base de cereales, sobre todo la destinada a niños pequeños.

El contenido proteínico por sí solo de ningun modo es indicación de su valor nutritivo. El contenido de aminoácidos esenciales y la disponibilidad de estos aminoácidos son factores de gran importancia. En este sentido es un hecho reconocido que los cereales considerados como grupo,son bajos en su contenido de lisina, y muchos son deficientes en uno o más de los otros aminoácidos esenciales. El patrón de estos aminoácidos se aleja significativamente del patrón ideal de aminoácidos. Finalmente, la proteína de los cereales contiene menor cantidad de la mayoría de los aminoácidos esenciales que las proteínas de origen animal, y aún que las de origen vegetal. Por lo tanto, generalmente son menos adecuados como fuentes proteícas, aún cuando se haya corregido su principal deficiencia de aminoácidos.

En esta comunicacion se reseñan parcialmente los trabajos llevados a cabo en animales de experimentación y en humanos, sobre el valor nutricional de la proteína del arroz como fuente única de alimento o en combinación con otros alimentos. Se compara también con otros cereales de importancia en la dieta latinoamericana.

CONSUMO DE ARROZ

En Centro América

La composición de ingredientes de la dieta humana varía grandemente a través del mundo. Sin embargo, la mayor diferencia estriba en lo que se refiere a la ingesta per capita de granos, ya sea que éstos se consuman directa o indirectamente. A pesar de que el trigo, el arroz y el maíz son los principales cereales consumidos por el hombre en el caso de la población latinoamericana, éstos solo constituyen parte de la dieta habitual. De los tres, el maíz es probablemente el más importante, por lo menos en la gran mayoría de los países.

Como sucede con otros alimentos, los hábitos y costumbres, así como las prácticas culinarias, el trasfondo antropológico y la disponibilidad, en gran medida influencian el nivel específico de consumo de estos cereales. Los resultados pertinentes de una serie de encuestas nutricionales llevadas a cabo en los seis países del Istmo Centroamericano se resumen en el Cuadro No. 1 (1-6). Los datos revelan el consumo de arroz en los sectores rural y urbano de cada uno de los países citados en el Cuadro. Para propósitos de comparación se exponen también los mismo datos para otros cereales. Con la excepción de Costa Rica, la ingesta de arroz es significativamente mayor en el medio urbano que en las áreas rurales de cada país, diferencia ésta que no ha podido esclarecerse a ciencia cierta. Es muy probable que ello se deba a varias razones ya citadas: baja producción, disponibilidad y alto costo, así como a causa de que los centro de procesamiento están localizados en el sector urbano, lo que hace su distribución en las zonas rurales más costosa. Más aún, el arroz se consumo muy rara vez en preparaciones tales como del pan de trigo o las tortillas de maíz, medida que contribuye al consumo de estos productos como acompañantes de otros alimentos.

El trigo y el maíz se incluyen bajo el acápite "Otros Cereales" del Cuadro No. 1, aún cuando las cifras que allí se citan corresponden principalmente a maíz, sobre todo en los sectores rurales. En este caso, la ingesta rural es más lata en todos los países salvo en Costa Rica y Panamá. Estos resultados han sido explicados en base de los antecedentes étnicos y otras influencias, así como a partir del estado socioeconómico de la población. En Panamá, la influencia oriental es probablemente el factor responsable del alto consumo de arroz por parte de la población panameña, mientras que el ancestro Maya ha hecho que el maíz sea el alimento más importante en los otros cinco países. En el caso de Costa Rica es probable que el estado socioeconómico de sus habitantes sea el responsable de que en ese país la ingesta de arroz sea similar a la de otros cereales.

<u>En América del Sur y México</u>

Estudios llevados a cabo en otros países latinoamericanos han revelado resultados similates. En el Cuadro No. 2 se resumen los hallazgos en cuanto al consumo de arroz en América del Sur y México, comparado con la ingesta de otros cereales (7). Entre los países que figuran en dicho Cuadro, Brasil acusa el consumo más alto, siendo éste similar a las ingestas determinadas en Costa Rica y Panamá, según se indicó. Argentina acusa la menor ingesta <u>per capita</u> - semejante a la del medio rural de Guatemala - pero por razones del todo diferentes. El consumo de otros cereales es tan alto o aún más elevado que el del arroz; en algunos países predomina el de trigo, y en otros, el de maíz.

Para propósitos de comparación, en el mismo Cuadro se incluyen también datos sobre el consumo de arroz en Formosa y en las Islas Filipinas,respectivamente, pudiéndose observar que con la posible excepción de Brasil, el consumo de arroz es mucho más bajo en todos los países latinoamericanos. En el caso de este país en particular el arroz y los frijoles constituyen en general el plato de consumo diario.

El aporte del arroz al consumo diario total de proteínas y calorías se reseña en el Cuadro No. 3 (7). Tal como lo indican claramente las cifras, es obvio que si la ingesta de arroz es relativamente baja en América Latina, la contribución de nutrientes de este cereal a la dieta también es muy baja.

Con base en la información expuesta, puede concluirse que en la mayoría de los países latinoamericanos, el arroz no es tan importante como otros cereales. Sin embargo, en algunos de ellos la ingesta de este cereal es relativamente alta, hecho sugerente de que el consumo de arroz bien podría incrementarse, siempre que los obstáculos que por el momento impiden su mayor disponibilidad, puedan subsanarse satisfactoriamente. Mucho podría hacerse a este respecto si la disponibilidad del frijol también se aumentara, puesto que las leguminosas constituyen un alimento que muy comúnmente se acostumbra consumir junto con el arroz en la mayoría de los países de Latino América.

FORMAS DE CONSUMO

Un aspecto importante que determina el grado de utilización de un alimento es la forma en que éste se prepara para consumo. Así, si se desea incrementar su uso, el alimento bajo consideración debe constituir parte importante de un plato o comida típica, o bien prepararse en las formas en que habitualmente se consume, es decir, en combinación con otros alimentos.

En América Latina el arroz se consume principalmente cocido, aunque también se come combinado con otros alimentos como pollo, camarón y carne. Sin embargo, estos usos son más comunes entre los grupos de población de alto nivel económico y en los sectores urbanos, y no así para la mayoría de los pobladores de la Región. El arroz con leche también se sirve como postre, pero como en el caso de otros productos animales, su consumo se limita a la población de mayores ingresos. A pesar de ello, un plato que se sirve en todo Latino América con frecuencia variable, es el de arroz con frijoles.

Esta costumbre es responsable en gran parte de la mayor ingesta de arroz en Brasil y en Costa Rica, en contraste en la que acusan otros países de América Latina. Por lo tanto, sería lógico que en el planeamiento de programas de fomento de arroz, se trate también de sentar pautas orientadas a incrementar la disponibilidad de leguminosas en grano.

Existen otras formas de preparar el arroz para consumo de la población humana en América Latina. Entre estas formas de uso popular cabe citar las "coladas", que consisten en harina de arroz o arroz molido, el cual se cuece en agua hasta lograr un atole ralo o potaje, y también como una bebida sazonada que en algunos países se llama "Horchata". En Ecuador se consume un producto de arroz fermentado cuya calidad nutricional fue evaluada por Van Veen et al. (8). Dichos autores encontraron que este producto contenía una proteína de calidad inferior a la del arroz sin fermentar y de menor digestibilidad, si bien acusaba una concentración de riboflavina significativamente más alta.

El arroz también podría usarse en otras formas, y ya se están implementando algunas de ellas. Entre éstas puede citarse su empleo como componente de alimentos de alto contenido proteínico para la alimentación infantil (9-10). La Incaparina Blanca y la Colombiaharina producidas en Cali, Colombia, constituyen ejemplos a este respecto. Sin embargo, las cantidades utilizadas en estas preparaciones son bajas, por lo que de no considerarse nuevos usos que impulsen el consumo de arroz en Latino América, es dudoso que sus niveles de consumo aumenten o superen los actuales.

Otro factor que probablemente ayudaría a incrementar la ingesta también sería el uso de arroz precocido, ya que con ello se reduciría su tiempo de preparación en el hogar. No obstante, se estima que la acción más significativa para promover el consumo de arroz sería aumentar la disponibilidad de alimentos que lo acompañen, entre los cuales las leguminosas serían las más indicadas.

COMPARACION DE SU COMPOSICION QUIMICA Y DE AMINOACIDOS CON LA DE OTROS PRODUCTOS

Composición Química

Desde el punto de vista de su composición química, se sabe que los cereales tienen un bajo contenido proteínico y son ricos en carbohidratos. Son, pues, alimentos calóricos.

La composición químico-proximal y el contenido vitamínico del arroz, en comparación con el maíz, la harina de trigo, la avena, y el sorgo, figuran en el Cuadro No. 4. Según se observa, existen algunas diferencias entre ellos, aunque también muestran ciertas similitudes. Las diferencias de interés atañen a su contenido de proteína y grasa. De todos los cereales, el arroz acusa la concentración proteínica más baja, mientras que entre todos los demás cereales la avena contiene el nivel más alto. Sin embargo, los resultados de estudios recientes notificados por el Instituto Internacional para la Investigación de Arroz (IRRI) indican que por selección y cruzamiento genético es factible aumentar el contenido total de proteína en los granos de arroz. Por otra parte entre los cereales que se detallan en el Cuadro, el arroz contiene los valores más altos de carbohidratos. El contenido vitamínico de los cinco cereales se presenta en la parte inferior del Cuadro, y las cifras demuestran que el arroz contiene bajos niveles de tiamina y riboflavina. A pesar de que sería deseable desarrollar variedades de arroz de mayor contenido vitamínico, esto no constituye ya un problema, puesto que los avances en el campo de la tecnología de alimentos hoy día permiten que la concentración de estos nutrientes, no sólo en el arroz sino también en otros alimentos, pueda incrementarse a través de la fortificación.

Contenido de Aminoácidos Esenciales

El contenido proteínico de un alimento dado es de significancia nutricional en términos de su contenido de aminoácidos esenciales. En el Cuadro No. 5 se da a conocer la concentración de aminoácidos esenciales de la proteína del arroz, comparándola con la de otros cereales. Se muestra también el patrón de aminoácidos esenciales de la proteína de la leche, usada como proteína de referencia.

Como en el caso de la composición química, también existen diferencias y similitudes en cuanto al contenido de aminoácidos esenciales del arroz y de otros cereales. La isoleucina, los aminoácidos azufrados y la fenilalanina presentan valores similares; en cambio, hay una notoria diferencia en el contenido de lisina y triptofano.

Al comparar el patrón de aminoácidos de los cereales con el patrón de referencia, en este caso la proteína de la leche, se observa que la proteína del arroz tiene una menor concentración en lisina así como en otros aminoácidos, pero en todo caso, el patrón del arroz se aproxima más al de la leche que el de los otros cereales.

Los valores más altos de lisina, en el arroz, sugieren que de todos los cereales esta proteína es la de mayor valor biológico.

Existen otras diferencias en cuanto al contenido de aminoácidos en los cereales que también deben señalarse. La calidad de la proteína depende principalmente de su contenido de aminoácidos esenciales. Sin embargo, las proporciones en que se encuentran presentes estos nutrientes esenciales también son de importancia. Por ejemplo, la proteína del maíz no es sólo deficiente en lisina y triptofano sino que además acusa un balance desventajoso entre la isoleucina y la leucina, relación ésta que es parcialmente responsable también de la calidad inferior de la proteína del maíz. Esta situación no se presenta en la proteína del arroz. En la actualidad, el cereal que contiene la proteína de mejor calidad es la variedad de maíz conocida como opaco-2 (11-12). Por considerarse de interés, en el Cuadro No. 6 se presenta el contenido de aminoácidos esenciales del arroz comparado con el del opaco-2. Según pueda apreciarse, el patrón de estos nutrientes en ambas fuentes de alimento es esencialmente similar. Si el maíz opaco-2 - cuyo patrón de aminoácidos esenciales es tan bueno - tiene un valor biológico alto, bien podría anticiparse que también la proteína del arroz es de alta calidad.

COMPARACION DEL VALOR NUTRITIVO DEL ARROZ CON EL DE OTROS CEREALES

La eficiencia de utilización de los aminoácidos esenciales por el organismo animal, es el principal factor determinante en la calidad de la proteína. Para obtener una mayor eficiencia de utilización, estos aminoácidos deben estar presentes en las cantidades apropiadas y guardando la debida proporción entre sí. Por otra parte, el valor nutritivo de la proteína mide el grado de cobertura de los aminoácidos esenciales requeridos, manteniéndose una ingesta proteínica fija. En el primer caso, cuando se hacen comparaciones de la calidad proteínica entre varias fuentes de este nutriente, el nivel de proteína en la dieta debe ser esencialmente el mismo para todas las proteínas bajo estudio. En cambio en el segundo caso, o sea para determinar el valor nutritivo de la proteína, la comparación se hace cuando todos los alimentos se suministran en cantidades iguales en la dieta.

El Cuadro No. 7 da a conocer la calidad de la proteína de cinco cereales incluidos en una dieta basal administrada a ratas en cantidades equivalentes a 7.5% de proteína. En la primera columna se indica el nivel a que se incluyeron los cereales en la dieta basal; según se observa, ésta contenía la mayor cantidad de arroz, por ser este cereal el de contenido proteínico más bajo. La segunda columna muestra el peso que ganaron las ratas: el arroz indujo las mayores tasas de crecimiento, siguiéndole la avena, el maíz y el sorgo, cereales con los que se obtuvo las respuestas más bajas. La eficiencia de utilización de la proteína siguió la misma tendencia y de nuevo el arroz demostró ser el de mejor valor.

El valor nutritivo de la proteína de estos mismos alimentos se detalla en el Cuadro No. 8. En este caso todos los cereales fueron sometidos a prueba al nivel de 90% de la dieta. Como lo revelan los datos, la avena demostró ser superior a los otros cereales, seguida del trigo, arroz, sorgo y maíz con respecto a ganancia ponderal. La eficiencia proteínica fue más o menos la misma para la avena y el arroz, una vez más seguidos del trigo y maíz y, por último, del sorgo con el menor valor.

De nuevo, estos resultados demuestran que la calidad de la proteína del arroz es bastante buena, aunque su valor nutritivo es bajo debido a la baja concentración proteínica del grano. Esto se hace más evidente al estudiar los valores en la última columna del Cuadro No. 8, los cuales representan la cantidad de proteína utilizable de los cereales. Se identifica como proteína utilizable el producto de la calidad por la cantidad de la proteína. A pesar de que puede decirse que la calid de la proteína del arroz es la mejor, su menor contenido proteínico lo sitúa en cierta desventaja con respecto a los cereales de calidad proteínica inferior.

La misma conclusión se obtiene usando diferentes animales de experimentación y distintos métodos. Los resultados de estudios de balance de nitrógeno practicados en perros semiadultos alimentados con arroz, maíz, harina de trigo y avena al nivel de 1.4 g de proteína/kg de peso corporal/día (Cuadro No.9), revelan que el balance de nitrogeno fue positivo con arroz y negativo con otros cereales, de los cuales la avena rindió valores intermedios. Los cambios en peso observados durante el estudio de balance siguieron la misma tendencia, lográndose pequeños aumentos con el arroz, y pérdidas con los otros cereales sometidos a prueba.

VALOR NUTRITIVO DE COMBINACIONES DE ARROZ CON FRIJOL Y DE MAIZ CON FRIJOL

Para la población latinoamericana de bajos recursos económicos, el frijol constituye la fuente de proteína más importante después de los cereales. El frijol también representa un alimento integrante de la cultura de estos países, que usualmente se consume junto con maíz o arroz. Por consiguiente, se ha tenido interés especial en conocer más a fondo la calidad proteínica de la dieta combinada de cereal y frijol.

Sobre la base de peso seco, el nivel del frijol consumido generalmente representa el 10% de las dietas. Por lo tanto, en los resultados que se muestran en el Cuadro No. 10, las dietas fueron preparadas con 90% de cereal y 10% de frijol negro cocido. Estas fueron administradas a ratas durante un período de 28 días al final del cual se estableció que la mayor ganancia ponderal la indujo la avena, seguida del trigo (bulgur), arroz, sorgo y maíz, en ese orden. La eficiencia de utilización de la proteína por otro lado, demostró ser más alta para el arroz y la avena, obteniéndose valores inferiores con los otros cereales estudiados. El cuadro no difiere en mucho al comparar la proteína utilizable.

Con el fin de eliminar el efecto producido por el contenido de proteína total, las ratas consumieron las mismas dietas con iguales niveles de proteína, obteniéndose los resultados que se presentan en el Cuadro No. 11. En este caso, la avena acusó los mejores resultados en términos de ganancia de peso y eficiencia proteínica, seguida de los otros cereales incluidos en el estudio.

Por estimarse de interés determinar hasta qué punto es factible obtener mejoras cuando el cereal es consumido juntamente con frijol, en el Cuadro No. 12 se incluyen algunos resultados representativos a ese particular. La adición de 10% de frijol negro al maíz, indujo un 74% de aumento en la ganancia ponderal; ese incremento fue de 68% al agregarse al trigo, y solo de 30% en el caso del arroz. En lo referente a la eficiencia proteínica, la adición de frijol aumentó ese valor en 40% para el maíz, 28% para el trigo y 8% para el arroz.

De nuevo, estos resultados confirman la calidad proteínica superior del arroz, en comparación con la de los otros cereales. El mejoramiento obtenido guarda una relación directa con el nivel de lisina en la proteína del cereal, que es más baja en el maíz, intermedia en el trigo, y más alta en el arroz. A pesar de que estos conceptos ya han sido expresados antes, viene al caso subrayar que la calidad proteínica del arroz podría mejorarse aún más si contuviera mayores cantidades de proteína.

En el Cuadro No. 13 se incluyen resultados de algunos estudios en animales de experimentación, en los que la proteína del arroz fue reemplazada por cantidades equivalentes de proteína de frijol (14). Los hallazgos revelan que el crecimiento máximo y la mayor utilización de la proteína se obtienen cuando el arroz aporta de 80 a 50% de la proteína de la dieta, y el frijol de 20 a 50%. Este hecho indica que entre los rangos citados, los patrones de aminoácidos de ambas fuentes se complementan mutuamente hasta el punto permitido por el aporte que de estos aminoácidos hace cada una de las dos fuentes para satisfacer las deficiencias de la otra. La mezcla de 80% de proteína de arroz y 20% de frijol, en cantidades absolutas representa alrededor de 90 g de arroz y 10 g de frijol; sin embargo, su contenido proteínico resulta ser bajo, del orden de 8.5 g por 100 gramos. Si las ingestas fueran 50% de proteína de arroz y 50% de frijol, lo que en valores absolutos sería alrededor de 75 g de arroz y 25 g de frijol para rendir 11% de proteína por 100 g de dieta, ello se traduciría en un mayor valor nutritivo. Si el pequeño descenso observado en cuanto a calidad proteínica fuese verdadero, éste se vería compensado en gran medida por el aumento en proteína, esto es, de 8.5 a 11.0. El 11% de mezcla proteínica representaría un incremento de alrededor de 25% más de proteína utilizable. Por consiguiente a menos que logre desarrollar variedades de arroz con un mayor contenido de proteína, desde el ángulo nutricional sería recomendable fomentar el consumo de arroz combinado con frijol. Según se indica en el Cuadro No. 14, la mezcla 50/50 de arroz y frijol, aunque nutricionalmente superior a cualquiera de los componentes suministrados por sí solos, aún es deficiente en ciertos aminoácidos. En efecto, los datos muestran que la adición de metionina, aminoácido en el que el frijol es deficiente, indujo una respuesta, sin observarse mayor efecto cuando la treonina se agrega junto con metionina. Sin embargo, cuando también se agrega lisina en presencia de los otros dos aminoácidos, el efecto obtenido es significativamente mayor.

Con propósitos comparativos, se juzgó de interés estudiar la calidad nutricional de mezclas de maíz y frijol en ratas (15), con los resultados que se muestran en la Figura 1. En este caso, con el nivel de combinación proteínica de 50/50, hay un punto cumbre de desarrollo máximo en el crecimiento de los animales experimentales, en contraste con el obtenido con las combinaciones de arroz y frijol, las cuales fueron esencialmente parecidas, esto es, del rango 80-50 y 20-50, como ya se indicó. Otra diferencia es que - a juzgar por los valores del PER - en el caso de la combinación de maíz - frijol, la utilización de la proteína fue significativamente menor de la que se obtuvo con la combinación de arroz - frijol. La mezcla de 50/50 de maíz - frijol es aún deficiente en lisina, metionina y triptofano (15).

En consecuencia, esta información indica que si el objetivo final de un programa determinado es producir alimentos que satisfagan los requerimientos nutricionales del hombre, dadas las características nutricionales de los cereales, es importante tomar en cuenta aquellos productos alimenticios que los complementan nutricionalmente. Más aún, los alimentos complementarios pueden tener un efecto definitivo en el aumento de ingesta del alimento bajo consideración.

MEJORAMIENTO DE LA CALIDAD PROTEINICA DEL ARROZ

Suplementación con Aminoácidos

La comparación del patrón de aminoácidos esenciales de la proteína del arroz con los patrones de aminoácidos de referencia, sugiere que la proteína del arroz es deficiente en varios de ellos. Sin embargo, los resultados obtenidos por varios investigadores (16-21), indican claramente que la proteína del arroz es deficiente en lisina, y que su calidad mejora aún más con el agregado de treonina en presencia de lisina. En el Cuadro No. 15 pueden apreciarse en forma resumida los resultados de un experimento llevado a cabo en ratas, en el que la adición de una pequeña cantidad de lisina indujo un aumento en la ganancia ponderal (16-20). Sin embargo, el agregado de treonina a la proteína del arroz, en presencia de lisina, provocó una mejoría en el desarrollo del animal y en la calidad de la proteína. No se esperaban estos resultados en vista de que las proteínas del arroz contienen suficiente treonina para satisfacer los requerimientos de la rata en crecimiento. El efecto de la treonina ha sido explicado de dos maneras diferentes según el punto de vista del investigador. Una explicación se basa en el balance que debe prevalecer cuando la proteína es suplementada con aminoácidos libres. La adición de una cantidad de lisina mayor a la requerida hace que la treonina se convierta en el primer aminoácido limitante; este efecto ha sido corroborado al agregarse treonina.

La segunda explicación sugiere que el efecto positivo resultante de la adición de treonina al arroz, en presencia de lisina, no se debe necesariamente a un imbalance entre estos dos aminoácidos, sino más bien a una limitación fisiológica en la disponibilidad de treonina para el organismo animal. La verdad es que una explicación no excluye la otra, dado que la proteína del arroz contiene niveles de treonina más altos que aquéllos determinados en otros cereales, y en cantidades similares a las que se encuentran en proteínas de origen animal tales como la leche.

La calidad de la proteína del arroz, por lo tanto, es susceptible de mejorar mediante la adición de lisina y treonina. Sin embargo, la evidencia experimental que se presenta más adelante, muestra que otra deficiencia importante del arroz es su bajo contenido de nitrógeno total. Este hecho podría ser también el factor responsable de las diferentes respuestas informadas por varios investigadores (16-21).

Suplementación con Proteínas

Las deficiencias en nitrógeno y aminoácidos de que adolecen las proteínas del arroz pueden corregirse por medio de la suplementación proteínica, particularmente cuando se utilizan proteínas que aportan cantidades apreciables de lisina y de treonina (18, 21, 22).

Algunos resultados representativos a este respecto se aprecian en el Cuadro No. 16. En este ejemplo se usaron dietas basadas en 76.0% de harina de arroz, las cuales se suplementaron con niveles de 2 a 14% de las proteínas que figuran en el Cuadro. Con excepción del concentrado proteínico de pescado, los niveles que se muestran suministraron un poco más de 4% de proteína a la dieta basal de arroz; por lo tanto, los resultados son comparables al mismo nivel proteínico en la dieta. A partir de estos hallazgos, es evidente que con la adición de más o menos la misma cantidad de proteína proveniente de los diversos suplementos usados, se logra un aumento significativo en la ganancia de peso y en la utilización de la proteína, tal como lo indica el PER. La mejora observada es el resultado sinérgico de la proteína adicional suministrada por el suplemento y del aporte que en lisina y treonina hace el propio suplemento a la proteína del arroz.

El efecto de los suplementos proteínicos no es característica única del arroz, ya que cuando los suplementos proteínicos se agregan a otros cereales también se obtiene el mismo efecto. El Cuadro No. 17 muestra los resultados de varios experimentos en este sentido (22-24). Los valores que constan en dicho Cuadro indican que, a juzgar tanto por el aumento de peso de las ratas como por el PER, las proteínas del arroz son de mejor calidad que las de la harina de trigo o del maíz, a pesar de que de los tres cereales, el arroz es el que contiene menos proteína. El agregado de la misma cantidad de suplemento proteínico a los tres cereales induce un mayor aumento ponderal en la mayoría de los casos; sin embargo, con

(8-9% Proteína en las dietas)

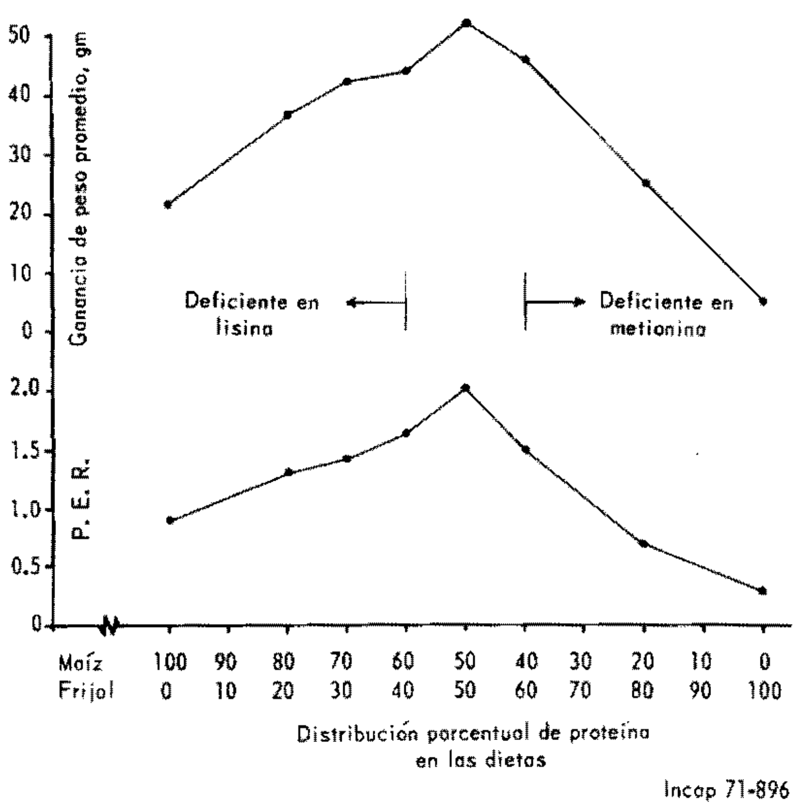

FIGURA 1

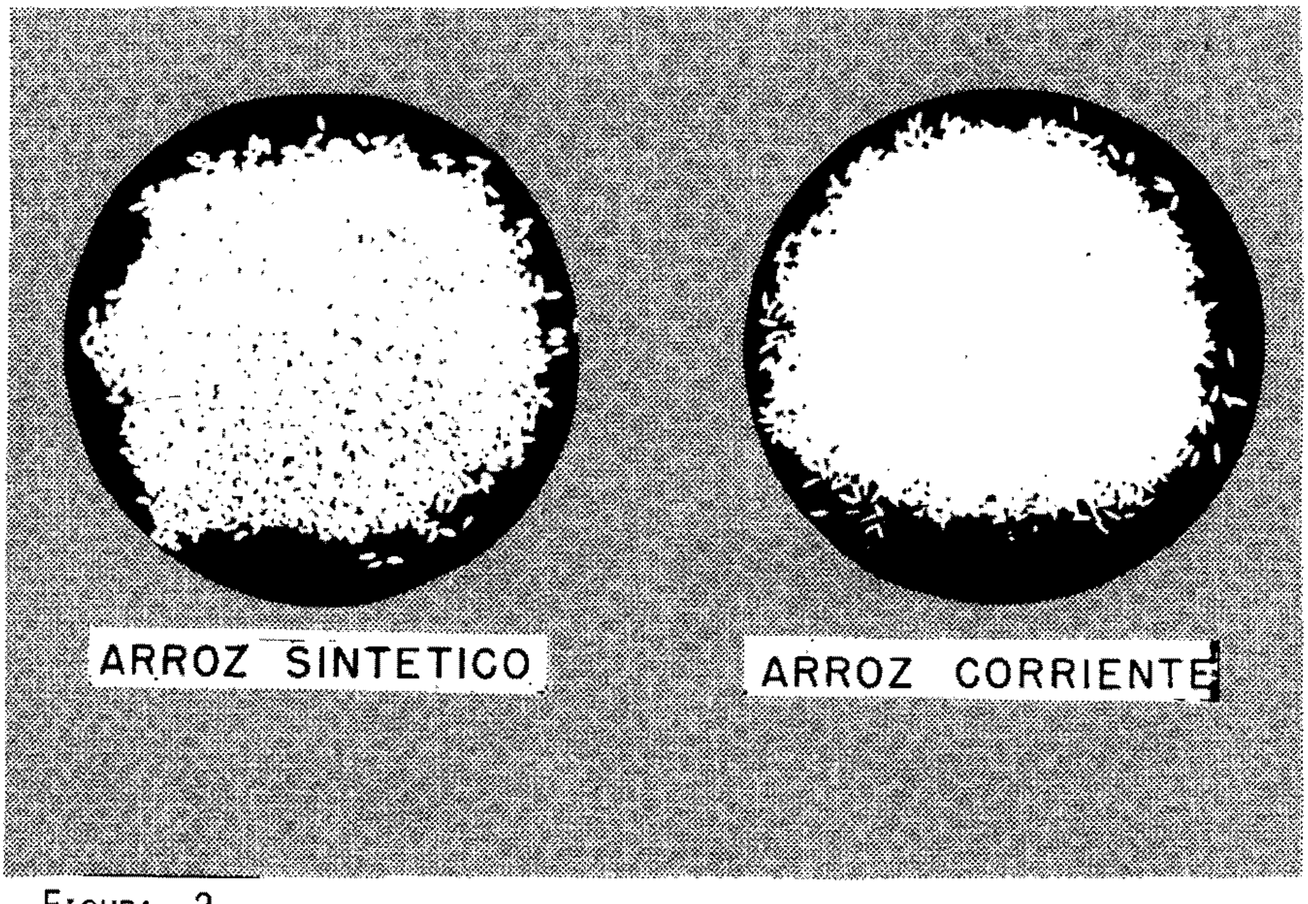

FIGURA 2

el arroz se obtiene un valor proteínico más alto (PER) que con los otros dos cereales.

Es probable que esta respuesta se deba, por un lado, al bajo contenido proteínico del arroz, y por el otro, a que comparada con la de la harina de trigo y la de maíz, su proteína es de mejor calidad.

Fortificación de las Proteínas del Arroz

En vista de los resultados de que se informa así como desde el punto de vista nutricional, sería deseable fortificar las proteínas del arroz para que - de lograrse que el consumo de este cereal aumente - contribuya también con más proteínas de mejor calidad. En los momentos actuales la tecnología en materia de fortificación de alimentos avanza a un ritmo rápido, y ya se ha logrado desarrollar granos de arroz simulados que contienen los aminoácidos limitantes, lisina y treonina, juntamente con vitaminas del complejo B, vitamina A y minerales. En la Figura 2 puede apreciarse una muestra de dichos granos sintéticos. Cuando éstos se agregan al arroz natural a un nivel de 1-2% por peso, es factible mejorar la calidad proteínica del arroz común, según se indica en el Cuadro No. 18. Los estudios a que se alude se llevaron a cabo en ratas alimentadas con arroz pulido suplementado con granos de arroz sintético (25). Los granos simulados contenían L-lisina HCl, L-treonina, vitamina A, tiamina y sulfato ferroso. Su adición incrementó la ganancia ponderal así como la razón de eficiencia proteínica (PER), tanto como al agregar aminoácidos sintéticos en forma cristalina.

También se han llevado a cabo estudios orientados a determinar si estos granos conservan su forma y calidad al someterse a cocción. Los resultados obtenidos hasta la fecha indican que en comparación con el arroz crudo suplementado, sí mantienen su forma, observándose tan solo pequeños cambios en su calidad nutritiva.

Los granos simulados de arroz también pueden prepararse a partir de proteína, siendo la de la harina de soya particularmente buena en este respecto. A pesar de que en este caso sería necesario agregar al arroz natural, mayores niveles de granos sintéticos elaborados con proteína de soya, este método de fortificación tendría la ventaja de aportar, tanto aminoácidos como proteína; además sería menos costoso.

CALIDAD PROTEINICA DE LA PROTEINA DEL ARROZ EN HUMANOS

Estudios en Adultos

A causa de las dificultades inherentes a los estudios de evaluación proteínica en seres humanos, la literatura cuenta con muy pocas publicaciones al respecto. Uno de los primeros estudios de esta índole fue el notificado por Hundley et al. (26) en 1957. Estos autores utilizaron cuatro sujetos del sexo masculino a quienes se les alimentó con 4.31 a 5.07 g de nitrógeno de arroz, como parte de dietas que aportaban de 2,800 a 3,500 calorías por día. La ingesta de arroz fue de 250 a 350 gramos diarios. En el Cuadro No. 19 se muestran únicamente los resultados del balance de nitrógeno correspondientes a dos de los individuos estudiados. El sujeto W.M. respondió favorablemente a la adición de lisina y treonina al arroz, y más aún cuando los aminoácidos lisina, treonina y metionina se agregaron juntos. Se obtuvo una mejor respuesta al suplementar el arroz con una mezcla de aminoácidos no esenciales. El aumento en la ingesta de proteína hasta 85 g diarios, dio como resultado una alta retención de nitrógeno. Por su parte, el sujeto V.L. también respondió al agregado de los mismos suplementos al arroz, a pesar de que nunca logró estar en balance positivo de nitrógeno.

En el caso de los otros dos sujetos, los resultados fueron similares. Hundley *et al*. (26) interpretaron tales resultados como indicativos de que la deficiencia primordial en las dietas de arroz usadas en el estudio fue la de nitrógeno disponible, ya fuese éste nitrógeno esencial o no esencial, a pesar de que sí se observó cierta respuesta al suplementar el arroz con lisina, metionina y treonina. Por consiguiente, la adecuación de la proteína de la dieta depende de la cantidad total de nitrógeno que ésta contiene, así como de la cantidad de aminoácidos esenciales.

El estudio de Chen *et al*. (27) demuestra el efecto del nitrógeno total en la dieta para adultos humanos alimentados con proteína de arroz. En dicha investigación 6 sujetos fueron alimentados con dietas que suministraban 6 g de nitrógeno de arroz, ya fuese solo o suplementado con: a) 2 g de nitrógeno de aminoácidos; b) 2 g de nitrógeno no específico, y c) 6 g de nitrógeno no específico (Cuadro No. 20). El balance promedio de nitrógeno de los 6 sujetos fue negativo cuando éstos recibieron 6 g de nitrógeno de arroz solo, ó 2 g de nitrógeno adicional proveniente de fuentes no específicas. Se obtuvo un balance de nitrógeno positivo al suministrarles los 6 g de nitrógeno de arroz juntamente con 2 g de N proveniente de aminoácidos esenciales, o bien al suministrarles el N del arroz con 6 g de nitrógeno de fuentes no esenciales, o no específicas.

Los mismos autores estudiaron también el efecto del agregado de aminoácidos específicos al arroz cuando éste fue suministrado para que aportase 6 g de nitrógeno proporcionando a los sujetos, al mismo tiempo, 6 g de nitrógeno de fuentes no específicas. Los resultados a este respecto también constan en el Cuadro No. 20. El promedio de retención de nitrógeno obtenido con arroz solo, fue negativo, y mejoró al agregar una mezcla de aminoácidos esenciales al arroz. La adición de solo lisina dio respuestas similares a las obtenidas con todos los aminoácidos. Por otra parte, la adición de treonina sola indujo un balance negativo de nitrógeno. La mejor respuesta se obtuvo al suplementar la dieta de arroz que contenía nitrógeno no específico, con lisina y treonina. Los autores llegaron a la conclusión de que cuando la dieta aporta un alto nivel de nitrógeno total, la lisina es el aminoácido que ocupa el primer lugar como limitante en la proteína del arroz en lo que a mantener la retención de nitrógeno se refiere.

Como ya se indicó anteriormente, la principal desventaja del arroz es su bajo contenido proteínico. Sin embargo, a través de procedimiento de cruce y selección, el IRRI logró desarrollar una variedad de arroz de alto contenido proteínico, que se conoce como BPI-76-1 y la cual contiene 14.3% de proteína. En un trabajo muy reciente, Clark *et al.* (28) informan sobre los resultados comparativos que obtuvieron en pruebas de alimentación con humanos adultos, quienes consumieron dietas a base de arroz de alto contenido proteínico y de una variedad popular del mismo cereal, conocida como Blue Bonnet. En dicho estudio, los sujetos fueron alimentados con 480 g de BPI-76-1, cantidad que proporcionaba 12.06 g de nitrógeno. La respuesta obtenida con esta variedad de arroz fue comparada luego con los otros tratamientos dietéticos que se indican en el Cuadro No. 21.

Estos fueron: a) 480 g de arroz Blue Bonnet que aportaba 6.72 g de nitrógeno; b) este mismo arroz con el agregado de nitrógeno no específico a un nivel de ingesta nitrogenada de 12.06 g, y c) 320 g de la variedad Blue Bonnet con nitrógeno adicionado a modo de suministrar 6.72 gramos. Como se indica en el Cuadro No. 21, se obtuvo un balance positivo de nitrógeno más alto con el arroz BPI. La misma cantidad de arroz Blue Bonnet, con y sin el agregado de nitrógeno, dio una retención significativamente baja, y al reducirse la ingesta de arroz a 320 g, el descenso en el balance de nitrógeno de los individuos fue aún mayor. Los autores concluyeron que desde el punto de vista nutricional el arroz BPI es mejor que la variedad Blue Bonnet, porque suministra mayores ingestas de lisina. Si bien la conclusión e interpretación de los resultados son correctas, ello no significa que el arroz BPI contenga una proteína de mejor calidad que la variedad Blue Bonnet, ya que los estudios no se llevaron a cabo con ingestas iguales de nitrógeno proteínico. Es un hecho reconocido que la ingesta de nitrógeno guarda relación directa con el balance de nitrógeno. Por lo tanto, una prueba más efectiva habría sido administrar el arroz BPI a una ingesta proteínica igual a la del arroz Blue Bonnet, es decir, a una ingesta de 480 g, que es la que corresponde a esta última variedad, comparándola luego con 225 g correspondientes al arroz BPI.

En el Cuadro No. 22, se resumen los resultados de un estudio de Bressani, Elías y Juliano (29) los cuales indican que el arroz BPI tiene una proteína de calidad inferior a la de otras variedades de ese cereal.

En ese estudio, varias muestras de arroz que contenían diferentes niveles de proteína fueron administradas a ratas jóvenes, con el propósito de suplir niveles crecientes de proteína. Se calcularon ecuaciones de regresión a partir de la relación ingesta proteínica-ganancia ponderal, la cual es linear a niveles bajos de ingesta de proteína. El coeficiente de regresión equivale a la calidad de la proteína. Según revelan los datos, la proteína de las variedades de arroz de menor contenido proteínico es de mejor calidad que la de aquellas variedades de mayor contenido proteínico. La variedad BPI acusó el valor más bajo. Si bien esto es cierto, las variedades de arroz de mayor contenido de proteína poseen ciertas ventajas, como son el de requerir una menor ingesta de grano que aporta los niveles mínimos de aminoácidos esenciales, y un menor consumo de alimentos suplementarios.

Según se mencionó es costumbre muy difundida consumir el arroz juntamente con otros alimentos, dentro de los cuales la carne de pollo parece ser la preferida. En diversas ocasiones (16-21) se ha podido comprobar, en animales de experimentación, que el consumo de arroz y pollo aumenta la utilización de la proteína ingerida. Recientemente, Lee y colaboradores (30) dieron a conocer un estudio de balance de nitrógeno en 6 sujetos del sexo masculino, quienes en un caso fueron alimentados con 6 g de nitrógeno de arroz (446 g), y en el otro con 8 g de nitrógeno de arroz (595 g), ya fuese solo o reemplazado en parte por carne de pollo. Los resultados se aprecian en el Cuadro No. 23. Los tratamientos dietéticos fueron: 100% de nitrógeno de arroz en las combinaciones siguientes: 85% de arroz y 15% de carne de pollo, y 70% de arroz y 30% de carne de pollo, respectivamente. A bajos niveles de ingesta de nitrógeno, el promedio de balance nitrogenado aumentó cuando el 85% del nitrógeno se derivaba del arroz, y el 15% del pollo. Sin embargo, este incremento careció de significado estadístico. A niveles altos de ingesta de nitrógeno, el reemplazo parcial de nitrógeno de arroz, por nitrógeno de pollo no tuvo ningún efecto, aunque sí se constató un efecto significativo del nivel del N ingerido sobre el N retenido. Los autores explican esa falta de significación estadística en base a que 6 u 8 g de nitrógeno de arroz bastan para suplir la lisina necesaria para satisfacer los requerimientos de este aminoácido en adultos jóvenes. Estos resultados concuerdan con los informados por Chen et al. (27).

COMPARACION ENTRE EL ARROZ Y EL MAIZ

El arroz es una fuente proteínica más adecuada que el maíz según lo indica la comparación de balances promedio de nitrógeno de sujetos alimentados con 6 g de nitrógeno proveniente de cualquiera de las dos fuentes (Cuadro No. 24). De acuerdo con Kies, Williams y Fox (31-33), 6 g de nitrógeno de maíz dan una retención nitrogenada de -0.50 g/día, mientras que la misma cantidad de nitrógeno de arroz da un balance de nitrógeno con un valor de -0.01 g/día. A este nivel de ingesta de nitrógeno, el arroz contiene mayores cantidades de lisina y triptofano que el maíz, aminoácidos éstos que son los limitantes en este cereal. Con base en estos datos, se ha estimado que cerca de 7 g de nitrógeno de maíz son necesarios para obtener una retención de nitrógeno igual a la producida por 6 g de nitrógeno de arroz. A estos niveles de ingesta de nitrógeno la ingesta de aminoácidos esenciales limitantes es prácticamente la misma. En base al contenido proteínico de cada cereal, para lograr un equilibrio de nitrógeno se necesitan 550 g de maíz y casi la misma cantidad de arroz, a causa del menor contenido de nitrógeno que el arroz tiene en comparación con el maíz. Es importante pues, que estos datos se tomen en consideración, sobre todo desde el ángulo económico. Por consiguiente, sería ventajoso seleccionar genéticamente variedades de arroz con un mayor contenido de proteína.

Estudios en Niños

Al igual que en el caso de los adultos, el número de estudios llevados a cabo en niños para evaluar la calidad de las proteínas del arroz, son muy limitados. En 1964 Parthasarathy *et al.* (34) publicaron los resultados de un estudio de balance de nitrógeno que dichos investigadores llevaron a cabo en niñas comprendidas entre los 8 y 9 años de edad, y cuyo peso promedio era de 18 a 23 kg.

Se les proporcionó 1.3 g de proteína de arroz libre de suplemento, y de arroz enriquecido con varios suplementos de aminoácidos, con los resultados que se muestran en el Cuadro No. 25. Según se observa, los valores indican que no se obtuvo ninguna mejoría en la calidad de la proteína con la adición individual de lisina o metionina, y que cuando ambos aminoácidos fueron agregados juntos sí se logró cierta mejoría, aunque pequeña. Por otro lado, la adición simultánea de lisina y treonina mejoró la calidad de la proteína del arroz, y aún más cuando a éstos se agregó metionina. Los autores llegaron a la conclusión de que 1.3 g de proteína de arroz/kg/día satisfacen todos los requerimientos de aminoácidos esenciales de los niños. Cuando también se toma en cuenta la proteína digerible, ésta se torna limitante en lisina. La proteína neta disponible, es decir, el producto resultante de la utilización neta de la proteína y de la ingesta proteínica, dio un valor de 0.71 g/kg para el arroz solo, cifra que es igual al requerimiento proteínico mínimo que establece la proteína de referencia de la FAO, esto es, 0.6 gramos. A partir de sus hallazgos Parthasarathy et al. de nuevo concluyeron que la proteína del arroz es deficiente en lisina, treonina y metionina, deficiencias que también lograron establecerse a través de sus experimentos con animales.

Un estudio del INCAP (35), cuyos resultados se exponen en el Cuadro No. 26, reveló que a niveles de una ingesta de proteína de arroz de 2.0 ó 1.6 g/kg/día, la adición de lisina induce una mayor mejoría en la calidad de la proteína del arroz. El agregado de metionina y treonina al arroz ya

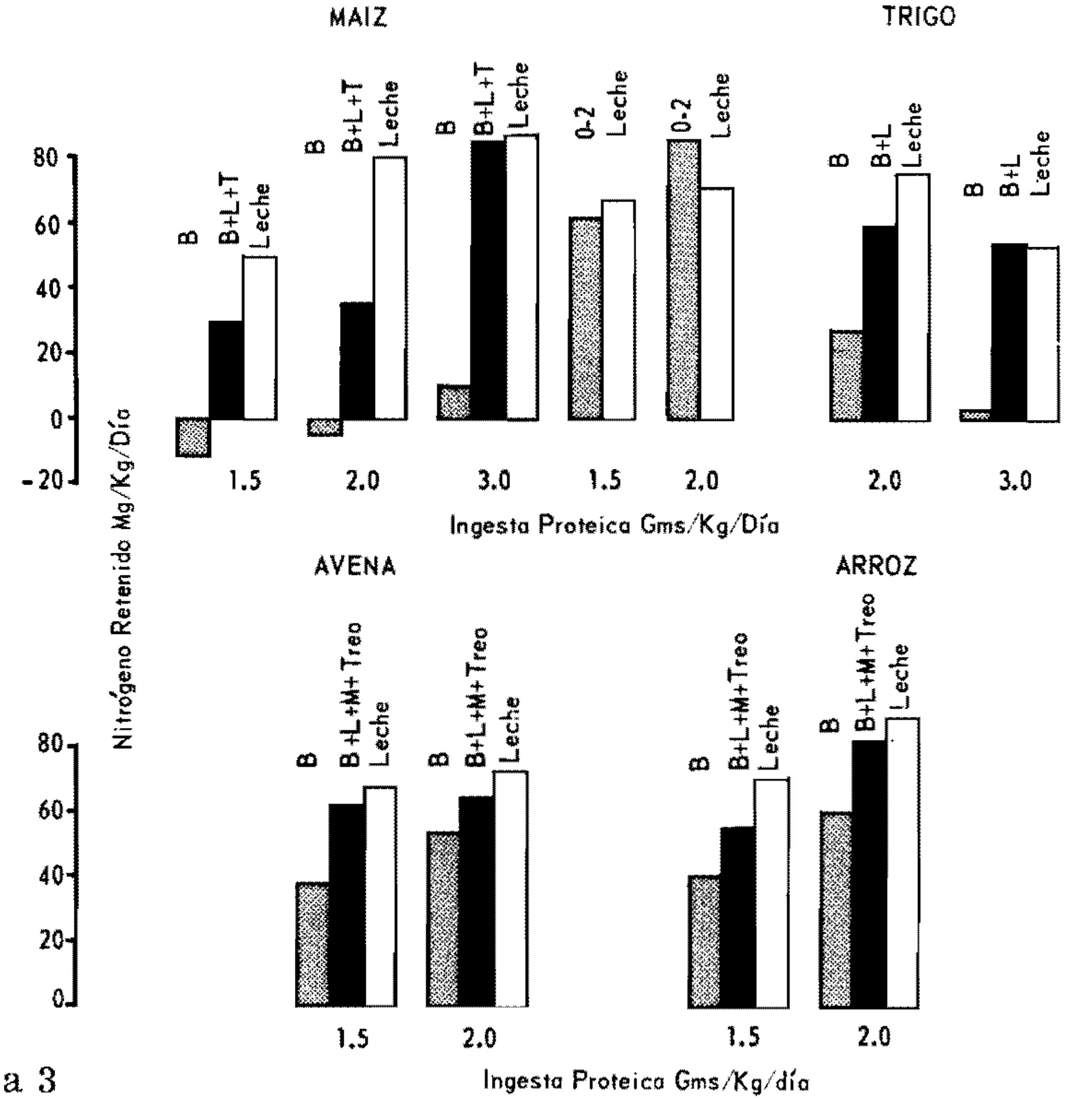

Figura 3

Incap 70-112

suplementado con lisina, indujo únicamente pequeños incrementos por encima de los obtenido mediante la suplementación con lisina. En general, estos resultados concuerdan con los hallazgos de otros investigadores.

Si se da por sentado que la metodología empleada por los diversos investigadores es adecuada, las diferencias obtenidas en cuanto a respuesta a la suplementación con aminoácidos podrían deberse a variaciones en los requerimientos de los propios sujetos. Sin embargo, no debe descartarse la posibilidad de posibles diferencias en el contenido de aminoácidos de las muestras de arroz usadas en el curso de los experimentos.

Comparación Entre el Arroz y Otros Cereales

La calidad proteínica de varios cereales libres de suplementación, y con el agregado de sus aminoácidos limitantes - según pruebas efectuadas en niños - se resume en la Figura 3 (36-41). Las barras muestran el nitrógeno retenido a la ingesta de nitrógeno que se indica en la parte inferior de la Gráfica. Según se observa, la proteína del arroz por sí sola es tan buena como las derivadas de la avena y del maíz opaco-2, mientras que las proteínas de la harina de trigo y del maíz común son de calidad inferior. La adición de los aminoácidos limitantes induce una mejora en la calidad proteínica, pero ésta no llega a los valores obtenidos con las proteínas de leche. La razon más probable de esta observación puede atribuirse a la digestibilidad de la proteína, la cual es inferior a la de la proteína de los cereales. Es de interés señalar que los resultados expuestos corroboran los hallazgos en animales de experimentación.

La digestibilidad de la proteína del arroz, en comparación con la de otros cereales, amerita algunos comentarios. En el Cuadro No. 27 se dan a conocer los resultados obtenidos en niños que recibieron dos o tres niveles de proteína proveniente de cuatro cereales. Como los datos lo revelan, el nitrógeno fecal es más alto cuando la ingesta de nitrógeno también es alta, incluso en el caso de las proteínas de la leche. Cuando el nitrógeno fecal se expresa como por ciento de la ingesta de nitrógeno, el valor obtenido es mayor en el caso de todas las proteínas a medida que la ingesta de nitrógeno aumenta, salvo en lo que respecta a la proteína de la harina de trigo. El nitrógeno absorbido, esto es, la diferencia entre el N ingerido y el N fecal - expresado como porcentaje de la ingesta de nitrógeno - muestra una relación inversa con la ingesta de nitrógeno en el caso de todas las proteínas, exceptuando la harina de trigo.

Aún cuando es difícil explicar la forma diferente en que la harina de trigo se comporta frente a los otros alimentos, la digestibilidad de la proteína del arroz es más baja que la de harina de trigo y la de leche, y similar a la del maíz y la avena. La relación negativa entre la ingesta de nitrógeno y el nitrógeno fecal expresado como nitrógeno absorbido, era de esperar. Sin embargo, lo que no se contemplaba es el hecho de que la digestibilidad de la proteína del arroz fuese similar a la del maíz, ya que el arroz es de calidad proteínica superior al maíz.

La menor digestibilidad de la proteína del arroz fue observada también en animales de experimentación (42), tal como se indica en el Cuadro No. 28. Como en el caso de los niños, la digestibilidad del arroz fue similar a la del maíz, e inferior a la determinada para la avena y la harina de trigo. Evidentemente, todos estos resultados son significativos y dignos de atención, ya que señalan la necesidad de impulsar el desarrollo de un arroz de mejor calidad proteínica para consumo humano.

CONCLUSION

La información expuesta en este trabajo indica que con la excepción de unos cuantos países, el consumo de arroz en Latino América no es tan elevado como el de maíz o trigo. Ello se debe a varias razones, algunas posiblemente de índole cultural, pero se tiene la impresión de que hay también otros motivos, por ejemplo, el costo más alto del arroz y la escasa disponibilidad de alimentos que comúnmente se consumen junto con el arroz. El frijol, por ejemplo, también amerita consideración.

Desde el punto de vista químico y en comparación con otros cereales, la principal desventaja del arroz radica en su bajo contenido proteínico, el cual fluctúa entre 6 y 8%. Esta proteína es de mejor calidad que la del maíz, el sorgo, y la harina de trigo. Tanto en el caso de animales de experimentación como de seres humanos, los aminoácidos deficientes son lisina, treonina y probablemente también, metionina. No obstante, el arroz contiene mayores niveles de lisina que otros cereales.

Al igual de lo que sucede con la proteína de otros cereales, la calidad de la proteína del arroz es susceptible de mejorar mediante la adición de los aminoácidos en los cuales es deficiente, o bien por el agregado de pequeñas cantidades de concentrados proteínicos. Estos hallazgos han servido de base para la formulación de mezclas de fortificación de arroz en forma de granos sintéticos, que si se usan, pueden no sólo mejorar la calidad de la proteína, sino también aportar proteína adicional.

La aplicación de estas medidas permitiría corregir las limitaciones nutricionales inherentes a las proteínas del arroz, es decir, sus deficiencias de aminoácidos y su contenido proteínico total.

La calidad de la proteína proveniente de mezclas de arroz y de frijol, alimentos de uso muy común en América Latina, es más alta que la de mezclas similares de otros cereales con frijol. Se estima que por su calidad nutricional, una mayor disponibilidad, y el consumo más frecuente de arroz con frijol, podría ser un instrumento muy útil para combatir la desnutrición proteínico-calórica, sobre todo si el arroz tuviese un mayor contenido de proteína, y si este cereal se consumiera combinado con frijol. Esta medida podría traer consigo mayores beneficios para las poblaciones jóvenes, puesto que el arroz por sí solo satisface las necesidades de aminoácidos de las poblaciones adultas.

Obviamente, esta afirmación no significa que para los adultos el consumo de arroz con frijol no sea mejor que el de solo arroz; todo lo contrario, el consumo de esta combinación debe estimularse a fin de lograr un mayor grado en su eficiencia de utilización.

La evidencia colectada indica, por lo tanto, que deben hacerse esfuerzos por aumentar la disponibilidad del arroz en América Latina. Sin embargo, también se cree que los esfuerzos agronómicos que se inicien en este sentido deben tomar en cuenta las limitaciones nutricionales de ese cereal, a fin de que el arroz pueda transformarse en uno, no sólo de mejor balance, sino cuyo consumo permita a nuestros pobladores tener un estómago lleno y una mejor nutrición.

REFERENCIAS

1. *Evaluación Nutricional de la Población de Centro América y Panamá. Guatemala.* Instituto de Nutrición de Centro América y Panamá (INCAP); Oficina de Investigaciones Internacionales de los Institutos Nacionales de Salud (EEUU); Ministerio de Salud Pública y Asistencia Social. Guatemala, Instituto de Nutrición de Centro América y Panamá, 1969, 136 p p y 5 apéndices.

2. *Evaluación Nutricional de la Población de Centro América y Panamá. El Salvador.* Instituto de Nutrición de Centro América y Panamá (INCAP); Oficina de Investigaciones Internacionales de los Institutos Nacionales de Salud (EEUU); Ministerio de Salud Pública y Asistencia Social. Guatemala, Instituto de Nutrición de Centro América y Panamá, 1969, 142 pp y 5 apéndices.

3. *Evaluación Nutricional de la Población de Centro América y Panamá. Nicaragua.* Instituto de Nutrición de Centro América y Panamá (INCAP); Oficina de Investigaciones Internacionales de los Institutos Nacionales de Salud (EEUU); Ministerio de Salud Pública y Asistencia Social. Guatemala, Instituto de Nutrición de Centro América y

Panamá, 1969, 110 pp y 5 apéndices.

4. Evaluación Nutricional de la Población de Centro América y Panamá. Costa Rica. Instituto de Nutrición de Centro América y Panamá (INCAP); Oficina de Investigaciones Internacionales de los Institutos Nacionales de Salud (EEUU); Ministerio de Salud Pública y Asistencia Social. Guatemala, Instituto de Nutrición de Centro América y Panamá, 1969. 113 pp y 5 apéndices.

5. Evaluación Nutricional de la Población de Centro América y Panamá. Honduras. Instituto de Nutrición de Centro América y Panamá (INCAP); Oficina de Investigaciones Internacionales de los Institutos Nacionales de Salud (EEUU); Ministerio de Salud Pública y Asistencia Social. Guatemala, Instituto de Nutrición de Centro América y Panamá, 1969, 124 pp y 5 apéndices.

6. Evaluación Nutricional de la Población de Centro América y Panamá. Panamá. Instituto de Nutrición de Centro América y Panamá (INCAP); Oficina de Investigaciones Internacionales de los Institutos Nacionales de Salud (EEUU); Ministerio de Salud Pública. Guatemala, Instituto de Nutrición de Centro América y Panamá, 1969, 117 pp y 5 apéndices.

7. Food and Agriculture Organization of the United Nations. Food Balance Sheets, 1960-1962 (Average). Rome, Italy, FAO, 1966.

8. Van Veen, A.G., D.C.W. Graham and K.H. Stenkraus. Fermented rice, a food from Ecuador. Arch. Latinoamer. Nutr., 18:363-373, 1968.

9. Bressani, R., A. Aguirre, L.G. Elías, R. Arroyave, R. Jarquín and N.S. Scrimshaw. All-vegetable protein mixtures for human feeding. IV. Biological testing of INCAP Vegetable Mixture Nine in chicks. J. Nutrition, 74:209-216, 1961.

10. Bressani, R., L.G. Elías and N.S. Scrimshaw. All-vegetabl protein mixtures for human feeding. VII. Biological testing of INCAP Vegetable Mixture Nine in rats. J. Food Sci., 27:203-209, 1962.

11. Mertz, E.T., O.A. Veron, L.S. Bates and O.E. Nelson. Growth of rats fed on opaque-2 maize. Science, 148: 1741, 1965.

12. Bressani, R.,L.G. Elías and R.A. Gómez Brenes. Protein quality of opaque-2 corn. Evaluation in rats. J. Nutrit

97:173-180, 1969

13. Mertz, E.T., L.S. Bates and O.E. Nelson. Mutant gene that changes protein composition and increases lysine content of maize endosperm. Science, 145:279, 1964.

14. Bressani, R. and A.T. Valiente. All-vegetable protein mixtures for human feeding. VII. Protein complementation between polished rice and cooked black beans. J. Food Science, 27:401-406, 1962.

15. Bressani, R., A.T. Valiente, and C.E. Tejada. All-vegetable protein mixtures for human feeding. VI. The value of combinations of lime-treated corn and cooked black beans. J. Food Science, 27:394, 1962.

16. Pecora, L.J. and J.M. Hundley. Nutritional improvement of white polished rice by the addition of lysine and threonine. J. Nutrition, 44:101, 1951.

17. Harper, A.E., M.E. Winje, D.A. Benton and C.A. Elvehjem. Effect of amino acid supplements on growth and fat deposition in the livers of rats fed polished rice. J. Nutrition, 56:198, 1955.

18. Deshpande, P.D., A.E. Harper, F. Quirós-Pérez and C.A. Elvehjem. Further observations on the improvement of polished rice with protein and amino acid supplements. J. Nutrition, 57:415-428, 1955.

19. Rosenberg, H.R. and R. Culik. The improvement of the protein quality of white rice by lysine supplementation. J. Nutrition, 63:477-487,1957.

20. Rosenberg, H.R., H.R. Culik and R.E. Eckert. Lysine and threonine supplementation of rice. J. Nutrition, 69:217-228, 1959.

21. Kik, M.C. Nutritional improvement of rice diets and effect of rice on nutritive value of other foodstuffs. Fayetteville, University of Arkansas, April, 1965 (Bull. 698 Agr. Exp. Sta. Div. Agric).

22. Elías, L.G., R. Jarquín, R. Bressani y C. Albertazzi. Suplementación del arroz con concentrados proteicos. Arch. Latinoamer. Nutr., 18:27-38, 1968.

23. Bressani, R. and E. Marenco. The enrichment of lime-treated corn flour with proteins, lysine and tryptophan and vitamins. J. Ag. Food. Chem., 11:517-522, 1963.

24. Jarquín, R., P. Noriega y R. Bressani. Enriquecimiento de harinas de trigo, blanca e integral, con suplementos de origen animal y vegetal. _Arch. Latinoamer. Nutr._, _16_: 89-103, 1966.

25. Gómez Brenes, R. Enriquecimiento de los cereales con proteínas y aminoácidos, o ambos. Aspectos nutricionales. En: _Recursos Proteínicos en América Latina_. (Capítulo IV). M. Béhar and R. Bressani (Eds.). Memorias de una conferencia de nivel latinoamericano celebrada en el Instituto de Nutrición de Centro América y Panamá (INCAP). Ciudad de Guatemala, del 24 al 27 de febrero de 1970. Guatemala, C.A., INCAP, agosto de 1971, pp 333-352.

26. Hundley, J.M., H.R. Sandstead, A.G. Sampson, and G.D. Whedon. Lysine, threonina and other amino acids as supplements to rice diets in man: amino acid imbalance. _Am. J. Clin. Nutr._, 5:316-326, 1957.

27. Chen, S.C., H.M. Fox and C. Kies. Nitrogenous factors affecting the adequacy of rice to meet the protein requirements of human adults. _J. Nutrition_, _92_:429-434, 1967.

28. Clark, H.E., J.M. Howe and Chung-Ja Lee. Nitrogen retention of adult human subjects fed a high protein rice. Am. J. Clin. Nutr., 24:324-328, 1971.

29. Bressani, R., L.G. Elías and B.O. Juliano. Evaluation of the protein quality of milled rice differing in protein content. J. Agr. Food Chem. In press.

30. Lee, Chung-Ja, J.M. Howe, K. Carloson and H.E. Clark. Nitrogen retention of young men fed rice with and without supplementary chicken. Am. J. Clin, Nutr., 24:318-323, 1971.

31. Kies, C., E. Williams and H.M. Fox. Determination of first limiting nitrogenous factor in corn protein for nitrogen retention in human adults. J. Nutrition, 86: 350-356, 1965.

32. Kies, C., E. Williams and H.M. Fox. Effect of non-specific nitrogen intake on adequacy of cereal proteins for nitrogen retention in human adults. J. Nutrition, 86:357-361, 1965.

33. Kies, C., H.M. Fox and E.R. Williams. Effect of non-specific supplementation on minimum corn protein

requirements and first-limiting amino acid for adult men. J. Nutrition, 92:377-383, 1967.

34. Parthasarathy, H.N., K. Joseph, V.A. Daniel, T.R. Doraiswamy, A.N. Sankaran, M. Narayana Rao, M. Swaminathan. The effect of supplementation of a rice diet with lysine, methionine and threonine on the digestibility coefficient, biological value and net protein utilization of the proteins and on the retention of nitrogen in children. Canad. J. Biochem., 42:385-394, 1964.

35. Bressani, R., D.M. Wilson, F. Viteri, L. Mosovich and J. Alvarado. Effect of amino acid supplementation of white rice fed to children. Arch. Latinoamer. Nutr., In press.

36. Scrimshaw, N.S., R. Bressani, M. Béhar and F. Viteri. Supplementation of cereal protein with amino acids. I. Effect of amino acid supplementation of corn masa at high levels of protein intake on the nitrogen retention of young children. J. Nutrition, 66:485-499, 1958.

37. Bressani, R., N.S. Scrimshaw, M. Béhar and F. Viteri. Supplementation of cereal proteins with amino acids.

II. Effect of amino acid supplementation of corn masa at intermediate levels of protein intake on the nitrogen retention of young children. J. Nutrition, 66:501-513, 1958.

38. Bressani, R., D.L. Wilson, M. Béhar and N.S. Scrimshaw. Supplementation of cereal proteins with amino acids. III. Effect of amino acid supplementation of wheat flour as measured by nitrogen retention of young children. J. Nutrition, 70:176-186, 1960.

39. Bressani, R., D.L. Wilson, M. Béhar, M. Chung and N.S. Scrimshaw. Supplementation of cereal proteins with amino acids. IV. Lysine supplementation of wheat flour fed to young children at different levels of protein intake in the presence or absence of other amino acids. J. Nutrition, 79:333-339, 1963.

40. Bressani, R., D.L. Wilson, M. Chung, M. Béhar and N.S. Scrimshaw. Supplementation of cereal proteins with amino acids. V. Effect of supplementing lime-treated corn with different levels of lysine, tryptophan and isoleucine on the nitrogen retention of young children. J. Nutrition, 80:80-84, 1963.

41. Bressani, R., D.L. Wilson, M. Chung, M. Béhar and N.S. Scrimshaw. Supplementation of cereal proteins with amino acid supplementation of rolled oats as measured by nitrogen retention of young children. J. Nutrition, 81:399-404, 1963.

42. INCAP. Unpublished data.

CUADRO No. 1

CONSUMO DE ARROZ Y OTROS CEREALES EN EL ISTMO CENTROAMERICANO

País	Arroz		Otros Cereales	
	Ingesta/persona/día			
	Rural	Urbana	Rural	Urbana
Guatemala	16	27	547	306
Salvador	27	55	560	320
Honduras	29	50	365	293
Nicaragua	54	80	255	168
Costa Rica	100	103	128	121
Panamá	186	150	82	87

CUADRO No. 2

CONSUMO DE CEREALES EN PAISES DE AMERICA DEL SUR Y MEXICO*

(expresado en g/persona/día)

País	Arroz	Trigo	Maíz	Avena	Todos los cereales salvo arroz
Argentina	11.4	238.6	----	----	238.6
Bolivia	20.6	104.2	119.1	1.4	246.7
Brasil	120.9	74.9	100.2	0.9	177.9
Chile	21.7	300.4	1.0	3.5	306.6
Colombia	53.5	28.4	122.3	0.7	152.9
Ecuador	55.8	50.3	65.0	1.8	133.6
Paraguay	15.5	100.8	90.1	----	190.9
Perú	64.7	99.3	73.5	----	208.3
Uruguay	26.6	245.3	2.1	1.1	248.5
Venezuela	23.9	100.9	108.4	5.0	215.2
México	14.7	62.4	271.7	0.2	334.3
China (Taiwan)	371.4	64.0	3.0	----	68.3
Islas Filipinas	238.5	1.9	59.2	----	85.8

* FAO Food Balance Sheets, 1960-1962 (7).

CUADRO No. 3

CONSUMO DE ARROZ EN PAISES DE AMERICA DEL SUR *

País	Consumo *per capita*			Ingesta total	
	g/día	Cal/día	Proteína/g/día	Cal/día	Proteína/g/
Argentina	11.4	4	0.8	2820	81.6
Bolivia	20.6	74	1.4	1840	47.9
Brasil	120.9	435	8.1	2780	66.3
Chile	21.7	78	1.5	2410	77.2
Colombia	53.5	193	3.6	2160	51.9
Ecuador	55.8	201	3.7	1890	48.4
Paraguay	15.5	56	1.0	2560	64.1
Perú	64.7	233	4.3	2230	55.9
Uruguay	26.6	96	1.8	3220	104.3
Venezuela	23.9	86	1.6	2310	58.7
China (Taiwan)	371.4	1336	25.3	2350	58.5
Islas Filipinas	238.5	876	17.5	1840	44.3

* FAO FOOD BALANCE SHEETS, 1960-1962 (7).

CUADRO No. 4

COMPOSICION QUIMICA Y CONTENIDO VITAMINICO DE CUATRO CEREALES (%)

Componente	Arroz	Maíz	Trigo	Avena
Humedad	12.0	10.6	12.0	8.3
Proteína	7.2	9.4	11.8	14.2
Grasa	0.6	4.3	1.2	7.4
Ceniza	0.5	1.3	0.5	1.9
Fibra cruda	0.6	1.8	0.4	1.2
Carbohidratos solubles	79.7	74.4	74.5	68.2
Calorías	364	361	365	390
Tiamina, mg	0.08	0.43	0.12	0.60
Riboflavina, mg	0.03	0.10	0.07	0.14
Niacina, mg	1.6	1.9	1.4	1.0

CUADRO No. 5

CONTENIDO DE AMINOACIDOS ESENCIALES DE VARIOS CEREALES

(expresado en g/16 g N)

Aminoácido	Arroz	Maíz	Harina de trigo	Avena	Proteína leche
Isoleucina	4.89	4.62	4.19	4.82	6.51
Leucina	7.84	12.96	7.02	6.99	10.02
Lisina	4.27	2.88	2.08	3.42	7.94
Aminoácidos azufrados totales	3.45	3.15	3.02	3.41	3.41
Fenilalanina	5.55	4.54	5.01	4.98	4.94
Treonina	4.10	3.98	2.62	3.09	4.70
Triptofano	1.35	0.61	1.12	1.20	1.44
Valina	6.24	5.10	3.94	5.55	7.01

CUADRO No. 6

CONTENIDO DE AMINOACIDOS ESENCIALES DEL ARROZ Y DEL MAIZ

OPACO-2

(expresado en g/16 g N)

Aminoácido	Arroz	Maíz Opaco-2
Isoleucina	4.89	3.10
Leucina	7.84	8.12
Lisina	4.27	4.10
Aminoácidos azufrados totales	3.45	3.01
Fenilalanina	5.55	4.27
Treonina	4.10	3.18
Triptofano	1.35	1.26
Valina	6.24	4.77

CUADRO No. 7

CALIDAD PROTEINICA DEL ARROZ Y OTROS CEREALES SEGUN PRUEBAS EN RATAS RECIEN DESTETADAS

Cereal	Nivel usado en la dieta g/100 g	Promedio de ganancia ponderal, g	PER
Arroz	90.0	43	2.15
Maíz	82.4	13	0.87
Trigo (Bulgur)	55.2	19	1.05
Avena	47.5	34	1.60
Sorgo	78.6	12	0.88
Caseína	7.7	75	2.71

CUADRO No. 8

CALIDAD NUTRICIONAL DE LA PROTEINA DEL ARROZ Y DE OTROS CEREALES

Cereales	Proteína en la dieta, %	Promedio de ganancia ponderal, g	Valor nutritivo relativo %	PER	Proteína utilizable g %
Arroz	6.9	43	58.2	2.15	4.01
Maíz	8.5	19	28.4	1.05	2.41
Trigo (Bulgur)	11.0	50	38.7	1.43	4.26
Avena	13.8	125	59.6	2.20	8.22
Sorgo	7.7	21	29.0	1.07	2.23
Caseína	10.7	124	75.0	2.77	8.02

CUADRO No. 9

CALIDAD PROTEINICA DEL ARROZ Y DE OTROS CEREALES EN PERROS SEMIADULTOS*

Cereal	Nitrógeno					
	Ingerido	Fecal	Urinario	Absorbido	Balance	b
	mg/kg/día					
Arroz	243	80	119	163	+ 44	
Maíz	225	72	181	153	- 28	
Harina de trigo	226	48	182	178	- 4	
Avena	225	39	180	186	+ 6	

* Promedio de tres perros semiadultos/cereal.

CUADRO No. 10

COMPARACION DEL VALOR NUTRITIVO DE VARIOS CEREALES CON 10% DE FRIJOL NEGRO

a	Proteína en la dieta %	Promedio de ganancia ponderal, g*	PER	Valor nutritivo relativo %	Proteína utilizable g %
z + frijoles	7.9	56	2.32	62.8	4.96
+ frijoles	10.3	33	1.47	39.8	4.10
ɔ + frijoles	8.6	41	1.69	45.7	3.93
ɔ + frijoles	12.0	84	1.83	49.5	5.94
a + frijoles	14.6	121	2.21	59.8	8.73

eso promedio inicial: 42 g.

CUADRO No. 11

CALIDAD PROTEINICA DE UNA MEZCLA DE 90% DE CEREAL Y 10% DE FRIJOL, ADMINISTRADA A UNA MISMA INGESTA DE PROTEINA

Dieta	Promedio de ganancia ponderal, g *	PER
Arroz + frijoles	56	2.32
Maíz + frijoles	32	1.40
Sorgo + frijoles	30	1.39
Trigo + frijoles	41	1.73
Avena + frijoles	75	2.37

* Peso promedio inicial: 42 g.

CUADRO No. 12

EFECTO DE LA ADICION DE FRIJOL A DIETAS DE CEREALES SOBRE LA GANANCIA PONDERAL Y EL PER

Dieta	Promedio de ganancia ponderal, g	Cambio	PER	Cambio
Arroz	43	+13 (30%)	2.15	0.17 (8%)
Arroz + frijoles	56		2.32	
Maíz	19	+14 (74%)	1.05	0.42 (40%)
Maíz + frijoles	33		1.47	
Trigo	50	+34 (68%)	1.43	0.40 (28%)
Trigo + frijoles	84		1.83	

CUADRO No. 13

VALOR NUTRITIVO DE COMBINACIONES DE ARROZ Y FRIJOL SEGUN PRUEBAS EN ANIMALES DE EXPERIMENTACION

Distribución de la proteína en la dieta		Promedio de ganancia ponderal, g	PER
Derivada del arroz	Derivada de frijoles		
100	0	39	2.25
80	20	53	2.62
70	30	51	2.53
60	40	52	2.52
50	50	51	2.52
40	60	46	2.27
20	80	18	1.19
0	100	-2	----
Caseína	-	79	3.40

Tomada de: Bressani, R. y T. Valiente (14).

CUADRO No. 14

SUPLEMENTACION CON AMINOACIDOS DE UNA DIETA DE ARROZ Y FRIJOL CON LA MISMA DISTRIBUCION PROTEINICA

Aminoácidos adicionados a la dieta de arroz y frijol	Promedio de ganancia ponderal, g	PER	Eficiencia del alimento
Ninguno	63	2.66	5.30
+ metionina (0.14%)	73	2.87	4.90
+ metionina (0.14%) + treonina (0.10%)	76	2.94	4.76
+ metionina (0.14%) + treonina (0.10%) + lisina (0.19%)	97	3.32	3.82
+ metionina (0.14%) + treonina (0.10%) + lisina (0.19%) + leucina (0.21%)	105	3.48	3.82

Tomado de: Bressani, R. y T. Valiente (14).

CUADRO No. 15

EFECTO DE DIETAS CON 90% DE ARROZ, SUPLEMENTADAS CON LISINA Y TREONINA, SOBRE EL CRECIMIENTO DE RATAS

L-lisina HCl %	DL-treonina %	Ganancia ponderal g/5 semanas
-	-	57
0.1	-	78
0.1	0.1	112
0.1	0.2	138
0.1	0.3	114
0.2	0.3	151
——	——	——
0.2	0.1	136
0.25	0.1	152
0.3	0.1	131
0.3	0.2	154

Tomado de: Rosenberg, H.R., H.R. Culik y R.E. Eckert (20).

CUADRO No. 16

EFECTO DE LA SUPLEMENTACION PROTEINICA DEL ARROZ

Suplemento	Nivel adicionado %	Promedio de ganancia ponderal, g	Indice de eficiencia proteínica
Ninguno	-	28	1.73
Harina de semilla de algodón	8	93	2.29
Harina de soya	8	116	2.88
Levadura torula	8	108	3.29
Concentrado proteínico de pescado	6	140	2.70
Caseína	4	151	3.35
Leche descremada en polvo	12	135	3.16

CUADRO No. 17

EFECTO DE LA SUPLEMENTACION PROTEINICA DEL ARROZ, HARINA DE TRIGO Y MAIZ

Suplemento	Arroz		Harina de trigo		Maíz	
	Ganancia ponderal g	PER	Ganancia ponderal g	PER	Ganancia ponderal g	PER
Ninguno	25	1.71	22	0.87	12	0.82
Harina de semilla de algodón, 8%	93	2.29	64	1.62	68	1.79
Harina de soya, 8%	116	2.88	95	1.75	96	2.23
Leche descremada en polvo, 8%	102	2.82	110	2.06	104	2.63
Leche descremada en polvo, 10%	117	2.79	127	2.19	125	2.43

CUADRO No. 18

SUPLEMENTACION DEL ARROZ CON GRANOS SIMULADOS DE ARROZ*

Dieta	Proteína en la dieta %	Promedio de ganancia ponderal, g**	PER
Arroz	7.2	45	1.94
+ 1% de arroz simulado	7.3	86	3.04
+ 2% de arroz simulado	7.6	108	3.32
+ 3% de arroz simulado	7.7	103	3.29

* El arroz simulado contiene 75.59% de L-lisina HCl, 15.12% de L-treonina y vitaminas.

** Peso promedio inicial: 45 g.

CUADRO No. 19

BALANCE PROMEDIO DE NITROGENO DE DOS SUJETOS ALIMENTADOS CON PROTEINA DE ARROZ, SOLO, Y SUPLEMENTADO CON AMINOACIDOS

Dieta sometida a prueba	Sujeto W.M. (g N / día)	Sujeto V.L. (g N / día)	Ambos
Dieta control	+0.52	-1.14	-0.31
Arroz	-1.16	-2.34	-1.75
Arroz + lisina + treonina	+0.07	-1.17	-0.55
Arroz + lisina + treonina + metionina	+0.22	-0.41	-0.10
Arroz	+0.10	-0.64	-0.27
Arroz + aminoácidos no esenciales	+0.57	-	+0.57
Dieta control (95 g de proteína)	+3.91	-	+3.91

Tomado de: Hundley *et al.* (26).

CUADRO No. 20

BALANCE PROMEDIO DE NITROGENO DE SUJETOS HUMANOS ALIMENTADOS CON ARROZ, SOLO Y SUPLEMENTADO CON DIVERSOS COMPUESTOS NITROGENADOS

Dieta administrada	Balance de nitrógeno g/día	Dieta administrada	Balance de nitrógeno g/día
5 g N de arroz	-0.01	Arroz	-0.38
5 g N de arroz + 2 g N (NNE)	-0.13	+ aminoácidos	0.15
6 g N de arroz + 2 g N de aminoácidos	0.23	+ lisina	0.14
		+ treonina	0.32
5 g N de arroz + 6 g N (NNE)	0.25	+ lisina + treonina	0.26

Tomado de: Chen, S.C. y C. Kies (27).

NNE = Nitrógeno no específico.

CUADRO No. 21

BALANCE PROMEDIO DE NITROGENO DE SUJETOS ADULTOS ALIMENTADOS CON DIETAS DE ARROZ DE NIVEL PROTEINICO ALTO Y BAJO

Dieta administrada	Nitrógeno, g/día			Digestibilidad %
	Orina	Heces	Balance	
480 g de arroz BPI 12.06 g N	8.00	2.65	1.41	78.0
480 g de arroz BB 6.72 g N	4.92	1.55	0.24	76.9
480 g de arroz BB + nitrógeno	9.92	1.66	0.48	86.4
320 g de arroz BB + nitrógeno 6.72 g N	5.89	1.41	-0.58	79.1

Tomado de: Clark, H.E., J.M. Howe y Chung-Ja Lee (28).
BPI = Arroz de alto contenido proteínico desarrollado por el Instituto Internacional de Investigación de Arroz (IRRI).

BB = Arroz Blue Bonnet.

CUADRO No. 22

CALIDAD PROTEINICA DE VARIEDADES DE ARROZ DE CONTENIDO PROTEINICO DIFERENTE

Variedad de arroz	Contenido proteínico %	Regresión de la ingesta proteínica sobre la ganancia ponderal	Calidad relativa de la proteína en relación a la caseína, %
INTAN	5.7	Y = -14.05 + 3.49 x	110.4
IR 8	7.3	Y = -14.35 + 3.25 x	100.0
IR 8	9.7	Y = -15.46 + 3.04 x	91.4
Caseína	87.7	Y = -14.44 + 3.23 x	100.0
BPI-76-1	14.3	Y = -11.1 + 2.78 x	72.4
Caseína	87.7	Y = -10.7 + 3.63 x	100.0

Tomado de: Bressani, R., L.G. Elías y B.O. Juliano (29).

CUADRO No. 23

EFECTO DEL REEMPLAZO PARCIAL DE NITROGENO DE ARROZ POR NITROGENO DE CARNE DE POLLO SOBRE EL BALANCE NITROGENADO DE SUJETOS ADULTOS JOVENES

Distribución de ingesta de N		Nitrógeno, g / día		
Arroz g	Pollo g	Orina	Heces	Balance
6	0	4.82	1.32	0.18
5.1	0.9	4.79	1.15	0.39
4.2	1.8	4.88	1.14	0.30
8	0	5.78	1.46	1.07
6.8	1.2	6.01	1.42	0.89
5.6	2.4	5.98	1.31	1.04

Tomado de: Lee, Chun-Ja *et al*. (30).

CUADRO No. 24

BALANCE DE NITROGENO DE SUJETOS ADULTOS ALIMENTADOS CON MAIZ O ARROZ COMO FUENTE UNICA DE PROTEINA

Nivel de nitrógeno de maíz en la dieta* g N/día	Balance de nitrógeno g/día	Nivel de nitrógeno de arroz en la dieta* g N/día	Balance de nitrógeno g/día
4	-1.00	-	-
6	-0.50	6	-0.01
8	+0.50	-	-

* Tomado de: Kies, C. *et al.* (31-33).

CUADRO No. 25

BALANCE PROMEDIO DE NITROGENO, DIGESTIBILIDAD PROTEINICA REAL,

UTILIZACION PROTEINICA NETA Y PROTEINA NETA DISPONIBLE EN

NIÑOS ALIMENTADOS CON PROTEINA DE ARROZ, SOLO

O SUPLEMENTADO CON AMINOACIDOS

Dieta	Nitrógeno g/kg		Digestibilidad proteínica real %	Utilización proteínica neta %	Proteína neta disponible g/kg
	Ingesta	Balance			
Arroz	4.11	0.39	82.6	52.9	0.71
+ metionina	4.08	0.49	84.0	55.7	0.74
+ lisina	4.22	0.53	80.4	54.8	0.76
+ lisina + metionina	4.21	0.57	80.6	55.8	0.77
Leche descremada	4.26	1.18	85.7	69.7	0.96
Arroz	4.05	0.34	82.5	54.9	0.71
+ lisina + metionina	4.22	0.80	82.0	63.4	0.85
+ lisina + metionina + treonina	4.26	0.98	81.7	67.1	0.91
Leche descremada	4.28	1.20	85.9	71.8	0.98

Tomado de Parthasarathy, H.N. *et al*. (34).

CUADRO No. 26

BALANCE PROMEDIO DE NITROGENO DE NIÑOS ALIMENTADOS CON PROTEINA DE ARROZ, SOLO Y CON EL AGREGADO DE VARIOS SUPLEMENTOS DE AMINOACIDOS

Dieta	Nitrógeno Ingesta (mg/kg/día)	Nitrógeno Balance (mg/kg/día)	Absorción % de ingesta de N	Retención % de ingesta de N
Leche	317	93	86.1	29.3
Arroz	320	60	79.1	18.7
+ lisina	320	80	79.7	25.0
+ lisina + metionina	344	74	77.3	21.5
+ lisina + metionina + treonina	349	81	78.8	23.2
+ lisina + metionina + treonina + triptofano	309	82	78.3	26.5
---	---	---	---	---
Leche	265	71	87.9	26.8
Arroz	235	40	83.8	17.4
+ lisina	249	42	79.9	17.7
+ lisina + metionina	260	68	82.3	22.7
+ lisina + metionina + treonina + triptofano	254	55	84.2	21.6

CUADRO No. 27

ABSORCION DE NITROGENO Y NITROGENO FECAL EN RELACION A LA INGESTA DE NITROGENO

	Nitrógeno Ingesta (mg/kg/día)	Nitrógeno Fecal (mg/kg/día)	% Absorbido	$\frac{NF}{IN} \times 100$
Arroz	235	38	83.8	16.2
	320	67	79.1	20.9
Maíz	238	58	75.6	24.4
	338	75	77.8	22.2
	469	128	72.7	27.3
Trigo	294	45	84.7	15.3
	335	49	85.4	14.6
	483	62	87.2	12.8
Avena	251	49	80.5	19.5
	330	68	79.4	20.6
Leche	259	36	86.1	13.9
	338	53	84.3	15.7
	464	80	82.7	17.2

CUADRO No. 28

DIGESTIBILIDAD DE LA PROTEINA DEL ARROZ Y DE OTROS CEREALES *

Cereal	Nitrógeno Ingerido mg/kg/día	Nitrógeno Fecal mg/kg/día	Nitrógeno Absorbido % de ingesta	$\frac{NF}{IN} \times 100$
Arroz	243	80	67.1	32.9
Maíz	225	72	68.0	32.0
Harina de trigo	226	48	78.8	21.2
Avena	225	39	82.7	17.3

* Promedio de tres perros semiadultos/cereal.

Leyendas de las Figuras

Figura 1: Crecimiento de ratas y calidad proteínica de combinaciones de maíz y frijol.

Figura 2: Granos de arroz natural y simulado.

Figura 3: Retención de nitrógeno de niños alimentados con cereales libres de suplemento y adicionados de sus aminoácidos limitantes, y con leche.

THE NEW HIGH-YIELDING RICE VARIETIES FOR LATIN AMERICA

Peter R. Jennings
Rice Specialist and Coordinator
Rice Production Systems, CIAT

The Green Revolution in parts of rice-producing Asia had its genesis with the establishing of the International Rice Research Institute (IRRI) in the Philippines in 1962. Research and training achievements by 1967 began to affect production in some Asian nations by 1968 or 1969. The rapid adoption of new high-yielding varieties and improved cultural practices provided large increases in production largely through increased yields per hectare.

The adoption of these varieties and practices in Latin America has been slower. This is because regional production and consumption have been nearly equal for many years, and, in addition, the first of the new varieties did not have the grain quality preferred by Latin American consumers or by potential international markets.

Nevertheless, the area planted to the new high-yielding varieties has steadily increased, and at present may be between 300,000 to 400,000 hectares. The variety IR8, with smaller amounts of IR5 and IR22, is cultivated extensively in Mexico, Cuba, Nicaragua, Costa Rica, Colombia, Venezuela, Ecuador, and Peru. The past harvest of IR8 in Colombia probably kept the country from importing rice. Peru, with 23 percent of its rice area in IR8 and IR5, has reached self-sufficiency. It is reported that Cuba has about 90 percent of its rice crop in high-yielding varieties. Despite large price discounts because of inferior quality in some countries (reaching 40 percent in Colombia in comparison with Bluebonnet 50), production of the new varieties is more profitable than the traditional varieties.

Rice culture in Latin America, extending from western Mexico to northern Argentina, is remarkably uniform. Older U.S.A. varieties and their derivatives predominate in much of the area. Quality standards and preferences are generally consistent. Cultural practices, excepting small areas where transplanting is practiced, are similar. The more important diseases and pests are common to most areas. A tropical to subtropical environment prevails throughout, excepting portions of Brazil, Argentina, Uruguay and Chile.

This uniformity in rice culture, coupled with a relative absence of language barriers throughout the hemisphere, constitutes a significant advantage in developing programs designed to increase total production and gains in productivity per hectare. It guarantees that a successful research program located in one specific area and closely linked to national rice programs can produce a wide impact throughout Latin America.

All rice-producing countries in Latin America presently conduct research on rice. Some countries have breeding, agronomy, and plant protection programs. Others lack breeding programs and emphasize the testing of breeding lines and varieties produced elsewhere.

The role and philosophy of CIAT's breeding program

The CIAT rice-breeding program is directed toward the practical solution of problems limiting yielding ability. The program is designed to serve Latin America, especially those countries unable at present to conduct large, local programs.

The wide experience with IR8 in many areas of Latin America shows that the new high-yielding varieties are as productive here as in Asia. Yields from hundreds of trials on experiment stations and commercial farms normally range from 50 to 100 percent more than those of traditional varieties. This productivity is of paramount interest to all rice workers because it permits Latin America to adopt the same guiding philosophy that resulted in the Green Revolution in Asia. In brief it:

a) Shows rice researchers that immediate large gains in yielding ability are easily achieved.

b) Permits researchers to focus program objectives and activities toward achievement of large increases in productivity.

c) Ensures that farmers, normally suspicious of minor improvements in farming practice, will readily adopt high-yielding varieties.

CIAT rice-breeding objectives and activities

From its inception the CIAT program, working closely with the rice program of the Instituto Colombiano Agropecuario at Palmira, defined the varietal characteristics needed for most of Latin America. This ideal varietal type includes:

1. Dwarf stature, which confers resistance to lodging, gives greater production of grain in relation to straw, and increases the responses to improved cultural practices.
2. Moderately high tillering ability to reduce seed requirements and to provide greater plasticity over a range of planting methods.
3. Erect leaves for greater use of solar radiation.
4. Responsiveness in grain yield to applied nitrogen fertilizer.
5. Strong seedling vigor.
6. Insensitivity to photoperiod (daylength) to permit two crops a year and to ensure adaptability over a wide range of latitude.
7. Early maturity of 105 to 130 days in the field.
8. Tolerance to low temperatures for planting at high elevations and in sub-temperate zones including Argentina, southern Brazil, Chile, and Uruguay.
9. Acceptable milling and cooking quality: a clear, long grain with minimum breakage in milling; endosperm low or intermediate in gelatinization temperature and an amylose content of 21 to 27 percent; a dry, fluffy cooking behavior without hardening upon cooling of the cooked rice. These quality traits are preferred throughout most of Latin America.
10. Resistance to major diseases and pests including:
    a) The hoja blanca virus.
    b) *Sogatodes oryzicola*, the insect vector of hoja blanca and a serious direct feeder on rice. This insect and the hoja blanca virus are major problems in northern South America, Central America, and the Caribbean area.
    c) Rice blast disease caused by *Pyricularia oryzae*. This is the most important disease of rice from Mexico to Argentina.

Simultaneously, it is important not to increase susceptibility to stem borers and to such presently minor diseases as stem rot, sheath blight, Cercospora leaf spot and *Rhyncosporium*.

Since 1967, the program has made 550 crosses among a wide range of parents to achieve these objectives. Simultaneously, to gain time while these crosses are being selected and stabilized, hundreds of more advanced selections from other countries have been evaluated. The program has developed adequate facilities to determine milling and cooking quality and resistance to diseases and pests. Each year several thousand individual plants are evaluated for the characteristics listed.

An equally important program activity is the training of people in rice-breeding and cultural practices. We have had 19 men in training from Argentina, Brazil, Colombia, Costa Rica, Dominican Republic, Ecuador, Honduras, Peru, United States of America, and Venezuela. These men usually remain at least 6 months at CIAT, handling a complete crop from seeding to harvest. Training emphasizes evaluation and testing of segregating and fixed material. With few exceptions, they are not trained to become rice breeders as several countries are not equipped to handle complete breeding programs. When they return to their countries, they are urged to test locally the best material from our program and other sources. Periodically, we send them new rice selections. When possible, CIAT staff visit the former trainees, observe the behavior of the rice materials being tested, and discuss their future programs.

Progress toward objectives

About 6 years are required in the tropics to develop and release a new variety. The first crosses made in 1967 are entering the final stages of selection. Many segregating lines supplied by IRRI were concurrently selected and evaluated. One, a segregating line from the cross IR8 x IR12, was particularly promising in preliminary tests following selection and purification. Large scale evaluation in Colombia followed. In about 20 tests on experiment stations and farmers' fields during 1969-70, this line yielded about 70 percent more than Bluebonnet 50, a traditional variety in much of Latin America, and yielded equal to IR8 (Table 1). These results prompted rapid international testing. Results (Tables 1 and 2) from Costa Rica, Panama, Ecuador, and Brazil and more recent preliminary trials in Argentina, Dominican Republic, Honduras, and Peru have duplicated the results obtained in Colombia.

These yields, coupled with the urgent need for an improved variety, led to a joint ICA-CIAT decision in 1971 to name and distribute this selection as CICA 4. CICA 4 was rapidly multiplied. About 400 hectares were grown in early 1971. At an average yield of 5 tons, Colombia should have seed to plant more than 15,000 hectares in the second crop of 1971.

CIAT, in an effort to help small marginal farmers, donated a large quantity of CICA 4 for free distribution through ICA to farmers in isolated upland areas.

Seed was made available internationally. CIAT shipped small quantities of 5 kilograms or less at no cost to all interested parties outside of Colombia. Larger quantities were sent collect, the only charge being for the shipping costs. To date 2,836 kilograms of CICA 4 have gone to 29 nations including 21 in Latin America.

In Ecuador, yield results with CICA 4 were outstanding, and INIAP began distributing seed in 1971, calling the variety INIAP 6. This change in name is completely in accord with our policy with respect to the local naming of new materials released.

CICA 4 combines many of the objectives listed on pages 2 and 3. As IR8, it is a dwarf, erect-leaved, high-tillering plant having excellent resistance to lodging and good responsiveness to nitrogen. It is photoperiod insensitive and matures in 140 days at high elevations and in about 125 days in coastal lowlands. It has a long grain, moderately clear endosperm, and mills satisfactorily. This constitutes its major advantage over IR8. Its cooking quality is good.

Both IR8 and CICA 4 have good resistance against Sogatodes oryzicola, and preliminary observations indicate that spraying programs may be greatly reduced for control of this insect. Susceptible varieties require repeated insecticide applications. Its resistance to the vector protects it from severe hoja blanca damage.

Apart from its yielding ability and quality, CICA 4 has five distinct advantages:

1. High tillering and insect resistance permit savings in seed rates and insecticide applications.
2. It yields well in areas of moderately low temperatures (Table 3).
3. It is adapted to a wide range of cultural conditions and will tolerate deficiencies in culture better than many other varieties.
4. Its erect flag leaves cover the panicles. This appears to offer significant protection against bird damage.
5. It appears to be adapted to upland rice culture (Tables 1 and 2).

Under upland conditions, rice is never irrigated and depends on rainfall. This ability to produce under such conditions may prove to be the outstanding virtue of CICA 4.

CICA 4 has some disadvantages. Its maturity is somewhat later than desired for certain areas where water is in short supply. Its milled grain appearance can be improved, and a lower amylose content in the endosperm would be desirable for rural areas. It tends to shatter slightly. This could lead to field losses if the crop is allowed to become over-ripe before harvesting. The variety will likely become susceptible to rice blast, thereby limiting its acceptance in areas of high disease incidence.

We view CICA 4 as a temporary variety of higher productivity than traditionally grown and superior to IR8 in grain characteristics. The program is identifying many lines superior to CICA 4. We expect one or more of these to be ready for release within two years. Thus, CICA 4 is considered as the first in a continuing series of lines offering different combinations of desired characteristics for different farm situations.

The ICA-CIAT program in 1971 also recommended, produced, and distributed internationally seed of the variety IR22 released by IRRI in 1969. This variety has good yielding ability and excellent grain appearance. It is less widely adapted than CICA 4 and is recommended only for the tropical lowlands. It is known as INIAP 2 in Ecuador.

Technological problems limiting rice production

1. Personnel and facilities for research, extension and seed production. Although perhaps not a technological problem, inadequate personnel and facilities directly affect progress in rice production. In Latin America, the numbers of competent, dedicated people working in rice research and extension are too few for the job ahead. Low salaries and poor facilities discourage young people, and turnover in personnel is high. Practical, field-oriented workers in agronomy, soils, plant pathology, and breeding are particularly needed.

Certainly seed production is the weakest link in the rice production chain. Few nations have satisfactory seed production, inspection, and sales programs. Even a superior-yielding variety becomes useless when mixed with red rice, weed seed, or other varieties or when germination is not protected. Governments can take the lead in formulating and enforcing standards for field and laboratory certification of seed fields. Where it has had the opportunity, private enterprise has demonstrated that it, rather than government in most cases, can best handle seed production and sales.

2. Resistance to the rice blast disease. Blast is the most important disease of rice throughout the hemisphere. It is particularly severe on upland rice. Chemical control does not appear practicable, and resistance is the ideal means of control. The pathogen is so variable that varieties having a narrow base of resistance inevitably become susceptible within a brief period following release. It probably is safe to say that all varieties grown in Latin America are susceptible to blast.

Recent work indicates that certain non-commercial varieties possess a broad, distinct type of resistance that is stable. The CIAT and IRRI programs are working to transfer this stable resistance to high-yielding varieties. A network of disease-testing facilities is needed in Latin America in order to evaluate this resistance against differing populations of the pathogen in distinct environments.

3. Upland rice. Upland (non-irrigated) rice probably represents about 70 percent of the rice in Central and South America. Yields are deplorably low with national averages ranging to a maximum of 1.5 ton/ha. Although upland rice will likely always yield less than irrigated rice, the area involved is so large that a doubling of yield would have a huge impact in total production.

At present no program, national or international, is grappling systematically with the problems of upland rice. Resistance to rice blast in upland varieties would be essential for increased yields. Certain varieties are better adapted to upland conditions than others; the dwarf plant type should be as important to upland rice as it is for irrigated varieties.

Latin America can benefit by emphasizing research on upland rice, particularly with stress on large-scale mechanized upland rice culture rather than the small primitive plots planted with a pointed stick. There is a critical need for breeders, pathologists, agronomists, and weed control specialists. A suitable area for such an undertaking would be Brazil.

The potential for new varieties

The information available suggests that Latin America is on the verge of a large increase in rice production. New high-yielding dwarf varieties are becoming available in increasing numbers. The original quality limitations of IR8 have been resolved with the development of CICA 4, Nylamp from Peru, IR20, IR22, IR24 and other varieties. As these varieties will probably receive a market price equal to that of traditional varieties, farmers will have an economic incentive to plant the improved dwarfs rather than IR8 and local varieties. Adoption of these new varieties will move rapidly where irrigation is available and more slowly in upland areas. If preliminary observations on the productivity of CICA 4 and other dwarfs under upland culture are confirmed, the take-off for rice production in Latin America is near.

In summary, many of the obstacles to high-yielding ability have been eliminated and others can be solved with additional research. Therefore, it appears that economic policies more than technology will affect rates of increase in rice productivity and production.

Table 1. Rice yields in ton/ha. during 1969-70

Variety	Testing Country: Colombia a/	Ecuador b/	Costa Rica c/	Panama d/
CICA 4	6.80	5.76	5.04	5.65
IR22	6.40	6.87	4.18	5.04
IR8	6.90	7.05	3.39	4.08
Bluebonnet 50	4.00	4.45	-	-

a/ ICA-CIAT average of 17 tests, irrigated, directed seeded
b/ INIAP: average of 5 tests, irrigated, four transplanted
c/ Ministry of Agr: average of 3 tests, upland.
d/ University of Panama: one test, upland

Table 2. Rice yields in ton/ha. during 1971.

Variety	Testing Area: Tocumen Panama a/	Tumaco Colombia b/	c/	Goias Brazil d/	El Triunfo Ecuador e/
CICA 4	4.52	3.38	5.70	3.55	5.70
IR22	2.24*	3.57	-	3.18	4.91
IR8	3.65	4.08	-	-	5.26
Bluebonnet 50	-	0.93*	-	-	3.45
Local 1	-	-	-	1.89	-
Local 2	-	-	-	1.59	-

a/ Irrigated, direct seeded; University of Panama
b/ Upland, replicated plots; ICA
c/ Upland, multiplication on 2 farms; ICA
d/ Upland; sementes agroceres, S.A.

Table 3. Yields in ton/ha. from four locations in the Cauca Valley, Colombia under relatively low temperatures. 1971, ICA.

	Testing Area				
Variety	Buga	Corinto	La Virginia	Jamundí	Average
CICA 4	8.00	6.10	8.08	7.80	7.50
IR22	7.00	5.08	5.01	5.78	5.72
IR8	4.88	5.39	6.17	6.71	5.79
Bluebonnet 50	3.88	2.53	4.90	3.39	3.68

AGRONOMIC PRACTICES FOR OPTIMIZING THE YIELD POTENTIAL OF SHORT-STATURED RICE VARIETIES IN LATIN AMERICA

Pedro A. Sanchez
Assistant Professor
Soil Science Department
North Carolina State University at Raleigh
and former Co-leader
National Rice Program of Peru

The drastic change in the architecture of the rice plant accomplished by the International Rice Research Institute in 1966 revolutionized rice production all over the world. In the Latin American tropics, several short-statured rice varieties are now extensively cultivated in several countries. The change from tall, lodging susceptible, low grain:straw ratio varieties to short, lodging resistant, high grain:straw ratio types such as IR8 has increased rice yields substantially at the farm level.

When farmers manage the new varieties the same as the old ones, sometimes they get limited yield increases or none at all. In order to maximize yields and profits of the new varieties, different cultural practices must be applied, some of which require further investments and more precise timing. The purpose of this paper is to illustrate the varietal response to specific cultural practices as examples of the kind of information needed for optimizing yields in each rice-growing area.

In tropical Latin America, rice is the third food crop (after cassava and corn) consumed in large quantities, according to calculations from an FAO report (FAO, 1965). Over 75 percent of Latin America's rice is produced under upland (secano) conditions characterized by direct seeding and rainfall dependency (Brown, 1969). About 21 percent of the total rice area is direct seeded and irrigated (Table 1). Transplanting is practiced on the remaining 4 percent (about 235,000 ha) including over 60 percent of Peru, the Dominican Republic and Surinam, and significant proportions of Ecuador and Venezuela. With over 5 million hectares in production, Latin America's average rice yields are 1.72 tons/ha or slightly below the world average of 2 tons/ha. National average yields range from 1.1 to 4.1 tons/ha.

TIME OF PLANTING IN RELATION TO WEATHER PATTERNS

Rice is sensitive to moisture stress, solar radiation and low temperatures. While there is little man can do to modify climate, he can subject his rice crop to the best probable weather pattern by planting at the optimum time for a particular area.

Upland rice and rainfall distribution

Total rainfall and its distribution during crop growth is probably the most important limiting factor affecting upland rice production. For reasons which are not yet understood, it is known that rice plants suffer from moisture stress at higher soil moisture contents than other crops (Jana and DeDatta, 1971). Upland rice is grown in areas and during seasons of high rainfall since the crop is completely rainfall dependent. These areas usually have at least 200 mm of monthly rainfall during the growing season (Brown, 1969; Kawano, et al, 1971). The performance of IR4-2, a short-statured variety, and Carolino, a tall, local variety, are compared during a two-year period under upland conditions in Yurimaguas, Peru (Fig. 1). This figure shows that when the monthly rainfall distribution was adequate, such as in the September and November plantings, IR4-2 produced between 4 and 6 tons/ha while Carolino produced between 2 and 3 tons/ha. During periods of poor rainfall distribution (May and June plantings), IR4-2 yielded about 1 ton/ha and Carolino about 0.5. This figure shows how closely upland rice yields follow the rainfall pattern and that in all cases the yield of the improved plant type was about double that of the conventional variety. Both varieties were grown under identical conditions but the short-statured plants produced more tillers, more grain in relation to straw, and resisted lodging. It is interesting to note that although the short-statured plant types were developed under irrigated, transplanted conditions, they are also superior under upland conditions (Nureña et al, 1970; DeDatta and Beachell, 1971). The new varieties, however, must have at least moderate tolerance to the rice blast disease and other important pests before they can successfully compete with the traditional plant types.

Irrigated rice and solar radiation

In hot, tropical areas the main climatic factor associated with flooded rice performance is the amount of solar energy received during the reproductive phase of rice growth (DeDatta and Zarate, 1970). Solar radiation levels approach their maximum during clear cloudless days, and are directly related with photosynthetic activity and nitrogen response. Figure 2 shows the performance of IR8 and H 4, a tall, lodging-susceptible variety, at different planting dates and at two levels of nitrogen application in an experiment conducted in the Philippines under constantly flooded conditions. As in the previous case, the yields of the short-statured plant type were substantially superior to that of H 4. Under these conditions, maximum yields were obtained when solar radiation values during the reproductive period were highest, which occurred when the crops flowered during the peak of the dry season. At low levels of nitrogen fertilization (30 kg N/ha), H 4 produced higher yields than at 120 kg N/ha, because this type of plant responds to added N by increasing its foliar area, causing mutual shading of leaves, and eventual lodging and subsequent yield losses. Lodging-resistant varieties such as IR8 can effectively combine the added nitrogen with the increased photosynthates produced under high solar radiation, resulting in tillering, more panicles and therefore higher yields. This figure also indicated that in order to obtain maximum yields with the new varieties, they should be fertilized at higher rates.

Growth duration and low temperatures

It has been recently recognized that low temperatures can be limiting to rice growth in the tropics as this crop usually suffers when the mean monthly temperatures fall below 20-21°C. On the Coast of Peru, the near-by Humbolt Current causes temperature decreases sufficient to produce spiklet sterility at the flowering stage. The traditional tall-statured varieties such as Minabir and Mochica, although higher yielding than other similar plant types, have the disadvantage of being very late maturing. A trial consisting of two planting dates was conducted for two years at Lambayeque, Peru (Fig. 3). The 1966-67 growing season had a normal temperature regime during which the Mochica variety produced 7.16 tons/ha when it flowered in late April, but when flowering was delayed by about 3 weeks and the temperatures dropped, the yield was reduced by 3.55 tons/ha. The following year, 1967-68, temperatures began to drop earlier. At the first planting date Mochica flowered at almost the same date as in the previous year but produced 3.50 tons/ha; the second planting date flowered at extremely low temperatures and produced 0.47 tons/ha. The IR8 variety, introduced during that year, was planted at the same time as Mochica. Being earlier maturing, IR8 flowered 30 to 45 days before Mochica, avoiding the low temperature periods and producing 5.9 and 5.4 tons/ha at the two planting dates. The advantage of the new plant types in this situation is earlier maturity in relation to the conventional varieties, as IR8 is not resistant to low temperatures. The new varieties are not necessarily earlier maturing, but when they are they possess an additional advantage which has proven to be crucial and partially responsible for attaining rice self-sufficiency in the case of Peru.

The new short-statured plant types, just as the old ones, must be synchronized as much as possible with the weather through proper planting dates. Unlike the traditional plant types, the new ones can maximize the climate advantages or reduce risks of weather-induced production decreases.

PLANTING SYSTEMS, SEED DENSITY AND SPACING

Upland rice systems

In the most primitive upland rice areas, the crop is planted with a stick, dropping several seeds in holes irregularly spaced at an average of 50 cms between holes. The use of machinery is limited by the abundant tree stumps and fallen branches. Experiment have shown that closing the spacing between holes to 25 x 25 cms increased yields substantially (Fig. 4). Although this effect was beneficial in both the short-statured IR578-8 and the tall-statured Carolino varieties, the combination of closer spacing and a short-statured variety quadrupled yields obtained by the conventional variety and cultural practice (Nureña, 1971).

In upland rice areas where mechanized planting is possible, most of the fields observed by this writer are drilled in widely spaced rows (40-70 cms aparts). Figure 4 also shows that closing the spacing from 50 to 25 cms is highly beneficial for this planting system. Closer spacing also decreases weed competition and increases harvest uniformity. In some areas, however, it is believed that closer spacing increases the incidence of the rice blast disease caused by Pyricularia oryzae, because of a more humid microclimate. Two uniform seed density-spacing experiments conducted at Yurimaguas in the presence and absence of blast disease attacks showed that these factors had no effect on the intensity of attack (Sanchez and Nureña, 1970).

Several seeding-density experiments conducted on upland rice in Peru (Salhuana and Sanchez, 1969; Sanchez and Nureña, 1970; Velez, 1970; Nureña, 1971; Zumaeta and Barba, 1971) show little effects of seed density on yields within a range of 25 to 100 kg/ha. Local experience is usually the best guideline. Tillering ability tends to compensate initial seed-density effects. Excessive amounts of seeds per hole in the primitive upland areas definitely decrease yields; 5 to 10 seeds per hole appear to be the optimum for conditions at Yurimaguas, Peru (Nureña, 1971).

Direct-seeded irrigated systems

Direct-seeded irrigated rice is planted in various ways in Latin America: it is drilled in rows by hand or by tractor; dry seeds are broadcast incorporated in dry soil; and pregerminated seeds are broadcast on flooded soils, usually by airplane. In all cases, the objectives are the same: to produce an optimum number of panicles/m^2 and to avoid mutual shading. The tillering ability of the variety, its height, nitrogen and solar radiation levels are the main factors affecting this optimum.

Seed density experiments conducted in Brazil, Peru and Colombia have shown little influence of this variable on yields within a wide range of 60 to 200 kg/ha, both for tall varieties (Gomes and Miranda, 1963; Salhuana and Sanchez, 1969) and short varieties (Caballero and Paredes, 1971; Cheaney, 1971; Sanchez and Larrea, 1971). Known adverse conditions such as poor land leveling, seedbed preparation or germination percentage, or excessive soil salinity or acidity, usually require higher seeding rates.

Under most circumstances, tillering ability can compensate for low initial stands, especially with short-statured plant types.

As with upland rice, spacing is probably the dominant factor. Most direct-seeded irrigated rice fields in Latin America show evidence of wasted space. An experiment conducted in Lambayeque, Peru (Fig. 5) shows large yield increases when spacing between rows was reduced from 33 to 17 cms in both the short, high tillering IR8 variety and the tall, low tillering SML-Apura. Optimum spacing for a given area is heavily influenced by solar radiation, nitrogen level and plant type. High solar radiation, as in Lambayeque, decreases the height of all rice plants and permits maximum utilization of light by closer spacing. High nitrogen rates increase leaf area, and, in cases of tall-statured plant types, this results in mutual shading and lodging. In general, tall leafy varieties require wider spacing than short ones with erect leaves.

The differences between planting systems for direct-seeded rice are small under controlled conditions. The choice usually depends on field and water management characteristics and available equipment. Table 2 shows the performance of a short and a tall variety subjected to seven different planting methods in Lambayeque, Peru. No yield differences were observed between drilling in 17 cm rows and broadcasting on dry or flooded soils. Yields of the short-statured variety were reduced when spacing was increased to 25 cms between rows, while this practice definitely benefited the tall variety.

Transplanted Systems

Table 2 also shows that properly managed direct-seeded systems can perform as well as transplanted rice at comparable spacings. Similar evidence has been found by Adair et al, 1943; IRRI, 1966; and Sanchez and Larrea, 1971. Nevertheless, transplanting is practiced in over 67 percent of the world's rice area and in important sections of Latin America. Several factors traditionally favor transplanting in these areas, such as a better synchronization between water supply and the growth of late maturing varieties, the need to puddle the soil, to control weeds and reduce water losses, poor land leveling, salinity conditions, etc. Under such conditions, direct seeding cannot outperform transplanting in spite of its lower labor costs until these limitations are eliminated.

One of the most critical practices affecting the yields of transplanted rice is the age of seedlings at the time they are transplanted. A review of the literature by Larrea and Sanchez (1971a) indicated that rice farmers in the tropics transplant traditional varieties between 25 and 120 days after seeding although experimental evidence indicates that optimum results were best obtained between 30 and 45 days. The main reason for delaying transplanting is the erratic distribution of water supply in over 75 percent of the world's transplanted acreage. A series of studies conducted in Peru showed sharp yield decreases with delays beyond 30 to 45 days irrespective of seedbed management (Larrea and Sanchez, 1971a, b; Gavidia and Ventura, 1971; Vergara, 1971). Figure 6 shows the average performance at four locations. IR8 yields decreased by an average of 92 kg/ha per day of transplanting delay while the traditional Minabir variety decreased at the rate of 52 kg/ha per day. It is significant to note that although IR8 is more sensitive to these delays, its yields were always higher than that of Minabir.

The differential response to transplanting densities in contrasting plant types is illustrated in Fig. 7, adapted from unpublished data of Gavidia and Saavedra (1971). While the tall, heavy tillering Minabir variety performs best at low transplanting densities, the short, high tillering IR8 performs best at higher densities. Of the two density components, spacing between hills has greater influence than the number of seedlings per hill. The interaction between transplanting spacing and nitrogen fertilization is shown in Table 3. While little yield differences were observed at low N levels and wide spacings, the effects of plant type are large at high N levels and close spacing.

RICE FERTILIZATION

Nitrogen response and management

Probably no other cultural practice affects the performance of short-statured rice varieties more decisively than nitrogen fertilization. Since this subject has been recently reviewed (Sanchez, 1971), only the highlights will be discussed in this section. The average response in ten experiments conducted during three years under transplanted, intermittently flooded conditions at Lambayeque, Peru appear in Figure 8. While both plant types yielded similarly at zero or low N levels, IR8 responded positively to increased applications, doubling the yields of the check plot at the highest level. The tall-statured Minabir variety responded positively to about 150 kg N/ha and negatively afterwards, because of lodging and increased incidence of the rice blast disease.

The high yields and high nitrogen rates used in this particular location are due to the high solar radiation levels and high nitrogen losses caused by alternate flooding and drying. In the Magdalena Valley of Colombia, Rosero and Moreno (1970) compared the nitrogen response of IR8 with the tall, low tillering Bluebonnet 50 variety under direct-seeded irrigated conditions (Fig. 9). While Bluebonnet showed small responses, IR8 responded economically to 50 and 100 kg N/ha applications. Under upland conditions in Yurimaguas, Peru, Sanchez and Nureña (1970) obtained positive nitrogen responses with IR4-2 and IR8, while no responses were observed in the two tall traditional varieties (Fig. 10). The wide differences in optimum rates between these three examples are mainly due to differences in solar radiation, water management and soil characteristics. Since there are no adequate soil tests for determining optimum N rates for rice, it is recommended that these rates be established through variety - nitrogen experiments on major soils and seasons in each rice-growing region or valley (Sanchez, 1971).

Several factors affect the efficiency of nitrogen fertilizer utilization and thus the economics of this crucial practice. In general, the rice plants recover from 40 to 60 percent of the applied nitrogen under constant flooding but only between 20 and 30 percent under alternate flooding and drying when management practices recommended for constant flooding are applied. Ammoniacal sources such as urea or ammonium sulfate are about equal in efficiency although urea is usually cheaper. Nitrate sources, however, are extremely inefficient in rice because of large denitrification and leaching losses under constantly or intermittently flooded conditions. Research conducted in

Peru by Ramirez and Sanchez (1971) indicated that 35 to 40 percent of the applied N as urea or ammonium sulfate was recovered while the figure for sodium nitrate was 7.8 percent (Fig. 11). Experiments are in progress to evaluate the potential of slow release nitrogen fertilizers — primarily sulfur-coated ureas. Evidence to date indicates that this source is no better than regular ammoniacal sources under constantly flooded conditions, but it seems very promising for intermittently flooded or upland conditions.

Another way of synchronizing the nitrogen needs of the plant with an available supply in the soil in the presence of high leaching and denitrification losses is through proper timing of N applications. Under the uncertain water management prevalent in Latin America, applications at seeding or transplanting are inefficient (Sanchez and Calderon, 1971; Cheaney, 1971). Figure 12 shows that in delaying single or split applications of 180 kg N/ha the yield response was almost doubled. Nitrogen recovery and profits were also almost doubled. The effects of timing are extremely influenced by local conditions, and only local research can provide practical answers to farmers.

Responses to other nutrients

With the exception of the acid, highly leached oxisols or ultisols and volcanic ash soils, rice seldom responds to nutrients other than nitrogen. No responses to phosphorus and potassium were observed in 38 experiments conducted by Carmen (1968) throughout Peru, in 11 experiments conducted throughout Colombia by the Programa Nacional de Arroz (ICA, 1970), and in 13 experiments on alluvial soils of the Brazilian northeast (Vasconcelos and Almeida, 1966). Phosphorus responses are occasional in Rio Grande do Sul, Brazil (Patella, 1962).

Phosphorus responses, however, are abundant on upland rice in the Campo Cerrado of Brazil (Miranda and Freire, 1962; Oliveira et al, 1964, 1965, 1966) and the Llanos Orientales of Colombia (Owen, 1970). Miranda and Freire further observed that the response of upland rice to phosphorus was much smaller than that of corn and cotton in the same localities. Lime applications are of dubious value in flooded rice because the pH tends to increase and equilibrate between 6 and 7 due to reduction reactions. No lime responses were observed by Oliveira (1964) in acid soils of Rio Grande do Sul. In the highly acid Llanos Orientales of Colombia, Spain (1971) reports that upland rice responds to moderate lime applications while flooded rice does not.

Secondary and micronutrient disturbances, particularly sulfur, zinc and iron, are being increasingly recognized throughout Latin America, especially in the short-statured plant types because of their yields and nutrient uptake.

WEED CONTROL

The high moisture environment of rice soils is excellent for weed development, particularly in the absence of constant flooding. The short-statured rice plant types compete less successfully with weeds than the tall, traditional types. Weed competition is considered to reduce yields by 20 percent in rice fields under conventional management (Cardenas, 1970). Table 4 shows some examples of the performance of the main post- and pre-emergence herbicides presently utilized in Latin America. When they are properly applied at the right times (ICA, 1971), weeds are satisfactorily controlled. Optimum herbicide rates for irrigated rice are higher in Latin America than in Asia, for reasons not yet understood. Table 4 also shows that weed control is more difficult in direct-seeded than in transplanted systems where rice seedlings have a head start over the weeds. Significant information on weed control in upland rice is lacking in Latin America Most of the research is limited to control of broad leaf weeds, but no solution is available for controlling the more vigorous grassy weeds which tend to dominate after the broadleaves disappear.

HARVEST TIMING

In addition to time of planting, transplanting and nitrogen applications, optimum harvest timing can have significant influence not only on yields but on milling quality. Generally, an optimum harvest time, in which grain yields are highest and the percent of broken grains lowest, exists for each variety under a specific environment. Premature harvests result in lower yields, poor milling recovery due to immature and irregularly shaped grains and high breakage. Overmature harvests often result in lower yields due to grain shattering and higher breakage due to cleavages formed in the endosperm by changes in relative humidity (Stout, 1966). Varieties with chalky endosperm areas such as IR8 or with very long, slender grains as the Surinam types are particularly susceptible to harvest timing (Ten Have, 1967). Experiments in several areas of Peru have quantified some of these differences. The tall, high milling quality Minabir variety (Fig. 13) showed little grain yield response when harvested between 30 and 60 days after 50 percent flowering. The percent breakage reached, however, was the lowest point (8 percent) at 40 days.

In contrast, the short, chalky IR8 variety (Fig. 14) showed a well defined yield peak at 45 days after flowering which coincided with the lowest breakage percentage (22 percent). For reasons not yet understood, IR8 is more sensitive to harvest timing than Minabir. Comparing the two figures, it is worthwhile to note that the total production of head (whole, milled) rice in kg/ha was almost the same when IR8 was harvested at the optimum timing. Larrea and Sanchez (1970) also reported that the short-statured variety IR4-93-2, with fewer chalky areas, produced minimum grain breakage percentages identical to that of Minabir and a significantly higher head rice yields/ha because of its superior grain yield. Some of the new short-statured plant types, CICA 4, IR22 and Naylamp, currently being introduced in Latin America should perform better than IR8 due to their superior milling quality. The same investigators observed sharp yield declines in a tall variety susceptible to grain shattering when harvest was delayed. Optimum harvest time can be more accurately specified in terms of grain moisture content, usually between 19 and 21 percent (Ten Have, 1967; Nangju and DeDatta, 1970; Larrea and Sanchez, 1970), but this measurement is beyond the reach of most rice farmers in the tropics. Environmental differences can change the optimum harvest time for the same variety. Optimum timing for IR8 is about 45 days after flowering in the cooler Lambayeque and Jequetepeque Valleys of the Peruvian coast but drops to 25 or 30 days in the hotter Amazon jungle areas of Iquitos and Yurimaguas (Larrea and Sanchez, 1970; Vergara, 1971; Zumaeta and Barba, 1971; Nureña and Mesia, 1971).

COMBINED EFFECTS AND ECONOMIC CONSIDERATIONS

Examples of interactions of cultural practices

The effects of individual cultural practices on varieties of contrasting plant types have been illustrated in the previous sections. The interaction between different cultural practices, however, is not so evident, except for the combined effects of solar radiation and nitrogen fertilization in Figure 2, transplanting spacing and nitrogen level in Table 3 and weed control-planting systems in Table 4. In certain instances one cultural practice is more limiting than another. Fig. 15 compares the performance of IR8 seeded at different dates and transplanted at different seedling ages. The interaction is present, although the detrimental effects of delaying planting dates had a more decisive influence on yields because of low temperature-induced sterility at the flowering stage. Fig. 15 also shows that the cultural practices package developed for IR8 and responsible for producing a yield of 11 tons/ha in the November planting had a most detrimental effect when applied to the traditional Minabir variety. When Minabir was grown with its traditional practices (early planting, late transplanting age, wide spacing, 160 kg N/ha applied all at tillering and harvest date at 60 days after flowering) it yielded 6.90 ton/ha. When the recommended practices for IR8 (later planting, earlier transplanting age, close spacing, 300 kg N/ha in split applications and harvest date at 45 days after flowering) were applied on Minabir, it yielded 1.65 tons/ha.

Total production costs and revenues 1/

Cost of production data from an average rice farm in the Lambayeque Valley of Peru, growing the Minabir variety with traditional cultural practices, is compared with the average costs of a 30 ha field of IR8 grown with the recommended cultural practices on a commercial scale (Hernandez,1971). Table 5 illustrates the production costs and revenues in the two packages. Total production costs per hectare, excluding land rent and matching contributions to social security which could not be determined, were 32 percent higher in the IR8 package because of additional land levelling, higher labor cost of transplanting younger seedlings at closer spacing, and higher fertilizer costs. Yields, however, doubled. The cost of production per kilo of rough rice was reduced from 3.94 to 2.60 soles (US$ 90.62 to $59.80 per metric ton) with the IR8 package. When no price differential between varieties was applied, the price of

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1 / The assistance of Mr. Carlos Pomareda, Graduate Student of the Economics Department at North Carolina State University, in this section is gratefully acknowledged

4.70 soles/kg (US$ 108/ton) produced net revenues of 3,677 soles/ha for the traditional package and 20,270 soles/ha with the IR8 package.

This situation was applicable up to the 1970 harvest of IR8 in Peru and should apply to the new, high-yielding high grain quality varieties like Naylamp, CICA 4 and IR22. For the 1971 harvest in Peru, recent rice marketing regulations with deductions for grain breakage percentages have effectively reduced the price of IR8 to 3.80 soles/kg (US$ 87/ton). At the yields and cost levels of Table 5, IR8 net revenues were reduced from 20,270 to 11,576 soles/ha (US$486 to $266/ha) which still compares favorably with the net revenue with traditional practices of 3,677 soles/ha (US$84/ton).

Table 6 illustrates the total and relative proportions of the different production cost components for the same comparison. Although all components but "labor for other cultural practices" increased in absolute amounts with the IR8 package, only land preparation, fertilizer and harvest costs increased inrelative proportion. Harvest costs (hand harvest, contract threshing and transportation) per kg of rough rice was reduced from 0.74 soles paid for Minabir to 0.56 soles for IR8 because of labor savings when non-lodged rice is hand harvested. The total labor requirement increased from 128 to 161 man-days/ha with the IR8 package but the proportion of labor in total production costs decreased from 57 to 51 percent.

Effects of nitrogen level on production costs and revenues

The average of two variety-nitrogen experiments* conducted during 1971 in Lambayeque was used to make the following comparison since rising labor costs and a cooler climate impeded the realistic application of 1971 cost to the three-year average response curve of Fig. 8. Next, partial cost calculations included additional fertilizer and harvest costs. This figure shows that maximum profits are reached with about 160 kg N/ha for Minabir. Without a price differential, profits continue to increase with N applications in IR8. With the price differential, the optimum level for IR8 is between 240 and 320 kg N/ha.

*IR8 yielded 4.32, 6.44, 8.14, 9.21, 9.68, 9.98 and 10.66 ton/ha and Minabir 3.92, 4.93, 5.64, 4.97, 3.40 and 3.10 ton/ha from 0 to 480 kg N/ha at 80 kg intervals.

The effects of these relationships on unitary production costs appear in Fig. 17. The lowest cost obtained with Minabir was 3.5 soles/kg (US$80/ton) at the optimum nitrogen rate of 160 kg N/ha. Lodging caused increased unitary costs at higher rates. With IR8, the minimum costs were about 2.6 soles/kg (US$60/ton) reached at about 240 kg N/ha and beyond. The necessity of using high-yielding varieties to significantly reduce unitary production cost is obvious from this figure.

SUMMARY AND CONCLUSIONS

The varietal response to a series of cultural practices was compared mostly under Peruvian conditions. Proper date of planting under rainfall uncertainty, solar radiation levels and minimum temperatures permitted the short-statured plant types to optimize climatic advantages more than traditional varieties. Upland rice yields, regardless of rainfall pattern, were doubled with a short-statured variety in the Selva. Regardless of the planting system employed, short-statured varieties perform better at closer spacings. Transplanting seedlings of early age contributed significantly to high yields and profits of the IR8 variety in spite of a 32 percent increase in labor costs of this operation.

Under conditions of good land leveling, lack of salinity and weed control, direct-seeded systems utilizing properly spaced short-statured varieties can yield as much as transplanting systems with considerable savings in production costs. No other cultural practice widens the performance differences between plant types as nitrogen fertilization, although proper rates and management practices vary substantially between locality. Chemical weed control for irrigated rice is a successful practice, but lack of clear results on upland rice in Latin America represents a major limiting factor. Optimum time of harvest not only increases yields but improves milling quality of varieties with chalky endosperm areas.

In actual practice, many of the specific cultural practices mentioned interact with each other and more research on varietal-cultural practice interaction is needed. The economics of an improved variety-cultural practice package was compared with traditional practices using commercial data. Although total production costs increased by 32 percent when the recommended practices were applied on IR8, the yields of IR8 doubled those of the traditional package, and profits per hectare increased several times even when a 19.1 percent price drop was charged against IR8 because of quality limitations. Data from Peru suggest that some new high-yielding high grain quality varieties have a similar agronomic potential to IR8. The possibilities of increasing yields throughout the different cropping systems in Latin America without sacrificing grain quality seems excellent if proper cultural practices are adopted.

LITERATURE CITED

Adair, C. R., Beachell, H. M., Jodon, N. E. and others. 1942. Comparative yields of transplanted and direct-sown rice. J. Amer. Soc. Agron. 34:129-137.

Brown, F. B. 1969. Upland rice in Latin America. Int. Rice. Comm. Newsletter 18(1): 1-5.

Caballero, F. B. y Paredes, J. 1971. Resultados experimentales de agronomía en el Valle del Chira. Progr. Nac. Arroz Inf. Tec. 53, 13 pp.

Cardenas, J. 1970. Weed control of irrigated rice in Colombia. Paper presented at the International Rice Research Conference, IRRI, Los Baños, Philippines. Mimeographed.

Carmen, M. L. 1968. Yield of rice as affected by fertilizer rates, soil and meteorological factors. Ph.D. Thesis, Iowa State University, Ames, Iowa. 174 pp.

Cheaney, R. 1971. Unpublished data. Centro Internacional de Agricultura Tropical, Cali, Colombia.

De Datta, S. K., and Zarate, P. M. 1970. Environmental conditions affecting the growth characteristics, nitrogen response and grain yield of tropical rice. Biometeorology 4(1): 71-89.

De Datta, S. K., and Beachell, H. M. 1971. Varietal response to some factors affecting production of upland rice. Rice Breeding Symposium. International Rice Research Institute, Los Baños, Philippines (In press).

Food and Agricultural Organization of the United Nations. 1965. The economic relationships between grains and rice. FAO Commodity Bulletin Series 39, 125 pp.

Gavidia O., A. y Saavedra, V. 1971. Distanciamiento y número de plantas por golpe al transplante. Datos no publicados. Universidad Nacional Pedro Ruiz Gallo, Lambayeque, Peru.

Gavidia O., A. y Ventura, C. 1971. Edad de transplante y manejo de almácigos en el cultivo del arroz. Datos no publicados. Universidad Nacional Pedro Ruiz Gallo, Lambayeque, Peru.

Gomes, A. G. e Miranda, H. S. 1963. Ensaios de espacamamento e densidade de semeacao de arroz do vale do Paraiba - período de 1954/55 a 1958/59. Bragantia 22(55): 685-697.

Hernández L., J. 1971. Datos no publicados, Programa Nacional de Arroz, Lambayeque, Peru.

ICA, 1970. Programa Nacional de Arroz, Informe Anual. Instituto Colombiano Agropecuario, Palmira, Colombia. 170 pp.

ICA, 1971. Control de malezas en arroz de riego. Instituto Colombiano Agropecuario, Departamento de Agronomía, Hoja Divulgativa 038, 4 pp.

IRRI, 1966. Annual Report. The International Rice Research Institute, Los Baños, Philippines.

Jana, R. K. and De Datta, S. K. 1971. Effects of solar energy and soil moisture tension on the nitrogen response of upland rice. Int. Symposium Soil Fert. Evaluation Proc. 1: 487-498.

Kawano, K., Sanchez, P. A., Nureña, M. A., and Velez, J. 1971. Upland rice in the Peruvian Selva. Rice Breeding Symposium, International Rice Research Institute, Los Baños, Philippines (In press).

Kawano K. y Gonzales, H. 1971. Datos no publicados. Programa Nacional de Arroz, Lambayeque, Peru.

Lagos, R. E., Cardenas, J. y de la Cruz, R. 1970. Investigación en control químico de malezas en arroz de riego en Colombia, 31 pp.

Larrea, N. y Sanchez, P. A. 1970. Epocas optimas de cosechar arroz para rendimientos y calidad molinera en la Costa del Peru. Progr. Nac. Arroz Inf. Tec. 44, 28 pp.

Larrea, N. y Sanchez, P. A. 1971a. Influencia de la edad de transplante y manejo de almacigos en el cultivo del arroz en Lambayeque. Progr. Nac. Arroz Inf. Tec. 51.

Larrea, N. y Sanchez, P. A. 1971b. Datos no publicados. Programa Nacional de Arroz, Lambayeque, Peru.

Lucena, J. M. 1971. Datos no publicados. Programa Nacional de Arroz, Lambayeque, Peru.

Lucena, J. M. 1971. Datos no publicados. Programa Nacional de Arroz, Lambayeque, Peru.

Miranda, H. S. and Freire, E. S. 1962. Efeitos de abudacao fosforada e potassica do arroz de sequeiro. Bragantia 21(50): 858-866.

Nangju, D. and De Datta, S. K., 1970. Effect of time of harvest and nitrogen level on yield and grain breakage of transplanted rice. Agronomy J. 62:468-474.

Nureña, M. A., 1971. Sistemas de siembra y distanciamientos óptimos para arroz de secano en la Selva Baja del Peru. Prog. Nac. Arroz. Inf. Tec. 58, 18 pp.

Nureña, M. A. and Mesia, R. 1971. Unpublished data. Sub-Centro Regional de Investigaciones Agropecuarias de Yurimaguas, Peru.

Nureña, M. A., Velez, J. and Kawano, K. 1970. Características varietales relacionadas con altos rendimientos de arroz en condiciones primitivas de secano. Progr. Nac. Arroz. Inf. Tec. 43, 26 pp.

Oliveira, A. 1964. Aplicacao de calcario na lavoura de arroz. Lav. Arroz 18(212): 31-33.

Oliveira D. de A., Montojo, J. C., e Igue, T. 1964. Abudacao do arroz de sequeiro I. Avaliacao da influencia de nitrogenio, fosforo a potassio sobre características de variedade precoce do arroz de sequeiro. Bragantia 23 (8) : 73-81.

Oliveira, D. de A., Montojo, J. C., Igue, T., Miranda, H. e Freitas, M. L. 1965. Ensaios preliminares de abudacao do arroz de seqeiro. II. Cultivar Pratao. Bragantia 24(33) : 437-446.

Oliveira, D. de A., Casado, J., Igue, T., Miranda, H. and Freitas, M. L. 1966. Ensaios preliminares de abudacao de sequeiro III. Cultivar Dourado Precoce. Bragantia 25(1) : 1-8.

Owen, E. 1970. Fertilizacion de arroz en los Llanos Orientales. Programa Nacional de Arroz Informe Anual, ICA, Palmira, Colombia, pp. 154-159.

Patella, J. F. 1962. Alguns resultades de abudacao fosfatada on solos de arroz irrigado. Lav. Arroz 16(186) : 16-17.

Ramirez, G. E. and Sanchez, P. A. 1971. Factores que afectan la eficiencia de utilización de nitrogeno en el arroz bajo riego intermitente. Progr. Nac. Arroz Inf. Tec. 59, 40 pp.

Rosero, M. J. and Moreno, P. 1970. Resultados preliminares sobre fertilización del cultivo del arroz in Aracataca, Magdalena. Programa Nacional de Arroz, ICA, Palmira, Colombia, pp. 144-153.

Salhuana, A. and Sanchez, P. A. 1969. Sistemas de cultivo del arroz en el Peru. In: Programa Nacional de Arroz: Curso de Capacitación sobre el Cultivo del Arroz, Lambayeque, Peru. pp. 273-300.

Sanchez, P. A. 1969. Present status of rice research in Peru. North Carolina State University Agricultural Mission to Peru. Report No. 371. 20 pp.

Sanchez, P. A. 1971. Fertilización y manejo del nitrógeno en el cultivo de arroz tropical. Trabajo presentado ante el II. Cologuio de Suelos "El Uso del Nitrogeno en el Trópico". Sociedad Colombiana de la Ciencia del Suelo, Palmira, Colombia. 43 pp.

Sanchez, P. A. and Nureña, M. A. 1970. Upland rice improvement under shifting cultivation in the Amazon Basin of Peru. Progr. Nac. Arroz Inf. Tec. 31, 26 pp.

Sanchez, P. A. and Calderon, M. V. 1971. Timing of nitrogen applications of rice grown under intermittent flooding in the Coast of Peru. Int. Symposium Soil Fert. Evaluation Proc. 1: 595-602.

Sanchez, P. A. and Larrea, N. 1971. Potencial de la siembra directa de arroz en la costa peruana. Progr. Nac. Arroz Inf. Tec. 54, 21 pp.

Spain, J. M. 1970. El problema de la acidez en suelos de los Llanos Orientales: Posibles soluciones. Suelos Ecuatoriales 3(1) : 206-209.

Stout, B. A. 1966. Equipo para la producción de arroz. FAO Cuaderno de Fomento Agropecuario 84: 125-129.

Ten Have, H. 1967. Research and breding for mechanical culture of rice in Surinam. Centre for Agricultural Publications and Documentation, Wageningen, Netherland, pp. 197-231.

Vasconcelos, D. M. e Almeida, L. M. de 1966. Abudacao quimica do arroz do nordeste. Pesquis Agropec. (Brazil) 1 : 353-356.

Velez, J. 1970. Unpublished data. Centro Regional de Investigaciones Agropecuarias El Tulumayo, Tingo María, Peru.

Vergara, R. 1971. Estudio sobre densidades de siembra en el transplante, manejo de almácigos y épocas óptimas de cosechas para rendimiento y calidad en el Valle de Jequetepeque. Progr. Nac. Arroz Inf. Tec. 49, 13 pp.

Zumaeta, R. E. and Barba, S. 1971. Investigaciones arroceras en sistemas de barrial en Iquitos. Progr. Nac. Arroz Inf. Tec. 52. 22 pp.

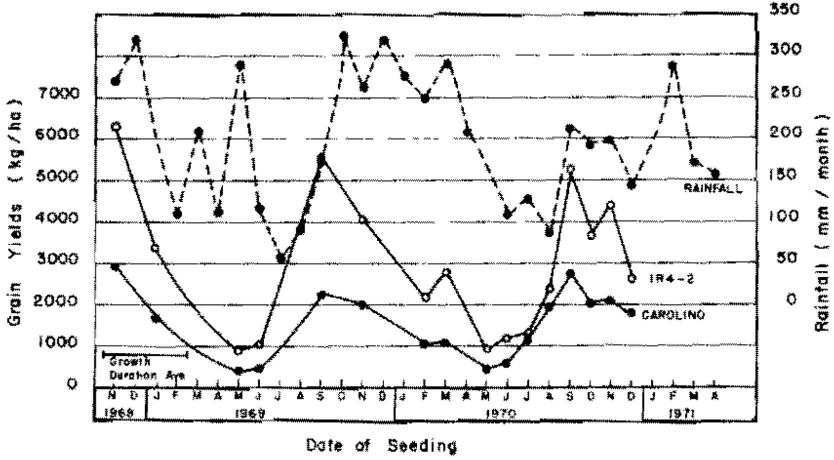

Fig. 1 Performance of IR4-2, a short statured plant type and Carolino the local variety as a function of date of planting under upland conditions and available rainfall, Yurimaguas 1968-71. (Kawano, Sanchez, Nureña and Velez, 1971).

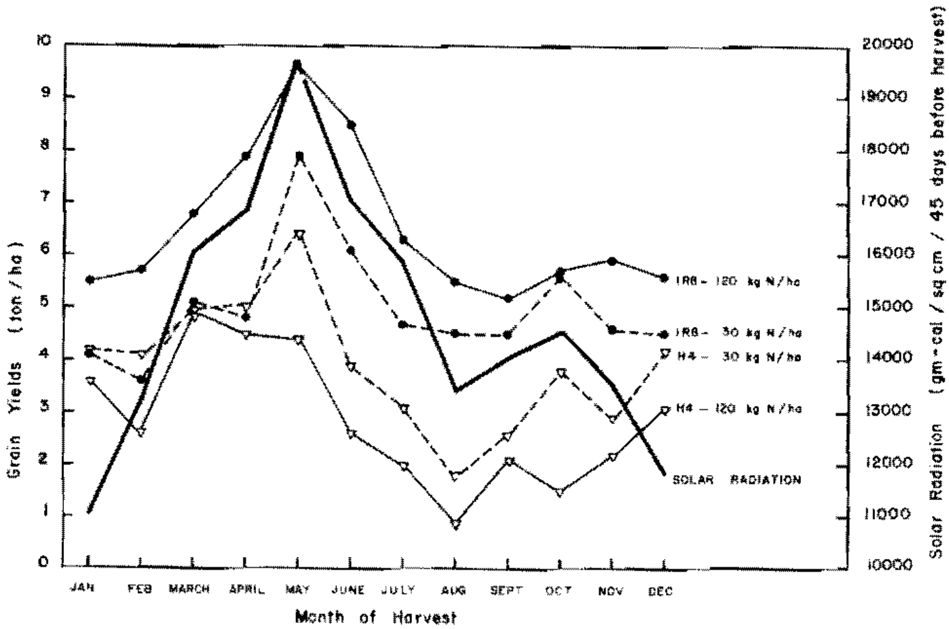

Fig. 2 The effects of solar radiation and nitrogen applications on the performance of a short (IR8) and a tall (H4) statured rice variety in Los Baños, Phillippines 1968-1969. Adapted from data presented by DeDatta and Zarate (1970).

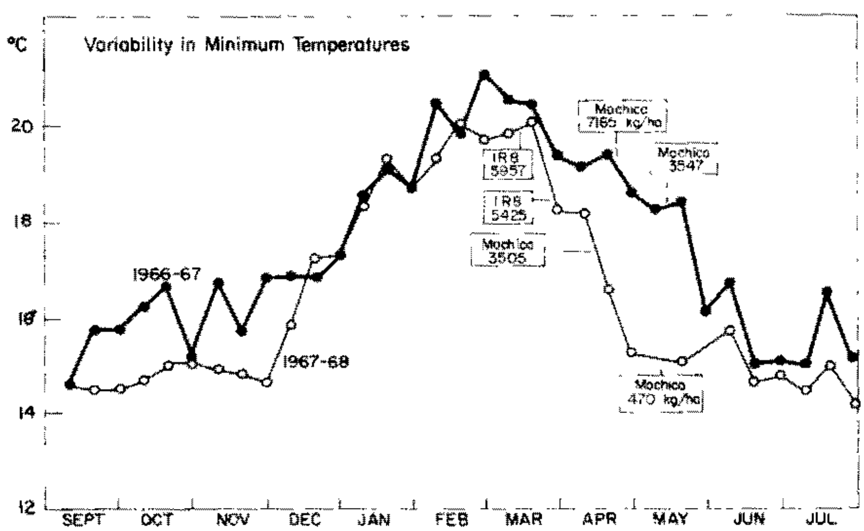

Fig. 3 The effect of minimum temperature variability and dates of flowering on rice yields in two cropping seasons at Lambayeque. Mean minimum

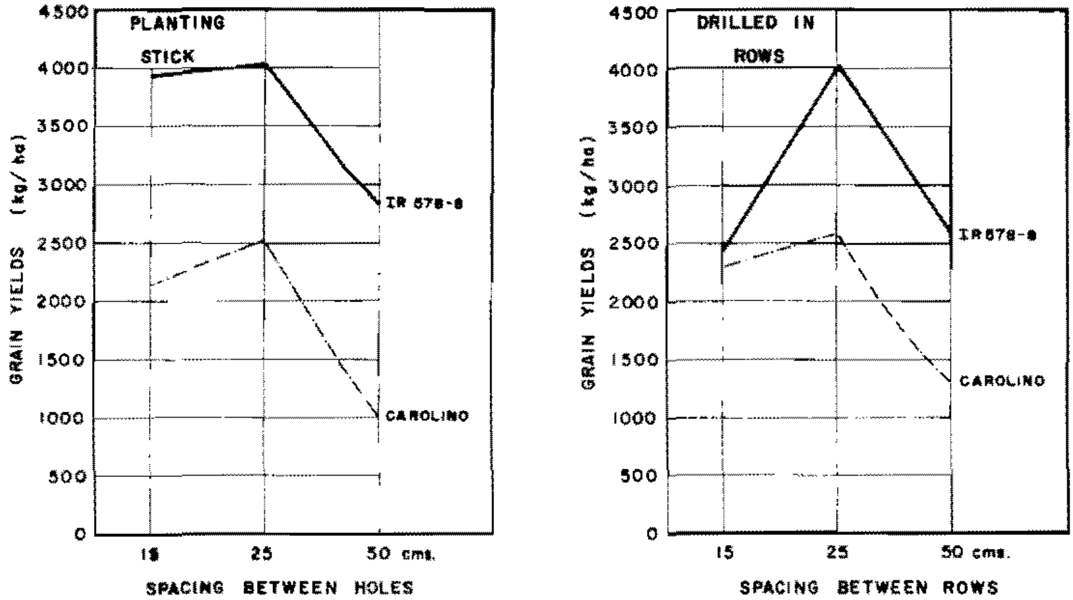

Fig. 4 Effects of spacing on upland rice yields of contrasting plant types in unmechanized and mechanizable planting systems. Yurimaguas, Peru 1970. (Nureña, 1971).

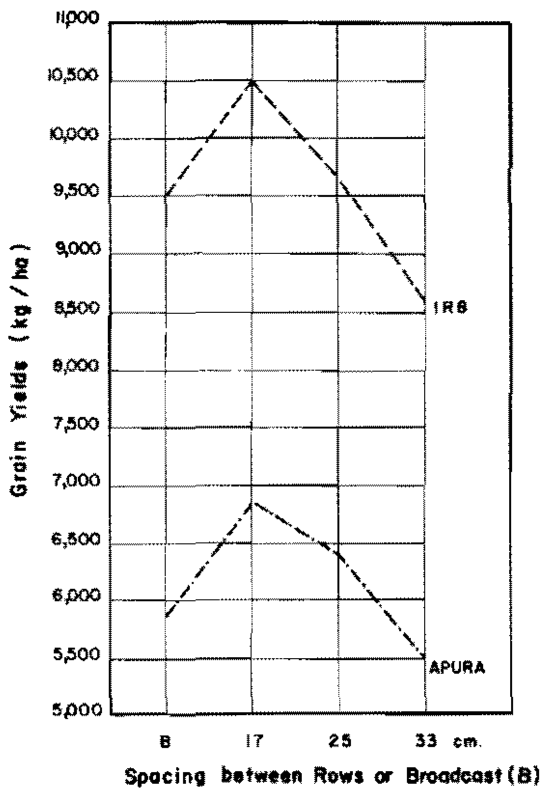

Fig. 5 The influence of spacing on the performance of varieties of contrasting plant type under direct seeded, irrigated, high solar radiation conditions. Lambayeque, Peru 1969-70. (Sanchez and Larrea, 1971)

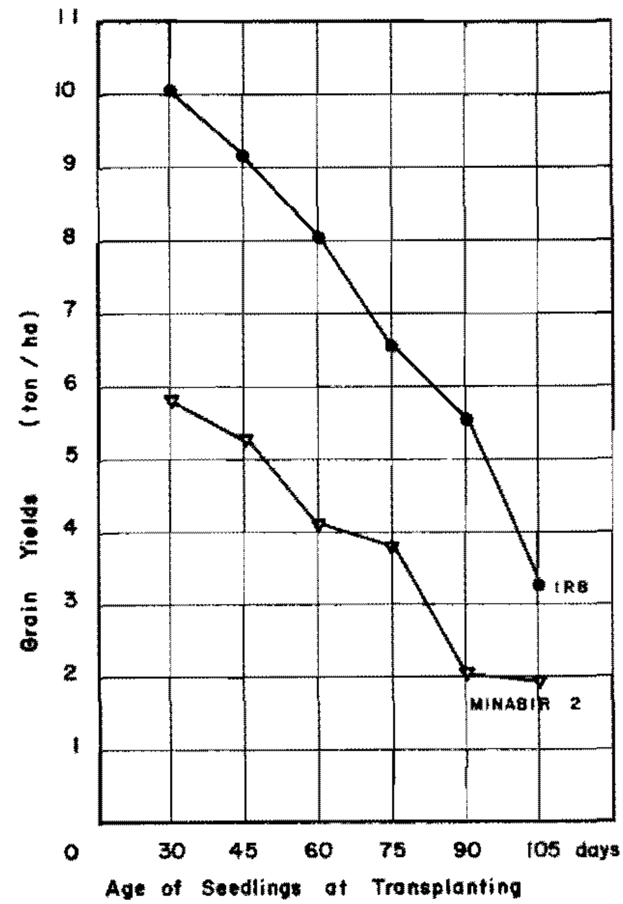

Fig. 6 Effects of seedling age on the performance of varieties of contrasting plant type. Mean of four locations in the Lambayeque and Jequetepeque Valleys of Peru.

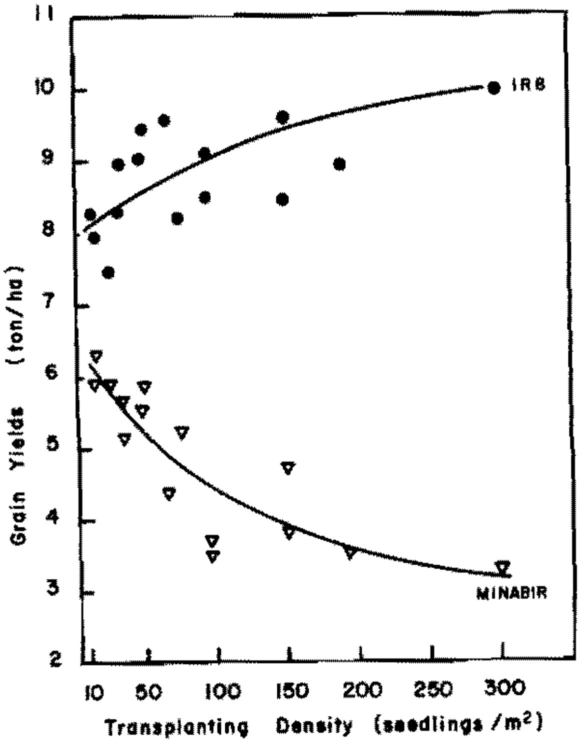

Fig. 7 The differential influence of transplanting density on rice varieties of contrasting plant types. Lambayeque, Peru 1970-71. Adapted from Gavidia and Saavedra (1971).

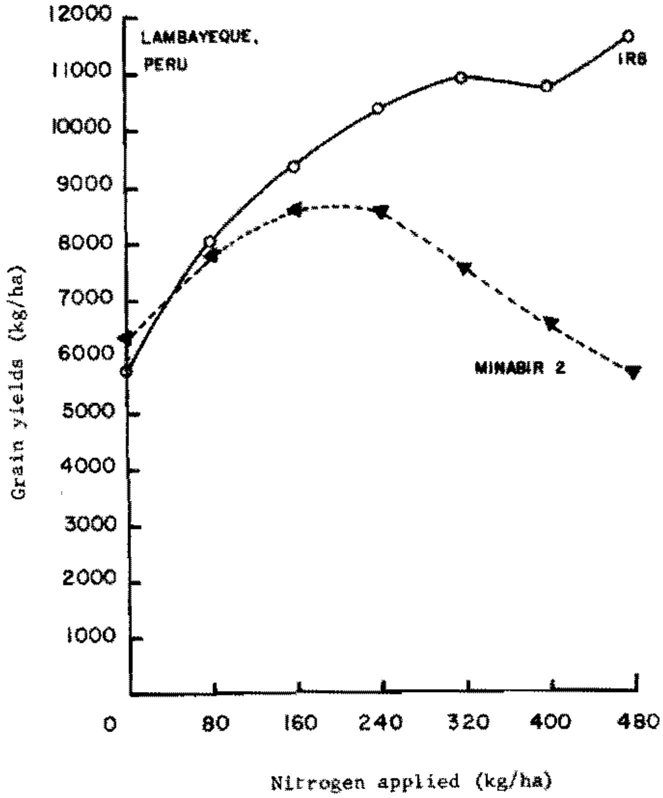

Fig. 8 Varietal response to nitrogen under high solar radiation and intermittent flooding in Lambayeque, Peru. Mean of 10 experiments during 1968-71. (Sanchez, 1971).

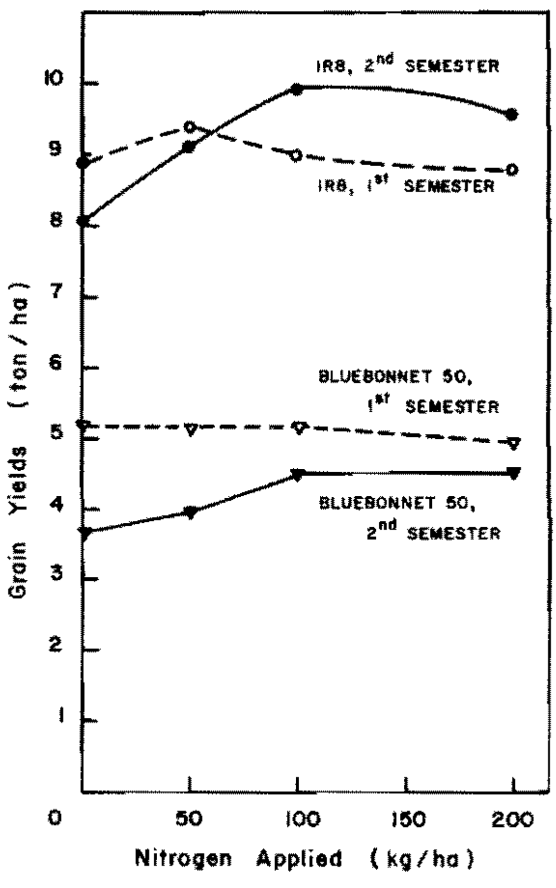

Fig. 9 Varietal response to nitrogen and

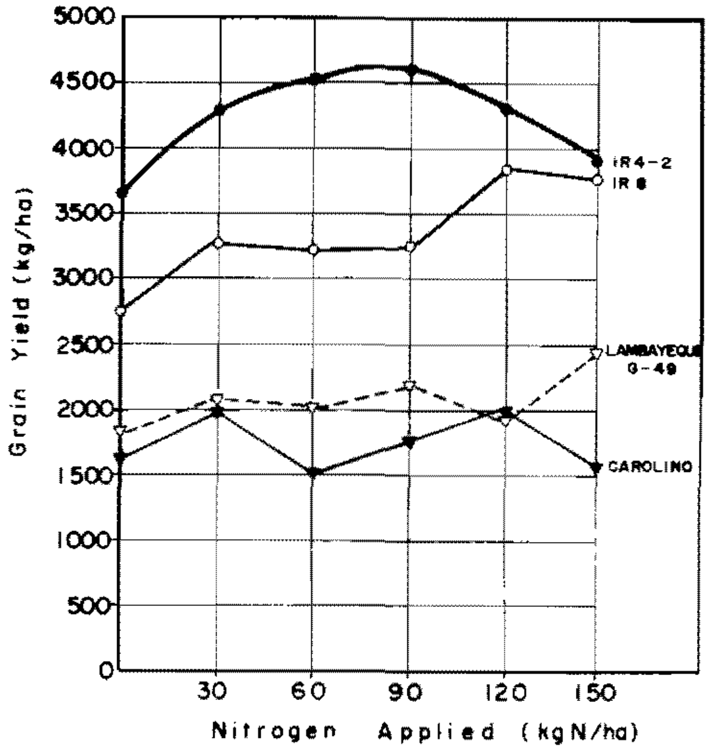

Fig. 10 Nitrogen response pattern of four rice varieties at Yurimaguas, Peru under upland conditions, 1969-70. (Sanchez and Nureña, 1970)

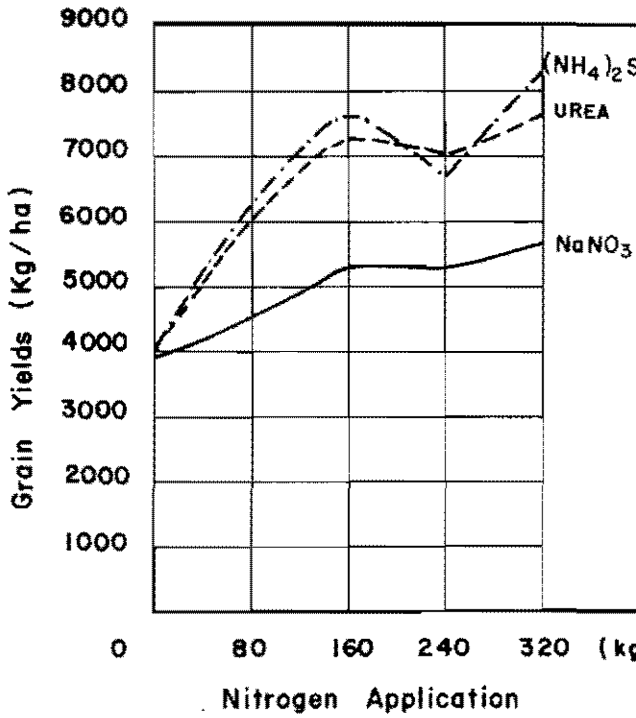

Fig. 11 The effects of nitrogen sour on rice response under inter mittent flooding (Ramirez an Sanchez, 1971)

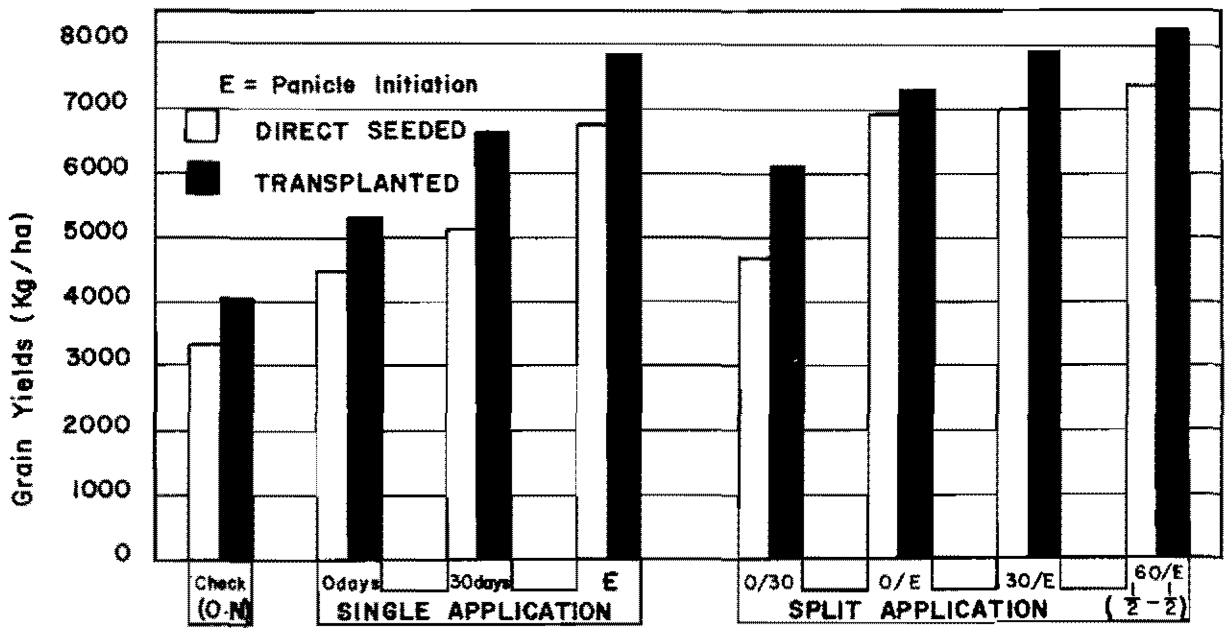

Fig. 12 Effects of timing of an application of 180 kg N/ha on rice performance under two planting systems. (Sanchez and Calderon, 1971)

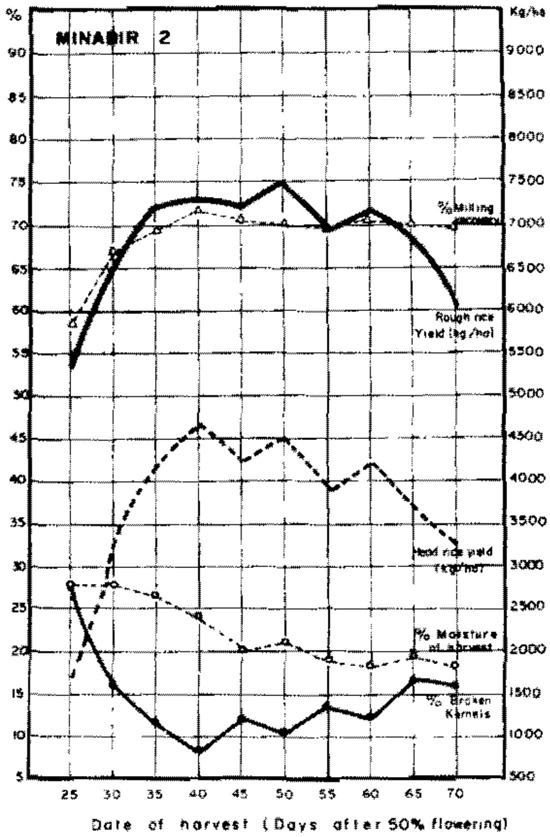

Fig. 13 Effects of date of harvest on grain yield and milling qualities of Minabir 2. (Larrea and Sanchez, 1970)

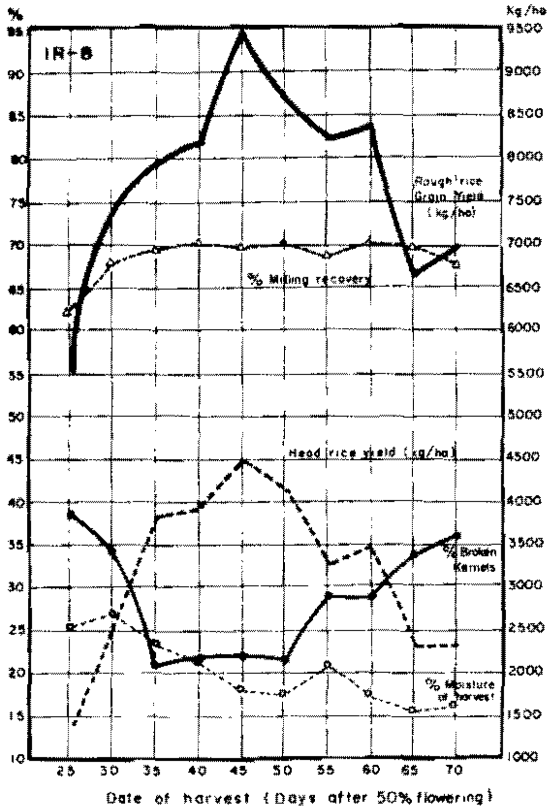

Fig. 14 Effects of date of harvest on grain yields and milling properties of IR8. (Larrea and Sanchez, 1970)

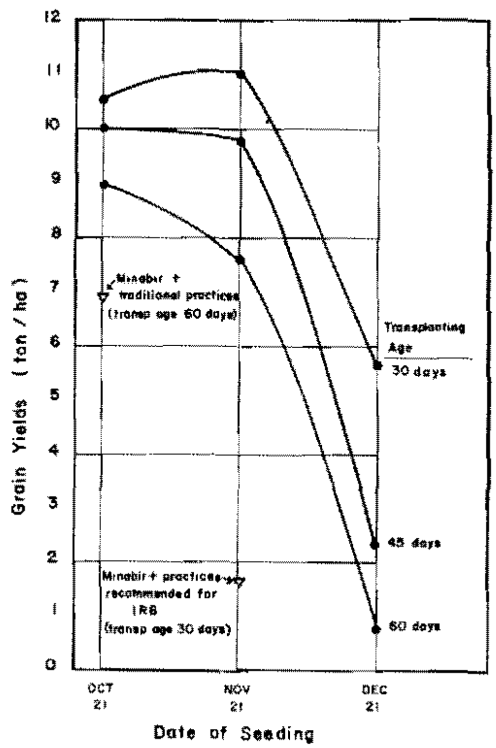

Fig. 15 Combined effects of date of seeding and transplanting age on IR8 performance in Lambayeque compared with Minabir with traditional and recommended cultural practices for IR8. (Larrea and Sanchez, 1971)

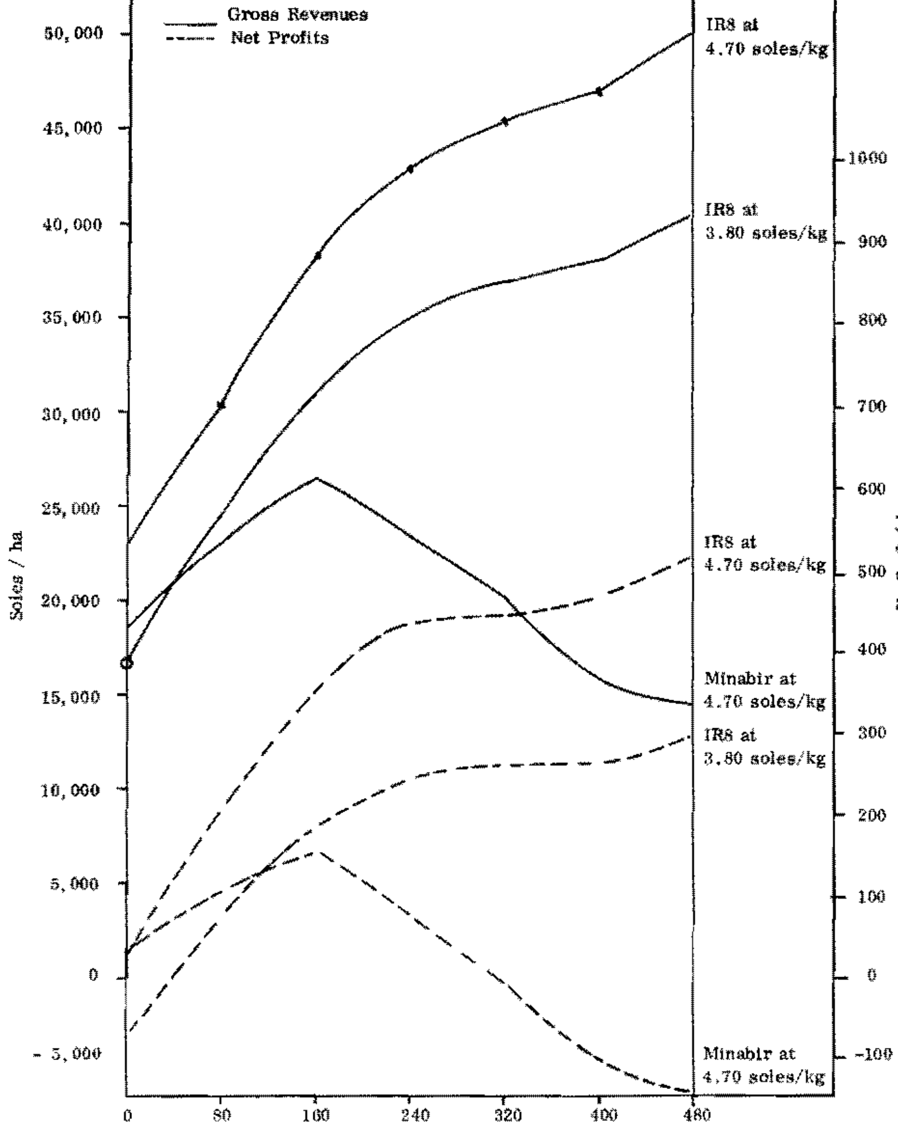

Figure 16. Gross revenues and returns of Minabir 2 and IR8 with or without price differentials as a function of N levels in Lambayeque, Peru. Average yields of two locatives in 1971.

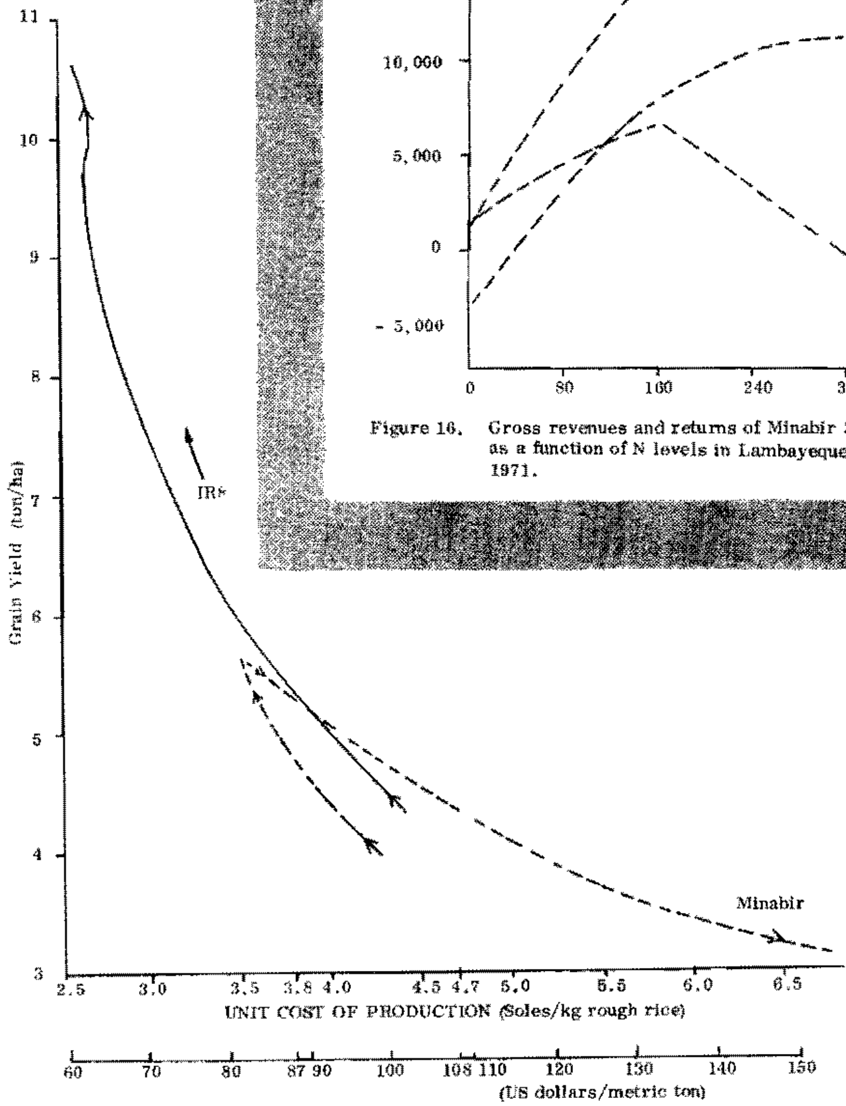

Figure 17. Unitary production costs of IR8 and Minabir as a function of yield in Lambayeque 1971. Arrows indicate N rates increases from 0 to 480 kg N/ha.

Table 1. Relative proportions of rice cultivation systems in the major Latin American rice producing countries or regions. (1960-64)

Country 1/	% Upland (Direct seeded-rainfall dependent)	% Direct seeded-irrigated	% Transplanted	Average yields tons/ha
Brazil	77	22	1	1.7
Colombia	65	35	0	2.2
Guyana	55	40	5	2.1
Mexico	25	70	5	2.2
Panama	95	5	0	1.1
Ecuador	63	2	35	1.5
Peru	21	10	69	4.1
Central America	90	10	0	1.3
Venezuela	80	2	18	1.8
Total Latin America	75	21	4	1.7

1/ Listed in order of area planted to rice

Table 2. Effects of planting systems on the performance of two rice varieties of contrasting plant type in Lambayeque, Peru. Mean of 4 seeding densities. N applied: 400 kg/ha. (Larrea and Sanchez, 1971).

Planting System	IR305-3-15 (short, high tillering)	IR253-3-1-3 (tall, low tillering)
Drilled in 25 cm. rows	10.75	8.75
Drilled in 17 cm. rows	11.30	7.77
Broadcast on dry soil and covered	11.64	7.38
Broadcast 1/ on flooded, unpuddled soil	11.58	7.72
Broadcast 1/ on flooded, puddled soil	12.09	7.93
Transplanted 25 x 25 cms 2/	10.52	7.82

1/ Pregerminated seeds

2/

Table 3. Effects of transplanting, spacing and nitrogen fertilization on the yields of several rice varieties (ton/ha) at Lambayeque, Peru. Source: Kawano and Gonzalez (1971).

Variety	Plant type		Nitrogen application (kg N/ha)			
	Height	Tillering ability	80		320	
			25 cms	50 cms	25 cms	50 cms
IR8	Short	high	7.82	6.78	11.17	8.61
Naylamp [1/]	Short	high	8.02	5.86	10.56	8.09
Minabir	Tall	high	8.22	7.37	8.40	7.97
Chiclayo	Tall	low	7.53	5.23	7.74	6.76

[1/] Newly released, high grain quality in Peru from the selection IR930-2-6

Table 4. Effects of two principal herbicides on rice yields (ton/ha) in four locatio in South America. Compiled from Lagos et al, 1970 and Lucena, 1971.

Herbicide	Active ingredient lt/ha	Colombia, direct seeded		Lambayeque, Peru	
		Turipana	Palmira	Direct-seeded	Transplan
Propanil (Stam)[1/]	3.5	2.38	2.94	2.79	8.78
Butachlor (Machete)[2/]	3.0	1.92	3.07	3.46	7.99
Hand weeding		2.27	3.01	3.14	7.45
No weeding		1.19	1.33	0.55	2.20

[1/] Postemergence, when weeds had 2-5 leaves.

[2/] Pre-emergence, 4-6 days after seeding or transplanting.

Table 5. Comparative production costs and returns per hectare between traditional varieties and cultural practices, and short-statured varieties with recommended cultural practices in Lambayeque, Peru. Source: Hernandez 1971. (1 sol = US $ 0.023)

Cost Components	Unit costs (soles)	Minabir variety and traditional cultural practices		Short variety and recommended cultural practices	
		Units	Cost (soles/ha)	Units	Cost (soles/ha)
Certified seed	8.7/kg	70	609	70	609
Tractor - land leveling	250/hr	0	0	4	1000
Tractor - plow and harrow	240/hr	5	1200	5	1200
Dike and canal repair	60/md [1/]	12	720	12	720
Seedbed and pulling	90/md	20	1800	30	2700
Transplanting	90/md	36	3240	44	3960
Irrigation, fertilizer applic, weed and bird control	80/md	35	2800	35	2800
Fertilizer (urea)	9.33/kg N	140	1306	275	2565
Herbicide (Stam)	500/gal.	3	1500	3	1500
Harvest by hand	90/md	25	2250	30	2700
Contract threshing	0.21/kg	4830	1050	9660	2100
Transportation	0.07/kg	4830	370	9660	700
Interests and administrative	7% + 1000	-	2179	-	2578
Total costs/ha [2/]			19,024		25,132
Total cost/kg rice			3.94		2.60
Grain Yields kg/ha	4.70/kg [3/]	4830	22,701	9660	45,402
Price/kg rice					
Net revenue/ha [2/]			3677		20,270
Net revenue/kg rice			0.76		2.10

1/ md = man-days (tarea), averaging 7 hours.

2/ Excluding land rent and matching contributions to labores, both of which are highly variable.

3/ Assumes no price differential between varieties.

Table 6. Comparative absolute and relative production cost components between commercial production of traditional and improved variety-cultural practices packages in Lambayeque, Peru. 1971

Cost components	Traditional variety and cultural practices		Short-variety and improved cultural practices	
	Soles/ha	%	Soles/ha	%
Mechanized land preparation	1200	6.3	2200	8.8
Labor for seedbed and transplanting	5040	26.5	6660	26.5
Labor for other practices	3520	18.5	3520	14.0
Fertilizer material	1306	6.9	2565	10.2
Seed, herbicides	2109	11.0	2109	8.4
Harvest labor, threshing, transport.	3670	19.3	5500	21.8
Interests and administrative	2179	11.4	2578	10.3
Total Production Cost	19,024	100.0	25,132	100.0
Total labor (man-days)	128	56.8	161	51.2

THE ASIAN EXPERIENCE WITH HIGH-YIELDING RICE VARIETIES - PROBLEMS AND BENEFITS

Randolph Barker
Agricultural Economist
The International Rice Research Institute
Los Baños, Philippines

The objective of this paper is to discuss the Asian experience with the high-yielding varieties of rice. Although my knowledge of rice-growing in Latin America is unfortunately limited, I am aware that there are major differences in the rice economies of the two regions. For this reason, I have chosen in the first two sections of the paper to describe the role of rice in the Asian economy and the production of rice on Asian farms. Those of you reading this paper, who are more familiar with Latin America than Asia, will thus have some basis on which to judge the relevance of the Asian experience with high-yielding varieties for your situation.

The third section of the paper deals with the spread of the high-yielding varieties and the impact on production. The final section discusses some of the problems and benefits of the new technology. I should say at the outset that the key problem in Asia is still one of removing the constraints to growth in production, and that the introduction of the high-yielding varieties has been only a first step, although admittedly a rather large step, in this direction.

Rice in the Asian Economy

Rice is the staple food throughout most of tropical Asia, and as such has a dominant role both as an item of production and consumption. The arable land in rice is as high as 80 percent in some countries, and, for most, Asian rice is the source of more than half of the calorie and protein intake. Perhaps the best way to demonstrate the significance of this in terms of the economy is to consider how the impact of an increase in the rice price is felt throughout the economy:

1. Rice producers. For the rice producer, a higher rice price means more income and greater incentive to grow rice. He may decide to increase the hectarage planted to rice or the production per hectare.

2. Agricultural sectors competing with rice. If farmers decide to shift hectarage to rice, production and income from other crops will decline.

3. Consumers. A higher rice price means a higher cost of living and thus a lower standard of living. If consumers must spend more of their income for rice, there will be less money available for the other needs. They may choose to eat less rice and more of other foods.

4. The economy. A higher rice price may force labor to demand higher wages. Higher wages mean a higher cost of production. A high cost of production for export goods negatively influences the competitive position of these goods on the world market. At the same time the high price puts inflationary pressure on the economy.

In summary, a change in the price of rice, whether due to changes in production or consumption patterns, may benefit some segments of the economy at the expense of others, and as a consequence the role of government policy is at times very critical. One example concerns the role of government policy relating to rice self-sufficiency.

Nearly all Asian governments have been committed for years to a policy of national self-sufficiency. The goal reflects both political and economic considerations. However, at the recent Rice Policy Conference held at IRRI, participants pointed to several seeming inconsistencies in the self-sufficiency policies being pursued:

> "In the Philippines self-sufficiency in rice apparently has great political significance although the growing imports of wheat cause little apparent concern. In Malaysia, the high prices designed to encourage self-sufficiency in rice production impose higher labor costs on the nation's major export commodities. In India and Indonesia, and in some other countries, the goal of self-sufficiency has in the past been pursued at the regional level at the expense, in the view of some participants, of national economic integration. These apparent contradictions led some participants to view self-sufficiency primarily in a political rather than an economic context." 1/

In spite of a commitment to self-sufficiency, few countries in Asia until recently had been able to make major strides toward this goal. In fact, the rising price of rice relative to wheat in international and domestic markets after World War II sharply worsened the terms on which the consumers in the rice-producting countries of the tropics had access to food grains.2/ By the mid-1960's, the rising level of food imports in Asia had led to a considerable pessimism in some circles.3/

Producing Rice on Asian Farms

The environmental conditions under which rice is grown in Asia vary widely. Water control is a major factor. Figure 1 represents our best estimate of the area and production of rice in South and Southeast Asia under four water environments: irrigated lowland, deep water, rainfed lowland, and upland.

Even in the so-called irrigated areas, the water control is highly variable. Most irrigation is of the gravity type. Dams are constructed to divert water from major rivers. There is normally no storage capacity. The principal function of the irrigation systems is to provide supplemental water during the rainy or monsoon season. Only a small portion of the area can be irrigated in the dry season. Water flows from the laterals over the rice paddies passing from one field to the next. The farmers farthest from the laterals are dependent on their more favorably situated neighbors for water.

In the major river basins on the continent of Asia (e.g., the Chao Phraya in Central Thailand, the Mekong in Vietnam, the Irrawaddy in Burma, and the Brahmaputra in East Pakistan) there are flood conditions. Rice is planted before the floods and harvested when the waters recede.

The largest area of Asian rice is grown under rainfed conditions. The monsoon rains are empounded by the use of bunds or dykes in level paddy fields. Frequently, the rainfall is sporadic resulting in alternate flooding and drying which encourages weed growth, soil cracking, and poor plant growth. The level of input use on these lands is understandably low.

In contrast with Latin America, upland rice grown on rolling land does not account for a major portion of the land area in production. Many of the upland and rainfed rice farmers use little, if any, commercial inputs such as fertilizer or insecticide.

Rice farms are in general small. At least two thirds of the operating units are less than three hectares in size. However, the term "small" is relative, as can be seen by examining Figure 2. There has been a tendency for countries with very small farms and high population pressure to intensify and increase the productivity of land. For example, in the early 1960's, Taiwan farmers produced 4 metric tons of rice per crop by obtaining a high yield on a small farm (about 1 hectare). Philippine farmers, on the other hand, produced an equal amount of rice for one crop by obtaining a low yield on a relatively large farm (about 3 hectares).

Table 1 shows in more detail the difference in degree of intensity of rice production in East Asia as compared with South and Southeast Asia. Notice that farms in East Asia are very small, are well irrigated, use a high level of fertilizer input, and obtain a high yield per hectare. The growing population pressure on a limited land area will over time force the other countries in Asia to move in a similar direction, increasing land productivity and labor productivity in order to increase output.

Finally, a word should be said about the labor force and the ownership of land. There are three major categories of farm workers--owner-operators, tenants, and landless laborers. A problem facing much of Asia concerns the rights of these farm workers with respect to land ownership, land use, and employment. The high degree of instability in the existing ownership and tenure patterns is a major obstacle to investment in land development in many areas. In a recent article, Gaitskell states that:

> "If we are right in making improved incomes of small farmers a major objective of our development purpose just now, disciplinary action may have to be taken to insure that they in fact become the beneficiaries. The first process in this respect may be a cadastral survey to ascertain who owns what land and the issue of a regular title to the actual farmer."4/

Hired farm labor is currently paid about $0.50 to $0.60 per day in much of the rice-growing area of South and Southeast Asia and rice is produced at a cost of $50 to $60 per ton. At this wage level there is scarcely a need for labor-substituting machinery. At the same time the relatively large farm size and low yield level does suggest that the improvement in the performance of some tasks (e.g., weeding) through mechanization or through the use of chemicals could increase land productivity without decreasing the demand for labor. Many countries do have subsidized credit programs to encourage mechanization, but have not given serious considerations as to the nature and form of mechanization that should be encouraged.

There is a feeling on the part of many Asians that large scale mechanized rice farming would lead to greater efficiency. In an economic sense, we can only interpret greater efficiency as meaning lower unit cost of production. There is no evidence to suggest that large mechanized farms in Asia are low-cost producers. Furthermore, the United States with perhaps the most highly mechanized production in the world is one of the highest cost producers of rice, relying on a government subsidy to maintain its position in the world market.

In summary, it must be acknowledged that in much of Asia today the physical and institutional environment is hardly conducive to the attainment of a high level of land productivity. At the same time, it is clear that these conditions are not likely to change overnight. For example, no matter how fast irrigation development proceeds, the bulk of rice will continue to be produced under unfavorable water control for the forseeable future. Those that undertake research to increase rice production in Asia should not ignore this fact.

The Introduction of the High-Yielding Varieties and the Growth in Rice Production

The story of the development of the short, stiff-strawed, fertilizer-responsive varieties is well know. In the context of our earlier discussion, the objective of this research in varietal improvement was to increase the production per hectare of rice in Asia and hence lower the unit cost of production. As Hayami states: the long-run significance of the "green revolution" in rice production in Asia is that, if its momentum can be maintained, food grains may again become available to the underdeveloped countries of tropical Asia on terms that are as favorable as in the developed countries of the temperate region. The rationale for self-sufficiency becomes more apparent when it is put in the context of removing the food-production constraint on economic growth rather than when it is cast in terms of self-sufficiency at any cost.5/

The argument is that the availability of an inexpensive food supply would allow resources to be diverted to other productive uses. At the same time wage rates and production costs of goods in the developing countries could be kept low to maintain a strong competitive position in world trade.

To what degree do the new rice varieties appear to be contributing to the goal of more rice production at a lower cost? The new varieties spread rapidly throughout many parts of Asia, but as can be discerned from our earlier discussion, acceptance was more rapid in the irrigated than in the non-irrigated areas,6/ and, particularly in India, more rapid on large farms than on small farms.

Table 2 shows where the new varieties have been adopted. The initial beneficiaries were the Philippines, Pakistan, and India. In a recent study in India, Mukerjee and Lockwood7/ observe that the adoption rate of the high-yielding varieties has been more rapid on large farms in the period 1967 to 1970 for both the wet season (kharif) and dry season (rabi) crops. They conclude, however, that participation has not been limited to the medium and large farms. Table 3 shows percentage acceptance of high-yielding varieties on irrigated and rainfed land in the Philippines.

The degree to which high-yielding varieties have led to a higher yield per hectare depends upon the degree of acceptance of a package of complementary inputs such as fertilizer and insecticides. F. S. Liu recently surveyed 513 farmers in the municipality of Gapan in Central Luzon, the major rice-growing area in the Philippines. Some results of his study of the adoption of inputs are shown in Figures 3 to 8. On the double-cropped irrigated areas, where inputs have increased sharply, the yield response has been good. On the rainfed areas where inputs remain low, there is essentially no difference in the performance of the high-yielding vs. the local varieties.

The growth in yield per hectare in Gapan (Figure 4) suggests that despite the rapid acceptance of the varieties, the sustained growth in production resulting from the new technology has not been as great as might have been anticipated. These results are further supported by the national figures for the Philippines which indicate a growth in rice production of 2.4 percent in the period 1957/59 to 1963/65 and of 4.1 percent in the period 1963/65 to

1969/71. The annual rate of growth in demand for rice may be as high as 3.7 percent combining the effects of population growth and higher per capita incomes. For three consecutive years during the period from 1967 to 1970, the real price of rice fell in the Philippines. Philippine rice self-sufficiency appears to have been short lived, however, as the sharp rise in 1971 prices resulting from a rice shortage following a relatively poor crop year has again necessitated importations.

For Asia as a whole, the introduction of the high-yielding varieties coupled with favorable weather has led to a steady increase in production of rice over the past few years. The growth in Asian production from 1963-65 to 1968-70 has been about 3.2 percent.

Only a small fraction of the world rice production enters into international trade (less than 3 percent) and as a result world rice prices are very sensitive to small changes in supply and demand. Figure 9 shows that the Bangkok export price rose sharply in 1967 as a result of shortages brought about by drought in India and Pakistan, by lower Burmese exports, and by the Vietnam war. Expanded production in the United States and surpluses of rice in Japan were in part responsible for the sharp drop in 1968. The impact of the high-yielding varieties on world price was probably not felt until the latter part of 1969. The continued decline of prices until 1971 has caused major concern among the leading exporters, particularly Thailand, which has had to revise its export policies. Just as the high prices in 1967 were accompanied by a wave of pessimism regarding aggregate production potential, so now the low rice prices in 1971 are likely to lead a wave of optimism concerning future growth in rice production. Although it may be somewhat early to judge the sustained growth potential of the high-yielding varieties, the experience of the Philippines suggests that Asia is still walking a very thin line between surplus and deficit.

Problems and Benefits of the New Technology

A recent correspondent to the International Rice Research Institute, seeking information for an article on the "green revolution", writes as follows:

"Our article will show the obvious benefits of these new strains of wheat and rice (such as larger, better crops, i.e., more food for everyone). However, we will also stress the problems brought about by these new agricultural developments. For example, since these new types need more water, fertilizer, and special equipment, only the wealthy farmers can afford to grow them.

Meanwhile, the poorer farmers are becoming even poorer in relation to the rich, and in many cases are leaving the rural areas. Therefore, the cities are becoming overcrowded due to the influx of these jobless peasants."

The author of this letter expresses a very common if simplistic view of the problems associated with the introduction of the high-yielding varieties. I would like to discuss the problems and benefits of the new rice technology under three headings: (1) maintaining the momentum of the current growth in production, (2) the effect on average income and income distribution, and (3) the implications for employment.

Maintaining Momentum

The agricultural problem that is still uppermost in the minds of most Asian policy makers today is how to maintain the growth in rice production. Some countries have as yet to feel the impact of the new rice technology. The crop year 1970/71 is reported to be the first year, for example, that Indian production had shown a significant rise as a result of the high-yielding varieties.8/ West Pakistan is the only major area that has had to deal with the problem of large surpluses and falling rice prices. The issues of diversification, income distribution, and employment, which are of major concern in academic circles, are not yet a paramount concern to many policy makers.

Shortly after the release of the first of the high-yielding varieties, several problems became obvious:

(a) In terms of milling and eating quality, the new varieties were considered to be inferior in many domestic Asian markets and in the international export market.

(b) There are many parts of Asia where the varieties performed poorly because of their susceptibility to local insects and diseases.

(c) The varieties were rapidly accepted in many of the well irrigated areas, but made no significant impact on production on the poorly irrigated, rainfed, and upland areas.

(d) Acceptance in some areas was restricted by poorly developed markets to channel rice to consumers and inputs to farmers.

The first three of these constraints to growth concern the need for further research at the experiment station, and I would like to describe briefly the steps that have been taken in this direction.

Improving Quality

As the technological base in agriculture grows, there is a tendency for the new varieties to become increasingly location specific.9/ Varieties must be developed which are suited to local tastes and local environmental conditions. Consumer preference for rice in Asia varies widely and is based upon a number of factors such as appearance,, taste, texture, and aroma. IR8 and IR5 rank poorly in both appearance and eating quality. Poor appearance was due to the chalkiness or "white belly" found in a portion of the kernel. This chalkiness also increases the percentage of broken grains in milling. A major factor affecting eating quality is the amylose content of the rice which influences the resulting degree of stickiness when cooked. IR8 and IR5 are high in amylose and as a result the cooked rice is dry and flaky, but tends to become hard when allowed to cool.

Whether due to appearance or cooking quality, IR8 and IR5 sell at prices from 10 to 20 percent below the better varieties and grades of rice throughout most of Asia. For example, in India they are classed as coarse rices, and in the Philippines they normally receive Class II milling (i.e., they are undermilled in comparison with the best quality rices). Appearance and percentage brokens are the major factors determining price in the export market. Hence, in Thailand, where rice is a major export, it was decided not to grow these varieties.

The experience of Thailand offers one of the best examples of the adoption of the new rice technology to local conditions. In 1970 the Rice Department released three new varieties, RD1, RD2, and RD3.10/ The odd-numbered varieties are the selections of a cross between the local Thai variety Leuang Tawng and IR8. The even-numbered variety is a glutinous rice suited to the local needs of Northeast Thailand. It is one of the IR253 lines bred at IRRI, a cross between the Thai variety Gan Pahi 15/2 and Taichung (Native) 1.

The new varieties embodying high quality and high yield potential have been developed in a number of other country programs: C4-63 (BPI-76 x Peta) in the Philippines; Pelita 1 and 2 (Syntha x IR5) in Indonesia; Jaya, Padma, Pankaj, Jagannath, Krishna, Ratna, Vijaya, and others in India.11/ In spite of this progress, there are still many parts of Asia where farmers are looking for a high-yielding variety well suited to local conditions. In some countries where these varieties have already been developed, inadequate methods of seed multiplication and distribution appear to be bottleneck.

While the latest IRRI releases (IR20, IR22, and IR24) represent a considerable improvement in quality over IR8 and IR5, the work of improving seed quality should continue to be an important part of the various country research programs. Meanwhile, research workers at IRRI have begun to examine another dimension of the quality problem, protein content.

Improving Resistance to Disease and Insects

Athwal noted recently that:

> "The increased productivity per unit area has also begun to create problems for plant breeders. The modern production practices used for the new strains provide environments which not only are good for plant growth but also provide ideal conditions for the development of diseases and harmful insects. The shift in varieties and plant environment is, no doubt, favoring the appearance of pests which were previously unknown or unimportant. To exploit fully the potential offered by the semi-dwarf plant type, a high degree of resistance to different plant parasites must be incorporated in the new varieties. Any complacency or inadequate investment in research could keep the new productive potential unrealized and precipitate renewed food crises."12/

Blast (a fungus) and bacterial leaf blight are widespread and destructive diseases in rice. Plant pathologists are working with rice breeders at the Institute and elsewhere to develop varieties with "generalized" or "horizontal" genetic resistance that is not specific to a particular race of the rice blast.13/

The most widespread and destructive pest is the stem borer. The principal method of control has been through the application of insecticides. Selecting and breeding for insect resistance had been tried in other crops, but not in rice before 1962. Over a period of four years, from 1962 to 1965, the world collection of varieties was screened for resistance to stem borer. Twenty varieties were identified as highly resistant by Pathak and his co-workers in entomology.14/ In 1965 several resistant varieties were crossed to combine stem borer resistance with improved plant type and other desirable characteristics, and in 1969, one of these selections (IR532-E-576) was named IR20 by the Institute and thus became the third variety to be released. IR22 was released on the same day. Both of these varieties have a quality accepted by international trade standards.

Research also was undertaken to identify varieties resistant to the green leafhopper which transmits tungro virus and the brown planthopper which transmits grassy stunt.15/ Viruses have been a particularly difficult problem in some areas of Asia. One objective is to combine in a single variety resistance to the virus with resistance to the insect transmitting the virus. It has also been discovered through genetic studies that in some varieties the location of insect resistance on the chromosome is distinctly different than in others. In such cases, it may be possible by breeding to combine in a single variety the two sources of resistance to an insect.

This work initiated by the entomologists in breeding for resistance to insects marked the beginning of what has now become a major objective of the rice-breeding program. Breeding for resistance would be the best long-run solution to many of the insect and disease problems. In the meantime, however, there will be a continuing need to explore economical ways of controlling pests through traditional methods such as the use of insecticides, or through less conventional methods such as biological control, Problems of pest management require a thorough understanding of the insect ecology, and in 1970 the Institute added a second entomologist to the senior staff to give particular attention to these problems.16/

Improving Yields in the Areas of Poor Water Control

In both Japan and Taiwan, population pressure and topography dictated the rapid expansion of irrigation facilities even before the introduction of the high-yielding rice varieties. Thus, there has historically been little need in these countries to devote a major research effort to the problems associated with growing rice under poorly irrigated, rainfed, and upland conditions.

The situation facing South and Southeast Asia today is far different. Improved irrigation and water control offer one avenue for increasing rice production in Asia. But regardless of how rapidly irrigation development proceeds, much of the rice in Asia will continue to be grown under rainfed, upland, and deep water conditions for the foreseeable future: Thus, there is need for a broad program of research focused on the problems of water management. On the one hand, attention must be given to the problems associated with the development and expansion of irrigation, whether by pumps or through gravity systems. At the same time, the problems of improving production on the non-irrigated areas must receive more attention than they have in the past.

In October 1969 a conference was held at IRRI to discuss the direction of rice research in the 1970's.17/ There was considerable discussion relating to rainfed and upland rice. In 1970 the Institute added a soil physicist to the staff to devote special attention to the problems of plant-water relations and water management. Several departments have undertaken research to find out what happens to the rice plant in situations of less than adequate water supply. We have also mentioned previously the fact that research was undertaken in Thailand to examine the other end of the spectrum -- deep water rices.

The objective of this research is to develop a set of inputs tailored specifically to these unfavorable environmental conditions. An important element of this input package would be a fertilizer-responsive variety that can withstand drought or deep water as the case may be. In addition, by the use of resistant varieties and low cost herbicides we should be able to substantially reduce the cost of the input package -- fertilizer representing the major item of expense. A low cost herbicide is important, because in many of the rainfed areas farmers using fertilizer cannot contend with the weed problem, the lack of water cover being a major stimulant to weed growth. Naturally, the level of fertilizer input and yield gain will be below that in the well irrigated areas. But we feel that there are potential benefits in this program through increased production and income on farms that have not yet been touched by the green revolution.

Product and Input Markets

We have previously mentioned the problem of surplus production in West Pakistan which led to a considerable disruption of the local rice market. However, the West Pakistan case in Asia has been the exception rather than the rule, largely due to the magnitude of the initial production gains resulting from very favorable environmental circumstances.[18/] In general, rice marketing in Asia is highly developed, although the quality of the product seldom meets export standards. The marketing system has been capable of handling the increased production.

The situation with input markets has not been as favorable. Participants at the IRRI Rice Policy Conference emphasized the constraints to producer response imposed by the lack of development of factor markets (for seed, fertilizer, pesticides, and credit) as opposed to product markets.[19/] As mentioned previously, unavailability of seed has in some cases been the major stumbling block. In spite of the expansion of institutional credit sources, farmers are for the most part dependent on private sources of credit with highly variable but invariably high interest rates.

Effect of the New Technology on Average Income and Income Distribution

The average income of farmers appears to have increased in the short run as a result of the new rice technology because average yields and gross returns have increased faster than the cost of factor inputs. The cost per unit of production appears to have been lowered, but the degree to which the benefits have been divided between producers and consumers varies throughout the region depending upon government policies. In most countries, however, the direct benefits of the new agricultural technology to society have been less than to the food grain sector because the subsidies provided to the farmers (in the form of credit, research, extension, infrastructure, irrigation water, price supports, trade controls, etc.) have outweighed the taxes. At the same time, it would be difficult to weigh the direct benefits of establishing a more prosperous rice-farming sector against the indirect benefits of reducing the food grain price.

A weak agricultural tax system coupled with subsidized credit and low interest rates makes it difficult to capture profits resulting from the new technology for public investment in economic development. There is, I think, legitimate concern that benefits are instead being capitalized into rising land values or dissipated on imported consumption goods. However, the low rate of taxation may have provided a stimulus to private capital formation.

The impact of the new technology on the distribution of income is a frequent topic in the literature of the "Green Revolution". I don't believe that this issue can be analyzed independently of the rural farming structure. For example, in India, where tenancy is comparatively low, and farm size varies widely, the question can be properly viewed in terms of big farmer vs. small farmer, or landowner vs. landless laborer. In the Philippines, with a high rate of tenancy and relatively small operating units, it is more appropriate to compare landowner vs. tenant vs. landless laborer. Central Java, with a large number of very small owner-operators, presents yet another situation.

In India, large landowners who grow rice have clearly benefited more than small landowners. In fact, the Indian government has created the Small Farmers Development Agency to deal with this problem. Despite stories of labor unrest and of repressive measures being taken by landowners against laborers, the evidence on the effect of new technology on landless laborers seems much less clear-cut than for landowners.

In a recent study in the Philippines, we examined how the benefits of the new technology are being shared.[20/] After cash operating expenses were subtracted from gross returns, the remaining net was divided -- 43 percent to the landowners for the provision of land; 32 percent to the tenant for the provision of carabao, tools, and equipment, family labor, supervision and management; and 25 percent to hired labor. In 1966, prior to the introduction of the new rice varieties, the shares of the net were 43, 37, and

20 percent, respectively. In this particular study area, because of the sharp increase in the demand for labor, the share of the "pie" going to hired labor has increased. The landowners have the additional long-term benefits of rising land values, as mentioned previously. Thus, the distribution of benefits presents a mixed picture, and it is very difficult to say how the new technology has influenced the power relationship between these groups. Nevertheless, where the rights of land ownership and employment are uncertain, as they are in much of Asia, there is the threat of open conflict among the claimants to the new profits.

Employment Opportunities

The issue here might be stated as follows: Does the new technology require more labor for more intensive crop practices? Or is the introduction of these improved practices accompanied by labor-saving devices such as tractors, threshers, and the like? A further question relates to the impact of the new technology on diversification of resources and upon non-farm employment.

Again, as in the case of income distribution, the answer to these questions must be related to local farming conditions and institutions. It can be said in general, however, that throughout South and Southeast Asia factor and product prices tend to be distorted by subsidization programs, minimum wage policies, and overvalued exchange rates. The distortions have lowered the cost of capital relative to labor. In this situation, as we have argued elsewhere[21], unemployment and underemployment is potentially more of a problem.

Although there is much conjecture about the employment problem, there is little empirical data available to clarify this issue. Consider the rice sector. Our studies in the more progressive areas of Luzon suggest that more labor is being used for weeding but less for land preparation as a result of increased mechanization. On balance per hectare, preharvest labor has changed little but the demand for harvest and threshing labor has increased as a result of higher yields. The most striking change has been the increase in demand for hired labor in the form of contract labor for land preparation, weeding, and harvesting-threshing.

The new rice technology requires somewhat more labor per hectare. Particularly in countries moving toward self-sufficiency, the rice sector will tend initially to absorb labor. But, the new technology also reduces the labor requirement per unit of production. Thus over the long run and beyond self-sufficiency, relatively less labor (and more capital) should be required to meet a nation's rice requirements. To take advantage of this increase in labor productivity, opportunities must be developed for the use of labor elsewhere. This brings us back again to the question of diversification and multiple cropping. Undoubtedly, multiple cropping of rice in combination with other crops has the potential to absorb more labor. Farm surveys in the Philippines and elsewhere confirm this fact. The problem is how to bring about its spread and development.

Finally, there is the matter of off-farm employment. The quantitative impact of the new technology on off-farm employment is simply not known. I am aware of only one study in the Philippines that is addressed to this problem, and this has just been initiated. We know that the new technology has increased the demand for fertilizer, chemicals, tractors, pumps, transistor radios, most of which are imported. We know that demand for domestically produced items such as lumber and cement blocks for improved housing has also increased.

Conclusions

The development of the high-yielding varieties removed a major constraint to the growth in rice production in Asia. Initial progress has been made in raising yield per hectare on irrigated lands. However, in contrast to East Asia, the irrigation in South and Southeast Asia is still poorly developed. Both productivity and equity considerations demand that more attention be given to increase the rice yields in the unfavorable water environments which characterize most of the rice-growing area of Asia. We do not know as yet the potential for yield improvement in these areas.

Other problems have also been encountered in the dissemination of the high-yielding varieties. Developing appropriate institutions for dissemination of inputs is a more critical issue than the improvement of rice marketing. The effect of the new technology on income and employment is difficult to assess. It seems clear, however, that in some areas of Asia tension is likely to arise over the struggle for control of new profits. A society that achieves viable economic, social, and political development must institutionalize transfer mechanisms and redistribute the income streams in a manner that will reduce the social and political stress resulting from development.22/

Table 1. Selected factors relating to rice production in the major rice-producing countries of Asia (excluding communist block countries), mid-1960's. a/

	Percent arable land in rice	Percent world production imported or exported b/	Rice yield per ha (mt)	size of farm (ha)	Percent riceland irri-gated	Percent ricefield area double-cropped	NPK per ha ara-ble land (kg)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
South Asia							
1. Ceylon	28	14	1.93	-	60	43	36
2. India	21	18	1.58	2.2	37	-	4
3. Pakistan	38	3	1.67	1.7	14	-	4
Southeast Asia							
4. Burma	32	24	1.63	3.0	12	c/	2
5. Cambodia	79	7	1.81	2.2	18	c/	2
6. Indonesia	57	20	1.82	1.3	54	31	7
7. Laos	75	0	1.14	3.5	-	-	-
8. Malaysia	14	10	2.09	1.6	44	19	20
9. Philippines	29	10	1.27	3.0	29	15	8
10. Thailand	60	28	1.60	2.6	28	7	3
11. Vietnam (South)	83	2	1.99	1.7	11	10	15
East Asia							
12. China (Taiwan)	87	3	3.87	1.2	98	63	237
13. Japan	54	14	4.83	0.8	97	c/	304
14. Korea (South)	56	0	3.14	0.9	79	c/	168

a/ Although the figures in this table are for the most part from official documents, they should be regarded as orders of magnitude rather than as exact estimates.

b/ Underlined figures represent imports.

c/ Less than 2 percent double-cropped.

Source of data: Number refers to column number.

(1) Demographic Yearbook of UN, 1963 and FAO Production Yearbook, 1965 growth computed for period 1962-64, and FAO Production Yearbook, 1965. Figures for the crop year 1964/65, except Laos, 1963/64.

(2) FAO Rice-Reports - 1963, 1964, 1965, and 1966. Percent based on average for years 1963-65.

(3) USDA, FAS, World Agricultural Production and Trade, June and Nov. 1966. Average of years 1963/64 - 1965-66.

(4) USDA, ERS, An Economic Analysis of Far Eastern Agriculture, Foreign Agr. Econ. Report No. 2, Nov. 1961, p. 11 - Figures for 1959.

(5) Based on International Rice Yearbook, 1961 Edition, and Asian Agricultural Survey, Asian Development Bank, Manila, 1968.

(6) Asian Agricultural Survey, Asian Development Bank, Manila, 1968.

(7) FAO Production Yearbook, 1965 and Fertilizers, Annual Review of World Production, Consumption and Trade, FAO 1966. Figures for crop year 1964/65.

Table 2. Estimated hectarage of new varieties of rice by country, 1969/70.

	Total rice hectarage[a/] (1000)	Hectares planted new varieties[b/] (1000)	Percent rice-land new varieties
South Asia			
Ceylon[c/]	671	26	3.9
India[d/]	38,001	4,371	11.5
Nepal	1,174	50	4.2
East Pakistan	10,265	264	2.6
West Pakistan	1,811	501	27.7
Southeast Asia			
Burma	5,018	144	2.9
Indonesia	7,972	749[f/]	9.4
Laos	769	2	0.3
Malaysia (West)[e/]	526	128	24.3
Philippines	3,100	1,239	40.0
Vietnam (South)	2,519	202	8.0

a/ U.S. Dept. of Agriculture, World Agricultural Production and Trade, Dec. 1970.

b/ D. G. Dalrymple, Imports and Plantings of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations, U.S. Dept. of Agriculture Foreign Economic Development Report No. 8.

c/ Excludes H_4 and H_8.

d/ Includes ADT-27 and Taichung (Native) 1.

e/ Includes Mahsuri and Malinja.

f/ There is particular uncertainty concerning this figure.

Table 3. Percent of lowland rice planted to high-yielding varieties on irrigated and rainfed lands in the Philippines 1967/68 to 1969/70. [a]

% of area in HYVs	1967/68	1968/69	1969/70
Lowland irrigated	25	46	60
Lowland rainfed	7	15	32
Total lowland	15	31	46

a/ Includes IRRI and UPCA varieties, principally IR5, IR8, and IR20, and C4-63.

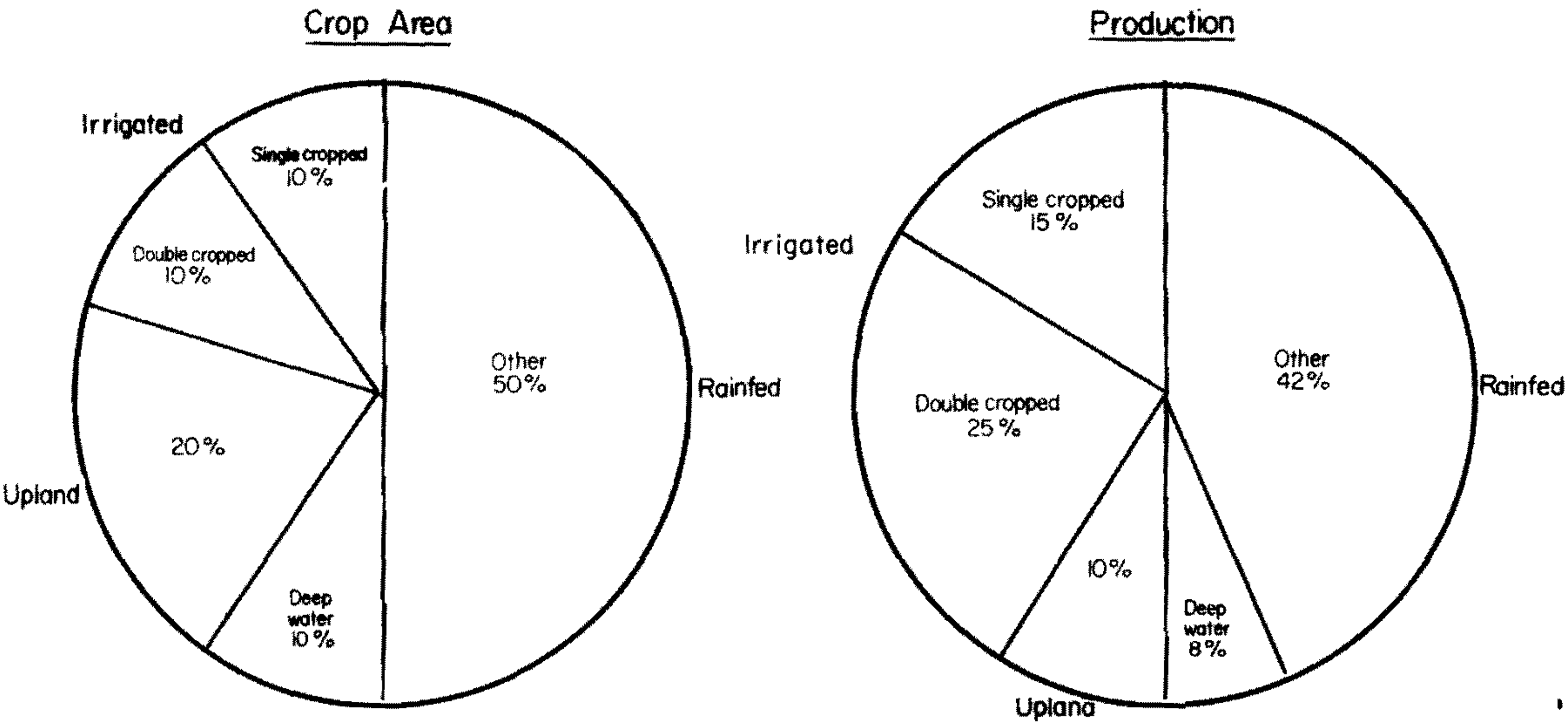

Fig. 1. Estimate of percent rice crop area and production by specified land type in South and Southeast Asia.

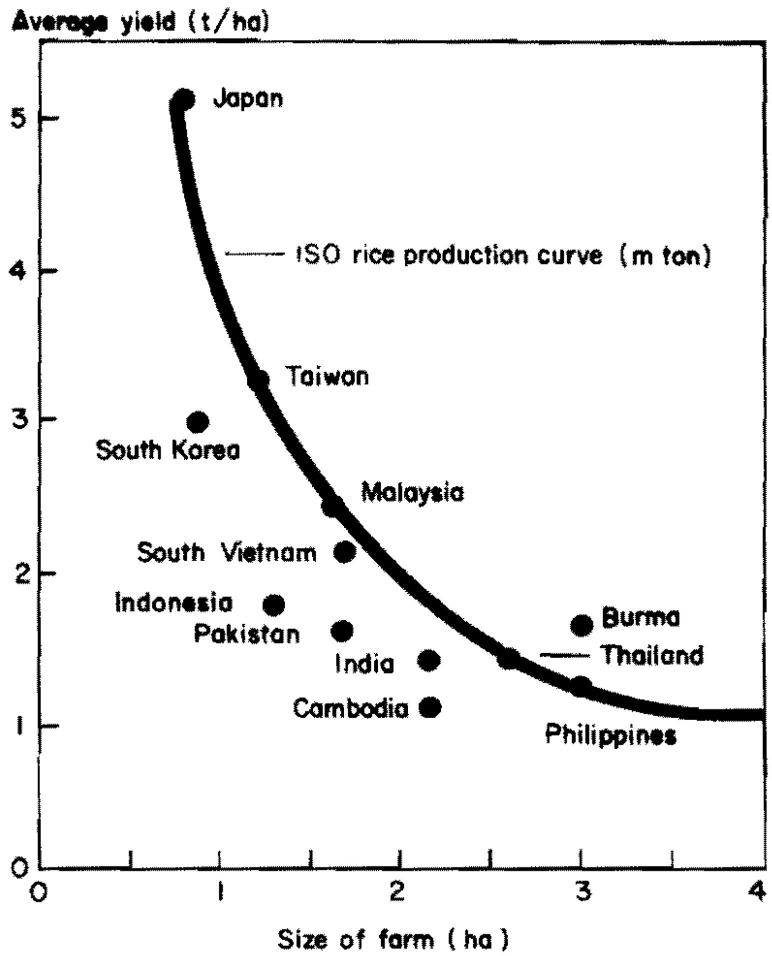

Fig. 2. Relationships between farm cultivated area and hectare yield of rough rice in selected countries, average 1959/60 to 1963/64.

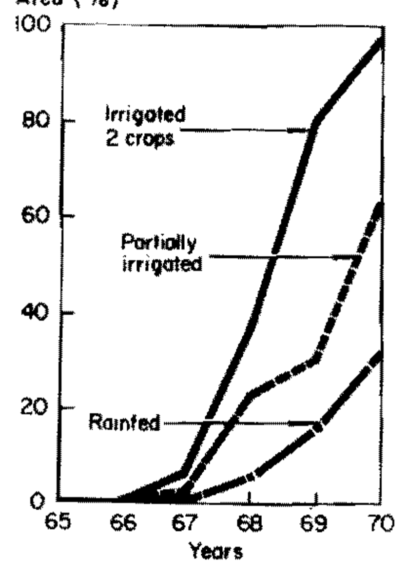

Fig. 3. Percent area planted to HYV, Gapan, N.E.

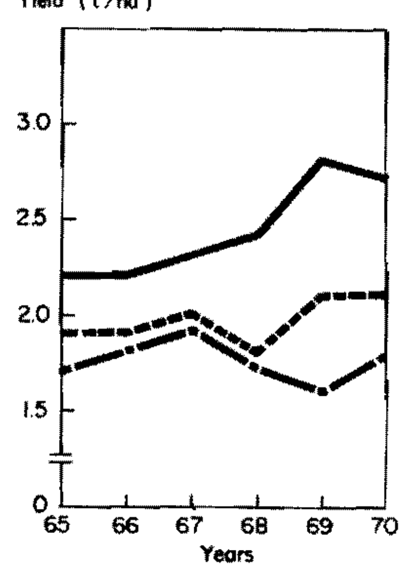

Fig. 4. Yield per hectare, Gapan, N.E.

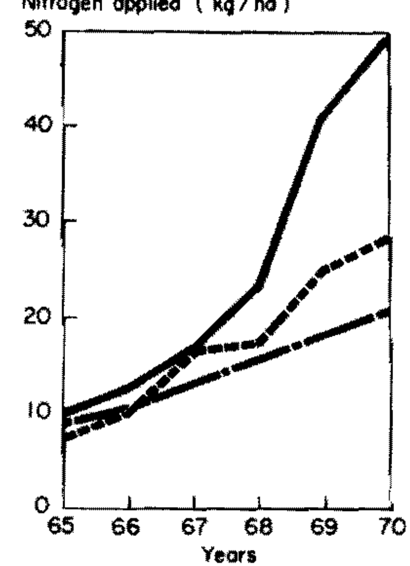

Fig. 5. Nitrogen used per hectare, Gapan, N.E.

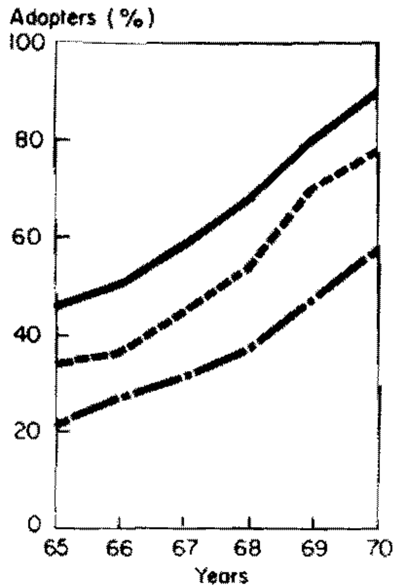

Fig. 6. Percent insecticide users, Gapan, N.E.

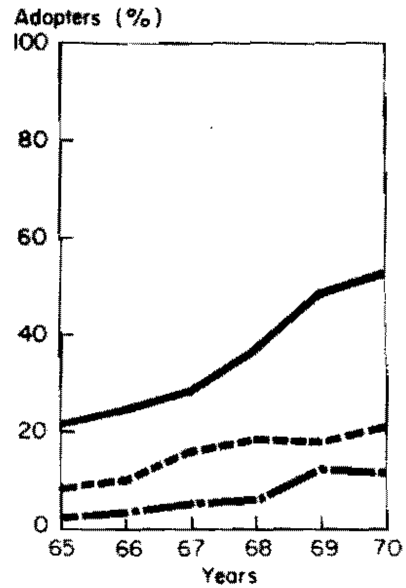

Fig. 7. Percent herbicide users, Gapan, N.E.

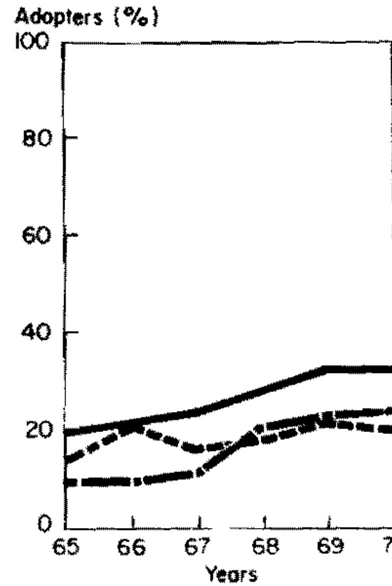

Fig. 8. Percent farmers using tractor for plowing only, Gapan, N.E.

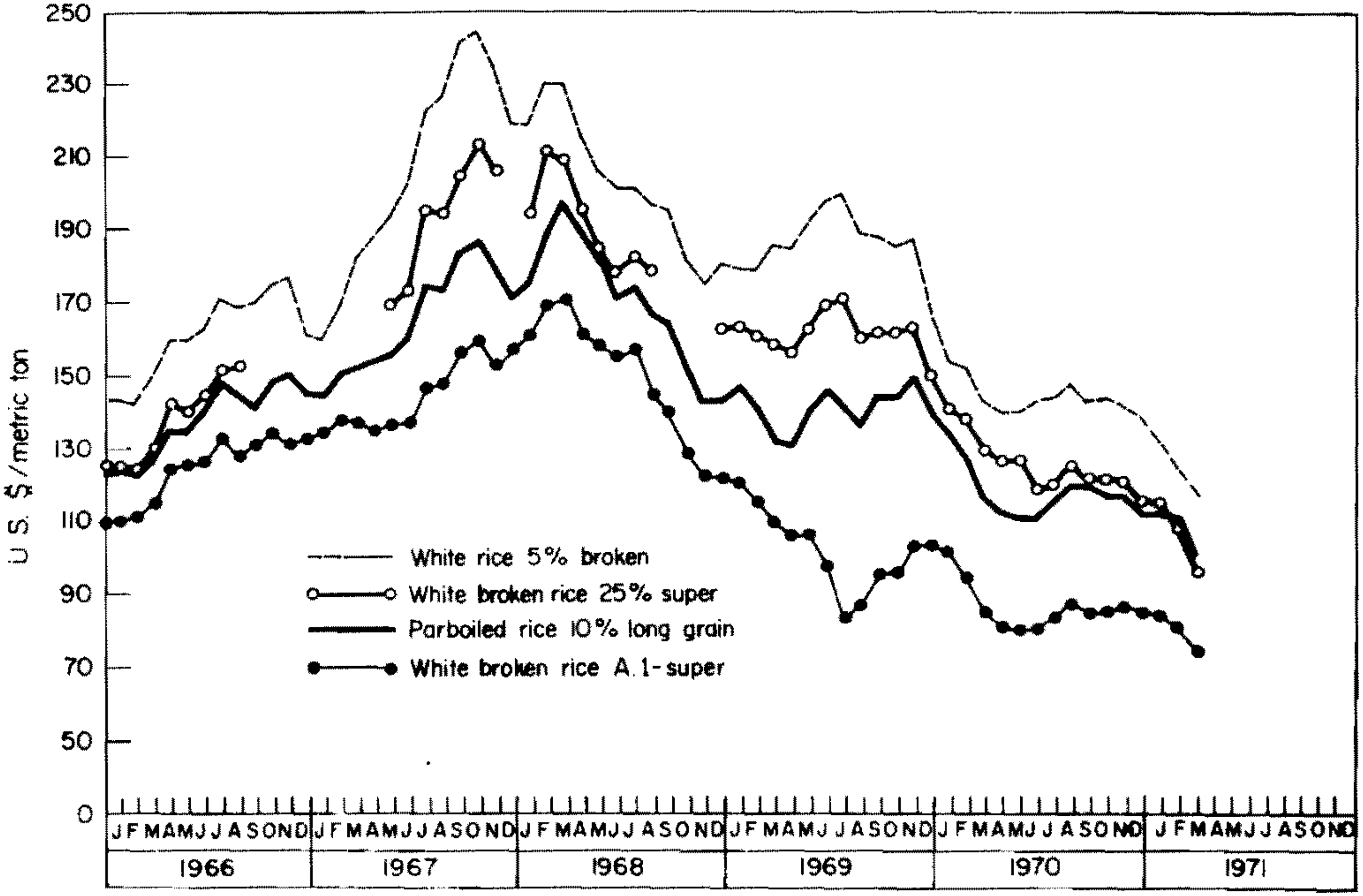

Fig. 9. The Thai export price of rice 5% broken, parboiled 10%, long grain, white broken 25% super and white broken A.1 super. F.O.B. Bangkok.

FOOTNOTES

1/ V. W. Ruttan, "Rice Policies in the 1970s: A Perspective on the IRRI Conference."A summary of the discussion that took place at the Rice Policy Conference, The International Rice Research Institute, Los Baños, Philippines, May 9-14, 1971, p. 3.

2/ Ibid, p. 3.

3/ See, for example, Lester R. Brown, "The Stork Outruns the Plow," Reprinted from Columbia Journal of World Business, Vol.II, No. 1, Jan.- Feb. 1967.

4/ Arthur Gaitskell, "Some of the Puzzles Facing Development Strategy in the Seventies and their Influence on the Choice of Institutional Machinery in the Agricultural Sector."Paper to be presented at the Conference on Agriculture and Economic Development, sponsored by The Japan Economic Research Center, Tokyo, Japan, Sept. 6-10, 1971, p. 17.

5/ Ruttan, op. cit. , p. 3.

6/ R. Barker and M. Mangahas,"Environmental and Other Factors Influencing the Performance of New High-Yielding Varieties of Wheat and Rice in Asia." Paper presented at the XIV International Conference of Agricultural Economists, Minsk, U.S.S.R., Aug.24 - Sept. 2, 1970.

7/ P. K. Mukherjee and B. Lockwood, "High Yielding Varieties Programme in India - Assessment."Paper prepared for the 28th International Congress of Orientalists, Canberra, Australia, January 6-12, 1971, pp.16-17.

8/ D. Narain, "Rice: Policies and Problems in India."Paper prepared for the Rice Policy Conference, The International Rice Research Institute, Los Baños, Philippines, May 9-14, 1971.

9/ R. E. Evenson, J. P. Houck, and V. W. Ruttan, "Technical Change and Agricultural Trade: Three Examples - Sugarcane, Bananas, and Rice."The Technological Factor in International Trade, National Bureau of Economic Research, New York, 1970.

10/ Ben R. Jackson, Worawit Panichapat and Sermsak Aakul, "Breeding, Performance and Characteristics of Dwarfs, Photoperiod Non-sensitive Varieties for Thailand."Thai Journal of Agricultural Science, Vol. 2 No. 2, July 1969, pp. 83-92.

11/ S.V.S. Shastry "All-India Coordinated Rice Improvement Project Organization and Program." Paper presented at the Seminar on National Agricultural Research Systems sponsored by the Indian Council of Agricultural Research in cooperation with the U.N. Food and Agriculture Organization and the Agricultural Development Council, New Delhi, March 8-13, 1971 (revised). Also, S.V.S. Shastry and W. H. Freeman, "New Dwarf Varieties for India in the Seventies AIRCRIP Publication No. 26, Rajendranagar, Hyderabad-30 Andhra Pradesh, India.

12/ D. S. Athwal, "Semidwarf Rice and Wheat in Global Food Needs." The Quarterly Review of Biology, Vol. 46, No. 1, March 1971.

13/ S. H. Ou and P. R. Jennings, "Progress in the Development of Disease-resistant Rice." Annual Review of Phytopathology, Vol. 7, 1969, pp. 383-410.

14/ M. D. Pathak, "Stem borer and leafhopper-planthopper resistance in rice varieties." Entomologia Experimentalis et Applicata, 12 (1969); 789-800 (North-Holland Publishing Co., Amsterdam). Also M. D. Pathak, Fausto Andres, N. Galacgac and R. Raros, "Resistance of rice varieties to striped rice borers." International Rice Research Institute Bulletin 11, 1971.

15/ Kazushige Sogawa and M.D. Pathak, "Mechanism of Brown Planthopper Resistance in Mudgo Variety of Rice (Hemiptera: Delphacidae)." Applied Entomology and Zoology, 5(3), 145-158, 1970.

16/ V. A. Dyck, "Principles of Pest Management and Ecology of Rice Pests." Paper given at the International Rice Research Conference, IRRI, Los Baños, Philippines, April 20, 1971.

17/ International Rice Research Institute, "Rice Research and Training in the 1970s." Report of the Rice Outlook Conference, IRRI, Los Baños, Philippines, Sept. 20-Oct. 3, 1969.

18/ Barker and Mangahas, op. cit.

19/ Ruttan, op. cit., p. 7.

20/ R. Barker and V. Cordova, "The Impact of New Technology on Rice Production-A Study of Change in Three Philippine Municipalities from 1966 to 1969." Paper presented at the 28th International Congress of Orientalists, Canberra, Australia, January 6-12, 1971.

21/ C. M. Crisostomo, W. H. Meyers, T. B. Paris, Jr., B. Duff, and R. Barker, "The New Rice Technology and Labor Absorption in Philippine Agriculture." Paper presented at the Conference on Manpower Problems in East and Southeast Asia," Singapore, May 22-28, 1971

22/ Ruttan, op. cit., p. 9.

INPUTS AND STRATEGIES IN NATIONAL RICE PROGRAMS

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Francis C. Byrnes
Communication Specialist
Centro Internacional de Agricultura Tropical
Cali

Three concepts are central to the process by which a country determines and reaches the objectives it sets for its rice action program.

First, while the problems and the issues usually are technical and economic, they must be resolved by, for and in terms of people. Technical change is inextricably linked with influencing and changing human behavior — what people know, what they understand, how they feel, and what they are able and willing to do.

Second, an action program involves a complex system of components. These include institutions (research, educational, economic, political), farms, inputs, markets, infrastructures, and relationships among all of these. To the extent that planning enables us to identify the relevant components which we must take into account, we thus identify the people upon whose present and future behavior depends largely the success or failure of the program.

Third, an elusive but indispensable ingredient is basic in planning, in making decisions, in coordinating programs, and in changing behavior. This vital input is relevant information— about the widest possible range of topics a total systems perspective introduces.

Before exploring each of these concepts, let us review the inputs and strategies associated with rice action programs in two countries, Pakistan and the Philippines. These brief reviews will help us to realize that it is possible to achieve production goals rather quickly, that with even the most detailed and careful planning something may be overlooked, and that unexpected consequences can be significant.

"Lessons" from Pakistan

Faced with the prospects of serious food shortages, the Government of Pakistan, with the cooperation of the Ford Foundation and other interests, embarked in 1965 on a program to achieve food grain self-sufficiency in wheat and rice, this objective receiving priority second only to national defense. It launched an Accelerated Crop Improvement Program to achieve the dual goals of self-sufficiency and the establishing of local agricultural research competence to support continued growth.

The first of the new high-yielding wheats and rices had been developed at CIMMYT and IRRI, respectively, and within five years total wheat production increased in West Pakistan by more than 60 percent and rice production by nearly 70 percent.

Among the factors contributing to the rapid and successful spread of these new varieties were:

1. The establishing of province-wide, multi-disciplinary, crop-oriented research programs and practical training for extension workers.
2. The new varieties, when accompanied by inputs and improved practices, gave spectacular results.
3. West Pakistan already had extensive areas under irrigation, and many farmers who wanted even better water control installed private tubewells.
4. Fertilizers already had been introduced at subsidized prices.
5. Supports were set for wheat and rice which offered farmers a minimum price for their products and the government guaranteed a market.
6. Where farmers had access to markets, they responded "as economic beings."
7. Extensive use of radio created an awareness among farmers and motivated them to seek more information and to participate in the production program.

Other factors facilitating the adoption were continual involvement of policy-makers and administrators, use of expert short-term consultants, travel and study awards for decision-makers and scientists, additional training for some nationals, and the importing of critically needed equipment and supplies.

By 1968, other problems emerged in West Pakistan. Transportation facilities were inadequate to cope with market gluts; when railroads were unable to move expanding supplies, rice prices dropped 40 percent. Rice processing facilities were antique, inadequate and, where parboiling was not practiced, the quality fell below that for which supports were provided. Prices fell drastically.

Because some areas without irrigation were not able to grow the new rices, some farms boomed while others remained stagnant. A few large land-owners returned to their farms with tractors and combines, thus displacing tenants.

Only the continued need for food imports in East Pakistan saved West Pakistan from the financially difficult position of dumping a half million tons of low quality, low value wheat and rice into highly competitive world markets.

Climatic conditions, insect and disease problems, lack of irrigation and other factors created barriers to the acceptance and spread of the first new rice variety, IR8, in East Pakistan.

When a more suitable variety, IR20, became available, the government in 1970 launched an Accelerated Rice Production Program to increase rice production through the growing of IR20.

Some of the special inputs and strategies included:

1. Appointment of a special director with rank equivalent to Departmental Secretary.
2. Importation of seed from the Philippines.
3. Selection of 175,000 acres for the transplanted crop in relatively flood-free zones.
4. Setting up blocks of 400 acres each in selected areas of 12 districts.
5. Providing credit to cover the total cost of inputs including labor.
6. Assuring a timely supply of chemicals, technical assistance, and other inputs.
7. Reorientation of extension organizations in function and organization; hiring of extra personnel for some areas.
8. Expansion of infrastructure, including markets and credit sources.

This pilot introduction program was carefully studied because of the exciting prospect that if farmers would accept and could successfully grow the new variety and manage the inputs, more than five million acres of relatively flood-free land could be brought into production to meet expanding food needs.

Although the devastating flood and cyclone of November 1970 disrupted government activity, the program was carried out and farmer experiences documented. Generally, the variety was well accepted, and most farmers said they would plant it again. In the areas achieving high yields and even where IR20 did not yield as well as local varieties, the input program was judged a success: — Seed was widely distributed; growers received fertilizer and some plant protection; most growers acquired loans; and many extension personnel as well as farmers received training.

Unfortunately, the civil strife which has shaken East Pakistan this past year has made it difficult to continue the program or to determine the fate of rice production.

"Lessons" from the Philippines

Release of the first new high-yielding rice variety IR8 by the International Rice Research Institute provided the Philippines with the first tangible hope of reversing the 50-year record of low rice productivity and importation of rice.

In 1966, production of rice was at least 100, 000 metric tons less than the country's needs, and the average amount imported for the previous four years was more than 300, 000 metric tons. The National Economic Council mobilized for action.

After experimental yield trials in two pilot provinces in late 1965, the government sponsored a seed multiplication program, beginning with the purchase of 50 tons of seed from IRRI.

Simultaneously, the government activated the Rice and Corn Production Coordination Council which became the driving, integrating force for a nation-wide rice production campaign. President Marcos, to accelerate the program, assigned his special assistant, Executive Secretary Rafael M. Salas, to serve as action officer of the RCPCC, and under his dynamic leadership the program moved. One year after its introduction, IR8 was growing on nearly 8 percent of the most productive rice lands in the Philippines.

The RCPCC first concentrated on raising rice yields in the "rice band," the 12 provinces with the most irrigated land. Credit was liberalized so that farmers could borrow up to 800 pesos* per hectare without real estate collateral. These loans were made possible by the establishing, with the help of USAID, an Agricultural Guarantee Loan Fund administered by the Central Bank and loaned by the rural banks. Trained agricultural credit teams from the Central Bank were assigned to each bank so that prospective farmer-borrowers could get sound advice.

With the cooperation of IRRI, special training programs were designed to upgrade the rice production knowledge and technology of hundreds of extension workers for the various rural agencies. Other groups, such as the Peace Corps, missionary bodies, and even the wives of owners of large rice land holdings, enrolled in special production courses.

Through these trained people, IRRI and the national agencies mounted a country-wide applied research program to test the adaptability and suitability of the new variety and associated cultural practices in local environments. This involved farmers first-hand in the final stages of the research process.

Concurrently, the ESSO company brought into operation a large urea fertilizer plant near Manila and began developing a network of some 500 agro-service centers throughout the Philippines. These centers placed fertilizers and other inputs close to the farmer. One obstacle arose when the government refused to let the ESSO stores obtain supplies of the new seeds with the rationale that this was too valuable a commodity to let private enterprise control.

Private enterprise got into the act in other ways, however. First, with the assistance of the National Economic Council and USAID, "Do It Yourself IR8 Rice Kits" were assembled. These contained sufficent IR8 seed to plant 2,000 square

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* At that time, the value of the peso was approximately 25 cents U.S.

meters, along with sufficient fertilizer, insecticides, and rat poison. The determining factor here was the 44 kilogram bag of ESSO fertilizer, sufficient for 2,000 square meters of rice.

Interest in the kits, which sold for 70 pesos, mounted rapidly, and eventually industry assembled and sold thousands. Not to be outdone, Atlas, a manufacturer of ammonium sulfate fertilizer, assembled a kit based on one bag of its product, and with sufficient seed and chemicals to plant 600 square meters. This kit, costing 37 pesos, made the new variety and technology available even to the smallest farmer.

The kit technique probably was as responsible as any other single factor for the rapid adoption and even more rapid spread of the new variety in the Philippines. With the harvest from a 2,000 square meter plot, a farmer could plant two hectares the following season.

Several private firms came into being to manage rice lands for landlords and tenants with the objective of maximizing the benefits to be derived from the new technology. These firms provided technical services, guidance, and supervision for all farm and off-farm operations, and, when necessary, became involved in financing plans and control systems covering all phases of farm operations and marketing. When growing rice became profitable, owners and farmers were willing to pay for competent advisory and management services.

Rice makes news in the Philippines, and when the press labeled IR8 "Miracle Rice," for many farmers obtaining some of the new rice to plant became a goal in itself. Simultaneously, through the RCPCC, the University of the Philippines, IRRI and various national agencies produced a comprehensive rice production manual which became the "bible" for the Philippines and many other countries in Asia. The government, in addition, printed a number of well-illustrated pamphlets and comic book style leaflets to reach those with little education. Agricultural industry, in cooperation with the RCPCC agencies, financed the production of comprehensive sets of photographic slides on rice practices, diseases, and insects.

With so many persons and agencies in the act, close coordination frequently was impossible, and sometimes it was difficult to subordinate inter-agency competition. But as we have heard from Dr. Barker today, IR8 spread rapidly as did the new varieties that followed.

By mid-1967, the unprecedented yields became evident in the piles of rice on farms, along the roads, and in the villages. The Filipino farmer, with the new rice and ready inputs and credit, had created an instant surplus— more rice than the transportation, drying, processing and storage industries could handle. Experts were rushed in from abroad; dryers, rusty and out-of-repair from years of non-use, were pressed into use, and the government, buying rice as promised at the support price, had to export some of it because it had no place to store it.

As with the Pakistan experience, the Philippines success story contains a lesson for economic planners and agriculturists. This item from The Economist puts it succinctly:

> "Two miracles in four years have been achieved by the administration of President Marcos. The Philippines, an importer of rice until 1967, recorded an exportable surplus in 1968. Since then the administration has been preoccupied with the problems of plenty caused by the grain revolution.
>
> "Now, four years later, the second miracle has occurred: The Philippines have once again become a rice importer. The government has decided to buy 300,000 tons of the 7 million ton surplus of 'political rice' that President Sato's government in Japan piled up last year to keep its farmer supporters happy. President Marcos wants the Japanese rice to depress local rice prices which have doubled in the past three years."

While officially the shortage of rice in the Philippines is blamed on the typhoon, others claim that there is sufficient rice in the country but that it is being hoarded in warehouses by dealers licensed to hold buffer stocks on behalf of the Rice and Corn Administration for controlling price fluctuations.

The Economist report continues:

> "Three years ago the country had a skilful administrator, Mr. Rafael Salas, who managed the application of the rice miracle to the Philippine fields and gave it a marketing system which has been widely admired and imitated. But he has now gone to the United Nations to head the new department of population, trying to reduce the number of rice-eating mouths rather than increasing the amount of rice they can eat."

When asked to analyze the Philippine experience, Mr.Salas replied:

> "There are three very important lessons in the Philippines experience in rice production. The first, is that after the initial quantitative success the government has been unable to sustain the inputs in the agricultural sector to maintain the production at a level adequate to meet the increase of the population; second, the importance of sustained managerial supervision at the highest levels to coordinate the various government agencies in mobilizing the farmers; and third, is that an adequate marketing system must be established before one can expect production to be maintained.
>
> "The Philippines is today importing rice from three countries in Asia because of the typhoons which damaged the buffer stock last year. I believe, however, that it was not just the typhoons that caused the shortage but the lack of attention to these three factors that caused this regressive development."

Concept One: Human Behavior

Human behavior and how to change it fascinates scientists and practitioners in many fields. With appropriate apologies to our psychologist friends, we can strip human behavior to the essential elements of knowledge, understanding, attitude, and action. This will serve our purposes here, as will the following simplification of the process of influencing behavior.

We can say that humans, in addition to acting and reacting to satisfy their personal needs (hunger, thirst, comfort, sex, etc.), can be changed through exposure to information, instruction, or the pressures or presence (actual or implied) of other persons.

The importance of a human behavior approach in development is emphasized by Farmer as follows:

> "... this sort of management activity is assumed away in most growth models, perhaps because model builders rarely are practicing managers.
>
> "What is missing in growth models is the notion that the behavioral and educational factors in a country are so important as to swamp the economic facts of life ---yet we ignore them because they are difficult to handle and potentially dangerous as political tools."

Because information and instruction are important in dealing with adults in action programs, we can sharpen our focus and consider the role of information and instruction in the development process. In so doing, we set aside a host of other aspects associated with behavior change less central to our present concerns.

Generally, an action program includes one or more of the following activities: Education, advertising, training, promotion, public relations, propaganda, and extension. If we were to ask you to indicate the differences among each of these activities the discussion would eventually lead us to advance the idea that what the individuals engaged in each of these activities are doing could be described as follows:

> "The production of messages or the manipulation of the environment so as to influence the behavior (or performance) of specified audiences (or individuals) in specified ways."

While there are subtle differences among these informational activities, the greatest is that of intent. The good teacher tries to help the student expand his range of alternatives for action and to assist him to develop criteria for making choices among these. The effective propagandist or advertiser systematically reduces the individual's alternatives for action until, in the end, the individual has one course of action—that which the advertiser desires him to do.

Initially, most people find it difficult to translate their goals into behavioral objectives. Yet, all we need to ask is: <u>What must this person do if our objectives are to be realized?</u> <u>To what extent, and in what way, must his behavior be different than it is now if he is to do this?</u>

Success in informational or instructional tasks depends upon being able (a) to state the behavior we wish the learner (or receiver) to be able to demonstrate at the time our influence over him ends, and (b) to plan and carry out the informational or instructional tasks that achieve this objective.

Action programs usually involve two classes of objectives: General and Specific. General objectives include these four broad categories: To create awareness or to arouse interest; to modify attitudes; to obtain commitments to action, and to sustain behaviors already present. Such goals might best be described as being to influence or persuade and to reinforce rather than inform or teach.

Specific objectives include these: To be able to identify things; to be able to follow procedures; to be able to state principles and concepts; to be able to apply principles and concepts in decision making and problem solving, and to be able to perform specific skills.

Each objective requires different informational or instructional approaches, but we shall leave this concern for your specialists in such matters. It is important that the administrator be able to define clearly the general and specific objectives for the persons in the relevant audiences. A national program implies many audiences. Changing the behavior of the farmer necessitates influencing the performance of many individuals and organizations — these are identified as various components in the total systems.

Before leaving the issue of human behavior, we must introduce a concept to which Dr. Andersen will speak more specifically tomorrow. This is how expectations govern people's behaviors.

Psychologists and communication specialists view a human decision to act as a function of the fraction of expected reward over expected effort:

$$\frac{\text{Expected Reward}}{\text{Expected Effort}} = \text{Fraction of Decision}$$

Reward, in terms of the receiver, ranges from monetary return to such less tangible aspects as increase in prestige and reduction in tension. Similarly, effort is not only the energy or cost involved, but the possible loss of face or increase in risk or uncertainty.

In advance of an experience, the decision of people is conditioned by the expectations that they have about reward in relation to those about effort. Also, rewards can be immediate or delayed, and the same is true for efforts. Part of the change strategy is to communicate and work with people so that their expectations approach reality, the rewards are more immediately visible and credible, and the efforts postponed and reduced. Those who advertise "Fly now, pay later" employ the immediate reward, delayed effort notion.

But let me insert a note of caution. In the enthusiasm of a production campaign, it is easy to go too far — to oversell, to promise more than can be practically realized. When individuals, institutions, and governments do this, they lose the cooperation and confidence of their clientele.

When communication breaks down, this may be the reason. The receivers no longer regard the source as reliable or credible. They no longer accept or believe what is said.

Another communication breakdown, and usually the one which happens first, is the failure to get the attention of the desired audience. The second failure is one of not being understood or, even worse, of being misunderstood. The techniques of getting attention, understanding and acceptance are well documented and can be supplied by your communication specialists.

But we all know of situations where people gave attention, understood and accepted, yet no action took place.

Analysis of such situations might reveal one or more of the following reasons as to why persons failed to act: They did not know how to do it, the instructional ingredient had been overlooked.

They did not know when to act, or where to go, or why; these data had not been made clear.

More frequently, the analysis will reveal that there was a failure to communicate effectively with other audiences upon whose performance satisfactory action on the part of the first audience depended. Awareness of the components of the total system help us to avoid such a breakdown.

Concept Two: Total Systems Approach

The examples from the Philippines and Pakistan illustrate the lengths to which countries must go to engineer success. Yet, in each case, the programs were less than totally and permanently successful because of inadequate consideration of certain components, and perhaps failure to consider others. Results of program planning and evaluation depend, in large part, upon who does it and the criteria they use. These experiences clearly indicate that it is not sufficient just to be concerned with increasing production.

Basic to the issue of defining the total system involved is to state the objectives of the action program and to analyze critically the underlying social philosophies associated with such objectives. It is possible for a country to manage a program so as to maximize the resulting benefits for a limited number of producers, processors and consumers. Or, a program can be mounted with the goal of sharing the abundance and benefits of increased productivity and production as broadly as possible in the total society.

Where the "concept of the limited good" prevails, there will be pressures on decision makers to choose the first alternative. Some people are just plain greedy, but even more have never experienced the range of benefits to be derived, individually and collectively, where the greatest number of people share in the consequences of a greatly increased agricultural productivity.

("The concept of the limited good", as used by Foster and others, relates to the perception or belief of non-sophisticated (and sometimes sophisticated) peoples that there is an absolute limit to all things which people value. Consequently, as they believe there rarely is enough of the total "good" for everyone, to the extent that one person shares in the "good" there is less available for other persons.)

Initially, an action program designed to distribute broadly the benefits of new and improved technology will be more difficult to plan, will take longer to launch, and will require more management and supervision throughout. But it is an effective way to link technological and social change to accelerate the total development of a country. The resulting dividends justify the increased investment in human and physical resources as well as the courage and patience the management of such a program requires.

Most of the things we find enumerated on various check lists of factors to consider are necessary but not sufficient conditions for success. Moreover, given all of the necessary components, there is the issue of strategies — there are many ways to put the pieces together.

It is not our intention here to attempt the impossible — to describe the total system which must be mobilized and energized if action is to result. This is a job for specialists, and it is best done on the scene. The total system in Country A does not necessarily resemble, have the same components, or behave as the system in Country B.

Moreover, there are undoubtedly many differences between Asia and Latin America. These may make some difference in the kind of inputs and strategies needed for successful programs. Some of these differences are evident in the preceding papers.

While production problems may be fewer here, the marketing issues may be greater. Latin America has relatively more upland rice area, bigger rice farms, more mechanization, a fairly well developed technology, and fewer pressures on the land leading to intensification in land use. The agricultural economy does not revolve around rice, and while there is considerable uniformity in consumer rice tastes, there is limited diversity in the ways rice is prepared and consumed.

What we have elected to do, therefore, is to reorganize the many possible factors to be considered in an action program. While this in itself produces another check list, it may help to sort the issues into three categories: Physical inputs, policies and finances, and management. Let us analyze eachof these in terms of an action program associated with a new rice variety.

Physical Inputs. A decision to launch an action program based on a new rice variety implies that the variety exists, but not necessarily that it is suitable for all of the areas where it is to be promoted. This requires a local testing program. Moreover, who will multiply the seed and certify, process, and distribute it?

This one issue identifies the questions which we must face with respect to physical inputs. To be effective, inputs must exist, be readily accessible to the farmer at the time he needs them, be in a form or size he can use, and be adapted or tested for his environment.

New varieties and new technology frequently do not respond as expected because fertilizers, insecticides or other industrial products were not available when and where needed.

Similarly, the planner may appropriately consider irrigation, machinery and labor requirements. But if he focuses only on the farmer and his operation, he may overlook transportation, marketing, processing and storage. These, too, represent major physical inputs.

Policies and Finances. Among the policies and procedures which a country can establish to stimulate agricultural production, the provision of adequate, timely, low-cost credit probably is most universally important. The lack of credit limits the access of the farmer, whether he be big or small, to the inputs necessary to take advantage of new technology. Frequently, it is not more money needed in credit channels but more liberal or creative ways of making the money readily available to farmers and others. Development planners here today may wish to explore this matter further.

Other policy issues intimately associated with agricultural production campaigns include production incentives, price supports and ceilings, marketing quotas, land tenure and ownership regulations, taxation, tariffs on imports of agricultural machinery, protective tariffs on agricultural commodities, consumer welfare programs, laws governing labor in agriculture and related industries, water rights agreements, both internal and international, and international agreements for trade and technical assistance.

What these policies are and how they are managed determine, in large part, not only the success of programs to increase production but the nature and severity of the so-called second generation problems. The role of the policy and decision maker is difficult but responsible.

Management. Too often we take management for granted. We do not have new varieties and improved agricultural technology unless we provide for and support adequate, continuing programs in agricultural research, education, and extension. Such institutions require capital and operating funds, competent people, and a continuity of professional leadership.

Interaction between agricultural scientists and national planners helps assure that science is seeking answers to present and anticipated problems and that the decisions planners make are based on the practical realities of agriculture. How can we strengthen these lines of communication and keep them open?

Direction and coordination of national campaigns call for high quality administrative input — men with ability, experience, access to policy makers, drive, and courage. In Rafael Salas, the Philippines had such an individual. In Pakistan, Former President Ayub, as chairman of the Planning Commission, served as chief of both the administration and economic planning, and as Havener describes:

> "Having almost absolute power, Ayub pursued food self-sufficiency with great single-mindedness of purpose and personally intervened when bottlenecks developed."

Leadership is needed not only for the campaign itself, but to anticipate and cope with problems that arise later. Havener refers to this as the second generation problem rarely considered:

> "This problem is best defined as a lack of administrative imagination and decisiveness when faced with problem-sets for which there is no precedent. Mobilizing a food grain revolution was just more and better of what they had been doing for years. But handling an ongoing revolution with its rapid dislocations and radically different set of priorities requires totally different conceptions and administrative modus operandi."

But even the most competent administrators flounder when they lack information or the information they have is out-of-date, distorted, or incomplete. This input is so important that we elect to treat it as the third concept, and at this point turn our concerns from inputs to strategies.

Strategy Decisions. Essentially, the administrator manages resources so as to accomplish the objectives efficiently, economically, and within the deadlines established. The administrator makes countless decisions and the criteria he uses in making these decisions are, in a sense, his strategy. But the difficulties lie in the fact that the criteria which he uses consist of at least technological, economic, political, and social components.

But the issue of when, if at all, to launch an action program already is academic in some countries. The new varieties exist, farmers know about them, and in less than a year the small amount of seed available will be increased, in two plantings, many times.

This creates a dynamic situation — the phenomenon of trying to push something that is moving faster than you are. In such cases, as with a rocket inadvertently launched in space, one can hope that appropriate policy and price mechanisms exist or can be quickly instituted to assure success and prevent disaster.

Aside from the urgency which the existence of the varieties creates, the issues of program strategies can be expressed most clearly as questions:

Locating — Where will the program start? In how many places?

Scope — Is this a national program from the beginning, or do we take an experimental approach?

Participation — To what extent do we encourage or permit what organizations and people to help decide on program matters?

Resources — How do we recruit and allocate physical, human, and financial resources to the program?

Organization — Do we establish a new organization to carry out this program? Do we assign the responsibilities to an existing organization? It is possible to focus and coordinate the work of many organizations? Should we form a consortium of organizations?

Continuity — Once the program is underway, what do we do for followup and evaluation?

Concentration — How do we take into account the possible effects of other national programs? Some may compete for resources or in terms of objectives, while others may be complementary.

Concept Three: Information, the Indispensable Ingredient

Implicit in the foregoing is the need for information and information systems at every step of planning, executing and evaluating action programs. First, we shall consider the kind of basic data needed in planning and some of the ways these may be attained. Second, we shall consider the role and flow of information in program implementation.

Data for Planning. Organizations charged with the responsibility for planning a rice action program will need, as a minimum, information on production and market, domestic and world. It will be important to know who the rice producers are, where they are, how they now grow rice, and with what problems. Yield information is important, not only averages, but the range and the mode.

How much of the area is in irrigated rice and how much in upland rice? What other crops do these farmers grow? What is their income, their ability to take risks, and their access to credit, inputs and markets?

What agricultural areas are best suited for rice production? What are the present and projected availabilities of fertilizer, agricultural chemicals, and irrigation systems?

More questions arise in the area of domestic and international markets. Who presently buys and consumes rice, and at what price? If the price of rice would drop, who would consume more rice and what new consumers might this attract?

How adequate are present facilities for drying, transporting, storing and milling rice? Would a price support program in which the government buys rice tax these facilities?

What is the comparative advantage of this country as a rice producer and exporter in relation to other countries in the region, or in other parts of the world?

What is the present size of the population, the growth rates, and where is the population growing most rapidly? What is the rice consumption pattern? Who needs more rice, and what are the possible ways of making it available to them?

One of the characteristics of a developing country is that frequently the data needed for good planning either do not exist or are difficult to get. The problems that Dr. Trant and his staff have had in bringing together the mass of data for your use in this seminar indicate that the data situation in Latin America is no better and we trust no worse than in many other parts of the world.

Faced with the necessity of making decisions, the planner needs to identify such data as do exist in provincial, regional, and national offices, and in the files and publications of international organizations. Frequently, he will find two or more sources for the same data; if they agree, he has one problem, and if they do not, he has another. In fact, both reports may be right, if one can determine how the data had been collected and analyzed.

Consequently, it is good practice to check the sources, determine how the data was collected, and by whom and for what purpose. Next, one can check parts of the data for face validity and, overall, for internal consistency.

If time permits, a sample study may be carried out to ascertain the reliability and validity of the data at hand.

When new data are needed, short of undertaking special studies to acquire these, it frequently is possible to insert questions in other studies about to be launched or already in the field. Another technique is the sample or pilot study as a prelude to more exhaustive studies later. The sample results give you something to work with right away.

As programs are developed and implemented, it is important to build data collection into regular operations. This will provide feedback information for program changes as well as data for later evaluative comparisons.

The absence of data or the lack of complete data about situations argues strongly for an experimental approach when introducing a new action program: To begin on a small scale in areas where you are most likely to succeed and about which you have the most data; or conversely, to begin on a small scale in an area that is most typical of the rice land to be changed eventually. Variations of these location strategies were evident in the Pakistan and Philippines cases.

Information for Implementation. Basically, everyone who has responsibility for any aspect of the action program needs to know what the program is about and what his particular duties and responsibilities are. This necessitates information systems within organizations, among organizations, and between the action agencies and the public generally and the farmer and other elements specifically. At all levels, there are needs for communications that are informational and in many cases instructional as well.

Leaflets, bulletins, sets of slides, motion pictures, demonstrations, field days and related events helped tremendously to arouse the interest of Filipino farmers and extension workers and to upgrade their knowledge and abilities. Inter-agency bulletins, some of these circulating down to workers at the village level, promoted co-operation and coordination. Public participation of national leaders, including the First Lady, in rice training and demonstration programs stimulated public interest, as did some unplanned raging controversies in the press triggered by zealous nationalists.

While I personally feel that greater attention needs to be given to the instructional and informational types of material; there is no denying that intelligent use of the mass media is positively linked with development.

When we consider the use of mass media in action programs of developing countries, it is well to remember that, in comparison with the developed world: (a) the mass media reach smaller audiences, (b) the audiences for radio and film are greater than for printed materials, (c) typically, messages tend to be of low interest and relevancy to rural people because of the strong urban orientation of the media, and (d) there is more government control, especially over radio and television.

Schramm suggests that results in the development process may proceed less from individual messages or media than from "a succession of impacts of related messages and reinforcing channels," both mass and interpersonal. He observes that planners of development campaigns find themselves thinking about systems of communication rather than about media alone:

"What combination of messages and channels, in what order, will be of most help in bringing about the changes that need to occur?"

Given this point of view, we can ignore the arguments as to whether mass media are more effective than interpersonal communication, or training people is more important than disseminating information. If action is to occur, Schramm states that people must have information about the need to change, the opportunities, and the methods and means. Secondly, they must have opportunity to participate intelligently in the decision-making process, and finally, the needed skills must be taught.

It is important, in final analysis, to assess what the various communication media can do to make information available to the public as contrasted with how they can help the instructor in the classroom. Education and training involve more than transmitting information and ideas. The desired changes in behavior or performance usually require a teacher to correct or reinforce, a discussion group, with which to interact, a situation in which to react, or a machine to be operated. Two-way communication and opportunity for teacher-, group- and self-evaluation of progress are both necessary.

In Conclusion

Given the importance of communication and information as both inputs and strategies in national action programs, I wish to comment briefly on how these can be employed most effectively to improve the informational and instructional inputs to action programs.

1. If we examine typical extension/community development materials, we find many of these to be promotional — they advocate the doing of things with little or no emphasis on how. We can increase the informational and instructional content of such materials.
2. We can make greater use of applied research or local trials and, subsequently, demonstrations. What a man sees he is more apt to believe. Moreover, he gains some knowledge about the practice or variety over the growing season. He learns what to expect. Research on the diffusion of innovation shows clearly that the most effective communication channels leading to adoption are those in which friends and neighbors are the information sources. Field trials and demonstration plots serve as information sources for these friends and neighbors.
3. We can develop our interpersonal communication skills. We can learn how to listen and observe carefully in interactions with individuals and in small

groups. We can learn how to ask questions that stimulate honest, informative responses. We can develop the ability to organize and monitor small discussion groups so that participants may learn from each other while at the same time we gain insight on the knowledge, attitudes, and thinking processes of the participants.

4. We can become more effective by developing more social science research skills. This includes the ability to ask questions and listen, as well as how to gather data about the people and area in which we work. Ideally, we can cultivate working relations with social scientists in our countries, and encourage and facilitate them to work on our problems.

5. Although some theme usually becomes a rallying cry, some of these themes can be dysfunctional for many of the people they are intended to inspire. A well-selected theme helps focus efforts and build national enthusiasm. But to be truly successful, it must be meaningful in a personal sense to each of the persons whose performance must be influenced if the goal is to be met.

The theme "To make the nation self-sufficient" will probably strike a responsive chord in rather narrow political and financial circles, but at most it will generate a "so what" response among farmers. While "To provide consumers in the city with cheaper food" will appeal to the urban dweller, it will have little impact on the many who grow the food. Conversely, "To increase profits" will appeal to the farmer, but will confirm the city man's belief that the farmer is getting rich at his expense.

When we speak to one audience, it is important to be aware that other audiences are also listening to or reading what we say. We do not communicate in a vacuum, nor does our action program operate in a vacuum. When it comes to evaluation, it may be well to collect data and evaluate so it is possible to assess the changes, positive and negative, which result, directly or indirectly, in the society.

Here again, we return to the matter of social philosophies involved in the decision about program objectives with respect to the persons in the society who are to share in the benefits of the new technology.

One of the consequences of an action program may well be new problems, but the man who has experienced a bumper rice crop for the first time in his life will never be the same. He now has new hopes, new expectations — and these are contagious.

It takes courageous and inspired leadership to manage this contagion so that the enthusiasm generalizes and moves from self-centered to societal-centered interest. Rather than struggling with each other for what they perceive as the limited good, through our policies and communication programs we can stimulate people to work together for an abundance in which all may share.

When people learn that science and technology, intelligently applied and managed, can change and benefit their lives, there is hope for mankind and the world. The output is worthy of the input, for a man's mind stretched to the limit of a new idea will never return to its original dimension.

Bibliography

Axinn, George H. "A Strategy of Communication in the Development Process." Paper presented at meeting of Society for International Development, 11th World Conference, New Delhi. 1969.

Berlo, David K. The Process of Communication. New York: Holt, Rinehart. 1960.

Byrnes, Francis C. "Where Does Change Begin?" Paper presented at seminar, International Rice Research Institute, 1967.

Brynes, Francis C. "The Pursuit of Abundance." FREE WORLD, Vol. XV., Number 11, 1967.

Castillo, Gelia T. "Miracle Rice" as "Produced by the Press." International Seminar on Communication Media and National Development. University of the Philippines, Nov. 13 - Dec. 2, 1967.

Castillo, Gelia T. Technology and Social Change: The Case of Miracle Rice. Paper presented at Second World Congress of Rural Sociology, Diernerlo/Enschede, The Netherlands. 1968.

Farmer, Richard N. "Have our Aid Programs Flopped?" Worldwide P & I Planning. March/April 1969. pp. 86-96.

Havener, R. D. Factors Involved in Agricultural Development. Paper presented at International Rice Research Institute, April, 1971.

Havener, R. D. "Potentials and Problems of Increasing Rice Exports from West Pakistan." In Turk, Kenneth L., editor, Some Recent Issues Emerging from Recent Breakthroughs in Food Production. Cornell University. 1971.

Lerner, Daniel and Wilbur Schramm, Editors. Communication and Change in the Developing Countries. Honolulu: East-West Center Press. 1967.

Lumsdaine, A. A. "A Basis for Decisions in Planning Communications." In Research, Principles and Practices in Visual Communication, edited by John Ball and Francis C. Byrnes.

Mager, Robert F. Preparing Instructional Objectives. Palo Alto, Calif.: Fearon Publishers. 1962.

McNelly, John T. "Perspectives on the Role of Mass Communication in the Development Process". In Mass Communication and the Development of Nations, edited by David K. Berlo, International Communication Institute, Michigan State University. 1968.

Republic of the Philippines. The Rice Production Program. National Media Production Center, Manila. 1967.

Rochin, Refugio I. Farmers' Experiences with IR20 Rice Variety and Complementary Inputs: East Pakistan, Amon-1970. Ford Foundation, Pakistan, Revised, May 1971.

Rogers, Everett M. "Mass Media Exposure and Modernization among Colombian Peasants." In Mass Communication and the Development of Nations.

Schramm, Wilbur. Mass Media and National Development Stanford, Calif: Stanford University Press. 1964.

U. S. Agency for International Development. The Philippine Story of IR*, AFLG and Do It Yourself Rice Kits. USAID, Manila, 1967.

U. S. Information Agency. Miracle Rice for Asia. Manila, Philippines. 1968.

PHYSICAL ISSUES AND CAPITAL COSTS ASSOCIATED WITH HANDLING RAPID INCREASES IN RICE PRODUCTION

Macon D. Faulkner
Professor and Superintendent
Louisiana State University
Rice Experiment Station
Crowley, Louisiana, U.S.A.
and
Dennis R. Stipe
Associate Professor and
Engineering Project Leader
Louisiana State University
Rice Experiment Station
Crowley, Louisiana, U.S.A.

INTRODUCTION

The systems of rice production, handling, processing, and marketing of rice are almost infinite in number. Consequently, all systems cannot be considered in depth in a discussion such as this.

Basically, we may consider the typical systems of production and handling as follows.

I. Traditional — Deficit

This system may be one in which production is essentially by hand methods with harvest by hand labor, transport by farm vehicles, and milling either by hand or in basic systems such as village huller mills. This system most probably will not involve sophisticated marketing, transport or processing facilities, and is considered to exist in a national net rice deficit situation.

II. Modified Traditional — Self-Sufficient

This system may be comprised of components of modern technology such as some mechanized production implements, limited motorized transport, and some modern elements of processing and marketing. This system is the most complex in its operation, due to the difficulty of integrating flow of grain between a portion — say, slow harvest or drying — to a rapid transport and processing system.

This system is considered to be one that operates in a self-sufficient national rice situation. It is also the system that undergoes the most drastic changes, as it evolves from traditional methods, and involves changes in basic production, handling, and marketing concepts.

III. Surplus System

This system almost invariably involves components of modern technology and may be completely mechanized, or will certainly be partially mechanized. The producer may use traditional production methods and sell at a modern drying facility where his grain may be mechanically handled, processed and marketed. Or he may use traditional production and drying techniques and sell his marketable surplus into a modern marketing stream; or he may produce, using mechanized methods, and mechanically dry and sell into a modern marketing stream. The possible combinations in a system such as this are unlimited. However, the central concept in this system is that the grain must be handled properly and usually quickly in order to maintain quality if it is to retain value and profit for the producer and processor.

This discussion will deal with physical problems and to some extent costs in rapidly progressing from a rice deficit situation to one of self-sufficiency and surplus.

Traditional System (Definition)

The traditional system, as defined here, is one in which production is done by hand methods. Land preparation will be done either by hand or animal-drawn implements. Planting is done by direct hand seeding or transplanting. Harvest generally is done by hand cutting, then removing the straw and panicle to some remote place for threshing by any number of means, but primarily flailing and/or trampling. Drying is done by spreading the grain in the open and hopefully reducing the moisture to a level sufficiently low enough to avoid spoiling until it is consumed.

In this system the farmer will commonly retain enough grain to assure a food supply for his family and possibly the families of his laborers. He may sell his marketable surplus over a long period of time, and will commonly sell only enough to buy products not readily available in the village or on his farm. This system, even though apparently erratic to an outsider, is one in which the sale, by farmers, of small quantities of one or two bags at a time, tends to keep a fairly steady supply to local and distant markets.

Product movement from the farm in this system usually involves the farmers' own or village transport vehicles. In many cases a local trader will periodically visit the village and buy and transport by motorized vehicle; but most commonly the farmer will move his rice directly to a market and sell in a marketing-processing center.

Processing for this system usually involves only the most basic machines. Rice processing for the farmers' use may be done in the family compound by hand pounding or in the village on a custom basis. Either case can be costly from the standpoint of product efficiency. Hand pounding may yield 50 percent, more or less, of rice from paddy and the village mill may be no better. The most common rice mill in the world is the "huller" mill. It consists of one or two machines, the huller itself, and a machine to aspirate and sieve bran, broken rice, and larger rice. This machine, the huller, was designed to hull wheat and was adapted to both hull and polish rice.

The operator of the huller mill will most probably mill the farmers' rice for the by-products of bran, hulls, and small broken rice. Even though the huller mill operator gets a large share, the arrangement is agreeable to all concerned.

Much of the rice that moves from production areas to cities or deficit areas is processed in huller mills or in the limited unit mill that processes superior quality rice. Operation of the huller mills involves multiple passes of the paddy through the huller until sufficient hulls and bran are removed to satisfy the consumer. Needless to say, the final product is of low quality and contains large quantities of brokens. As long as the market demands for food will allow this kind of product to be sold, little may be done to improve the processing system.

Almost invariably, the capacity for processing rice production in rice deficit areas exceeds the amount to be processed. Traders and processors depend more on market variability than on plant efficiency and stable markets to make a profit. The trader buys when there is a surplus of paddy and prices are low, and holds the product until rice prices are high enough to make a profit. Consequently, little concern is shown for improved plants and processing systems.

Transport of rice in a deficit area is done largely by public carriers such as trains and/or trucks and other modes of transportation. Normally, the marketing agency does not supply the transport vehicles, except possibly those required for local sales.

Self-Sufficient and Surplus Systems (Defined)

As an area progresses from deficit to surplus in rice, new and unfamiliar generation of problems begins to occur. These problems generally occur where no experience or tradition can be called upon for solution. Where the farmer has traditionally held his paddy until he is assured of his own supply, he is now faced with moving paddy directly into markets to take advantage of high market prices or to simply move an excess product from his farm, one which he is unable to adequately handle.

The first problem he faces is possibly threshing his grain the first year he plants an improved variety, uses fertilizer, or improved practices that lead to drastic increases in production. He will most certainly be faced with moving the freshly harvested paddy to a market center more rapidly than ever before. The farmer very seldom has sufficient transport himself or in the village to move the grain into the processing chain before damage occurs in the grain. He has traditionally waited until the grain is fairly dry prior to harvest and has had enough time to sun dry before storage. In this situation, which is new to him, he will tend to harvest and thresh the rice as early as possible,and at a high moisture level unsafe for storage. Since the grain cannot move rapidly from the farm to a market center where drying and processing may take place, the grain may be in a state of deterioration when it is finally marketed. My experience has been that it is almost impossible to impress the farmer with the need to dry rice soon after harvest, or move it to a drier soon enough to avoid spoilage.

The second set of problems to be faced with the rapidly expanded rice production following inadequate drying and transport problems, involves storage. Where marketing of paddy has been fairly orderly, with a surge at harvest, then leveling off to a reasonably steady flow from farm to market, there tend to be large amounts of grain arriving in markets at harvest. The trader and processor have traditionally found themselves in the position of dealing with fairly low percentages of the crop, but are now faced with larger amounts of grain than ever before. Storage in warehouses of bagged grain is normally adequate if properly dried and protected; however, in this new situation it probably will not be adequate. Since there is a tendency, by farmers, to underdry the grain, the trader or processor either cannot store or dry the grain to assure storage quality. This then sets the circumstances for someone to receive far less for rice than normal, and also to create situations where well developed production planning may be offset by poor drying and storage considerations.

The next set of problems centers around the processor or rice mill. The processor has traditionally operated his plant to a limited extent, and may have depended on price variations to assure a profit. He may have operated his plant at a level of only 10 percent rated capacity, and is suddenly faced with operating at far greater capacity to move the produce. As stated earlier, milling capacity tends to exceed production in deficit regions, and the processor will be reluctant to exceed his previous plant output. In addition, he will probably not be in the position to take advantage of price variation for profit. If he is operating the traditional huller mill, his losses and low product efficiency in the mill may reduce margins to the extent that he cannot make a profit.

Once the rice is processed, market demands in self-sufficient countries or surplus countries may be fairly stable and the miller may plan on processing enough to meet these demands. However, he must provide enough rice to assure his share of this market and also enough to meet sudden demands and market fluctuations. In order to do this he must have ready rice storage and transport facilities — neither of which the processor will have at the time a rapid increase in rice production occurs. The overall situation then becomes one where:

(1) The producer will tend to harvest earlier and market grain at moisture levels unsafe for storage. He will sell large quantities into a system that is unprepared to handle or process the grain.

(2) Insufficient driers or no driers exist, and much of the grain may be lost due to spoilage.

(3) Little or no bulk storage exists and flat storage is inadequate to handle the rapid increase in production.

(4) Rice mills may have enough capacity to process the increase, but have no tradition in operating near rated capacity.

(5) Markets may be available for the product, but will tend to be more discriminating, and product efficiency may be so low from the plants. that it may not be profitable to process and sell into the marketing system.

(6) Inadequate rice storage will make rice processing and marketing erratic.

(7) Transport facilities may be limited and not allow the processor to meet sudden market demands.

PLANNING A HANDLING SYSTEM FOR INCREASED RICE PRODUCTION

Often the decisions are made to increase rice production by introduction of the necesary inputs to allow farmers to do so in a relatively short time. All too often these decisions are made with no planning regarding disposition and handling once the crop is produced. Policy makers, in many instances, may decide to allot money or other inputs to a system to handle increased production at the same time the decisions are made that will lead to the increase. When this occurs it is almost impossible to establish requirements, components, engineering criteria, and set the system in operation in time to meet the demands of large, sudden increases in production.

It is impossible to say how much lead time is necessary to meet the demands of increased production. Most generally, the decisions to change the handling system are made after production has already increased.

The System

Physical issues in a handling system must be established in order to design and implement plans for the system. Quantities and time available for handling is the first order of priority.

Table 1 shows a typical harvest, drying, storage, milling, and marketing schedule. This schedule is for commercially produced rice going into markets, and does not include local consumption, which will be processed either on the farm or locally.

The analysis in Table 1 shows the following:

(1) Total product to be handled is over 92,000 metric tons of rough rice (paddy).

(2) Maximum rough rice storage capacity must be 31,004 tons in December.

Table 1. Minimum milling and storage scheduled for commercially produced rice in Nicaragua.

Area	Rice movement	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
I	Harvested 1/	2100	2100	-	-	-	-	-	2624	2624	-	-
	Milled or moved	871	871	871	871	871	871	871	871	871	871	871
	Rough rice in storage	2122	3351	2480	1609	738	(Add.	10%)	1753	3506	2635	1764
	Milled 2/ (Store-Market)	610	610	610	610	610	610	610	610	610	610	610
II	Harvested	926	926	-	-	-	-	-	1158	1158	-	-
	Milled or moved	384	384	384	384	384	384	384	384	384	384	384
	Rough rice in storage	938	1480	1096	712	328	(Add.	10%)	774	1548	1640	780
	Milled (Store-Market)	269	269	269	269	269	269	269	269	269	269	269
III	Harvested	4500	4500	-	-	-	-	-	5624	5624	-	-
	Milled or moved	1867	1867	1867	1867	1867	1867	1867	1867	1867	1867	1867
	Rough rice in storage	4546	7179	5312	3445	1578	(Add.	10%)	3757	7514	5647	3780
	Milled (Store-Market)	1307	1307	1307	1307	1307	1307	1307	1307	1307	1307	1307
IV	Harvested	2103	2103	-	-	-	-	-	2629	2629	-	-
	Milled or moved	873	873	873	873	873	873	873	873	873	873	873
	Rough rice in storage	2123	3353	2180	1607	734	(Add.	10%)	1756	3512	2639	1766
	Milled (Store-Market)	611	611	611	611	611	611	611	611	611	611	611
V	Harvested	5080	5080	-	-	-	-	-	6350	6350	-	-
	Milled or moved	2108	2108	2108	2108	2108	2108	2108	2108	2108	2108	2108
	Rough rice in storage	5132	8104	5996	3888	1780	(Add.	10%)	4242	8484	6376	4268
	Milled (Store-Market)	1476	1476	1476	1476	1476	1476	1476	1476	1476	1476	1476
VI	Harvested	3856	3856	-	-	-	-	-	4820	4820	-	-
	Milled or moved	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
	Rough rice in storage	3896	6152	4552	2952	1352	(Add.	10%)	3220	6440	4840	3240
	Milled (Store-Market)	1120	1120	1120	1120	1120	1120	1120	1120	1120	1120	1120
Total all areas	Harvested	18565	18565	-	-	-	(9278	10%)	23205	23205	-	-
	Milled or moved	7703	7703	7703	7703	7703	7703	7703	7703	7703	7703	7703
	Rough rice in storage	18757	29619	21916	14213	6510	(Add.	10%)	15502	31004	23777	15598
	Milled (Store-Market)	5392	5392	5392	5392	5392	5392	5392	5392	5392	5392	5392

1/ Considering commercial production only: 40 percent harvested in April and May, 50 percent harvested in November and December; the addit
10 per cent harvested outside these months. All figures in metric tons.

2/ 70 percent mill yields — maximum milled rice storage 30 days.

(3) Milling capacity must be at least 7703 tons per month.

(4) Minimum milled rice storage must be 5392 tons.

(5) That drying and transport requirements can be established.

(6) Threshing capacity required, of course, is evident.

Equipment for the System

Taken in order from the farm, threshing must be considered first. The only decisions that can be made on types of threshers is either self-propelled combines, stationary threshers, or hand threshing. Large stationary threshers are no longer common, but can be purchased. However, due to their limited supply, it is usually more reasonable to use small threshers, hand threshing, or combines.

If hand threshing in an area of rapid increase of rice production is common, it may be advisable to continue as long as the farmer can harvest in this manner. Sudden introduction of power equipment usually results in under-tuilization and inefficiency. Lack of parts, mechanics, and supplies may make the equipment less than effective. Where power equipment is traditional, desirable, or necessary, then the decision must be made on type of threshing equipment to use.

Where farms are concentrated and fairly large, combines may be used successfully; otherwise, stationary threshers may be more efficient. The author considers 10 acre farms usually sufficient to use self-propelled combines. However, the combines used for rice need to harvest about 250 acres per year to be justified, but should harvest about 500 acres or 1000 tons to be most practical. Either stationary threshers or self-propelled combines will cost approximately $15 per ton harvested annually or per crop. From Table 1 the capital cost for combines or threshers would be approximately $696,000 (46,400 tons in November-December x $15/ton).

Transport for the System

Transport from the farm to market or to a threshing facility may be done by animal-drawn or motorized vehicles. However, the product must be moved quickly. Consequently, motorized vehicles may be indicated if spoilage is to be avoided. Trucks or tractor-drawn trailers are commonly used for this purpose. Tractors and trailers are used quite commonly to transport rough rice to market or driers. The tractors have the advantage of being able to operate in some fields and on roads where trucks cannot go. Also, tractors have the added advantage of being used for production purposes, and since the farmer is generally responsible for the product up to market, tractors may be in order. One estimate by the author indicates that the capital cost for transport vehicles is on the order of approximately $8.50 per ton-mile per crop. Using Table 1, then, for November-December, 43,410 tons must be moved; and for purposes of example, consider a travel of five miles. Total cost would be about $1.8 million. Using tractors and trailers will allow much of this cost to be assigned to production.

Drying for the System

The most frequent problem concerning drying is what techniques to use and type drier to select. Systems that require capacities over 1000 tons drying per season can normally justify continuous flow driers; lower amounts normally lend better to batch driers. Figures 1 and 2 show typical arrangements for both systems.

Batch driers are normally cheaper to operate, but dry slower than continuous flow driers. Controls and operation are fairly intricate for continuous flow driers and create problems that lead to damaged rice. Rice temperatures should not exceed about 105°F in drying. Most commonly, the air temperature in batch driers will not exceed 110°F and little chance for damage exists. Continuous flow driers may use air temperatures over 200°F and the operator must use techniques that will not allow grain temperature to go over 105°F. These decisions then lead to problems of operation and damage to the product.

Continuous flow driers, operated properly on a multi-pass system, will dry approximately one-half their holding capacity per hour. This means that if the drier holds six tons, its hourly drying capacity will be on the order of three tons. This rule applies in humid regions when the moisture to be removed is on the order of 10 percent. A fair estimate of harvest moisture is around 22 percent and the grain should be dried to 12 percent for safe storage. The common problem and tendency in drying is: (1) to underdry usually to around 14 percent and, (2) operate improperly. The operator in an attempt to reduce weight loss underdries then loses in storage. He will almost always want to use the continuous flow drier as a

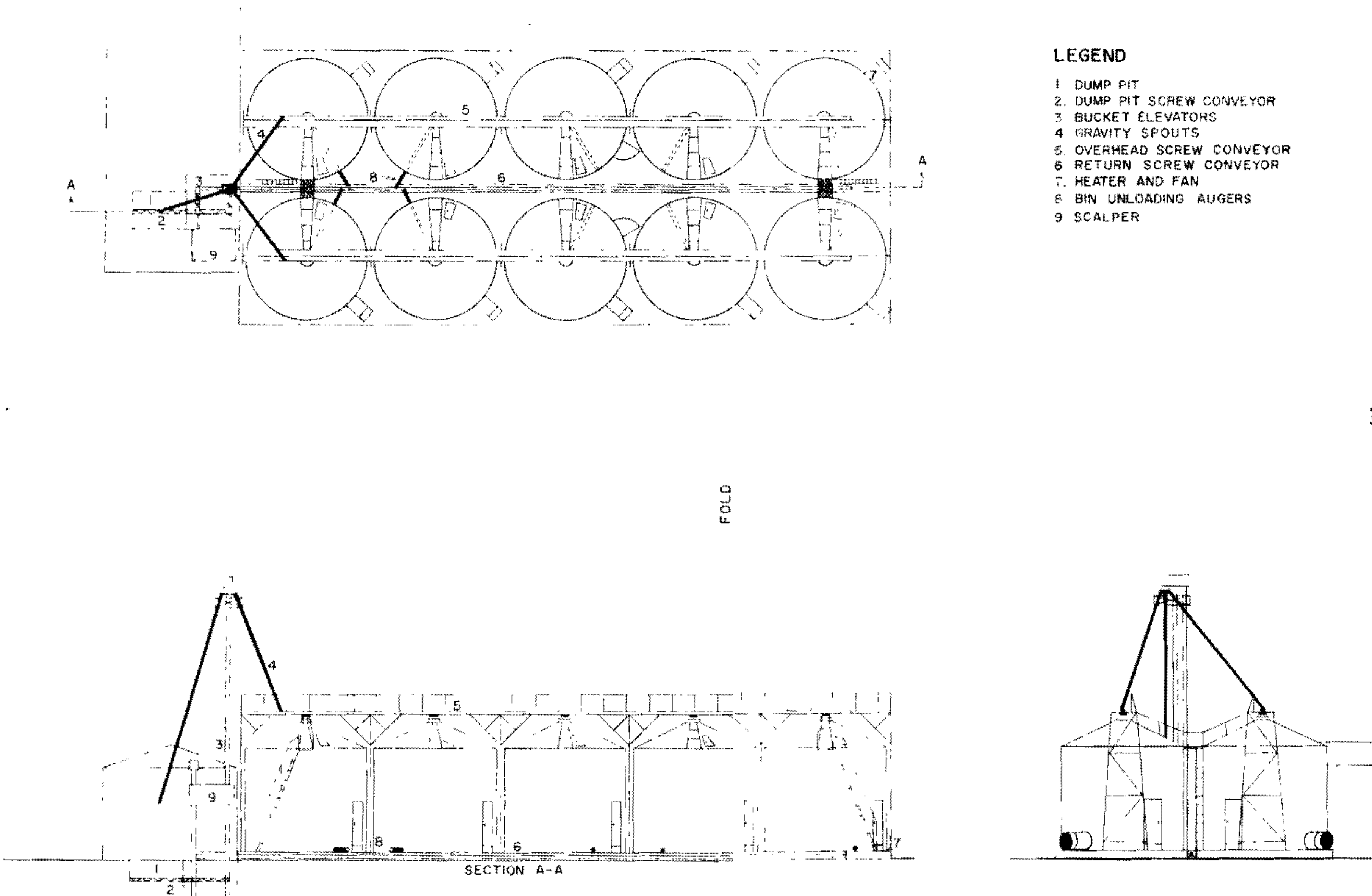
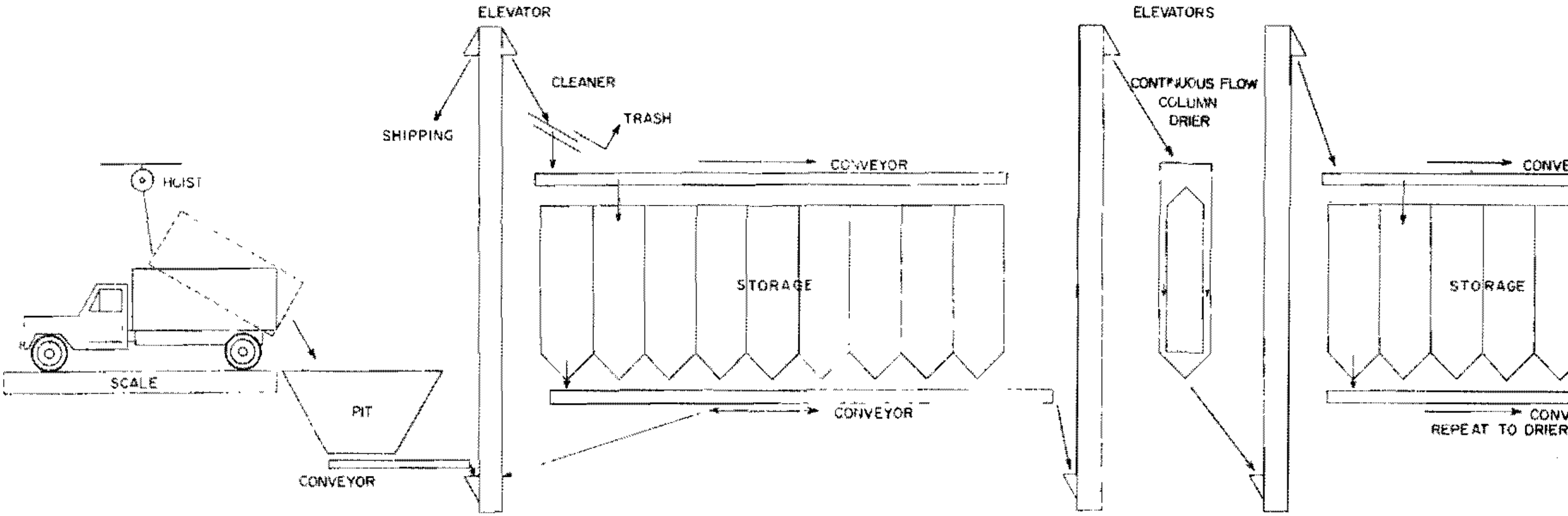


FIG. 1 – TYPICAL INLINE DRYING AND STORAGE SYSTEM



OPERATIONAL SEQUENCE

1. TRUCK ARRIVAL FROM FARM
2. WEIGHING & RECORDING
3. DUMPING FROM TRUCK TO PIT
4. CONVEYING - CLEANING
5. TEMPORARY STORAGE - MAXIMUM 10-12 HOURS
6. DRYING - 30 MIN - 20% M.C. TO 17% M.C.
7. TEMPORARY STORAGE - 12-24 HOURS
8. DRYING - 30 MIN - 17% - 15% M.C.
9. TEMPORARY STORAGE - 12-24 HOURS OR LONGER
10. DRYING - 30 MIN - 15% - 13.5% M.C.
11. TEMPORARY STORAGE - 24 HOURS OR LONGER
12. DRYING - 30 MIN. - 13.5% - 12% M.C.
13. PERMANENT STORAGE UNTIL MARKETED
14. AERATION AND MAINTENANCE

FIG. 2 - TYPICAL ROUGH RICE HANDLING - DRYING - STORAGE SYSTEM

circulating batch drier instead of a multi-pass drier with tempering between passes. This kind of operation reduces capacity by as much as 75 percent and will damage the grain by breaking it.

Fuel is always a problem in rice drying. Approximately 2000 to 2400 BTU/lb of water removed is required in rice drying, using continuous flow driers. Batch driers in most cases will require less fuel than continuous flow driers, due to the ability to utilize energy contained in natural air. However, if we consider fuel costs on the basis of 2400 BTU/lb water removed, it will require approximately 30 pounds of diesel or equivalent to dry each ton of rice. Operators and managers always feel this is an excessive amount and will tend to try and reduce it, usually resulting again in damaged grain.

Using Table 1 again, the maximum drying to be accomplished per month is 23,205 tons. Consider 20 days of 24 hours each, or 480 operating hours per month. Then hourly capacity should be 48 tons per hour net. In order to accommodate uneven receipts, 50 percent is normally added, then 72 tons per hour capacity would be required. A fair estimate of cost of continuous flow driers may be on the order of $2,500 per ton of hourly capacity. The system would require about $180,000 worth of driers. In addition, it would require at least $1.5 million for storage with the driers (31,000 tons). The total cost then would be around $1.75 million.

These figures are minimum and can vary several times over, depending on location of equipment, number of installations, etc.

Batch or bin type driers have certain advantages over continuous flow driers in that they will dry small lots and normally require less fuel for heating the drying air stream. They also have the advantage of requiring lower levels of technical competence to operate. Costs for batch driers in most cases will be lower than continuous flow systems, since they combine drying and storage in the same facility. They dry much slower than do continuous flow driers, but at less cost. Figures 1 and 2 show typical batch and continuous flow systems.

Milling for the System

Milling equipment capacity normally exceeds production. This situation creates the greatest single problem for operators and policy makers. It is hard to convince

Table 2. Typical rice mill evaluation (India)

Mill Designation		Variety	Rep.	Moisture content (%)	Weight of paddy (kg)	Paddy in rice (kg)	Paddy in rice % rice	Net weight of rice Head (kg)	Net weight of rice Broken (kg)	Net weight of rice Total (kg)	Mill outturn of rice (% paddy)	Potential outturn of rice (%)	Mill outturn (% of potential)	Broken % of rice total
A		CO-25	I	11.6	4005.3	0	0	2323.8	597.6	2921.4	72.9	73.6	99.0	20.5
A		CO-25	II	11.4	4005.6	0	0	2228.0	773.7	3001.7	74.9	74.3	100.8	25.8
A		CO-25	III	11.5	4005.6	0	0	2147.2	781.4	2928.6	73.1	74.4	98.3	26.7
	Mean			11.5				2233.0	717.6	2950.6	73.7	74.1	99.4	24.3
B		CO-25	I	11.5	995.4	8.3	1.2	293.7	395.7	689.4	69.3	73.4	94.4	57.4
B		CO-25	II	11.4	996.5	12.4	1.8	217.6	473.3	690.9	69.3	74.0	93.6	68.5
B		CO-25	III	11.6	994.6	12.4	1.8	199.6	488.6	688.2	69.2	74.2	93.3	71.0
	Mean			11.5		11.0	1.6	237.0	452.5	689.5	69.3	73.9	93.8	65.0
C		CO-25	I	11.9	999.5	2.8	0.4	222.1	472.1	694.2	69.5	73.3	94.8	68.0
C		CO-25	II	11.4	998.0	8.4	1.2	146.0	549.3	695.3	69.7	73.6	94.7	79.0
C		CO-25	III	11.4	995.9	3.5	0.5	154.4	547.6	702.0	70.5	74.0	95.3	78.0
	Mean			11.6		4.9	0.7	174.2	523.0	697.2	69.9	73.6	94.9	75.0
D		CO-25	I	10.9	2997.8	12.5	0.6	720.5	1367.9	2088.4	69.7	74.3	93.8	65.5
D		CO-25	II	11.1	2997.8	17.1	0.8	747.8	1388.7	2136.5	71.3	74.2	96.1	65.0
D		CO-25	III	11.3	2997.8	17.4	0.8	1042.0	1128.9	2170.9	72.4	74.1	97.7	52.0
	Mean			11.1		15.7	0.7	836.8	1295.2	2131.9	71.1	74.2	95.9	60.8

A - Complete modern rice mill.
B - Huller mill.
C - Huller mill.
D - Sheller-Huller mill.

anyone to invest in equipment where adequate capacity already exists. However, as much as 5 percent increase in total rice is common in modern mills, compared to huller mills. In addition, there may be considerably more broken grain content in the huller mills compared to complete modern mills. This may be particularly important as buyers become more discriminating in markets with sufficient rice to meet consumer demands. Table 2 shows a typical rice mill evaluation where various mills are compared, and indicates both increase in total yields and value, as gauged by broken rice.

Figure 3 shows a complete modern mill with the components required to produce a good quality rice with a minimum of broken grain. This mill contains rubber roll shellers, accurate steel hullers, and separation equipment.

Once the decision is made to install a modern mill, the capacity must be determined. A rice mill operating at capacity should run 300 - 20 hour days per year. This schedule allows 4 hours per day maintenance and 65 days each year for repair and holidays. Some modern mills introduced in areas for the first time have operated longer and some for shorter periods each year. Consequently, this figure may be used as an average. Hourly capacity can be rated as multiples of 6000 per year. Each one ton per hour of capacity of the mill will process 6000 tons per year. From Table 1, there are 92,000 tons to be processed each year; consequently, the hourly capacity must be 15.33 tons (92, 000 ÷ 6000).

One principle issue in modern mills is replacement parts and operating techniques. Rubber rolls for the shellers must be procured and in place when needed. If they are not in the mill when old ones are worn out, the mill will have to cease operation. Technical competence is also an issue in modern mills. If no experience is available when the mill is installed, it is advisable to include staff training along with the mill purchase agreement.

A reasonable figure to use as the cost of modern rice mills is $20,000 per ton of hourly capacity. The mill then required to process the 92,000 tons shown in Table 1 would be $306,000 ($20, 000 x 15.33 tons per hour).

Returns for modern rice milling can be computed by estimating increases in outturn of rice from paddy. As an example, consider a one ton per hour mill processing

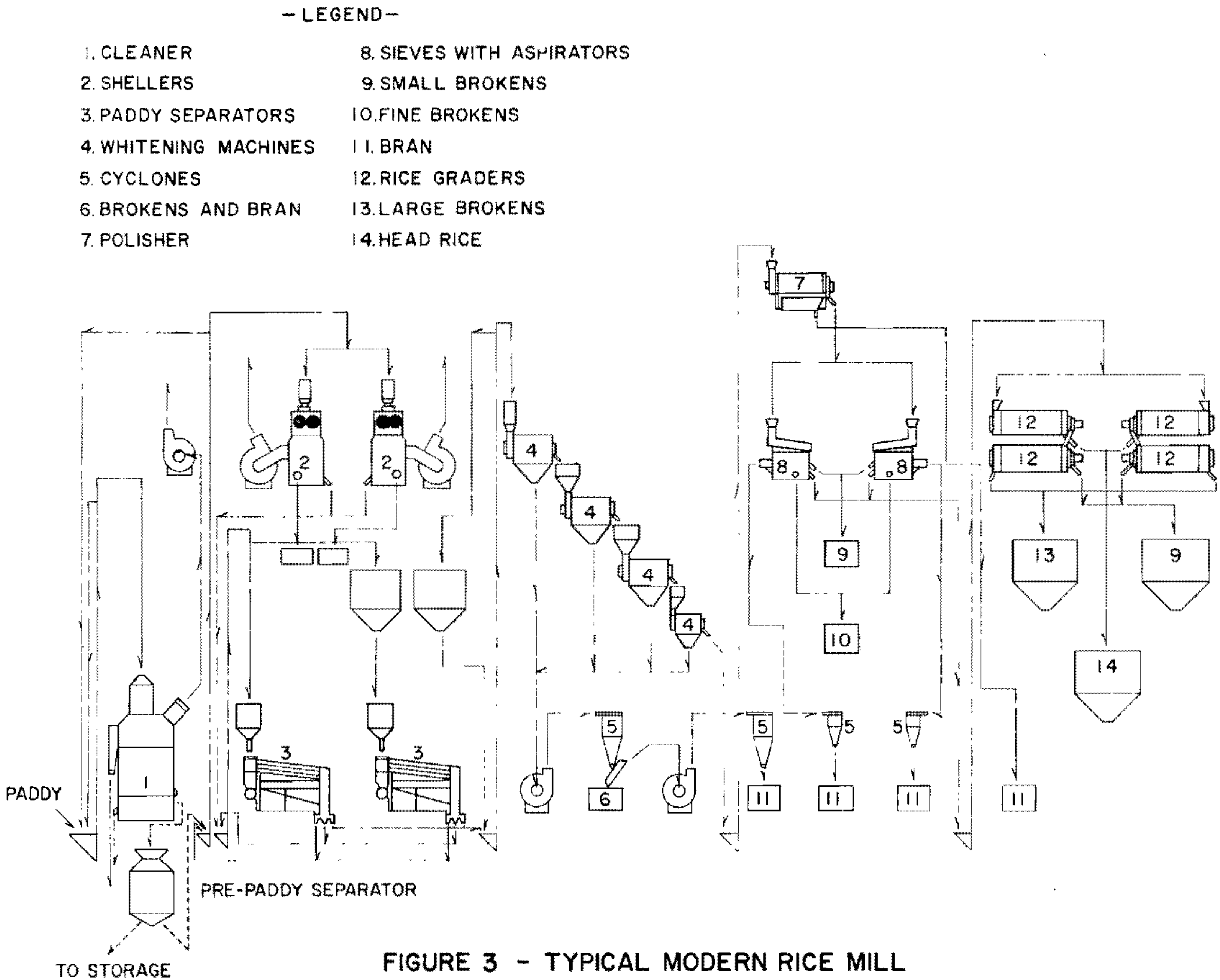


FIGURE 3 - TYPICAL MODERN RICE MILL

6000 tons per year. For each one percent increase in mill yield, the increase in the product would be 60 tons, worth about $9,000 (60 tons x $150/ton). Where huller mills are replaced with complete modern mills, the increase in product will be on the order of 5 percent, with higher value per ton than from the huller mill.

Rice Storage for the System

Storage of rice in bags can be in any dry, well ventilated, insect-free warehouse. Fifty percent total warehouse volume can be used for bag storage. However, the grain must be protected from insect infestation and should be well ventilated.

Arbitrarily, milled rice is usually not generally considered to store well for long periods. One common figure used for time of storage is 30 days for milled rice. However, if the grain is protected, it can be stored at least up to 90 days with no significant loss in quality.

THE WORLD RICE MARKET SITUATION

J. Norman Efferson
Vice Chancellor and Professor
of Agricultural Economics
Louisiana State University

The world rice situation changes so rapidly that the assignment of preparing an accurate paper on the subject in mid-August for delivery in mid-October is difficult, if not impossible. In atomic energy terms, the half-life of existing facts on the world rice market situation as of any given date is only one month. This means the facts of mid-August are only 50 per cent correct in mid-September and only 25 per cent reliable in mid-October. Thus, this paper is presented with the understanding that the author reserves the right to present a concluding section which cannot be written until the day before the paper is presented.

World Rice Production

From 1965 to 1970, the total world production of rice increased from slightly more than 240 million tons of paddy to the current level of nearly 290 million tons (Table 1). Asia normally produces about 90 per cent of the world's rice crop; the overall increase in world production from 1965 to 1970 was caused primarily by the expansion of production in Asia. In this region, about one-fourth of the expanded volume of rice was caused by a gradual increase in the acreage planted and three-fourths by increased yields per acre. In most of the other rice regions of the world, acreage remained relatively constant and the modest increases were the result of higher yields.

Causes of the Production Expansion

As indicated in Table 1, a large part of the total increase in production from 1965 to 1970 occurred during a one-year span between 1966 and 1967. In this period, production increased about 15 per cent. This was the result of unusually unfavorable weather conditions in Asia in 1965 and 1966 followed by unusually favorable weather conditions in 1967. From 1967 to 1968, there was little change in total production.

Table 1. Paddy Rice: Production by Major Producers, and World Total, 1964-69

Country	Year Beginning August 1					
	1964	1965	1966	1967	1968	1969 1/
	Million Metric Tons					
Mainland China	85.0	87.0	82.2	86.4	88.6	92.5
India	58.6	46.0	45.7	56.4	59.7	60.6
Pakistan	17.8	17.7	16.4	19.0	20.1	21.3
Japan	15.7	15.5	15.9	18.1	18.1	17.5
Indonesia	13.0	13.6	14.1	14.3	16.2	17.5
Thailand	11.1	10.8	13.5	11.2	11.2	13.4
Burma	8.2	8.1	6.6	7.7	8.0	8.0
Brazil	7.6	5.8	6.8	7.0	6.4	----
Philippines	4.0	4.1	4.1	4.4	4.4	5.2
United States	3.3	3.5	3.9	4.1	4.7	4.1
South Vietnam	5.2	4.8	4.3	4.7	4.4	5.1
South Korea	5.4	4.8	5.3	4.9	4.4	5.6
Total - Major Producers	235	222	219	238	246	251
World Total 2/	257	245	243	269	273	286

Source: Rice Situation, U.S.D.A., March, 1961

1/ Preliminary

2/ Excludes North Korea and North Vietnam

From 1968 to 1969 world rice production increased 5 per cent. In the most recent period, 1969 to 1970, the preliminary estimates indicate that total production increased only 2.4 per cent.[1]

Some observers have attributed most of the increase in rice production during the last five years to the introduction of the new improved varieties along with the additional inputs supplied with these varieties. A closer look at the timing of the increases, however, and of the areas where they occurred, leads to the conclusion that much of the increased production was due to factors other than the new varieties and the additional inputs. Table 2 presents a summary of the area planted to the high-yielding rice varieties, by year, from 1965-66 to 1969-70, in most of the major rice-growing countries of Asia. It should be noted that the most substantial increase in production, from 1966 to 1967, occurred before the high-yielding varieties were planted in large volume. Between 1969 and 1970, when the high-yielding types were greatly expanded, total production increased only slightly.

Most of the rice produced in the world depends upon natural rainfall for moisture and for weed control. In much of Asia, this rainfall is the product of the monsoon season between May and October. If the monsoon rains are on time, are of the right amount, and the storms not too severe, the crops are good; if not, yields are low. In general, of the rice production increase that has occurred in the last five years, it appears that about one-half of this expansion should be credited to improved weather during the latter years of the period and the remaining 50 per cent to a combination of factors including the contribution of the newly-developed, high-yielding varieties, the additional volumes of fertilizer, pesticides, and other inputs used, and the development of new and improved irrigation systems.

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1 World Agricultural Production and Trade, Foreign Agricultural Service, United States Department of Agriculture, June, 1971.

Table 2. Area Planted to High-Yielding Varieties of Rice in Less Developed Countries

	1965-66	1966-67	1967-68	1968-69	1969-70 1/
			Acres		
South Asia					
Ceylon 2/	--	--	--	17,200	65,100
India 3/	17,650	2,195,000	4,408,000	6,625,000	10,800,000
Nepal	--	--	--	105,000	123,000
East Pakistan	--	500	166,000	381,500	651,700
West Pakistan	--	200	10,000	761,000	1,239,000
East Asia					
Burma	--	--	8,500	412,400	355,900
Indonesia	--	--	--	488,100	1,850,400 4/
Laos	--	900	3,000	5,000	4,900
West Malaysia	--	104,500	157,000	224,700	316,000
Philippines 3/	--	204,100	1,733,400	2,500,000 4/	3,345,600
South Vietnam	--	--	1,200	100,000	498,000
Total	17,650	2,505,200	6,487,100	11,620,200	19,249,600

Source: Indexes of Agricultural Development, Less Developed Countries, 1970
U. S. Department of Agriculture, May, 1971.

1/ Preliminary

2/ Excludes improved local varieties

3/ Includes improved local varieties

4/ Unofficial

To make sound policy decisions affecting future programs, it is important in countries where rice is a significant crop that future world rice production trends be evaluated. The headlines and the thirst for spectacular journalism in recent years appear to have over-emphasized the contributions of the new varieties of rice to the production increase and, as a result, may lead some policy makers to erroneous conclusions. The new improved varieties along with additional inputs and better farm practices have played a large role and have also served as a catalyst to stimulate major changes in other areas such as transportation, storage, and the like. These contributions will be important in the future. However, as spelled out by Staub and Blase in their recent paper on genetic technology and agricultural development,[2] genetic technologies provide necessary but not sufficient conditions for agricultural development, and other factors must be considered.

In Asia, variable weather conditions are likely to continue to be the most important factor affecting the production of rice. Low-production years can and most likely will occur occasionally just as they have in the past. It also follows that in any given rice area in monsoon Asia, the maximum impact of the improved varieties, added inputs, and new methods can be obtained only when more and more of the region is provided with effective irrigation and water control. This will take time.

World Rice Trade

Most of the rice produced in the world is consumed in the countries where it is grown. Traditionally, only 4 to 5 per cent of total milled rice production moves into international trade. This proportion has held relatively constant in recent years. As indicated in Table 3, total world rice exports amounted to about 6.5 million tons in 1968; 6.3 million tons in 1969; and 6.5 million tons in 1970. For 1970, this amounted to about 4 per cent of total world production.

In this recent period, the United States has been the leading exporter, shipping 1.7 to 1.8 million tons yearly. Thailand was second with about 1 million tons a year, mainland China third with from 0.8 million to 1.0 million tons, and Burma fourth with about 0.4 to 0.6 million tons annually. In 1969 and 1970, Japan became an important exporter. In the three-year period, 1968 to 1970, UAR, Italy, and Australia had small but significant percentage increases in exports.

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2 "Genetic Technology and Agricultural Development," Science, Vol. 173, No. 3992, American Association for the Advancement of Science, July 9, 1971.

Of the annual volume exported from surplus-rice countries, about one-half of the total exports moved to deficit-food countries in Asia. These included Indonesia, East Pakistan, Ceylon, South Korea, Malaysia, South Vietnam, Hong Kong, Singapore, and in some years the Philippines. An additional 15 per cent of total world exports moved to high-quality specialty rice markets mostly in Europe and the Near East. The remaining 35 per cent moved to scattered markets mostly in Africa and Latin America.

Table 3. World Rice Exports by Major Exporters, Calendar Years 1968, 1969 and Preliminary 1970

Country	1968	1969	1970 1/
	1,000 Metric Tons — Milled Basis		
United States	1,847	1,850	1,695
Thailand	1,068	1,023	1,024
Mainland China	1,025	900	800
Japan	2 /	341	700
UAR	497	499	575
Burma	352	549	610
Italy	186	179	250
Cambodia	191	85	180
Australia	97	121	150
Total Major Exporters	5,263	5,547	5,984
World Total	6,469	6,255	6,500
Major Exporters			
Per cent of Total	81%	89%	92%

Source: U.S.D.A., Grain and Feed Division, FAS, March, 1971.

1 / Preliminary Estimates

2 / Less than 500 metric tons

After averaging about 7 million tons annually in the early 1960's,world rice exports dropped to 6.5 million tons in the late 1960's and in 1970. Current indications are that the 1971 level will be about 6.5 million tons.

World Rice Prices

Long-time trends in the export prices for 5 per cent broken-grain, medium quality milled rice, f. o. b. Bangkok, and the index of rice prices for exporting nations from 1960 to 1970 are presented in Figures 1 and 2.

From 1960 to 1965, world rice prices were relatively stable at around $160 per metric ton at f. o. b. exporting ports for high-quality, long-grain, well-milled rice with less than 5 per cent broken grains; $140 per ton for medium-quality, medium-grain or long-grain rice, reasonably well-milled with 5 to 10 per cent broken grains; and $110 to $120 per ton for undermilled, low-quality short, medium, or long-grain rice with around 25 per cent broken grains or for the usual parboiled 10 per cent broken-grain-off-color types. Good quality broken rice sold for around $90 per ton.

From 1966 to 1968, world rice prices increased substantially to a level of around $230 per ton for high-quality types, $200 per ton for rice of medium quality by export standards, and $170 per ton for low-quality grades. This price increase was due to increased demand from major consuming countries due to shortages caused by unfavorable weather years in Asia, along with an increased demand from the continual population increase.

World rice prices began to decline in mid-1969 as supplies became more abundant in both importing and exporting countries. As indicated in Table 4, the price of high-quality, long-grain types declined from around $215 per ton f.o.b. Bangkok in mid-1969 to about $140 per ton in early 1971. For medium quality 5 per cent broken grain types, the decline was from around $200 per ton in mid-1969 to $125 per ton in early 1971. During this period low-quality 25 per cent broken grain types or parboiled qualities declined from $160 to $100 per ton.

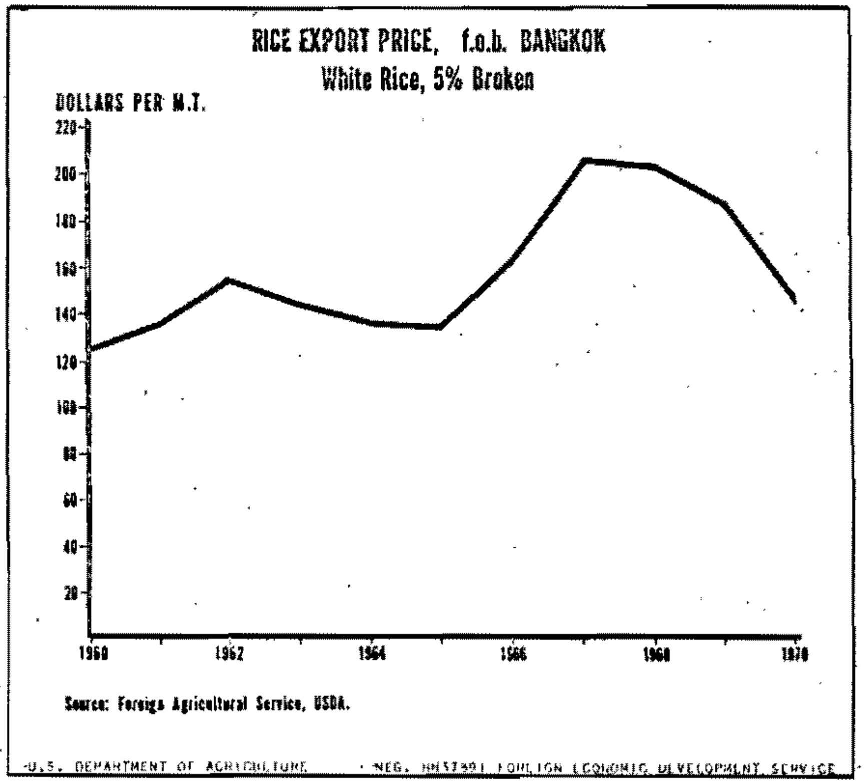

Figure 1

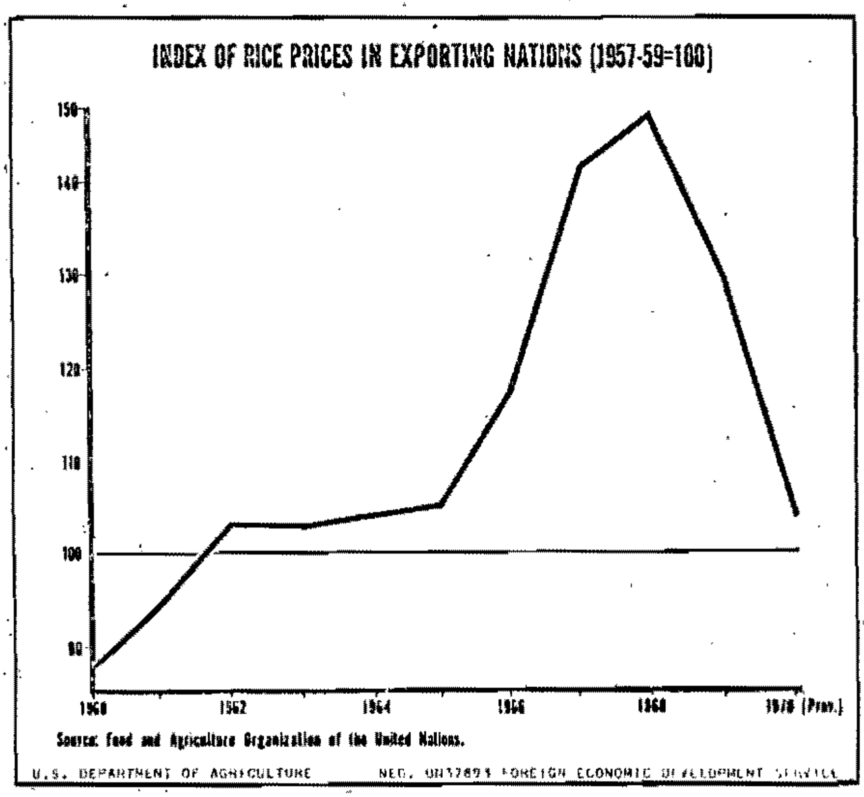

Figure 2

Table 4. Export Prices at Thailand for Milled Rice, by Months, White Rice f.o.b. Bangkok, 1969-71 1/

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Month						
					Dollars per Metric Ton							
					100% 1st Grade							
1969	192.60	192.60	199.68	198.90	205.80	212.16	213.00	205.05	201.12	199.80	200.40	192.96
1970	166.20	164.40	156.24	152.40	152.40	159.60	160.80	163.68	160.20	160.50	159.60	156.00
1971 2/	157.20	142.20										
					100% 2nd Grade							
1969	187.50	186.00	192.48	191.70	198.60	204.96	205.80	195.60	193.92	192.60	193.20	185.84
1970	161.40	159.60	151.44	147.60	147.60	150.00	151.20	154.08	150.60	150.90	150.00	146.40
1971 2/	147.60	132.60										
					5% Brokens							
1969	181.20	178.80	185.28	183.60	190.80	197.76	198.60	188.40	186.68	185.40	186.00	178.56
1970	154.20	151.20	143.04	139.20	139.20	141.60	142.80	145.68	142.20	142.50	141.60	138.00
1971 2/	139.20	125.10										

Source: U.S.D.A., C & MS, Grain Division, from weekly bulletins of San Francisco Market News.

1/ Milled rice, includes export premium, export tax and cost of bags. Packed in bags of 100 kgs. net.

2/ Preliminary.

Since the low point of the current marketing season was reached in February 1971, export rice prices have stabilized and strengthened somewhat. According to reports from Bangkok,[3] high-quality, long-grain types were selling at around $145 per ton and medium-quality 5 per cent brokens at about $130 per ton. Low-quality, high-percentage broken grains types, however, were lower, selling for $80 to $90 per ton. At this time, the standard quality 100 per cent broken grains type, C-1 Special, was being exported at around $60 per metric ton f.o.b. Bangkok.

As an indication of current world export prices for rice, several recent sales are of interest. According to a report from Karachi,[4] Pakistan, the Pakistan Trading Corporation, which is the sole exporter of rice for this country, closed a contract with a Kuwait rice importer to supply 150,000 tons of Basmati rice over an 18-month period at a price of $201 per metric ton f.o.b. Karachi. Basmati is the special-quality scented rice produced in West Pakistan (and in the Punjab of Northern India) which usually sells in the Near East for about $30 per ton more than non-scented high-quality types.

On the low side, Thailand completed a contract to sell the Philippines 50,000 tons of "white rice Philippines Special" at a price of U.S. $73.20 per metric ton, packed in 100-kilogram single gunnybags f.o.b. Bangkok in early June, 1971.[5] This was a 15-year credit sale at 7.5 per cent per annum, with a first 3-year grace period. It was to be delivered from June through August, 1971. The special Philippine grade contracted for was a mixture of one-half 15 per cent broken grains rice and one-half A-1 Special 100 per cent broken grains. The mixture results in a milled rice of approximately 42 per cent whole-grain rice and 58 per cent brokens. Although such a mixture would not be acceptable in many markets, the Philippine consumer has traditionally accepted a large proportion of broken grains and, in some cases, mixtures of large-grain corn grits with broken rice.

[3] Rice Prices, report of the Foreign Agricultural Service, U.S.D.A., from Bangkok, Thailand, as of July 22, 1971.

[4] Private communication from Mr. James Wimberly, The Ford Foundation, Karachi, Pakistan, as of July 30, 1971.

[5] Rice Prices, report of the Foreign Agricultural Service, U.S.D.A., from Bangkok, Thailand, as of June 23, 1971.

Of special interest to Latin America is the fact that Thailand sold 8,000 tons of white rice 15 per cent brokens (the medium-quality, slightly undermilled, somewhat mixed variety with some foreign materials type) to Costa Rica in late June, 1971, for U.S. $92.50 per metric ton f.o.b. Bangkok.[6] Assuming transportation and handling costs of $20 to $30 per ton to deliver this product to Costa Rica, this means that the competitive price for nearby surplus producers in Latin America would have been around $120 per metric ton or slightly less than six cents per pound.

Japan - A Special Problem

The most dominant influence on world rice markets at the present time is the situation in Japan. The situation in this country is a classic illustration of the impact of specific policies regarding rice on national and international production and trade.

Japan's most important food produced and consumed is rice. In the pre-World War II period, the per capita consumption was more than 300 pounds yearly. Currently, consumption is about 225 pounds. Japan traditionally has produced most of its rice needs, about 11 million tons of milled rice, but has not been self-sufficient and has imported some of the total needs. Imports in the 1960-64 period averaged about 225,000 metric tons annually. In 1966, total imports were about 800,000 tons and in 1967, 500,000 tons. The imports usually were brought in from Taiwan, with smaller amounts from the United States and other exporters where the round-grain, semi-sticky Japonica varieties preferred by the Japanese population are produced.

Because of food shortage periods in the 1930's and 1940's, rice has been an important element in the political history of Japan, and Japanese rice policy in recent years has been aimed at self-sufficiency. The government has been very active in all phases of rice production and marketing. Beginning in 1960, for 10 consecutive years the government each year increased the support price for rice. By 1969, this

[6] Rice Prices, report of the Foreign Agricultural Service, U.S.D.A., from Bangkok, Thailand, as of July 2, 1971.

price support level was about $395 per ton, brown rice basis, which amounts to about $380 per ton of milled rice. This price support level is currently about three times the world export price of equivalent round-grain rice.

With this incentive, Japanese farmers responded, as do farmers throughout the world, by greatly intensifying their production and gradually in the late 1960's large surpluses began to develop. These surplus supplies were intensified by Japanese barter purchases of rice from mainland China in 1967 and 1968 in return for sales of Japanese machinery to China. By October, 1968, the Japanese rice carry-over or surplus prior to the beginning of the harvest season reached 2.7 million tons. In 1969, the carry-over was 5.6 million tons. By 1970, it had reached 7.3 million tons, or more than enough rice to supply the entire import needs of the remainder of the world.

The political situation in Japan is such that they have not considered it wise to reduce support prices or to introduce direct production controls. They are attempting to cut back production by indirect subsidies encouraging land use shifts out of rice, by planning to use up to 1.5 million tons annually for feed, by expanding industrial uses, and by exports on a long-term, low interest rate basis. So far, they have been only partially successful.

The impact of the Japanese rice situation on overall world rice stocks and exports is shown in Figure 3. In 1965, world stocks and exports were in reasonable balance. In 1970, world stocks were about double world exports. The primary difference was the increased surplus stocks in Japan.

Although the surplus rice situation in Japan is serious and is likely to have a major impact on world rice trade for several years, it is not as serious as has been indicated by some observers. Even with a one-year total world export supply on hand in Japan, other surplus-producing nations still have export markets for rice.

Japan produces exclusively the short-grain or round-grain, semi-sticky or low-amylose grain types. The round-grain, low-amylose rices are greatly preferred by consumers in Japan, Taiwan, and in South Korea. In most of the remainder of the rice

Dr. Trant. Let us illustrate these relationships by a hypothetical example (Table 4).

The distribution of benefits

Who will benefit from the introduction of new rice varieties? Initially, early adopters will obtain large economic gains. The early adopters are likely to be found among large commercial farmers with access to irrigation. Growing of non-irrigated rice, particularly in regions with large variations in the pattern of rainfall, is usually associated with higher risks and a large number of early adopters are not likely to be found under these conditions. Unless special attention is paid to small farmers, they are not likely to get the information on the new varieties at an early stage. Furthermore, the small farmers are likely to avoid the risk associated with early adoption, as pointed out previously.

Since all the producers are faced with essentially the same price, those who reduce costs by adopting the new varieties will benefit more than those who do not. As prices begin to fall, the non-adopters will begin to experience a reduction in net revenues as compared to those obtained before the introduction of the new varieties. As the price falls below the cost of producing traditional varieties, the farmers who did not change to the new varieties will experience economic losses. If the price is permitted to drop even further, those farmers who grow the new varieties may find that their production costs are not being met. If prices fall by about one-third, the total benefit from the cost reductions obtained by means of adopting the new varieties will base: the large commercial farmers will be the early adopters, and only after being reassured that the risk is low will the small farmers join.

What will be the consequences of the adoption of the new rice varieties?

The analysis of the economic consequences of the adoption of the new rice varieties is divided into three parts:

1. The impact on production, prices and net returns.
2. The distribution of benefits.
3. The resulting adjustments within the agricultural sector.

Impact on production, prices and net returns

It is reasonable to believe that the adoption of the new rice varieties will be gradual, beginning with a relatively small number of farmers. While many of these farmers will obtain considerable yield increases, the national production expansion will be small, and under a well-functioning market system national prices are not likely to be affected significantly. Net returns to these early adopters will increase sharply except for those encountering crop failures. As more farmers become aware of the potential gains obtainable from the new varieties, the rate of adoption will increase and the production expansions will be sufficiently large to create a downward pressure on rice prices. As production increases still further, severe price drops may be expected in the absence of government intervention, export or import substitution. This point will be further elaborated upon by influencing his decision-making. Hence, as pointed out by Dr. Byrnes, he must be made aware of where and how to obtain it.

Expected net economic gains

For the well-informed farmer who does not expect to influence prices by increasing his production, in most cases a correct expectation, the potential net economic gains are quite obvious.

By adopting the new rice varieties, costs per ton of rice produced are reduced by one-third; the reduction is added to the farmer's net return. As a large number of farmers take advantage of this opportunity, the aggregate production expansion will reduce prices and the cost reduction may be partially or completely offset by decreasing prices, as discussed later.

The risk factor

The commercial farmer with a considerable resource base is likely to change from the rice variety he presently grows to a new one if he expects to be able to increase net returns by doing so. The farmer with a very limited resource base, including maybe a very uncertain land tenure arrangement, is likely to place the goal of risk minimization before that of increasing net returns. To him a crop failure would have severe consequences. The degree of risk is heavily influenced by the quantity and quality of information available to the decision-maker. Here again, the small farmer is usually disadvantaged because of his low level of education and lack of communication with the various agencies distributing the information. Therefore, it may be expected that the rate of adoption of the new rice varieties may be closely correlated with the farmer's resource the latter case, the individual farmer usually does not expect that his own production expansion will influence product prices.

Hence, while industrial firms with a large market share of a particular product may adjust their production according to the expected influence on its price, the individual farmer usually makes his production decisions on the assumption that prices will not be affected. However, as will be discussed later, when a large number of farmers expand or reduce production, prices will be affected. Hence, the farmer's expectations may not materialize.

In so far as the new variety IR8 is concerned, it should be mentioned that in some countries this variety can be sold only at a price considerably below that of traditional varieties. This is because of its poor milling quality and/or low consumer acceptance. CICA 4 does not have these handicaps in Latin America. Hence, considering that all other important characteristics are the same for CICA 4 and IR8, it appears that the well-informed farmer would not be interested in growing IR8 if seed of CICA 4 were available.

Availability of inputs

It is obvious that unless the new seed is made available to the farmer, he will not be able to adopt it. Availability of other related inputs such as fertilizers, irrigation water and labor, particularly during peak seasons, is also likely to influence the rate of adoption. While the physical availability of the inputs is essential for adoption, it is not sufficient. The farmer's perception as to the availability and the degree of difficulty of obtaining it is the important variable marginal cost is of great importance if a two-price scheme for rice is considered. If the farmer can sell an amount of rice equal to that traditionally produced, at unchanged prices, the additional production can be sold at a price as low as one-seventh of the current price and the farmer would still make the same net return per ton of the additional production as he would per ton of the present production. The rapidly increasing production of IR8 in Colombia and certain other countries despite very low prices for this rice may be partly explained by these relationships.

Estimated costs of producing present and new varieties in certain Latin American countries are shown in Table 3 and Figure 1.

The structure of the local rice market and rice prices

The farmer's perception of the structure of the local rice market and his expectations concerning future prices of rice are likely to influence his decision as to the adoption of a new rice variety.

In remote regions with little outflow of agricultural products, the farmer may be faced with a rigid market structure for his products. Increasing production may result in sharp decreases in local prices and/or problems of actually finding a buyer for the additional production.

Local marketing facilities may be unable to handle large increases in the quantity of rice brought to market. Lack of drying, storage and transportation facilities may result in considerable grain losses.

To the extent that the farmer is aware of these potential marketing problems, he may decide to avoid adopting production-expanding technology. However, most rice producers are faced with a somewhat more flexible demand situation, with access to markets outside the region and where local prices at least to some degree are related to national prices. In and harvesting costs to about 20 per cent. Assuming a 70 per cent increase in yields, the cost per hectare of producing the new varieties will then be approximately 10 per cent above that for traditional varieties 2/.

However, the costs of production per ton of rice decrease. Again assuming a 70 per cent yield increase and a 10 per cent increase in production costs per hectare, the costs per ton decrease by about one-third 3/. The marginal cost, i.e., the costs of producing the additional quantity of rice, is much lower. If the cost per hectare increases by 10 per cent, the cost per ton of the added production is one-seventh of the cost of production per ton using traditional seed 4/. This difference between average and

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2/ Expected change in total cost per ha.:

a) due to change in harvesting costs: $\frac{20 \times 70}{100} = +14\%$

b) due to change in seed costs: $\frac{4 \times (-30)}{100} = -1.2\%$

c) due to change in insecticide costs: $\frac{7 \times (-50)}{100} = \underline{-3.5\%}$

$\underline{\underline{-9.3\%}}$

3/ Let

TC = total cost of production per unit of land

Q = yield per unit of land

AC = average cost of production per unit of output

$\%\Delta$ = percentage change

then

$TC = Q \times AC$

$\%\Delta TC = \%\Delta Q + \%\Delta AC + (\%\Delta Q \times \%\Delta AC)/100$

$\%\Delta AC = (\%\Delta TC - \%\Delta Q)/(1 + \%\Delta Q/100)$

if $\%\Delta TC = 10$

and $\%\Delta Q = 70$

then

$\%\Delta AC = \frac{10 - 70}{1 + 0.7} = \underline{-35.29\%}$

4/ Let MC = the cost of production per ton of the additional output i.e. the marginal cost assuming constant cost per unit of additional output.

Then $MC = \frac{\%\Delta TC}{\%\Delta Q} \quad \frac{10}{70} = 0.14$ or 14% of initial average costs (AC).

exchange rates may not correspond with relative domestic purchasing power within the various countries, hence a direct comparison of dollar costs may be biased.

It appears that, while the cost of producing rice is low in Ecuador, it is high in Peru. Since the costs are estimated on the same yield base, the cost per hectare shows the same tendencies as those per ton of rice produced. A relatively large proportion of the cost of producing rice under irrigation and high level of technology is associated with purchased inputs such as fertilizers and insecticides while the large proportion of the costs of producing non-mechanized upland rice is associated with labor which to a large extent is supplied by the farmer and his family. A more detailed discussion of the cost of producing rice in Latin America may be found in "Background Information No. 3", which has been distributed for this Seminar.

The new varieties require less seed per hectare and are resistant to direct damage caused by Sogatodes. Hence, the costs of seed and insecticide are likely to be reduced. However, because of the higher yields, harvesting costs will increase. It is expected that the quantity of seed can be reduced by about 30 per cent and the cost of insecticides by about 50 per cent.

The relative importance of each cost item in total costs of production depends on the quantity used of the various inputs and their relative prices. However, for most regions it may be assumed that the cost of seed amounts to about 4 per cent of the total cost of producing traditional rice varieties under high levels of technology, the cost of insecticides to about 7 per cent under experimental conditions. It appears that the yield capacity of CICA 4 and that of IR8 are essentially the same. It is expected that, under high levels of technology, these two varieties will yield about 70 per cent more than the previous improved varieties such as Bluebonnet 50. This appears to hold true both under irrigated and non-irrigated conditions. The increases in yields obtainable from changing from a non-improved variety to CICA 4 or IR8 may be considerably higher and would depend on the yield capacity of each particular non-improved variety.

Potential yield increases obtainable from introducing the new varieties under low levels of technology are likely to be smaller. This is because of the responsiveness of the new varieties to fertilizers and improved cultural practices. If the introduction of the new varieties is associated with improvements in other technology, such as better land preparation and application of fertilizers, the yield increases may be considerably more than the previously mentioned 70 per cent.

Relative costs

Estimated costs of producing traditional rice varieties under irrigation and non-irrigation in Colombia, Ecuador and Peru are shown in Tables 1 and 2. The estimated costs of production reported in the tables should be interpreted as rough guidelines rather than exact figures. The cost of production tends to vary among regions within any one country and even among farmers within a region. The cost data for each one of the three countries are expressed in a common currency (U.S.$) to be able to make direct comparisons. It should be kept in mind that the official and the willingness to assume the risk 1/ that the expectations may not materialize. The expectations are subjective and the degree to which they are realized depends on the quantity, timeliness, relevance and accuracy of the information available to the decision-maker and his perception of the information. Hence, as pointed out by Dr. Byrnes is his paper yesterday, the approach and capability of the change agent to make factual information available to the farmer that he can understand and believe is extremely important for a successful introduction of new farm technology.

The basis for deciding whether to change from traditional to new rice varieties may be translated into economic terms as (1) the expected net economic gains obtainable from the change, and (2) the willingness to assume the risk that these expected net economic gains may not be forthcoming. The potential net economic gains obtainable from the change would depend on such factors as relative yields, prices and costs of production, availability and prices of inputs such as fertilizers, irrigation water and the improved seed itself, and the local market structure for rice. The willingness to assume risk, in turn, may depend on a large number of factors such as land tenure, the resource base controlled by the farmer, and his attitudes towards change.

Relative yields

Yield data on the new rice variety CICA 4 are extremely scarce at the time of this analysis and essentially limited to yields obtained

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1/ The term "risk", as used in this paper, covers both actual risk and uncertainty.

ECONOMIC IMPLICATIONS OF PRODUCING NEW RICE VARIETIES IN LATIN AMERICA

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Per Pinstrup-Andersen
Agricultural Economist
Centro Internacional de
Agricultura Tropical

An analysis of the economic implications of producing new rice varieties may conveniently be divided into two parts: (1) The implications at the producer level, and (2) those at the national level. This paper is an attempt to analyze some of the most important economic implications at the producer level while those at the national level will be treated by Dr. Trant.

In this discussion, the term "new rice varieties" refers primarily to the two varieties, CICA 4 and IR8, although the analysis may apply to other similar varieties as well.

The analysis is divided into two parts:

1. The economic factors influencing the farmer's decision about adopting a new rice variety.
2. The economic consequences to the individual farmer and the farm sector of the adoption of new varieties.

Why does the farmer adopt a new rice variety?

Rational decision-making is based on the expected benefits of the decision, the expected efforts needed to carry out the decision

3. Countries that establish support prices for rice higher than the equivalent of the above-listed export prices, are likely to be left with supplies which cannot be sold without a loss.

4. In the long run, 5 to 15 years hence, the demand for rice is likely to exceed potential production, because breakthroughs such as the improved varieties occur infrequently. Thus, a soundly-based rice industry, based on economic production and efficient management, is likely to produce a foreign exchange winner as well as a domestic contribution to improved standards of living.

5. In the short run, the next 3 to 5 years, expanded rice industries in countries without a firm export base should be limited to the volume needed for domestic needs. If the crop can be produced to sell at the above-listed export prices, then the development of an export market is justified. In this connection, however, it should be kept in mind that export quality rice is generally much higher in quality than that produced for domestic sale in many countries of Latin America. The lowest export quality normally moving in international trade has a maximum of 25 per cent broken grains, is well-milled, and contains very little foreign materials. Thus, any nation planning to develop a rice export industry must first provide a modern, efficient rice-milling industry and establish rigid quality standards.

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There will be special needs in some countries which are likely to be filled by various international or other organizations. In early August, 1971, the U.S. Department of Agriculture announced the issuance of a Public Law 480 Purchase Authorization for 350,000 metric tons of rice for Indonesia to be delivered between September, 1971 and June, 1972. At the same time, it was announced that a Public Law 480 Purchase Authorization for 50,000 metric tons be made for Pakistan to be delivered on an emergency basis between August and September 1971. This initial shipment to East Pakistan is likely to be the first of several as East Pakistan is a food deficit area this year to the extent of about 2 million tons due to the severe storms in late 1970 and the internal disturbances of recent months. Although from 300,000 to 500,000 tons of these needs can be supplied from the expanding rice-growing area of West Pakistan, the remaining 1.5 million tons will have to come from other areas. There is little chance that this deficit food situation will be changed in the next five years.

As to prices, on the low side as a rough guess export prices f.o.b. exporting ports should be from $90 to $110 per ton for low-quality, 25-per cent broken grains undermilled raw white rice or off-color parboiled milled rice, $110 to $130 per ton for medium-quality types such as Thailand 5 per cent brokens or U.S. #3 medium-grain, and $130 to $150 per ton for high-quality completely whole grain long-grain milled rice. These are the low-side prices; with temporary shortage periods, the export prices could be 20 to 40 per cent higher than the indicated levels. There is a 50-50 chance that such shortage periods may occur.

The implications of these potential developments to policy makers involved in rice production in Latin America are as follows:

1. The world rice situation for the next few years is likely to be a buyers' market rather than a sellers' market and export markets will be difficult to establish.

2. Export rice prices, f.o.b. exporting ports, are likely to be around $100 per ton for low-quality types, $120 per ton for medium-quality, medium-grain and long-grain types, and $140 per ton for high-quality long-grain types. These prices are about 40 per cent below 1966-69 price levels.

If weather conditions deteriorate and/or the overall rate of the production increase in Asia is reduced by other reasons to 2 per cent or less, as was the case between 1969 and 1970, the supply-demand situation will reverse itself to the 1966-67 situation; the demand for rice will greatly exceed the available supply, and prices will increase to the 1968 levels.

The chances are that the 1972-76 situation will be somewhere between these two extremes. The continued impact of the new varieties and added inputs will result in smaller percentage increases than in the 1968-70 period as the mass of producers react more slowly than the early achievers, and weather conditions are likely to rever to normal rather than relatively favorable. Also, the continued availability of the adde inputs needed in terms of fertilizer and pesticides will be dependent on continued and expanded assistance and subsidized programs for these needed supplies. However, the impact of the improved varieties and new methods will prevail to some extent regardless of the availability of inputs and the educational activities associated with their development.

The "miracle rices" will not fulfill the expectations of the headline promoters (these were never the forecasts or expectations of the developers of these varieties). The breakthrough resulting from the development of nitrogen-responsive, lodging-resistant rice varieties will result in production increases larger than the normally expected increases without the new varieties, regardless of prevailing weather conditions, or input availabilities. With these assumptions, rough guesses can be made as to rice trade and rice prices in the next five years.

With these assumptions, the increased population growth, variations in production due to weather conditions, the comparative-advantage costs of producing rice versus other products in some countries, the increased demands for rice in some areas along with decreased needs in others, and other similar factors, all point toward a continued world rice trade of from 6 million to 7 million tons a year. There will be changes from country to country but international rice trade will not dry up and blow away.

In Japan,the per capita consumption of rice has been decreasing at the rate of about 2 per cent annually as their industrial prosperity provides the opportunity for more diversified foods. In South Korea, where rice supplies have been short, production increases have been accompanied by substantial per capita increases in rice consumption. A recent study in South Korea on food consumption patterns indicates that the per capita consumption of rice will increase at a faster rate than domestic production with the availability of greater supplies at a reasonable cost; this country imported more than 500, 000 tons annually in 1969 and 1970. Similar trends are likely in other countries of the region.

Finally, the population increase in the developing nations of Asia, Latin America, and Africa where rice is an important food continues to move at the rate of around 3 per cent annually. This means an increased demand for rice, even assuming no per capita consumption advance, of 30 per cent every 10 years.

Prospective Rice Trade and Prices in the Next Five Years

Rice trade and rice prices, f.o.b. exporting ports, in the next five years will depend on the demand for rice from importing nations, the supplies produced by both importing and exporting countries, and general business, economic, and political conditions affecting trade between nations. Assuming that political conditions will not deteriorate and that reasonable trade between nations will be no more difficult than in 1971, the following estimates can be made:

If Asian rice production continues to increase at the average rate of more than 4 per cent annually as was the case in the five-year period, 1966 to 1970, the need for rice imports by deficit nations will decline and available export markets for surplus-producing countries will be severely reduced. In this case, rice prices internationally and nationally will decline as supply will outstrip demand. In this instance, the lower level of export rice prices is likely to be the value of rice as a feed for livestock. Although this will vary from country to country, depending on feed needs and alternative carbohydrate feeds available, it should be in the neighborhood of $60 to $80 per ton.

These two potential adjustments combined with the gradual adjustment of the Japan surplus situation because their costs are so high that the government will have to reduce production or go bankrupt are likely to result in lower world rice export supplies than is indicated by the current statistical position.

In addition, the rapidity and extent to which many of the deficit rice countries will reach their planned goals of self-sufficiency should be examined. Malaysia already has had second thoughts on this matter and now plans a level of 90 per cent of self-sufficiency rather than eliminating exports. In this case, the quality of rice which can be purchased at a relatively low cost from nearby Thailand is such that self-sufficiency is not economic. With the recent developments in East Pakistan, the self-sufficiency goals in this area have been set back from 5 to 10 years. India and Ceylon are not moving as fast in increased rice production as was once thought possible. The Philippines made detailed plans for becoming an exporter in 1969 but after making an initial shipment or two, soon found that their increased production was worth more at home than abroad and since then have had production difficulties so that additional imports have been necessary. These examples all point toward a supply-demand situation not as critical as the 1968-70 statistical picture would indicate.

Self-sufficiency is a sliding target, not a rigid one. As production increases in the developing countries where food supplies have been sufficient only for a minimun diet, additional food will be consumed. In West Pakistan, where reasonably accurate data are available, it was found that a substantial part of the increased wheat productio resulting from the introduction of new varieties and additional inputs disappeared between the time it was produced and the time it was inventoried by the government. The answer proved to be a simple one; when the rural people were questioned, they universally answered that with the more abundant supplies they were now eating two or three meals a day instead of the usual one meal a day common before the period of higher yields. A similar situation is likely to develop in all the poor diet, deficit rice countri in Asia as additional supplies become available.

their usual practice was to sell about 1 million tons of rice annually and with this income buy more than 2 million tons of wheat.

World rice prices have declined about 40 per cent from 1969 to 1971. This change has adjusted the relationship between rice prices and wheat prices. Under declining world rice export prices and steady wheat prices, Mainland China has fewer and fewer opportunities to convert 1 calorie of food to 2 calories of food by exporting rice and importing wheat. As a result, Mainland China's exports of rice have declined from about 1 million tons in 1968 to 0.8 million in 1971. If the current relationship between wheat and rice prices continues to prevail, the export supplies of rice from Mainland China are likely to decline to less than one-half or even lower of the recent level. This will open up export markets for rice to other producers for around 500,000 tons of rice annually.

The second important development involves the largest rice exporter, the United States. United States' rough rice has a price support amounting to about \$5.00 per hundredweight. Converted to milled rice, this amounts to about \$160 per ton. This support price, however, is tied to a very rigid enforced acreage control program, established so that Government losses in low-price periods would be small. In the 1966-68 period, world prices were above the support level, and acreage restrictions were relaxed. With the increasing world surplus situation, the restrictions were again tightened. Thus, a forced 10 per cent acreage reduction was applied in 1969 and an additional 15 per cent reduction was established in 1970. On August 6, 1971, the Secretary of Agriculture announced a further reduction of 10 per cent for 1972. Thus, in four years the United States' rice acreage has been reduced 35 per cent. With a yield increase approximating 3 per cent annually, this means that total rice production in the United States will be at least 25 per cent less than in 1968. Since roughly one-half of United States' rice production is consumed domestically, this means that United States' export supplies for 1972 and future years are likely to be less than 1 million tons as compared to the recent level of 1.5 to 1.8 million tons. This reduced supply will also reduce pressures on world rice markets.

concludes that rice surpluses will grow substantially through the 1970's and that traditional trading patterns for rice will turn virtually upside down. Another study by a Harvard Advisory Group[8] concludes that when proper adjustments are made for specialized, captive and government-to-government rice exports, the world market for export rice in the early 1970's will amount to only 1 to 2 million tons annually and the expected f. o. b. export price will be around $80 per ton. A recent U. S. D. A. report[9] points out that if rice production continues its upward trend, exporting countries will suffer from reduced sales, depressed world markets, and lower overall receipts.

These studies were made by competent people and have been carefully done. These and similar works should receive the scrutiny of all individuals interested in possible developments in the world rice industry. In general, they are accurate as to indicating the direction of the trend. However, they all overstate the case. Although their computers are efficient, the limited statistical data available are at best far from complete or accurate. More important, they have not considered new developments which cannot be programmed into the computer.

One of the more important new developments concerns Mainland China. In the last few years, Mainland China has exported from 800, 000 to 1 million tons of rice annually. Mainland China is not a surplus food producer. The nation has a food deficit of 2 to 3 million tons of grain annually. The export of rice has been accomplished by forced movement of rice from production areas and then replacing this rice with cheaper imported wheat. Under the price relationships between export wheat and export rice which prevailed in the 1966-69 period, Mainland China could buy 2 calories of food energy in terms of imported wheat for each one calorie of food energy in terms of rice which was exported. Thus, under a rigidly-controlled econom

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[8] The World Rice Market and Its Implications for Pakistan's Fourth Five Year Plan. Harvard Advisory Group to Pakistan, Working Paper #2, 1969.

[9] "Problems of World Rice Trade," by James W. Willis. Foreign Agriculture, U. S. D. June 28, 1971.

world, the long-grain and medium-quality freely-separating, high-amylose Indica types are preferred by consumers. This preference is so strong in some markets that consumers will buy other grains rather than short-grain rice if long-grain rice is not available. In other markets, they will pay up to twice as much per pound for the long-grain as compared with the short-grain Japonica rice. In other markets in Asia, parboiled, medium-grain and long-grain rice are preferred rather than raw white milled rice. The Japanese rice-milling industry does not have parboiling facilities.

The Japanese surplus rice supply will compete directly with the short-grain rice production of Australia, Egypt, Italy, and U. S., California-grown rice. It will compete indirectly with the low-quality, medium-grain and long-grain rice supplies of the surplus-producers in Asia and in the United States for markets such as Indonesia, East Pakistan, and Ceylon, where the price factor is so important and the need for food calories is so urgent that consumers will utilize any quality of rice so long as it is inexpensive. It will not compete for the high-quality markets of Europe and the Near East, or for scattered markets around the world where long-grain, low amylose or parboiled quality is desired. Roughly, about one-half of world export markets for rice will not be affected by the accumulating Japanese rice surplus, one-fourth will be indirectly and partially affected, and the remaining one-fourth will be seriously affected by these excess supplies.

Recent Developments in the World Rice Situation

Some observers of the developing world rice situation have concluded that because of the impact of the new improved varieties and additional inputs, production in both the importing and the surplus-producing nations will continue to increase. They further conclude that world supplies will greatly exceed demand with a resulting further substantial decline in rice prices to exporting nations and to growers in other areas. A recent carefully documented statistical study by Canterberry and Bickel[7]

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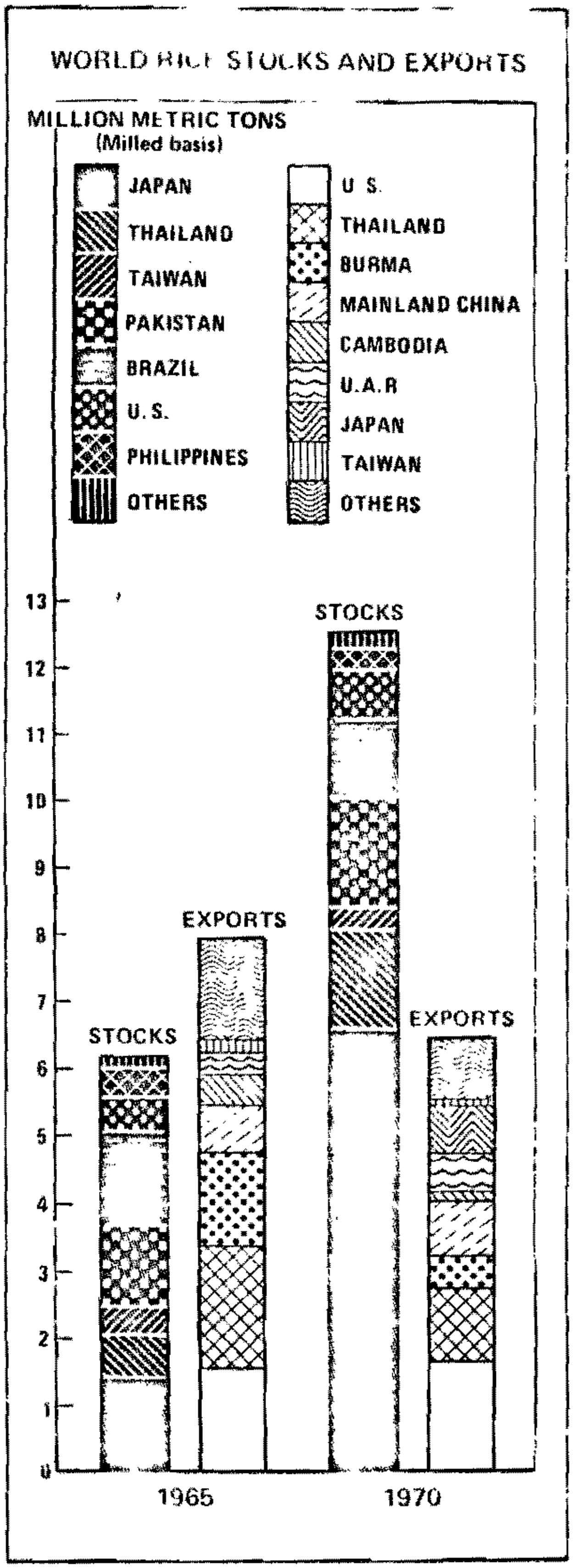
[7] "The Green Revolution and the World Rice Market, 1967-1976," by E. Ray Canterberry and Hans Bickel. American Journal of Agricultural Economics, Vol. 53, No. 2, May, 1971.



Source: Foreign Agriculture, USDA, Vol. ..., no. 26, June 28, 1971 go to the consumers and marketing agencies, such as wholesalers, millers, etc., leaving the farmer who changed to the new varieties with the same net return as before the introduction of the new varieties. Had the farmer not introduced the new varieties and prices had fallen by one-third, he would have been able to cover only about 60 per cent of his total costs. Hence, the distribution of economic gains among farmers will be determined primarily by the adoption pattern.

The adoption rate may differ considerably among regions. Regions with highly efficient rice production are likely to obtain considerable gains while the marginal, high risk rice regions may experience economic losses. The regional distribution of benefits may be heavily influenced by the capacity of the local marketing facilities to handle increasing quantities of rice.

The distribution of economic benefits between the agricultural and other sectors will be determined primarily by the price flexibility of demand for rice at the farm level, i.e., the reduction in farm prices associated with increasing market supply of rice, and the structure of the input market. The demand for rice increases by 2-5 per cent per year in most Latin American countries because of increasing consumer incomes and population expansion. If the domestic supply of rice increases more than domestic demands, price will fall.

In virtually all Latin American countries the demand structure for rice is such that to sell more rice on the domestic market, in the absence of government intervention, the price must be reduced relatively more than the additional quantity of rice to be sold. Hence, the total revenue to the rice-producing sector decreases as more rice is produced.

However, if expanded production of rice is associated with reducing rice imports or expanding exports, domestic supplies may not increase, hence price decreases would not be expected. In this case the agricultural sector will obtain large economic gains from adopting the new high yielding varieties.

As more rice flows through the marketing channels, the various marketing agencies are likely to obtain considerable economic benefits. However, heavy investments in marketing facilities such as warehouses and transportation and drying facilities will be required to obtain these benefits. The fertilizer industry may gain considerably as fertilizer demands increase. The labor force will gain from expanded employment, particularly in the marketing sector.

Agricultural adjustment

Given these general economic implications, what adjustments may be expected to occur within the agricultural sector? Initially, the farmers who shifted to the new varieties will find the shift extremely profitable, as already pointed out. These farmers will find it profitable to allocate more land to rice and expand the use of fertilizers and other inputs. Likewise, more farmers may come into rice production. Land prices may increase in the important rice-producing regions, resulting in higher production costs. Land owners may try to obtain all or part of the additional net revenues by increasing land rents and conflicts may arise between landowners and tenants. To the extent that rents are determined on the basis of quantity produced, the distribution of gains among landowners and tenants may be determined more or less automatically. As land prices increase, the cost of producing other crops competing with rice for land will increase. Furthermore, increasing demands for fertilizers will cause pressures on the fertilizer distribution system, and fertilizer prices may increase. Additional domestic production or importation of fertilizers will be required. In regions where water is in short supply, water right conflicts may develop.

Likewise, it may be expected that more labor will be allocated to rice production, although the extent to which this occurs will depend on the available farm labor particularly during planting and harvesting and the relative cost of labor vs. machinery. If, even during peak seasons, sufficient labor is available, for which there is little or no alternative employment, the government may find it desirable to control the importation of labor-saving farm machinery in such a way as to promote employment.

The long run adjustments will depend on the extent to which the price of rice falls. If the expanded production is added to domestic supplies and prices are allowed to decrease, a number of farmers, particularly those who, for one reason or another, did not adopt the new varieties, will not find it profitable to produce rice. These farmers will attempt a reverse adjustment. Rice land will be used for other crops; farmers with few resources may decide to leave farming and for the most part join the large number of urban unemployed. The most efficient farmers will probably continue to make a fair net revenue, at least in the long run, while the less efficient ones may drop out. Some farmers with small cash costs may continue to produce rice, absorbing the price decreases by reducing the payment to family labor. A large number of

Large scale adoption of the new varieties is likely to cause certain adjustments in the agricultural and the marketing sectors. These adjustments may be guided by government policies on issues such as domestic rice prices, foreign trade, credit and agricultural input prices and availability.

TABLE [illegible]. ESTIMATED COST OF PRODUCING RICE UNDER IRRIGATION WITH HIGH LEVELS OF TECHNOLOGY IN COLOMBIA, ECUADOR AND PERU 1/

t items	Colombia U.S.$/ha. 2/	Colombia % of total cost	Ecuador U.S.$/ha.	Ecuador % of total cost	Peru U.S.$/ha.	Peru % of total cost
ad preparation	23.77	5.9	33.26	13.2	59.45	14.1
bor and equipment cost ring growing season	60.53	15.0	35.52	14.1	84.13	20.0
ed, fertilizers, insecticides and herbicides	116.25	28.8	55.94	22.2	50.21	11.9
rvesting and transportation	67.84	16.8	59.78	23.7	82.77	19.7
ad rent	73.52	18.2	11.88	4.7	58.75	13.9
timated interest	26.40	6.5	16.50	6.5	27.58	6.5
her costs	35.29	8.8	39.27	15.6	58.75	13.9
tal costs per ha.	403.62	100.0	252.15	100.0	421.64	100.0
tal costs per ton	80.72	-	50.43	-	84.33	-

The estimation is based on a yield of 5,000 kg/ha.

The following exchange rates were used: U.S.$ 1 = 20.40 Colombian pesos
25.25 Ecuatorian sucres
42.55 Peruvian soles

TABLE 2. ESTIMATED COST OF PRODUCING RICE WITHOUT IRRIGATION AND UNDER LOW LEVELS OF TECHNOLOGY IN COLOMBIA, ECUADOR AND PERU 1/

Cost items	Colombia		Ecuador		Peru	
	U.S.$/ha.	% of total cost	U.S.$/ha.	% of total cost	U.S.$/ha.	% of total cost
Land preparation 2/	8.82	10.7	9.50	11.5	35.25	23.9
Labor cost during growing season 2/	8.82	10.7	26.13	31.7	23.50	16.0
Seed and other inputs	11.12	13.4	12.78	15.5	11.75	8.1
Harvesting and transportation 2/	22.94	27.7	18.03	21.8	60.16	40.8
Land rent	14.70	17.7	7.92	9.6	-	-
Estimated interest	5.42	6.5	5.40	6.5	9.64	6.5
Other costs	11.02	13.3	2.77	3.4	6.99	4.7
Total costs per ha.	82.84	100.0	82.53	100.0	147.29	100.0
Total costs per ton	51.78	-	51.58	-	92.06	-

1/ The estimates are based on a yield of 1,600 kg/ha. "Low levels of technology" refers to a system with little use of purchased inputs and less than optimal cultural practices, as opposed to the so-called "mechanized upland rice farming systems". For a more detailed explanation, see "Background Information No. 3" of the Seminar.

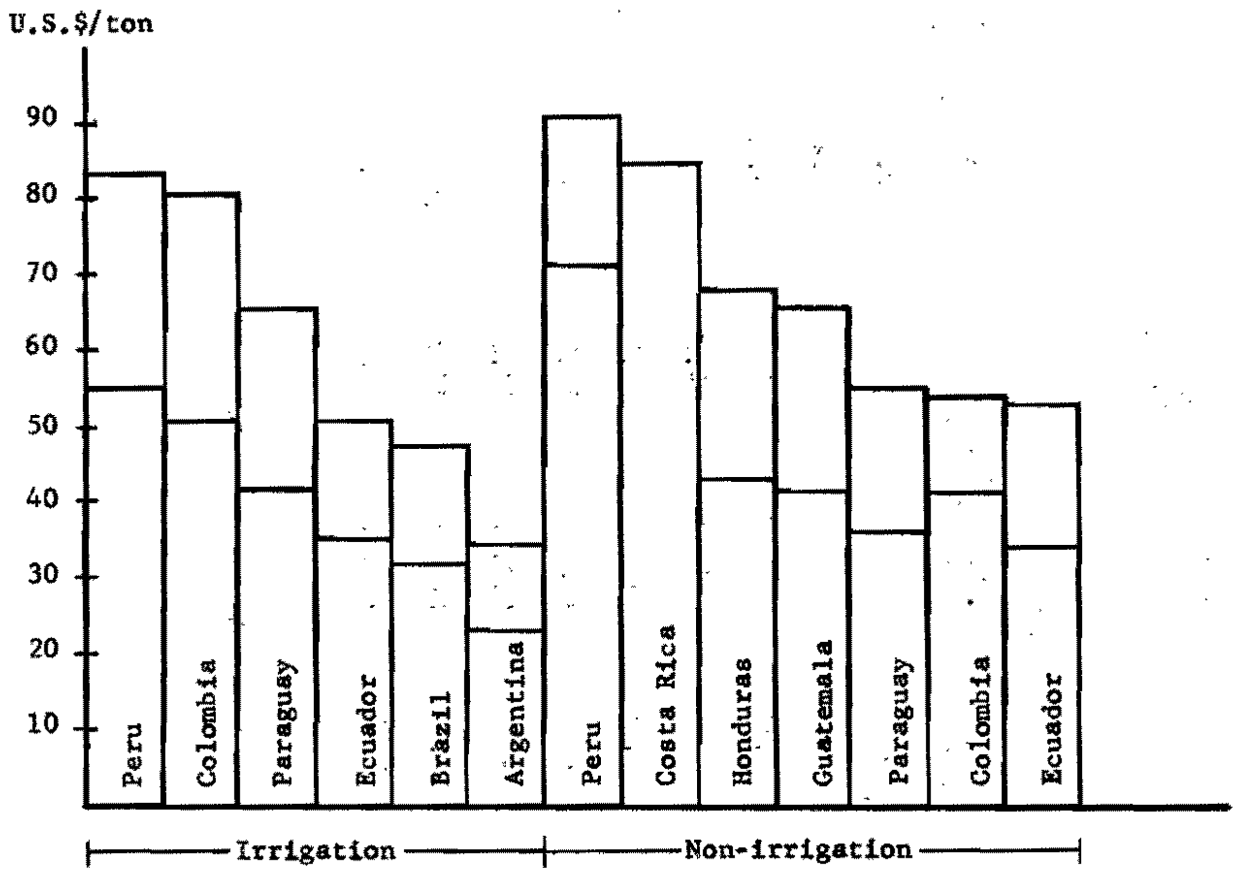
2/ Primarily labor costs.

TABLE 3. ESTIMATED COST OF PRODUCING PRESENT AND NEW VARIETIES IN CERTAIN LATIN AMERICAN COUNTRIES (U.S.$)

Country	Present variety				New variety			
	Irrigation		Non-irrigation		Irrigation		Non-irrigation	
	Costs/ha.	Costs/ton	Costs/ha.	Costs/ton	Costs/ha.	Costs/ton	Costs/ha.	Costs/ton
Argentina	170.71	34.14	-	-	190.13	22.37	-	-
Brazil	166.08	47.45	-	-	189.48	31.84	-	-
Colombia	403.30	80.66	86.65	54.16	433.63	51.02	112.32	41.29
Costa Rica 1/	-	-	295.34	84.38	-	-	295.34	84.38
Ecuador	178.00	50.86	74.57	53.27	208.96	35.12	81.42	34.21
Guatemala	-	-	198.55	66.18	-	-	211.59	41.49
Honduras	-	-	203.50	67.83	-	-	217.70	42.69
Paraguay	164.08	65.63	110.48	55.24	179.14	42.15	120.74	35.51
Peru	461.36	83.57	183.55	91.77	520.14	55.43	240.05	70.60

1/ In Costa Rica, "present variety" refers to the new variety IR8.

FIGURE 1. ESTIMATED COST OF PRODUCING PRESENT AND NEW RICE VARIETIES IN CERTAIN LATIN AMERICAN COUNTRIES (U.S./TON) 1/



1/ See "Background Information No. 3" for data sources.

TABLE 4. EXPECTED CHANGE IN YIELDS, COSTS OF PRODUCTION AND NET REVENUES ASSOCIATED WITH THE ADOPTION OF THE NEW RICE VARIETIES */

	Traditional varieties	New varieties	Difference Absolute	Difference Percent
Stage 1: assuming no price decrease				
Yields (kg/ha.)	4.000	6.800	+ 2,800	+ 70
Costs of production (US$/ha.)	400	440	+ 40	+ 10
Costs of production (US$/ton.)	100	65	- 35	- 35
Price of rice (US$/ton)	110	110	0	0
Gross return (US$/ha.)	440	748	+ 308	+ 70
Net return (US$/ha.)	40	308	+ 268	+ 670
Net return (US$/ton)	10	45	+ 35	+ 350
Cost of producing the added output (US$/ton)	-	14	- 86	- 86
Stage II: assuming a 10 per cent price decrease			Change from the original	
Price of rice (US$/ton)	99	99	- 11	- 10
Gross return (US$/ha.)	396	673	+ 233	+ 52
Net return (US$/ha.)	- 4	233	+ 193	+ 483
Net return (US$/ton)	- 1	34	+ 24	+ 240
Stage III: assuming a 35 per cent price decrease				
Price of rice (US$/ton)	71	71	- 39	- 35
Gross return (US$/ha.)	284	483	+ 43	+ 9
Net return (US$/ha.)	-116	43	+ 3	+ 8
Net return (US$/ton)	- 29	6	- 4	- 40

*/ A hypothetical example of a farmer currently producing 4.0 tons/ha. under irrigation and high levels of technology, assuming that the cost of production is U.S.$400/ha. and that the price of rice is U.S.$110/ton.

THE ROLE OF PRICE POLICIES IN RELATION TO DOMESTIC RICE PRODUCTION AND CONSUMPTION

0541
Gerald I. Trant
Agricultural Economist
Centro Internacional de Agricultura Tropical
Cali, Colombia

Efficient agricultural production is usually envisoned in terms of machinery, equipment, chemicals, plants and animals that go to make up a highly technical modern agriculture. It is perhaps less well recognized that most countries of the world that have achieved a technically efficient agriculture have done so in conjunction with relatively stable and remunerative agricultural prices. Is is no exaggeration to say that the technically efficient modern agriculture of the developed nations owes as much to favourable price relationships between agricultural products and agricultural inputs as it does to the new techniques, equipment, and varieties themselves. These favourable price relationships have in general come about as a result of very definite price policy decisions.

At present, or within the next year or two, most of the rice-producing countries of Central and South America are going to face significant rice price-policy problems as a consequence of the new higher yielding varieties which have been developed. Adequate supplies of seed will soon be available. Furthermore, in the Latin American environment these new rice varieties do not require major additional expenditures beyond those already being made to grow existing varieties such as Bluebonnet 50. In fact, experience to date indicates that per hectare costs are in many cases the same as, or only slightly higher than, those associated with conventional varieties of rice, implying a substantial reduction in costs per ton of rice produced, particularly when yields can increase by nearly 70 per cent.

This situation is in marked contrast to that of many other kinds of improved plants such as maize and wheat, which have typically required a considerable increase in cash expenditures as well as changed techniques of production before their yield potential can be realized.

When Latin American rice growers obtain this new seed in quantity, it is going to mean a dramatic increase in their yields and a consequent increase in the supplies of rice available throughout the whole area. There is no reason for believing that this increase in production will be evenly spread within or among countries. Some rice growers and some ministries of agriculture are going to be much more active in promoting the new varieties than others. It will be they, the first users, who will receive the first and perhaps the largest economic benefits from the new varieties. These benefits may be expected to be accompanied by problems which each country and individual will have to deal with in their own way. Since there is such a great diversity of conditions, not only among but also within Latin American countries, it is impossible to make an adequate estimate of all the problems that will be encountered. However, there are enough conditions common to all to permit a foreward look at some of the possible problems that may arise.

This may best be achieved by briefly outlining the economic consequences of the introduction of the new rice varieties in a hypothetical but typical Latin American country where the policy is that of no government intervention in price formation. It is assumed that the country is just on the border of self-sufficiency and that rice growing is confined to a few regions which are not necessarily near centers of population. Market, storage, and transportation facilities are no better than they should be, and tend to be somewhat overtaxed, particularly on a regional basis at harvesting time. Both upland and irrigated rice is grown, but upland is much more important in terms of total area than irrigated rice. There is a rice growers' association and its members are the larger growers. Most of the smaller growers, in fact the majority of growers, do not belong to the association. Virtually none of the smaller growers has irrigation facilities for rice.

The problem begins when the rice growers' association distributes the new varieties of seed. During the first growing season a good number of the larger growers start using the new seed. Their profits per hectare increase, for some growers, by 100 percent. Demand for the new seed increases among knowledgeable growers and in many cases the early innovators are able to sell their rice for seed at a considerable premium. People who have not grown rice recently make plans to grow it next season.

At the end of one or perhaps two growing seasons, production has increased by as much as 20 or 30 percent in some regions. The regional marketing systems are not able to handle the increased volume, and considerable losses are incurred by some growers who are neither able to dry, nor store, nor sell the rice that they have produced.

At the end of the next growing season, rice prices throughout the country have dropped by 30 percent, but an estimate made later shows that rice production has only increased by about 8 percent above the previous crop level. Growers who have not been able and/or willing to use the new seed, mostly small producers, find their profits from rice strongly reduced; in some cases they have suffered considerable losses. Growers who have managed to increase their yields by 50 percent or more with the new varieties, mostly large growers who belong to the rice growers' association, still find their profits to be better than before the new varieties were introduced.

In the next growing season, nearly all rice growers try to use the new rice seed, although there are now fewer growers than before.

Once again production increases and prices decline by a futher 10 percentage points or more. Many growers become discouraged and look for other crops to produce. Some efforts are made to seek foreign markets for the increased production, but the market system is not able to handle the problem; besides, world prices are, if anything, still lower than internall domestic prices for rice.

Meanwhile, domestic consumption of rice has increased somewhat, but less than had been expected because retail prices of rice have not decreased in the same proportion that the price to farmers has.

The final result of the introduction of the new rice varieties is that a new equilibrium price has been achieved that is below previous levels; at the same time a larger number of people have been forced out of rice growing as a result of losses in several production seasons. Consumers are able to buy rice cheaper than before, and, in some cases, limited amounts of rice are being used as livestock feed. Export markets have not been penetrated for lack of an adequate rice-exporting organization.

The foregoing type of price policy may be adequate and perhaps appropriate for some countries and some circumstances. It does have important disadvantages which may well include a rapid outmigration from agriculture, considerable economic damages to individual rice producers, and an unwillingness on the part of remaining producers to make needed productive investments.

There are many other alternative price policies that can be considered. In general terms they include not only some type of price stabilization or support system, but also an overhauling and modification of the existing marketing systems and communications, as mentioned by Byrnes in his paper.

Agricultural prices may be supported or stabilized at various levels; however, very few Latin American countries are in a position to carry out a full-scale price stabilization or support system for more than one or perhaps at most two major products at a time. In fact, many of the developed nations have had serious problems with their agricultural price support or stabilization programs' costs, despite the fact that agriculture is of relatively small importance in their overall economies.

There is no perfect price policy for any agricultural commodity and even the best represents a compromise of conflicting interests. Ideally, a price policy would achieve at least some of the following goals:

1) provide a steady and adequate supply of rice to consumers at "fair" prices
2) provide an "adequate" and stable level of income to rice growers that will permit them to produce rice efficiently
3) improve the distribution of real income
4) promote the export of rice, or reduce imports
5) avoid large, hard-to-manage surpluses of rice
6) be of moderate cost to society

It must be obvious that these goals are, to a considerable degree, arbitrary, and that their importance and ordering will have a great deal to do with the unique circumstances that face each individual country.

It is probably useful to distinguish betweeen two general types of price policies, namely between price support policies and price stabilization policies. In the case of a price support policy, the usual primary goal is to provide a certain minimum level of income for the "typical" rice grower. Usually the levels of prices that are associated with price support programs are above the levels that would equate quantity supplied and quantity demanded in a free market.

If the level of the prices is considerably above the free market equilibrium price, the result of such policies may be expected to be a considerable increase in production and a consequent build-up of a hard-to-manage surplus that cannot be sold in the domestic or world market at the support price. These surpluses, when they occur, have a considerable social cost in terms of the other commodities that were not produced instead of rice. In many instances the social costs for a price support program at incentive levels may be greater than for any other type of price policy. Management of growing surpluses of agricultural commodities presents serious administrative problems. On the supply side, there emerges the problem of reducing production by means of marketing quotas, hectarage controls, or some combination of both. Up to the present, no country has a good record of success in the area of production control in the face of incentive levels of agricultural price supports. It is also worth mentioning that for a price support program to be workable at all, high levels of tariffs or import restrictions must necessarily accompany it. Such restrictions have special significance for the countries that are members of the ALALC.

On the marketing side, equally serious problems are faced in terms of strong pressures on existing drying, storage, and transportation facilities. For those countries that have faced the second generation problems of the "green revolution", there is little doubt that crop production can increase much faster than physical or other marketing facilities when new seeds are combined with incentive level price supports.

One of the few advantages of a price support system for a commodity such as rice, aside from the income benefits to producers, is that it does permit the build-up of stocks that can be used as a basis for starting an export program. However, to the extent that the support price is above the world price, exports can only be made if some type of export subsidy is used. The same would be true for certain special utilization programs, such as use of subsidized rice in livestock feed.

Few, if any, Latin American countries would find it desirable to carry out a full-scale price-support program for rice. Consequently, it seems appropriate to consider the possibility of alternatives such as a price stabilization program.

The goal of a price stabilization program is not to fix prices on a once and for all basis, but rather to reduce the magnitude of price variations whether they are decreases or increases. What is sought is a range of prices such that at their upper limit consumers do not suffer unduly, and at their lower limit efficient producers are protected. Price stability in this sense is an essential component in the development of an efficient agricultural industry. In the absence of such stability, producers will be unwilling to make needed productive investments and consumers may suffer.

Basically there are two essential components to a price stabilization program. First, a floor or minimum price set and guaranteed by the government, and second, controlled imports or sales out of stocks when prices rise beyond the maximum.

The minimum price must be set at a non-incentive level but at the same time be high enough to encourage efficient producers to stay in production. Even if the appropriate minimum price level has been selected and funds are available, the stabilization program will not be effective if producers have to be turned away for the lack of physical drying, storage and transportation facilities. However, probably the most critically important aspect of the program will be the selection of the appropriate level for the minimum price. If the price is set too low, it will not provide the requisite stability for producers to make needed productive investments. If, on the other hand, it is set too high, it will be the same as a production incentive, and unwanted surpluses will result.

A minimum price for rice may be put in effect by using a number of mechanisms; however, two types are commonly used. One is to make direct purchases of the commodity at a previously agreed upon price; the other is to make loans on the commodity when it is stored in a suitable elevator or warehouse. In both cases, the government must be willing to purchase or loan on the amount of the product that is offered to it. Failure to do so will result in loss of faith in the program, with a resultant decrease in its effectiveness and a reduction in productive efficiency combined with considerable hardship for producers.

The other aspect of the price stabilization program is that of controlling too strong an upward increase in rice prices. These upward price fluctuations may still occur in the presence of new varieties as a result of seasonality of production. Again, several mechanisms are available. The government may, for instance, simply attempt to set a maximum price by decree; this will tend to be effective only for a very short time and will frequently be accompanied by the development of a "black market" in which rice is traded above the legal maximum price. A more effective way of controlling upward movements of rice prices is to permit the importation of a certain amount of rice when prices tend to rise to the maximum level. Provided, of course, that the world price is not above the desired level.

Another technique which may be used in stabilizing prices, but which requires considerable storage facilities and very careful management, is that of buffer stocks. The idea here is to purchase rice when prices are low and then sell it out of storage when prices rise beyond some predetermined level. Such a program has the advantage of being virtually self-financing, if the long term rice production is in balance with domestic and foreign demand for the product.

The functioning of the system depends upon seasonal production associated with an inverse movement in rice prices. The system is not adequate to handle long term imbalances in supply and demand. Experience elsewhere suggests that the buffer stock programs will result in building-up of stocks as production outstrips demand, unless the buying and selling prices are extremely carefully selected. Probably the most important role of a buffer stock system in Latin America is that of reducing wide variations of price among regions and seasons.

Any overall price policy can, of course, be further modified to achieve subsidiary aims. For example, a well thought out and organized price stabilization program should: a) provide a reasonable supply of rice with "fair" prices to consumers and producers; b) be of moderate cost; c) not result in large surpluses, and d) be consistent with increased production.

It does not, however, achieve much in the way of a better distribution of real income among consumers in the sense that, even with a stabilization scheme, low income consumers will most likely be unable to switch to rice from yuca or platano. Consequently, it may be desirable to modify a rice price stabilization program to reduce the cost of rice to low income consumers. One device that can be used, if an increase in rice consumption by low income consumers is regarded as a desirable goal, is to charge a milling tax for rice and to use the proceeds to subsidize the sale of rice to these consumers. Another device, which has much to commend it, would be to sell high quality rice on the world market, and with the proceeds buy lower priced broken grain rice which is of equal nutritive value.

Before leaving the theme of price policies and passing on to alternative uses for rice, it is perhaps worth giving a brief outline of an alternative price policy which appears to offer many of the advantages of both a price support program and a stabilization scheme, while at the same time being consistent with improved income distribution and/or increased exports.

It was mentioned above, and was previously demonstrated by Andersen in his presentation, that increased rice production may be obtained at a very slight increase in cost to the producer when he uses the new rice varieties in lieu of the older standard varieties. This important relationship may be used in the development of an alternative rice price policy which is outlined below.

The essentials of the program involve paying a relatively high price to producers for basic production, and a lower one for increased production—the lower cost production to be used to aid low income consumers, or for export.

In general terms the plan is as follows: (1) Determine the present production and/or seeded area of all existing rice producers in the country. As Byrnes has mentioned in his presentation, this may be fairly difficult to do. (2) On the basis of these data, assign to all rice producers who are interested in participating in the scheme a marketing quota which may be between 70 and 100 percent of their present year's production. (3) Set a price for this amount somewhat below present levels, but also above the world market price for rice. Each producer would receive, for rice produced under his quota, the above mentioned price. (4) For rice produced in excess of this quota, the producer would receive the world market price for that grade of rice, less the transportation costs to the nearest ocean port. In some instances a price even lower than the world price may be desirable.

All purchases would be made by a government marketing agency or its representatives on the basis of regionally and individually assigned quotas. As population, and hence domestic demand, increases, it would be possible to adjust individual producer's quotas upward. An amount of rice corresponding to the quota plus annual additions to domestic demand would be released for normal domestic consumption which would result in retail prices somewhat below previously existing levels. Additional supplies of rice could be introduced to the market for low income consumers at a retail price corresponding to world market prices. Even lower prices would be possible if, for additional production, producers received less than the world price.

Although it may be argued that low income consumers will sell at least part of their low price rice to retailers or others, they may still benefit from the resultant increase in their real incomes, which is of course the objective of this aspect of the program. Alternatively, if it were thought to be desirable from a nutritional point of view to increase the consumption of rice by low income consumers, it would be possible to dye it prior to retail sale, which would tend to reduce its resale value while leaving its nutritional quality the same as before.

The amount which would be introduced in this way would depend at least in part upon the magnitude of increased supplies resulting from the use of the new varieties. If stocks appeared to be building up to more than satisfactory levels, rice could be used for export or as livestock feed, or as a wheat substitute.

The advantages of the policy are:

1) Producers would receive a higher price than would result in the absence of the program, but with the rapid introduction of the new varieties.
2) Consumers in general would benefit from the new rice varieties in terms of lower prices, although not as low as prices under a free market.
3) Program costs to the national government would tend to be low, relative to other types of price policies.
4) Specific account is taken of the needs of low income consumers.
5) Exports could be stimulated.

The disadvantages of the policy are:

1) A large amount of detailed information is required about existing rice producers.
2) The administration of the program would be relatively detailed and complex.

Since the demand for rice as a human food has kept its price considerably above the price levels of feed grains and even wheat on world markets, it has seldom received much attention as a substitute for either feed grains or wheat. However, available research suggests that if rice is of a sufficiently low price, it may be used as a substitute for at least part of the wheat used for bread flour, or alternatively as an ingredient in poultry or hog rations.

In the case of substitution for wheat in bread flour, it would appear that rice flour can be substituted up to a maximum of 20 percent for wheat flour, provided that the rice is of a variety that is relatively sticky. When non-sticky varieties are used, only smaller amounts can be substituted for wheat in the production of bread flour. Available evidence suggests that significant savings in foreign exchange could be made by substituting rice for some of the wheat that is now imported. The magnitude of these savings would depend on present levels of wheat imports, market acceptance of the modified bread flour, and the relative magnitude of increases in rice production.

There is no technical reason for not including rice in the diets of hogs; in fact, it can be substituted for up to 100 percent of the grain component with only minor increases in protein being required. Rice may also be substituted for grain in poultry rations; however, the levels of this substitution are considerably less than those for hogs.

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RICE TRADE POLICIES :

THEIR PROBABLE CHANGES AND EFFECTS

Reed Hertford

Program Advisor, The Ford Foundation

INTRODUCTION

I embarked on my topic with a casual familiarity with recent developments in rice production and minimal acquaintance with policies affecting international trade of the commodity. After preliminary review of literature available to me, I concluded that a person with these credentials of innocence could be justifiably accused of unnecessary heroism were he to continue to write on the topic without first investing more time than I had allocated to acquiring background data and other information on a first-hand basis.

Rather than shirk the challenge of this certain conclusion, I decided on an uncertain compromise: namely, to attempt to provide a framework for ordering current questions about changes in rice trade policies and their possible effects on such key variables as world prices, internal producer prices, utilization, supply, and exports and imports. Such an effort recommended itself to me on two counts. First, world rice production and trade are passing through a period of rapid change which has sponsored a myriad of urgent questions. Given the time constraint urgency implies, policy research over the near-term must focus on questions of highest priority. Which ones are they? Second, recent work in the U. S. Department of Agriculture and elsewhere, particularly on producer supply response, has provided data which can be most usefully bent to the task of ordering questions and outlining

priorities for future research. While there may be the usual reservations about the confidence attached to point estimates of these early thrusts, good as I personally judge them to be, there would be few qualms about using such estimates as ordinal indicators of which issues are more or less important for future in-depth research. Thus, on these two grounds, I saw an uncommon coincidence between needs, on the one hand, and resources, or data availability, on the other, which recommended the tack this paper takes.

THE MODEL

My first step was to develop a framework which could assess the importance of individual questions in terms of their effects on world price, internal prices, supply utilization, and rice trade. For this purpose I worked out an ostensibly simple, but fairly general, model of three relations for each exporting and importing country, including an internal utilization (or demand) function, an internal supply function, and a trade relation. Demand is viewed in this model as being determined by an internal rice price, a relevant world price, and independent variables like prices of competing and complementary products, per capita real incomes, population, policies operating on internal consumption, etc. Supply is a function of internal rice prices and factors shifting supply independently of those prices, including such things as input prices and "technology". The trade relation is taken to depend on the difference between the relevant external and internal price of rice and variables

embodying trade policies.

This "country model" was then solved for that level of total utilization, or total supply, and internal price which would equate supplies to consumption, given world prices, prices of competing and complementary products, income, population, input prices, technology, trade policies, etc. At a subsequent stage a world price (or linear combination of relevant world prices) was found which would equate rice exports of all countries to world imports, thereby assuring an equilibrium between, as well as within, countries. Details of the model and its solutions are shown in the Appendix of this paper.

Tables 1 through 3 summarize main results. The first table demostrates the model's implications for the effects of changes in independent variables on exports, imports, internal demand and supply, internal prices, and world prices. The last column of the table, for example, shows that a change in trade policies of an exporting nation which leads to (say) increased exports would, in the final analysis, raise exports, reduce consumption, increase internal supplies, and raise the internal price of rice. Similarly, a change in trade policies of an importing nation, implying increased imports, would ultimately raise imports and internal demand, but reduce supplies and internal prices of rice. The two signs in the last line of the same column simply indicate that a shift in trade policies towards increased imports will increase the world price and a shift towards increased exports will reduce the world price of rice.

Table 1 -- Changes in Basic Dependent Variables of the Model Associated with Shifts in Principal Independent Variables[a]

Dependent Variables	Independent Variables			
	Change in World Price	Shift in Internal Demand	Shift in Internal Supply	Shift in Trade Poli
<u>Exporting Nations</u>				
Exports	+	-	+	+
Demand	-	+	+	-
Supply	+	+	+	+
Internal Price	+	+	-	+
<u>Importing Nations</u>				
Imports	-	+	-	+
Demand	-	+	+	+
Supply	+	+	+	-
Internal Price	+	+	-	-
<u>World Price</u>		+	-	+ -

a/ Signs shown follow directly from derivations presented in the Appendix.

Table 2 -- Rice Exporting Countries (Regions): Selected da
computation of World Price-Trade Policy Elast:

Country e/ (Region)	Country a/ Exports Divided by: Country Production	World Exports	Price Elasticities: Demand World Price b/	Demand Internal Price b/	Supply Internal Price b/	F
	------Ratio-------		----------------Elasticity-			
S. E. Asia	0.13	0.42	-0.50	-0.50	0.30	
United States	0.60	0.27	-0.20	-0.20	0.20	
Communist Asia	0.01	0.16	-0.10	-0.10	0.20	
East So. America	0.08	0.07	-0.30	-0.30	0.40	
North Africa	0.26	0.06	-0.50	-0.50	0.30	
Australia, N. Zealand	0.52	0.01	-0.30	-0.30	0.30	
Argentina	0.21	0.01	-0.30	-0.30	0.40	

a/ These ratios represent averages for the 1964-66 period. Basic d
unpublished discussion paper by Rojko, A. S., Urban, F. S., and Naiv
Prospects for Grain in 1980 with emphasis on trade of less developed
Research Service, U. S. Department of Agriculture, (March, 1971),

b/ Ibid., Tables 11 and 12. The demand-world price and demand-in
were assumed equal. This implies an indifference, on the part of co
"national" and "international" rice.

c/ Derived from elasticities of the three previous columns. See Ap
used in this derivation.

d/ This computation is detailed in the Appendix. It corresponds to t
in world prices which would result from a 10 percent price-independ
individual country.

e/ The regional groupings of countries is defined in Hutchison, John
and Tsu, Sheldon K., "World Demand Prospects for Wheat in 1980 w
by Less Developed Countries," FAER 62, Economic Research Servic

Table 3 -- Rice Importing Countries (Regions): Selected data rel computation of World Price-Trade Policy Elasticity

ountry (Region) e/	Country a/ Imports Divided by: Country Consumption	World Imports	Price Elasticities: Demand World Price b/	Demand Internal Price b/	Supply Internal Price b/	Imp Wor Pri
	--------Ratio------		-------------Elasticity-----			
. Asia, Pacific	0.09	0.30	-0.30	-0.30	0.30	-(
outh Asia	0.02	0.19	-0.30	-0.30	0.30	-2
apan	0.06	0.12	-0.30	-0.30	0.40	-1
entral Am.	0.35	0.06	-0.50	-0.50	0.40	-
est Africa	0.25	0.07	-0.40	-0.40	0.10	-
est Asia	0.28	0.06	-0.30	-0.30	0.30	-
ast Europe	0.75	0.05	-0.30	-0.30	0.30	-
SSR	0.42	0.04	-0.30	-0.30	0.30	-
. C.	0.30	0.03	-0.30	-0.30	0.30	-
ast Africa	0.15	0.03	-0.30	-0.30	0.20	-
anada	1.00	0.01	-0.30	-0.30	-	-
. K.	1.00	0.02	-0.40	-0.40	-	-
o. Africa	0.97	0.01	-0.30	-0.30	0.10	-
est So. Am.	0.08	0.01	-0.30	-0.30	0.30	-
ther W. Europe	0.06	-	-0.30	-0.30	0.30	-

See footnotes Table 2.

Table 2 and 3 attempt to quantify the effects of a change in trade policies on the world price. (Note that only the direction of these effects was indicated in the last line and column of Table 1). These tables are central to the purpose of this paper. Knowing which countries, or regions, can have largest impacts on world prices of rice through changes in export and import policies, we can begin to sort out the more important from the less important issues. Further, having some feel for the size of world price changes resulting from trade policy changes, we will be in a position to assess the strength of trade, demand, supply and internal price reactions on the part of individual countries of particular concern.

The first six columns of Tables 2 and 3 give basic data used in quantifying what I have called the "world price-trade policy elasticity" (column 7 of these tables), or the percentage change in world rice prices associated with a shift in trade policies of individual countries which change the level of trade by one percent independently of world and internal rice prices. Columns 1 and 2 were calculated directly from information made available to me by the U. S. Department of Agriculture which related to average rice exports, imports, production, and consumption by country (region) over the three year period, 1964-66. Estimated price elasticities, shown in columns 3 through 5, come from the same source and represent a synthesis, for the most part, of estimates made by a wide range of individual researchers who have studied rice demand and supply price responses of the countries and regions shown in the two tables. I derived the elasticity of

country exports (imports) of column 6 from the demand-world price, demand-internal price, and supply-internal price elasticities, being unable to find direct estimates of this parameter for major exporting and importing countries. This derivation, detailed in the Appendix, essentially assumed that the trade-price elasticity of a country was a weighted sum of its internal price elasticities of supply and demand. This assumption had the effect of reinforcing a direct relationship which exists between country shares of total trade and the world price-trade policy elasticities. However, it did not probably alter the ordering of world price effects of exporting and importing nations reflected in the world price-trade policy elasticities, since they are insensitive to values used for elasticities of exports or imports with respect to world prices. For example, if the latter elasticities ranged from zero to infinite values, the world price-trade policy elasticities would range from zero to only 0.63 (in absolute terms).

Results indicate that only six countries, or regions, could have significant impacts on world prices of rice were they to shift their current trade policies. Among rice exportors, Southeast Asia, the U. S., and Communist Asia could depress (raise) world prices by from one to almost three percent were they to raise (depress) their exports by 10 percent through changes in trade policies. Among traditional rice importors, East Asia and the Pacific, South Asia, and Japan[1/] could raise (depress) world prices

1/ By selecting 1964-66 as the "base period" for this analysis, certain countries--notably Japan--are put in a net trade position which diverges from their present ones. However, if we are concerned primarily with "normal" rice trade patterns, the 1964-66 period is generally judged to be the most suitable base. Using procedures shown in the Appendix, the interested reader could, of course, change the "base period" of analysis

between about one and two percent by raising (depressing) their imports 10 percent via trade policy changes. Other exporting and importing countries individually would have an almost imperceptible effect on world prices were they to alter trade policies. Stated in another way, Canada, the U. S., South Africa, West South America, or "other" Western Europe would have to increase its imports by about 190 percent to have the same effect on world prices as a 10 percent upward shift in imports of East Asia and the Pacific. Similarly, Australia, New Zealand, or Argentina would have to increase its exports by 260 percent through changes in trade policies to have the same depressing effect on world prices as a 10 percent upward shift in exports of Southeast Asia.

There are two important implications of these results. First, since annual changes in world prices of the order of at least 10 and up to 20 percent have been observed in recent years (1966-70)[2/], the generally "small" world price-trade policy elasticities imply that changes on the part of individual countries in trade policies have probably been a less important factor in world price changes than have been shifts in country demand and supply conditions. Second, because world price-trade policy elasticities appear to be individually small, we need be less concerned with policies pursued independently than with policies shared by groups of countries, or regions. A pervasive change in rice export policies of (say) Southeast Asia, the U. S., and Communist Asia could have a striking effect on world prices.

2/ See, for example, "Rice Report, 1970", FAO, United Nations, Rome, 1970, page 12.

Even the joining of Latin American nations in a common rice policy change could have a substantial impact on world rice prices.

The balance of this paper briefly discusses these possibilities for a common rice trade policy, summarizes current trade policies of six countries with highest world price-trade policy elasticities, and indicates implications of changes in their policies for world prices of rice.

TRADE POLICIES

The two major rice projections studies made in recent years both assumed no significant change in rice trade policies of major exporting and importing nations during the decade of the Seventies. The FAO study appears to go even further with the statement:

> National rice policies, affecting production, are assumed to remain as they were in late 1970 and/or early 1971. The actual content of national policies, e.g., the level of price supports, acreage allotments, aids to production etc., are assumed to remain unchanged until 1980 from their late 1970 and/or early 1971 levels. Policy objectives... are assumed to remain unchanged. 1/

The USDA projections contain the following statements:

> For all other major developed importors, it is assumed that recent food and fiber policies will be continued [to 1980]... Japan would be a major exception, since her self-sufficiency ... seems destined to decline. It is further assumed that the major exportors will maintain a stock and production policy to support relative [world] price stability. 2/

1/ Committee on Commodity Problems, Study Group on Rice, "Projections of Demand and Production of Rice, 1970 to 1980, Preliminary Results", FAO, United Nations, Rome, (March, 1971).

2/ Rojko, A. S., Urban, F. S., and Naive, J. J., op. cit., pages 141 and 146.

Much of what follows in this section confirms the appropriateness of these assumptions. While major policy changes have been effected on the production side which could bring substantial pressure to bear on world rice prices --particularly in importing countries, information available to me indicates that changes in trade policies will not be radical and their effects on world prices will be correspondingly slight.

Before turning to that evidence, I do wish to remark on the likelihood of the emergence of a common rice trade policy among exporting and importing nations. As I mentioned in the previous section, such a policy could alter the implication of estimated world price-trade policy elasticities that independent trade policy changes might not have large effects on the world price.

I have gleaned from the literature that the likelihood of agreement on such a policy is extremely small. First, the International Grains Arrangement (IGA) has apparently had rough going. This arrangement became effective in 1968 and prescribed a price range for international trade of wheat and coarse grains. It also specified contributions by participating countries of 4.5 million tons of wheat and coarse grains, or the cash equivalent, as aid to less developed countries. "Rough going" is reflected in the fact that, under current world supply and demand conditions, wheat prices are already well below the established minimum. Second, FAO formed a Working Party which, during 1970, examined alternative proposals for cooperative action in rice trade, including intra-regional trade arrangements, reductions in trade barriers, stock policies, non-food use policies for rice, establishment

of international buffer stocks, multilateral contracts, informal trade arrangements, export subsidies and restitutions. The Working Party was unable to agree on any one single proposal. Finally, there is the evidence later in this section, supported in part by FAO's and USDA's projection studies, that radical changes in world prices are unlikely to result from foreseeable changes in trade policies of rice exportors and importors. This has the very simply implication that gains from a common trade policy in the case of rice may be so small as to fail to induce a common agreement like the IGA in the case of wheat and coarse grains.

In what follows, I discuss trade policies of the United States, Communist China, Thailand, Japan, Indonesia, and the Republic of Korea. Communist China is the principal exportor of the region, "Communist Asia", referred to in earlier sections of this paper; Thailand is the principal "Southeast Asia" exportor and Indonesia and South Korea belong respectively to the "South Asia" and "East Asia and Pacific" regions. In 1970, these six countries accounted for about two thirds of world exports and roughly 15 percent of world imports.

United States(Exportor)

1. Policy Objectives. Rice export policies of the U. S. Government are directed at facilitating export of supplies in excess of domestic requirements, maintaining traditional U. S. export markets, and increasing exports on commercial terms.

2. Policy Instruments.

a. Credit is provided to commercial traders for up to six months through the Commodity Credit Corporation (CCC) to encourage rice exports to markets unable to purchase on a cash basis.

b. Barter agreements can be made to permit exports to countries when the possibility of sales through regular commercial channels is limited. Very few barter agreements involving rice were made during the 1960's.

c. Concessional exports can be made through P. L. 480, the Agricultural Trade Development and Assistance Act of 1954, as amended. Half of all U. S. exports during the 1960's moved under P. L. 480 provisions; most sales were made in exchange for foreign currencies. As a result of an amendment to the Act in 1968, there is a movement towards sales for dollars or dollar credits. The transition to dollar-based sales is expected to be completed by the end of 1971.

d. Export subsidies are paid U. S. exportors when world market prices fall below U. S. farm price supports plus marketing costs. All U. S. rice exports, made either on concessional or commercial terms, are subsidized when export payments are in force. Initiated on rice in 1959, export subsidies remained in force until 1967/68 and were then re-introduced in March, 1969. The maximum subsidy paid on average during any year of this period was US$64 per metric ton in 1960/61, representing about 40 percent of the prevailing world price for medium-quality, medium-grain or

long-grain rice, reasonably well milled. Subsidy payments currently average about US$25 per ton, representing 25 percent of the 1971/72 season announced price support, about 10 percent of U. S. wholesale rice prices, and almost 20 percent of a world price of US$140 per metric ton.

3. Policy Changes - Effects. As a foreign producer of rice, I would be most concerned with changes in U. S. export subsidy payments. Applying to almost all U. S. exports, they have general, world market impacts; concessional U. S. exports are more selective in their effects, being made primarily where they do not compete with normal commercial transactions.

I think it would be reasonable to assume that export subsidies could range to a high of 40 percent of world prices and to as low as zero percent over the near-term future. I would not expect subsidies to rise above their previous high of 40 percent in relation to world prices for the simple reason that U. S. assistance to rice producers is the most costly income support program the Government has in agriculture. Total assistance per rice producer, including net realized loss on price support and production programs and the cost to the CCC of the commodities exported under P. L. 480, CCC Export Credit, and Barter Programs, ranged from 3 to 11 times that provided the crop with the next highest average over the period 1960-70. In the 1969 crop year, these costs per participating farm equalled $16, 055.[1/]

1/ Task Force on Rice, "Rice Report", Economic Research Service, U. S. Department of Agriculture, (June, 1971), Table 3, unpublished manuscript.

If we assume that the subsidy on U. S. rice exports could range between zero and 40 percent and that such a change could occur between any two years, then the maximum change in U. S. exports resulting from policy change would be of the order of 10 percent.[2/] Referring back to Table 2, it can be seen that the maximum world price change, corresponding to this 10 percent change in U. S. exports, would be of the order of two percent.

Thailand (Southeast Asia, Exportor)

1. Policy Objectives. The Thailand Government seeks to maintain a minimum of 1. 5 million tons of milled rice for export annually.

2. Policy Instruments. To ensure enough rice for local consumption, the Government introduced an export quota system in 1967, later abolished in June, 1968.

Rice exportors are required to pay a premium to the Government for their rice exports. This premium, or tax, is designed to keep domestic supply of rice in line with domestic demand. With recent declines in the world price of rice, the rate of the export premium has been considerably lowered. In 1971 it was reduced to zero on all rice containing more than five percent broken grain.

3. Policy Changes - Effects. It would seem safe to assume that, with reductions in world rice prices forecast, no changes over the near-term

2/ I have assumed in this estimate that the percentage change in exports associated with a one percent change in the factor, 1. 0 + subsidy/world price, is the same as the percentage change in exports to be expected from a one percent change in world prices.

will take place in Thailand's current export trade policy. Exports will continue to be conditioned by interaction of normal forces, including internal and world prices, and no specific policy instrument will be brought to bear on trade.

Mainland China (Communist Asia, Exportor)

In 1970 China exported 885,000 tons of milled rice, maintaining its position as the third largest exportor after the U.S. and Thailand. During the 1960's, exports averaged about 800,000 tons. Most exports go currently to Ceylon (310,000 tons), Cuba (130,000 tons), Pakistan (99,000 tons) and Hong Kong (93,000 tons).

It is estimated that China harvested a record rice crop of 100 million tons in 1970, compared with 95 million in 1969. Larger areas have been planted to rice in recent years as a result of wasteland reclamation and introduction of early maturing varieties which permitted expansion of the doubled-cropped area.

As of mid-1971, the amount of rice available for export looked to be larger than in 1970. Two rice export contracts have already been made with Ceylon and Pakistan equal to 250,000 tons.

As a centrally planned economy, China's rice exports could go in most any direction. However, there is a relation between Chinese rice exports, world rice prices, and world wheat prices which permits some tenuou predictions to be made. At previous world price ratios for wheat and rice, China's policy was to export rice, import cheaper wheat, and thereby obtain a net gain in calories of food energy. However, over the 1970's, USDA

predicts a decline in world rice prices from all causes of about 30 percent; practically no change is foreseen in wheat prices.[1/] This would have the effect of reducing the ratio of world rice: wheat prices to levels of the 1960-64 period, at which time Mainland China exported on average 700,000 tons of rice, or about 20 percent less than in 1970.

Hence, I would suggest that Chinese exports could drop by as much as 20 percent over some unspecified period of time during the 1970's. This would translate into a maximum decline of 5 percent in world prices, using data of Table 2.

Japan (Current Exportor, Traditional Importor)

Traditionally, Japan has been an importor of rice. With acreage and yield fairly stagnate throughout the 1950's and until the mid-1960's, imports rose to a high of almost one million tons of milled rice in 1965.

However, after 1965, following an incentive program which led Government price supports to producers to high levels, rice yields began an upward trend from 3,800 kilos per hectare (husked) to 4,400 kilos. Simultaneously, rice prices paid by consumers rose, reflecting a cost-plus distribution program of the Government with a fixed subsidy slightly under farm price support acquisition costs. Utilization for food, feed, and industrial uses thus did not rise--in fact, total consumption may have declined slightly from 1960-64 average levels of about 12 million tons. Per capita consumption of rice did decline from 118 kilos in 1960-64 to about 95 kilos

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1/ Rojko, A.S., et. al., op. cit., page 251.

in 1970. Thus, after 1965, "surplus rice stocks" began to accumulate at an average annual rate of slightly under one million tons. By mid-1971, Government-held stocks had reached a level which approximated total world exports for 1970.

In late 1968, the Japanese changed rice policies in production with the objective of reducing area planted to rice from the 1968 level of 3. 2 million hectares to about 2. 2 million hectares by 1977. This policy has been implemented via subsidy payments to rice growers to divert ricelands to other crops or fallow. Also, direct acquisitions and subsequent diversion of ricelands have been made by the Japanese Government. At yields slightly below current levels, this diversion program would reduce production by 4 million tons. Two million of this would return production to pre-1965 levels; the other 2 million would probably just cover reduction in consumption, barring radical changes in rice prices paid by consumers. Thus, supply and disposition would be brought more or less into equilibrium. Current "surplus stocks" would have to be sold in the world market.

Japan is now holding stocks worth something over US$420 per ton, including support price plus marketing and storage costs. Concessional sales are currently being made by Japan at about US$140 per ton. Why should the Japanese Government sell stocks valued at US$420 for US$140 in international markets, when Japanese consumers paid between $280 and $420 per ton for rice in 1970 ? 1/

I would argue that, if land diversion plans were not effective,

1/ The consumer price data come from the Committee on Commodity Problem Study Group on Rice, FAO, United Nations, Rome, (March, 1971).

"surplus stocks" would be disposed of abroad. However, if land diversion plans do evidence prospects of success--and this should be known by, say, 1972, net trade will fall to zero, relative internal price will float downwards as rice stocks are marketed nationally, and Japan will come to a self-sufficient, no trade position well before 1977. Over the longer-term, I would expect Japan to become an occasional or regular importor, simply because it is a high-price rice producer. In fact, I would see no reason why it should not attempt to return to something like its 1964-66 position in world rice trade.

The implication of this argument is that Japan could exert some, but short-term, downward pressures on world rice prices. This assumes that Japan will react to the higher costs of disposing of its rice stocks in world markets and that rice diversion programs will be successful.

I might also mention the fact that Japan's current concessional exports are to be "made with consideration so as to avoid harmful interference with the usual rice exportation from developing countries". Further, there is the fact that Japanese short-grain, semi-sticky rice appeals to a very limited set of the world's consumers and thus does not compete directly with the long-grain Indica type rice which dominates trade. Each of these latter considerations would dampen "expected" world price effects of even short-run exports from Japanese rice stocks.

Indonesia (South Asia, Importor)

Rice imports are now (1970) at the level of about 750,000 tons.

The policy objective in production is to increase supplies 50 percent (or by about 5 million tons) between 1968 and 1974 by means of the introduction of high-yielding varieties, increased use of fertilizers, pest and disease control, improved water management, and better cultivation techniques. Under this Rice Development Plan, a package of inputs is supplied a farmer for the rough equivalent of US$50 to 60 per hectare. After harvest,payment is made in rice which is valued at a fixed price equivalent of US$130 per metric ton.

While I judge this program could have depressing effects on world prices, if successful, I find no specific references to Indonesian trade policies or instruments of policy with relevance to this paper.

Republic of Korea (East Asia and Pacific, Importor)

Korean imports have risen sharply in recent years, owing to unfavorable weather, insect and disease damage. Imports were about 500, 000 metric tons in 1970.

From a long-run point of view, the Second Five-Year Economic Development Plan (1967-71) is attempting to move Korea towards self-sufficiency with a 35 percent increase in production over the 1967 figure of 3. 6 million tons of milled rice being expected in 1971 or 1972. Simultaneously, the Government has been moving ahead with a rice saving program designed to reduce demand for rice gradually and improve national health standards through correction of nutritional handicaps resulting from an unbalanced diet of rice only.

As in the case of Indonesia, I see these production and demand programs having strong downward effects on world rice prices, if they succeed. However, I did not identify any policy with respect to trade which would dampen or otherwise alter the effects onworld prices of the success of supply and demand policies.

FOR FURTHER STUDY

This paper has led to a general conclusion that world prices of rice will not be greatly affected by trade policies of exporting and importing nations during the 1970' s. A corollary would be that more attention should be given to predictions of supply and demand policy shifts than to changes in trade policies.

There is, of course, uncertainty related to these conclusions, stemming from assumptions used and unanswerable questions which arose in the course of the analysis. I list some of these below in the hope that they might form a useful agenda for future research on rice in world trade.

1. What is the form of rice import and export functions and the response of trade to price for countries with highest world price-trade policy elasticities ?

2. What is the systematic relationship between U. S. farm price supports and export subsidies on rice ? It would be most useful to have this relationship at hand to predict likely changes in U. S. exports and world prices resulting from changes in the export subsidy policy.

3. Given the export potential and the central plans which characterize China, could some greater certainty be attached to the effects of the rice: wheat price ratio on rice exports ? What other variables might be used to embody Chinese trade policies in rice ?

4. Attention should be given to developments in riceland diversions in Japan and changes in consumer prices paid for rice.

5. What would be the likely gains enjoyed from a rice trade arrangement similar to the IGA ?

SELECTED BIBLIOGRAPHY

Barker, R., "Economic Aspects of High-Yielding Varieties of Rice with Special Reference to National Price Policies," Monthly Bulletin of Agricultural Economics and Statistics, (June, 1969).

Committee on Commodity Problems, Study Group on Rice, FAO, United Nations. Selected Papers.

Food and Agricultural Organization, United Nations. "National Grain Policies," selected issues.

____________________. "Rice Report, 1970," Rome, (1970).

____________________. "Report of the fifteenth session of the Study Group on Rice," Rome, (May, 1971).

____________________. "National Rice Policies, 1970," Rome, (1970).

____________________. "Developments in Agricultural Price Stabilizati and Support Policies, 1965-70," Rome, (August, 1971).

Hsiech, S. C., and Ruttan, V. W. "Environmental, Technological, and Institutional Factors in Growth of Production: Philippines, Thailand, and Taiwan," Food Research Institute Studies, VII, No. 3, (1967).

Hutchison, John E., Naive, J. J., and Tsu, Sheldon K. "World Demand Prospects for Wheat in 1980 with Emphasis on Trade by Less Developed Countries," FAER 60, Economics Research Service, U. S. Department of Agriculture, (1970).

Mangahas, Nahar, Rector, Aida E., and Ruttan, V.W. "Market Relationships for Rice and Corn in the Philippines," Journal of Farm Economics, Vol. 48, (August, 1966).

Mellor, John W., and Dar Ashok, K. "Determinants and Development Implications of Foodgrains Prices in India, 1959-64," American Journal of Agricultural Economics, Vol. 50, No. 4, (November, 1968).

Roger, W. Fox. "Estimating the Effects of the EC Common Grain Policy," Journal of Farm Economics, Vol. 49, No. 2, (May, 1967).

Rojko, A.S., Urban, F.S., Naive, J.J. "World Demand Prospects for Grain in 1980 with Emphasis on Trade of Less Developed Countrie Economic Research Service, U.S. Department of Agriculture, (March, 1971), unpublished manuscript.

Task Force on Rice, ERS, U.S. Department of Agriculture. "Rice Report," Washington, (June, 1971), unpublished manuscript.

APPENDIX

I divide the rice-producing world into one of exportors and importors of rice and develop simple "internal" models for a rice exportor and rice importor on the assumption that there exists a world price, or a series of highly correlated "world prices", which the individual country cannot influence. I then "internalize" the world price, i.e., make it subject to trade of exportors and importors, by imposing the condition that total world exports and imports must be equal.

Exportor

I begin by dividing total supply, Q_1, of an exporting country among its principal components: internal demand, D, and exports, E. I take internal demand to be equal to a function of the world rice price, p_t^*, the country's internal rice price, or the price received by producers, p_t^e, and a vector of variables, e_1, which shift internal demand independently of prices. Country supply, Q_1, is a function of the internal price, p_t^e, and variables, e_2, which shift supply independently of the producer price received. Finally, exports, E, are written as a function of the difference between world and country prices, $p_t^* - p_t^e$, and a vector of variables, e_3, which shift exports independently of these prices. I further assume, for simplicitly, that these three functions are linear such that they can be specified, together with the trade identity, as follows:

1. $D = A_1 p_t^* + A_2 p_t + e_1$

2. $Q_1 = A_3 p_t^e + e_2$

3. $E = A_4 p_e^* - A_4 p_t^e + e_3$

4. $Q_1 \equiv D + E$

Solutions of this system can be represented, in terms of its independent variables, by:

5. $Q_1 = \pi_{11} p_t^* + \pi_{10}$

6. $p_t^e = \pi_{21} p_t^* + \pi_{20}$

Further, assuming that, in general, $A_1 < 0$, $A_2 < 0$, $A_3 > 0$, and $A_4 > 0$,

7. $$\pi_{11} = \frac{-A_3 (A_1 + A_4)}{A_2 - A_3 - A_4} > 0,$$

8. $$\pi_{21} = \frac{-(A_1 + A_4)}{A_2 - A_3 - A_4} > 0,$$

provided $/A_4/ > /A_1/$. Also,

9. $$\pi_{10} = \frac{(A_2 - A_3)e_2 - A_3 e_1' - A_3 e_3}{A_2 - A_3 - A_4}$$

10. $$\pi_{20} = \frac{e_2 - e_1 - e_3}{A_2 - A_3 - A_4}$$

Thus, for example, we see (from 7) that an increase in the world price will increase country production, an increase in world prices will increase the prices paid producers (from 8), and an improvement in technology will increase country supply (from 9) and reduce country price (from 10), independently of the world price existing.

Importor

Here I divide total utilization Q_2, of an importing country among its principal components: internal production, S, and imports, I. I take total utilization to be a function of p_t^*, p_t^i, and a vector of variables, I_1, that shift demand independently of these prices. Country output, S, is a function of internal price, p_t^i, and variables, I_2, which shift the supply relation. Finally, "I" is written as a function of the difference in prices, $p_t^* - p_t^i$, and shift variables, I_3.

A model for the importing country can then be written as:

11. $Q_2 = B_1 p_t^* + B_2 p_t^i + I_1$

12. $S = B_3 p_t^i + I_2$

13. $I = B_4 p_t^* - B_4 p_t^i + I_3$

14. $Q_2 = S + I$

Solutions of this system can be represented, in terms of its independent variables, by:

15. $Q_2 = \pi_{31} p_t^* + \pi_{30}$

16. $p_t^i = \pi_{41} p_t^* + \pi_{40}$

Further, assuming that, in general, $B_1 < 0$, $B_2 < 0$, $B_3 > 0$, and $B_4 < 0$.

17. $$\pi_{31} = \frac{B_1B_4 + B_2B_4 - B_1B_3}{B_4 + B_2 - B_3} < 0$$

18. $$\pi_{41} = \frac{B_4 - B_1}{B_4 + B_2 - B_3} > 0$$

provided $/B_4/ > /B_1/$. Also,

19. $$\pi_{30} = \frac{(B_4 - B_3)I_1 + B_2 (I_2 + I_3)}{B_4 + B_2 - B_3}$$

20. $$\pi_{40} = \frac{I_2 + I_3 - I_1}{B_4 - B_2 - B_3}$$

Thus, for example, an increase in the world price will decrease total utilization (from 17) and improvement in technology will increase total utilization and decrease the internal producer price.

The World Price

I now internalize the world price of rice, making it a function of the behavior of individual countries, by setting equal the sum of all country exports to imports. The result is a world price which equilibrates

exports and imports and is itself a function of parameters and price independent variables of every exporting and importing nation.

First,

21. $\sum_{e} E = \sum_{i} I,$

implies that

22. $p_t^* \sum_{e} A_4 - \sum_{e} A_4 p_t^e + \sum_{e} e_3 = p_t^* \sum_{i} B_4 - \sum_{i} B_4 p_t^i + \sum_{i} I_3 ,$

where the subscripts, "e" and "i", denote respectively that the sum is being taken over exporting and importing nations. Rearranging terms and substituting from 6 and 16, we have that

$$23. \quad p_t^* = \frac{\sum_{e} A_4 \pi_{20} - \sum_{i} B_4 \pi_{40} + \sum_{i} I_3 - \sum_{e} e_3}{\sum_{e} A_4 (a - \pi_{21}) - \sum_{i} B_4 (1 - \pi_{41})}$$

Rewriting Equation 23 explicitly:

$$24. \quad p_t^* = \frac{\sum_{e} \left(\frac{A_4}{A_2 - A_3 - A_4}\right)(e_2 - e_1 - e_3) - \sum e_3 - \sum_{i} \frac{B_4}{B_2 + B_4 + B_3} (I_2 + I_e + I_1) + \sum_{i} I_3}{\sum \left(\frac{A_4}{A_2 - A_3 - A_4}\right)(A_1 + A_2 + A_3) - \sum_{i} \frac{B_4}{B_2 + B_4 + B_3} (B_1 + B_2 + B_3)}$$

Let me denote the reciprocal of the denominator of 24 as λ , positive-valued by hypotheses previously stated. Further, let us denote

$$\frac{A_4}{A_2 - A_3 - A_4} = a_1 < 0,$$

$$\frac{B_4}{B_1 - B_2 - B_3} = b_1 > 0,$$

such that 24 can be rewritten as:

$$25. \quad p_t^* = \lambda\left\{\left[\sum a_1(e_2 - e_1 - e_3) - \left[\sum b_1(I_2 + I_3 + I_1) + \sum I_3 - \sum e_3\right]\right\}$$

The effect on the world price of a change in independent variables of a given country is then:

$$26. \quad \frac{\partial p_t^*}{\partial e_1} = -\lambda a_1 > 0 \qquad 29. \quad \frac{\partial p_t^*}{\partial I_1} = \lambda b_1 > 0$$

$$27. \quad \frac{\partial p_t^*}{\partial e_2} = \lambda a_1 < 0 \qquad 30. \quad \frac{\partial p_t^*}{\partial I_2} = -\lambda b_1 < 0$$

$$28. \quad \frac{\partial p_t^*}{\partial e_3} = -\lambda(a_1 + 1) < 0 \qquad 31. \quad \frac{p_t^*}{I_3} = \lambda(1 - b_1) > 0$$

If, as in the text, A_1, A_2, A_3, A_4, B_1, B_2, B_3, and B_4 are all expressed as elasticities, then prior to aggregation in 25, A_1 and A_2 must be multiplied by $(1-s_i)$, A_4 by s_i, B_3 by $(1-s_e)$ and B_4 by s_e, where s_i and s_e are a country's import/consumption and export/production ratios respectively. Further, each summation sign in 25 must be followed by S_i and S_e, or the ratios respectively of each country's imports and exports to total rice trade.

With these transformations of parameters, the derivatives in 26-31 are in terms of the log values of the variables and the parameters on the right of the equality signs in 26-31 can be interpreted as elasticities. Relations 28 and 31 are equivalent to the "world price-trade policy" elasticities discussed in the text.

Finally, I note that the elasticities, A_4 and B_4, were derived in this paper on the assumption that:

$$A_3 = A_2 (1-s_e) + A_4 s_e,$$

$$B_2 = B_3 (1-s_i) + B_4 s_i$$