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Paper presented at the Deutscher Tropentag, Oct 08 – 10, 2003, in Goettingen

Assessing nutritional impact of agricultural research - The case of Mungbean in South Asia

Abstract

Evaluation of agricultural research often neglects consumption and nutrition aspects. This paper briefly reviews the conceptual linkages between the two sectors agriculture and nutrition. It presents a methodology for assessing the nutritional impact of mungbean, and it summarizes current impact evidence on the pathway from mungbean research to consumption. Impact on nutrition, measured as productivity effects, is shown to be substantial. The paper concludes by highlighting future research needs.

Keywords: Impact assessment, evaluation, agricultural research, nutrition

Introduction

The world has seen declining rates of hunger over the past decades. The average per capita calorie consumption in developing countries has risen from 2054 calories per capita and head in 1966 to 2803 calories per capita and head in 1999, leading to a decline in the number of hungry from approximately 900 hungry to approximately 700 million hungry people in 2000 (FAO, 2003). Undoubtedly, much of this can be attributed to the successes of the 'Green Revolution'. Yet, despite these accomplishments, the number of those suffering from micronutrient malnutrition remains high, with an estimated 2 billion people at risk of iron deficiencies, 1.5 billion people at risk of iodine deficiencies, and 0.95 million people at risk of vitamin A deficiencies (WHO, 2000). Micronutrient malnutrition – the hidden hunger – with its many health related effects has a number of adverse consequences on the development of poor countries. It reduces labor productivity, lowers the school attainment in children, reduces school enrolment and attendance rates, and leads to increase mortality and morbidity rates, thus increasing overall health care costs (Underwood, 2000). The consequence is huge human and economic losses for economies, due both to current and future productivity losses. Quantifications of productivity losses due to iron deficiency range from 5 to 17% among agricultural laborers in India (Weinberger, 2003) to 17% losses in heavy labor and 5% losses in blue-collar work (Horton, 1999). Cognitive losses in children due to iron deficiency anemia have been estimated at 4US$/ capita (Ross and Horton, 1998). For economies as a whole, overall losses have been estimated between 0.9% (ACC/ SCN, 2000) and 1.25% of gross domestic product (GDP) (Horton, 1999). Combating micronutrient deficiencies is therefore not only a goal in itself; it is also an important means to decrease poverty in developing countries.

The role of agriculture for enhancing nutrition: a review of the linkages

The question is whether agriculture and agricultural research should strive to address micronutrient deficiencies through food-based approaches. Certainly, there are many non-food related causes of malnutrition, and agriculture cannot be expected to address them all.

Usually, micronutrient deficiencies are attacked through supplementation and fortification programs. There is however concern that results in reducing the prevalence of micronutrient deficiencies will not be sustainable and impact not broad enough if this approach is not underpinned by food-based approaches (Underwood, 2000). Food-based approaches are associated with certain advantages as opposed to medical approaches. They are considered to be more sustainable and the ideal long-term goal for society, since responsible consumers acquire and prepare a nutritionally diverse diet (Howson *et al.*, 1998). Yet often donors prefer medical approaches (Ruel and Levin, 2000, Levin et al., 2003), since the impact of a, say, supplementation program is easier to quantify than the impact of food-based approaches, which are more complex and require a wide variety of inputs and outcomes to be measured.

Different forms of impact of agriculture on nutrition can be distinguished. On one side, impact can either be generic or specific. Generic effects are not sector-specific, meaning that any sector that employs a large percentage of a malnourished population in a labor-intensive fashion will generate income and employment and would have such impacts. In contrast, specific effects are generated because food – and not some other commodity – is being produced (Haddad, 2000). In addition to separating these two forms of impact, it is also worth making a second distinction. Malnutrition, and especially micronutrient malnutrition, relates not only to the amount of food that is being consumed, but also to the diversity of the diet. Agriculture can contribute to both, by improving both quantity and quality of food intake. The different forms of impact are summarized in Table 1. Specific effects include declines in food prices, own consumption, processing and preparation, and plant breeding. Generic effects include the effect of enhanced income on purchasing increased quantities of food, and, by purchasing more varied food items, enhancing the diversity of nutrient intake. Plant breeding is a younger approach and a very direct form of contributing to the nutritional goal of agriculture. It includes increasing the micronutrient concentration in the crop, decreasing the concentrations of absorption inhibitors, and increasing the concentration of promoter compounds (Ruel and Bouis, 1998).

Table 1. Impact of agricultural research on food and nutrient consumption

Effect	Specific	Generic
Quantity	• Enhanced food availability • Declines in food prices • Enhanced own-consumption	• Enhanced income
Quality	• Enhanced nutrient content • Enhanced post-harvest handling (processing and preparation)	• Diversity of nutrient intake

These various forms of impacts of agriculture, both on quantity and quality of diets, have been found to be especially strong when women earn and control income, when there is a regular stream of income, and when income is, at least partly, in-kind (Bonnard, 2001). Especially the consumption – nutrient intake link is conditioned by a variety of other factors, such as health and care (von Braun and Kennedy, 1986, Smith and Haddad, 1999). The effects of agriculture on nutrition can pay off in terms of productivity impacts and growth: in form of an immediate impact on the workforce, which will be stronger and healthier[1], and a longer term impact through enhancing cognition in better-nourished school children.

The potential for mungbean

The rice-wheat system is the most important source of food supply in South Asia and has greatly contributed to the reduction in malnutrition and hunger in this region. Yet, a negative side effect of this system has been the declining production of pulses (Grover et al., 2003). As a result, the real market price of this traditional protein source has increased three-fold as compared to cereals and pulses are no longer available to poor household

Mungbean (*Vigna radiata*) is a pulse crop with origin from Myanmar with major production areas found in Asia. As a low input, short duration crop, it fits very well into the intensive rice-wheat cropping systems of the Indo Gangetic Plains. This has a window of three to four months for growing a crop after wheat and before the main rice crop planted in July. Mungbean is also a highly nutritious crop. It is regarded as a quality pulse due to its rich protein content and excellent digestibility. Although mungbean primarily serves as a protein source, its high consumption rate and the improvement of its iron content and bioavailability also make it an important contributor to iron consumption in the South Asian diet (Yang and Tsou, 1998).

Table 2. Mungbean area (1000 ha) and its growth rate in Asia

	1980	1985	1990	1995	2000*	Annual average growth rate (%)
South Asia						
Bangladesh	15.0	59.5	57.9	55.0	55.0	8.0
India	2845.9	3000.0	3351.1	2706.3	2887.1	-0.1
Pakistan	69.0	93.6	143.8	179.7	202.7	5.8
Sri Lanka	14.2	21.5	38.1	33.2	na	7.6
South East Asia						
Myanmar	42.1	48.2	116.6	460.5	650.6	22.0
Indonesia	252.4	286.4	345.3	361.1	323.9	1.5
Thailand	395.0	529.1	427.8	332.8	288.8	-1.8
Philippines	50.4	37.4	36.7	34.9	38.5	-1.3
East Asia						
China	na	546.7[a]	728.0	782.2	772.1	1.7
Total	3684.1	4622.4	5245.3	4945.6	5166.7	

** or latest year available, [a] 1986, na not available*

Source: data for Bangladesh (2000) provided by the Bangladesh Agricultural Research Institute, for India (2000) in Grover, Weinberger and Shanmugasundaram (2003), for Pakistan (2000) provided by Economic Advisor's wing, Finance Division, for Sri Lanka (1993) provided by the Department of Agriculture, for Myanmar (2000) provided by Myanmar Agricultural Statistical Office, for Indonesia (2000) provided by Indonesian Ministry of Agriculture, for the Philippines (1999) provided by the Bureau of Agricultural Statistics, for Thailand (1998) provided by the Office of Agricultural Economics for China (2000) in Zhang et al. (2002).

Mungbean research at AVRDC has focused both on the production and consumption side. This has resulted in the availability of short duration varieties with uniform maturity and high yields and higher iron content, and in the identification of utilization

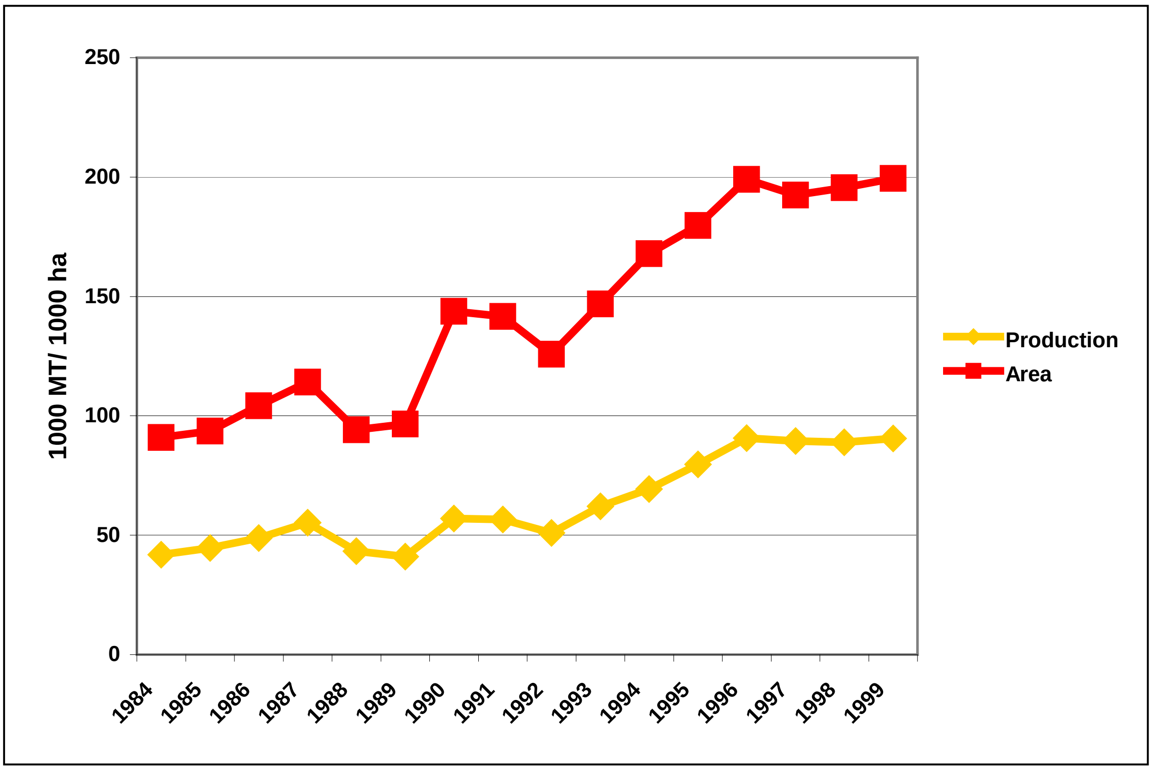
[1] To be noted in this respect is also the enhanced capacity of individuals to overcome diseases such as HIV/ AIDS when micronutrient intake is sufficient (Friis, 1998, Beisel 2002).

practices that increase iron bioavailability. In some Asian countries the availability of new varieties has led to remarkable adoption rates, such as in Bangladesh, Pakistan and Sri Lanka (see Table 2).

In Pakistan, area under mungbean has increased from approximately 100.000 ha to more than 200.000 ha between 1985 and 2000. In the same time, production increased sharply, rising from 50.000 metric tons to over 100.000 metric tons in 2000 (see Figure 1).

Earlier research at AVRDC had analyzed the impact of mungbean research for consumer and producer surplus in Pakistan and estimated a net present value (NPV) of approximately 19.7 million US$ (Ali et al., 1997). Since mungbean is important in diets of South Asians, it is worth asking what additional productivity impact research on this crop may have had. Mungbean provides an excellent source of iron in the vegetarian based diets on the South Asian subcontinent. The role of mungbean for enhancing iron intake has been well researched (AVRDC, 1997, 1999, Yang and Tsou, 1998). Mungbean supplementation has been shown to increase blood hemoglobin values in a one year feeding trial conducted among school children aged 10 – 12 in southern India. Children receiving supplementation with mungbean dishes high in bioavailable iron (IR1 and IR2) showed higher increases in hemoglobin (on average + 8g/l) as compared to the group receiving a supplementation with 'traditional' low bioavailability (TR, on average + 3g/l) and the control group (CG) (Vijayalakshmi *et al.* 2003).

Figure 1. Mungbean production in Pakistan.



Source: NARC 2000.

Assessment of nutritional impact of mungbean research

Methodology

In the following we quantify the impact enhanced iron consumption through mungbean has had on overall productivity in Pakistan. This quantification is based on a consumption survey among female piece-rate workers in Pakistan, estimating the effect of enhanced iron intake on overall productivity, and extrapolating based on secondary production and consumption data of mungbean between 1985 and 1995. This year was chosen as the final year or the assessment in order to make the value comparable to the study cited by Ali *et al*.

Women were interviewed concerning their consumption patterns (based on a 7 day food recall), their health status (blood hemoglobin value, Body-Mass Index as well as the incidence of diseases) and their wage levels. The survey was repeated three times in order to smooth out seasonal variation in consumption and wages, and approximately 200 women participated in the survey from June 2001 through February 2002. Because observations on nutritional, anthropometric and other variables were missing for some women in the three survey rounds, models are estimated using the complete data on 187 women, resulting in 561 observations.

Pulses were found to be an important contributor to overall dietary iron intake, being the source of approximately 25% of all iron. The major two other sources were cereals (50%) and vegetables (20%). Four different varieties of pulses were found to be consumed, namely chickpea, lentils, mungbean and urdbean. Chickpea was most frequently consumed (approx. 3 kg per capita and annum), followed by mungbean and lentils (both at 1.2 kg per capita and annum), and urdbean (0.4 kg per capita and annum). This may be explained by the price of the different pulses, chickpea being the least expensive at 37 Rs/kg, followed by 45 Rs/ kg for mungbean and lentils, and 58 Rs/kg for urdbean. Roughly one third of all households had consumed mungbean the week preceding the survey. Total pulses consumption was 5.8 kg per capita and annum. (Weinberger et al., 2002)

It is a relatively old idea that at low income levels there is a relationship between nutrition and labor productivity. This hypothesis is known as the Efficiency Wage Hypothesis. Leibenstein (1957) and later Mirlees (1975) and Stiglitz (1976) argued that an increase in caloric intake enables workers to perform more demanding tasks, expressed in a greater marginal productivity as measured by wages. Since iron is known to affect the productivity of individuals, because it transports oxygen from the lung to the cells, an increase in iron intake may also lead to an increase in productivity as measured by wages. If this is recognized by the market, i.e. local labor markets operate relatively free and higher productivity is rewarded with higher wages, then better nutrition should result in higher market earnings, since workers would either be paid more for a given time unit of work, or they would be able to work in particularly taxing and rewarding activities, or both (Strauss, 1993). However, in estimating this relationship, a methodological pitfall occurs: the causality can run in both directions. Better-nourished workers should be more productive and hence earn higher wages, and higher income will probably be spent for more nutrients and make household members more healthy, so that they can earn higher wages. If this simultaneity is not accounted for, estimates will be biased and inconsistent.

In order to account for simultaneity involved in household decisions regarding food purchases and wages received, the endogeneity of both variables is controlled for. Ignoring simultaneity results in inconsistent overestimates of the coefficients and biased standard errors. To eliminate the potential problem of reverse causality, wages and iron intake are simultaneously predicted, employing a two-stage least-squares (2SLS) estimation procedure. The 2SLS procedure is defined as first regressing each of the endogenous variables on all of the exogenous variables in the system, in order to calculate the estimated values of the endogenous variables. In the second stage, the estimated values are used as regressors in an OLS regression. The semi-log wage equation takes the following form (equation 1).

$$\ln W_{it} = \alpha_i + \gamma_t + \beta \hat{fe}_{it} + \chi \hat{BMI}_{it} + \delta \hat{HB}_{it} + \varepsilon X_{it} + \varepsilon_{it} \quad (1)$$

Since the sample was collected over three rounds, a fixed effect model was estimated, where *t* indexes time and *i* indexes the group. In this model, α_i is the industry effect and γ_t is the time effect. Three variables are considered to be endogenous to the system: nutrient intake *N*, and Body-Mass-Index *BMI* as well as the blood iron level *HB*, which outcome depends on past investments. *X* is a vector of control variables (age, age squared, school years, and sick days reported) and ε is the error term. The instrumental variables that were used to estimate nutrient intake, BMI and blood hemoglobin level included a dummy each for current pregnancy and breastfeeding, the number of all children ever born, household size, per capita income and per capita replacement value of assets, and a price index each for cereals, pulses, vegetables, and animal products.

The net present value (NPV) of enhanced productivity (ΔW) due to the enhanced iron content of a modern variety (MV) of any crop as opposed to iron consumption based on traditional varieties (TV) can then be estimated based on equation (2). The change in overall iron availability is given by the vector of iron consumption (*fe*) based on the quantity (*q*) of modern and traditional varieties consumed in a given year and difference to iron consumption of that particular crop in base year, and total iron consumption in base year, and multiplied by the iron intake elasticity on wages η_{fe} and wages *W*.

$$NPV(\Delta W) = \sum_{n=1}^{t=n} \frac{\left((fe^{MV} \times q_t^{MV}) + (fe^{TV} \times q_t^{TV}) - (fe^{TV} \times q_0^{TV}) \big/ fe_0^{TOT} \right) \times \eta_{fe} \times W_t}{(1+i)^t} \quad (2)$$

Relationship between iron intake and workers productivity

Iron intake was measured as intake of bioavailable iron[2] (see table 3 for a summary of results). A Lagrange Multiplier test indicated that a fixed effect model was favorable to the classical regression model. The model is highly significant and the R-square is 0.36. The results of a Hausman test indicate that the hypothesis, that women's iron intake and blood hemoglobin values are endogenously determined through women's wage level, cannot be dismissed. This does not hold true for the Body-Mass Index. Additionally, piece-rate wages of women is determined by their education and age, as well as through their health status (proxied by the days reported sick in the month preceding the survey). Current intake of bioavailable iron have a positive impact on current productivity, significant at the 0.10% level. The Body-Mass Index, a proxy for household health investments made earlier, does not

[2] In the following equations, FeTOT indicates the total iron intake, and FeBIO indicates the bioavailable iron. Heme iron is assumed to constitute 40% of FeMFP. the enhancing factor (EF) for a meal is EF = (M + F + P) + AA where M, F and P are the edible quantities of MFP (in g), respectively, and AA is the intake of ascorbic acid (in mg). If EF is > 75, then EF is assumed to be 75. To take account of the inhibitory effects of phytates (PHY), a "correction term" (CT) (0 < CT < 1) is estimated that gives the proportion of FeBIO. For PHY < 2.88 mg, CT is defined as 1 (i.e., it is assumed that there are no inhibitory effects of phytate intake for such small values). For other values of PHY, CT is defined by CT = $10^{[-0.2869 \log_{10}(PHY) + 0.1295]}$, where log10 is logarithm to the base 10. Assuming that body iron stores are 0, 250 and 500 mg, the FeBIO can be calculated, respectively, from the following three equations, $\log_n$ being the natural logarithm (Bhargava *et al*., 2001).

show a significant impact on the productivity level of women. However, it does have a negative sign, indicating that obesity (shown to affect nearly one third of the sample) has a negative impact on productivity as measured in piece-rate wages.

Table 3. 2SLS with fixed effects: determinants of wage level

	Coefficient (t-value)	Marginal effect	Elasticity	Mean values
Hb level[a] (g/dl)	0.207*** (3.119)	6.76	2.347	11.34
BMI[b] (kg/m^2)	-0.002 (-0.402)	-0.07	-0.045	22.54
Iron intake[a] (mg)	0.281* (1.781)	9.17	0.056	0.20
School years	0.024*** (3.307)	0.80	0.035	1.43
Age	0.016 (1.578)	0.53	0.519	32.16
Age squared (*10^{-3})	-0.299** (-2.169)	-9.79	-0.350	1.17
Days reported sick	-0.018*** (-3.224)	-0.57	-0.033	1.87
Constant	0.885 (1.144)			32.68
R2	0.364			
F value	23.090***			

Dependent variable is log of daily wages, a) endogenous variables, variables include food prices, household income and assets, household size, number of all children born, and dummies for current pregnancy and breastfeeding b) not treated as endogenous, because of results of Hausman Test
*, **, *** significance levels at <0.10%, <0.05%, <0.01% respectively.
Source: Based on survey conducted by PERI in cooperation with AVRDC (2001/02), N = 561

The elasticity of bioavailable iron on productivity measured in wages is 0.056, the marginal effect is 9.17 Rupees per additional mg of bioavailable iron consumed. The elasticity of blood hemoglobin level on productivity is higher at 2.347. Levin (1986) reports a similar output elasticity in respect to rises in hemoglobin levels of between 1 and 2 (i.e. a 10 percent rise in blood hemoglobin levels would be associated with a rise in work output of 10 to 20 percent). In contrast to these high elasticities, at the sample mean one extra year of school education for women would only result in 0.7 and 0.8 Rupees higher daily wages. This is not to say that education for women is not important. But the results also show that without substantial improvements in the health status, particularly as far as iron deficiency anemia is concerned, rises in income and overall wealth of nations will be difficult to achieve.

Quantifying the nutritional impact of mungbean research

The success of the joint mungbean breeding efforts between National Agricultural Research Institutes in Pakistan and AVRDC has been documented elsewhere (Ali et al., 1997). Over the years, mungbean production in Pakistan has increased sharply, with an average annual growth rate of 5.8% between 1984 and 2000. This has resulted in an increase of annual per capita availability of domestic mungbean from 453g to 739g (total consumption has increased from 1.08 kg in 1984/85 (Ali *et al.*, 1997) to 1.42 kg per capita and annum in 1998 (NARC, 2002)). Apart from improved productivity characteristics, the modern mungbean varieties also have another, hidden, advantage. These varieties record 6.0mg of iron per 100g dry matter, as compared to 3.5mg of iron for traditional varieties (Vijayalakshmi *et al.*, 2003).

Based on equation 2 we can now calculate the benefits of modern mungbean varieties from enhanced nutrition. In order to make the estimation of the NPV comparable to an earlier study on producer and consumer benefit by Ali *et al*., the years 1985 (first release of new mungbean varieties) to 1995 are chosen for this analysis. The area under modern varieties has grown to 88% in 1995 (we assume linear annual increases of 8.8% per year). Total iron available from mungbean has increased from 16.64 g/annum in 1985 to 36.97 g/annum in 1995, as compared to 14.95 mg in the base year. Compared to total iron intake, the increase in total bioavailable iron has been 0.07% in 1985 and 1.1% in 1995[3]. Based on the elasticity estimate of 0.056, per capita productivity increases due to enhanced consumption of bioavailable iron grew from 0.2 PKR per capita and annum in 1985 to 9.8 PKR per capita and annum in 1995.

The total female workforce increased from 7.8 million in 1985 to 11.7 million in 1995 (World Bank 2003). Given that effects of increased iron intake on productivity can only be observed among anemic individuals, we only consider the share of the workforce that is anemic. Estimations are in the range of 50 to 60% (Mason et al., 2000, Micronutrient Initiative, 2002). We use wage data provided by ILO for the textile industry (an important sector for women's work) and multiply with the annual additional income per woman. The sum of net present value of this additional income is in the range of 3.1 to 4.2 million US$, depending on the number of anemic women in the workforce (see the annex for details).

This quantification does not include reductions in forfeited productivity due to deficient iron intake during childhood and youth, which could potentially be very large, nor productivity losses due to anemia among the male workforce. These benefits of mungbean research are in addition to the total consumer and producer benefit attributable to mungbean research that has been estimated at 19.7 Mio. US$ (Ali *et al.,* 1997). This analysis shows that the additional benefit of mungbean consumption in terms of enhanced human productivity are substantial and can well be compared to direct research impacts.

Conclusion

This study has shown that nutritional impact of agricultural research, measured in productivity increases of population groups deficient in micronutrients, is substantial. In the case studied here, they amounted to between 3.1 and 4.2 million US$, approximately one fifth of total consumer and producer surplus estimated for the crop. The approach presented here can be adapted for other crops to do assessments at macro level. For the assessment of the impact of agricultural research on the nutrition status at micro level, the quality and reliability of data remains a question of major concern. The collection of anthropometrical data, the most reliable indicator for success, is expensive, as are food intake recall variables. Some progress has been made in linking dietary diversity to overall food intake (Engle et al. 1999). Another approach is taken by AVRDC where currently research is undertaken that links attitude towards and knowledge about vegetables to their actual intake.

Agriculture certainly plays an important role in the reduction of malnutrition. Agricultural research has greatly contributed to the reduction of hunger and starvation by providing millions of hungry people access to low cost staple foods. Now, as the challenge becomes reducing the micronutrient deficiencies, more efforts need to be directed towards crops high in micronutrients, such as pulses and vegetables.

[3] Based on a total iron intake of 6.7mg daily for women in the base year and the assumption that on average 5% of the iron intake in the diet are bioavailable.

Highlighting and measuring linkages between agriculture and nutrition will certainly become even more important in the future.

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Annex: Quantification of nutritional impact of mungbean research

	PC availability	Area under MV	Iron MV	Iron TV	Total iron	Total bioavailable iron	Change in iron availability	Productivity increase	Wage rate	Female workforce	Additional income	Additional income	NPV	NPV
	g	%	mg	mg	mg	mg	%	PKR	PKR	1000	1000 PKR (50% Anemia)	1000 PKR (60% Anemia)	1000 US$ (50% Anemia)	1000 US$ (60% Anemia)
1985	470	8.8	2.5	14.2	16.6	0.8	0.070	0.2	437.9	7864.4	814.0	976.8	41.5	49.8
1986	501	17.6	5.3	13.6	18.9	0.9	0.165	0.5	477.1	8126.3	2147.6	2834.9	86.1	113.7
1987	553	26.4	8.8	13.4	22.2	1.1	0.301	1.0	515.7	8394.1	4374.3	5774.0	147.7	195.0
1988	422	35.2	8.9	9.0	17.9	0.9	0.124	0.4	496.5	8673.0	1791.7	2365.0	56.7	74.9
1989	390	44.0	10.3	7.2	17.5	0.9	0.107	0.4	593.3	8950.5	1904.9	2514.4	53.8	71.0
1990	528	52.8	16.7	8.2	24.9	1.2	0.415	2.7	954.6	9235.8	12280.6	16210.3	308.5	407.2
1991	511	61.6	18.9	6.5	25.4	1.3	0.432	2.8	954.6	9692.6	13427.5	17724.3	315.5	416.4
1992	448	70.4	18.9	4.4	23.3	1.2	0.347	2.2	954.6	10165.2	11305.3	14923.0	249.5	329.3
1993	533	79.2	25.3	3.7	29.0	1.5	0.583	3.5	891.6	10654.0	18599.6	24551.5	399.1	526.8
1994	580	88.0	30.6	2.3	32.9	1.6	0.746	4.3	866.4	11165.9	24251.8	32012.4	487.7	643.7
1995	651	88.0	34.4	2.6	37.0	1.8	0.913	9.8	1590.0	11692.7	57026.1	75274.5	1053.5	1390.6
Total													**3199.5**	**4218.3**

MV = modern varieties TV = traditional varieties total bioavailable iron = 120 mg η_P = 0.056

Data sources: Per capita availability of mungbean: NARC, 2002; Wage rate ILO LABORSTA (2003), women's wage assumed to be 60% of that of men; Workforce: World Bank development indicators (2003); Exchange rate PKR/ US$: ILO statistics