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GM Crops and Gender Issues

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To the Editor:

The correspondence in your December issue by Gressel[1] not only states that gender issues in rural settings have not been adequately addressed, but also asserts that weed control biotech can increase the quality of life of rural women in developing countries. Improved weed control is a labour saving technology which can result in less employment in a labour surplus rural economy. Often in rural areas, wage income is the main source of income and an important determinant of quality of life, particularly where employment opportunities are generally limited[2]. Apart from soil preparation, planting and weeding, harvesting is also 'femanual' work that can generate more employment if yields are higher. Biotechnology can enhance the quality of life of women if the technology is associated with overall generation of rural employment.

On the basis of these issues, we feel that Gressel presents only part of the story and that quality of life for women in developing countries depends not only on the 'femanual' work, but also on the incomes they earn. Hence, addressing gender issues in biotechnology requires rigorous analysis and a comprehensive evaluation beyond that carried out by Gressel. Here, we summarize two of the authors own recent research on the gender effects of insect-resistant Bt cotton in India[3,4], which proves that this technology generates more employment for females, who happen to earn much more than males.

Since its commercialization in India in the year 2002, the area under Bt cotton increased to 7.6 million hectares in 2008[5]. Several studies show sizable direct benefits of the technology and also indirect benefits from spillovers to other rural markets and sectors[6,7,8], but none analysed the gender aspect of this technology. In order to analyze the gender implications of Bt cotton adoption, we carried out two household surveys[3,4]. The first survey was undertaken in one village where we collected comprehensive data on household characteristics and interactions across various markets. The study village, Kanzara, is located in Akola district of Maharashtra, the state with the largest area under cotton in India. Kanzara can be considered a typical setting for smallholder cotton production in the semi-arid tropics[9]. Interviews with all village households and institutions were conducted in 2004, capturing all household economic activities and transactions for the 12-months period between April 2003 and March 2004. Of the total 305 village households, 102 are landless; the other 203 own land suitable for agricultural production. The average farm size of land-owning households in the village is 4.7 acres. All farm households cultivate at least some cotton, mostly next to a number of food and fodder crops for subsistence consumption and for sale.

This information was updated using the second survey; panel data from a farm sample survey conducted over a period of five years[10]. We used this more representative survey data to further improve the robustness of the results[3,4]. Based on these two data sources, we developed a social accounting matrix (SAM) for Kanzara, which represents the flows of all economic transactions that take place within the village economy (**Supplementary Methods** online). In 2003-04, the gross domestic product of the village was about US

$0.53 million. Village SAMs have been developed and used previously in different contexts[11-13]. Yet, our SAM is distinct in two respects. First, unlike previous SAMs, which are all based on sample surveys, our SAM builds on a village census. Since a SAM by construction requires both receipts and payments of all transactions, availability of census data reduces the problem of unbalanced markets and thus of biased results. Second, our SAM explicitly considers Bt and conventional cotton as two different activities, which allows us to evaluate both technologies' distributional impacts.

However, the SAM as such is a static representation of the village economy and does not allow making statements about income distribution effects of individual activities like Bt cotton. This requires a SAM multiplier model, which we refined (**Supplementary Methods and Supplementary Fig. 1** online) and used for different simulations. In particular, we ran two simulation experiments – Simulation I for Bt cotton and Simulation II for conventional cotton, both considering an expansion in the village cotton area by 10 acres.

Using a village modeling approach taking into account both direct and indirect benefits, our study found that Bt cotton technology generates not only higher income, but also more employment, especially for hired female labour[3,4]. Compared to conventional cotton (Fig. 1; simulation II), Bt cotton (Fig. 1; simulation I) generates additional employment raising the total wage income by $ 40 per hectare[4]. The largest increase is for hired females with a gain of 55 percent from Bt cotton. This translates to about 424 million additional employment opportunities for female earners for the total Bt cotton area in

India. Increase in returns to hired female labour is mostly related to higher yields in Bt cotton, due to the additional labour employed for picking the increased production of cotton. Harvesting of cotton is primarily a female activity in India.

For family female labour, additional income from Bt cotton leads to withdrawal of in-house females from farming activities, raising the quality of life of women. Although reduced pesticide applications in Bt cotton is labour saving, the returns are mainly to family male labour that largely carries out this activity is higher (Fig. 1). However, some of the saved family male labour involved in scouting and spraying for pests are reallocated to other household economic activities, previously carried out by female family members increasing the returns to this labour category. Overall, therefore Bt cotton enhances the quality of life of women through increasing income and reducing ‘femanual’ work.

Note: Supplementary information is available on the Nature Biotechnology website.

Competing Interests Statement:

The authors declare no competing financial interests.

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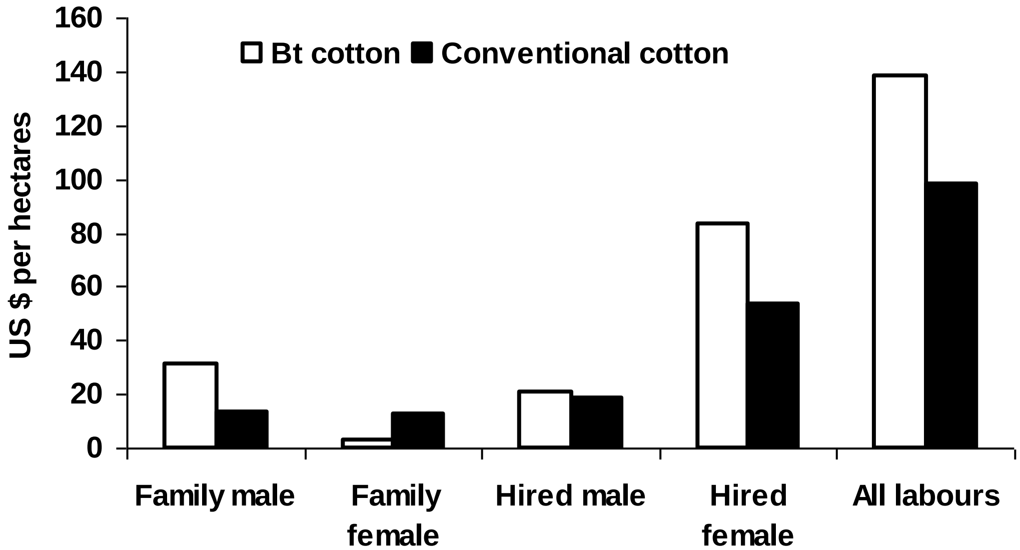

Figure 1 Returns to labour from Bt cotton and conventional cotton in rural India. Family labourers are household members working in their own farm. Hired labour work in others farm earning wages. Returns to non-farm labour are not included here. Simulation I: Increase in Bt cotton area by 10 acres. Simulation II: Increase in conventional cotton area by 10 acres. Both simulations are based on SAM multiplier model (For more details, see **Supplementary Information**).

Supplementary Information

to

GM Crops and Gender Issues

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This PDF file includes:

Supplementary Table 1 Aggregate village SAM for Kanzara village (2003-04 in US $)

	Activities	Commodities	Factors	Households	Village temple	Village government	Capital	Maintenance	Stocks	Rest of India
Activities	-	530,732	-	-	-	-	-	-	-	-
Commodities	226,021	857	-	180,999	1,009	538	49,342	8,214	38,964	395,666
Factors	189,792	-	-	0	0	0	0	0	-	42,389
Households	99,220	-	141,570	12,492	-	111	-	-	-	35,942
Village temple	-	-	2,047	767	-	-	-	-	-	309
Village government	105	-	-	489	99	-	-	-	-	268
Capital	-	-	-	54,021	1,121	12	-	-	-	-
Maintenance	2,114	-	-	5,042	785	273	-	-	-	-
Stocks	-	38,964	-	0	-	-	-	-	-	-
Rest of India	13,479	331,058	88,564	35,525	109	27	5,812	-	-	-
Total	530,732	901,610	232,181	289,335	3,123	961	55,154	8,214	38,964	474,574

Supplementary Methods

The SAM

The village SAM considers 156 agricultural and non-agricultural activities. Agricultural activities include the cultivation of cotton and numerous other crop and livestock enterprises. Non-agricultural activities include agricultural services (e.g., hiring out machinery), village production (e.g., construction and small-scale manufacturing), retail trade, private services (e.g., barber, doctor), government services (e.g., ration shop, post office) and transportation. An aggregate version of the SAM is shown in Supplementary Table 1.

The SAM Multiplier Model

The SAM provides the basis for a simple linear model formed by dividing each column by its total. This coefficient matrix has the property of yielding, when it multiplies the vector of row sums of the original SAM, the row sum vector itself – a property that can be expressed as a system of linear equations. Since each column of the coefficient matrix sums to unity, it is singular. Hence, this system can be solved by considering some flows as exogenous and the rest as endogenous. The rows and columns of the SAM can be partitioned into endogenous and exogenous (Pyatt and Round 1979), with N representing the matrix of SAM transactions between endogenous accounts, X the matrix of injections from exogenous into endogenous accounts, L the matrix of leakages from endogenous into exogenous accounts, and R the matrix of SAM transaction between exogenous accounts. Let A_n and A_l be the sub-matrix of the average endogenous expenditure propensity and average propensity to leak, respectively. The column sum vectors for the endogenous and exogenous accounts are denoted by y_n and y_x. The row sums of N, X, L, and R are denoted by n, x, l, and r. Since expenditure and receipts must tally for each account, the row and column sum vectors must be the same:

$$y_n = n + x = A_n y_n + x, \tag{1}$$

$$y_x = l + r = A_l y_n + r. \tag{2}$$

Provided that $(1 - A_n)^{-1}$ exists, the fixed price multiplier matrix M_n can be written from equation (1) as,

$$y_n = (1 - A_n)^{-1} x = M_n x. \tag{3}$$

Some studies have used fixed price multiplier models to impose production constraints in the form of perfectly inelastic supply in some sectors or beyond predetermined output levels (Subramanian and Sadoulet 1990; Parikh and Thorbecke 1996). The resource constraints accommodated by these models generate high shadow prices on the resources whose supply is fixed and guide the scarce resources to their most productive use. These complex price effects generated by imposing constraints on the production sector cannot be handled in the SAM framework, and they also complicate the interpretation of the results. Hence, we do not pursue this approach in our multiplier model.

Corresponding to the above partition, the matrix of expenditure propensities is (note that only A_{33} is the marginal expenditure propensity),

$$A_n = \begin{bmatrix} A_{11} & 0 & A_{13} \\ A_{21} & 0 & 0 \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \tag{4}$$

The endogenous accounts are segregated under three blocks, where commodity and activity accounts form one block, factor accounts another, and the rest forms the third (Subramanian and Sadoulet 1990). Let $\tilde{A}_n$ be given by,

$$\tilde{A}_n = \begin{bmatrix} A_{11} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & A_{33} \end{bmatrix} \quad (5)$$

From equation (3) it follows that for any matrix $\tilde{A}_n$ of the same size as A_n and such that $(I - \tilde{A}_n)^{-1}$ exists, y_n can be written as,

$$y_n = (A_n - \tilde{A}_n)\, y_n + \tilde{A}_n y_n + x, \text{ or} \quad (6)$$

$$y_n = A^* y_n + (I - \tilde{A}_n)^{-1} x \ , \quad (7)$$

where $A^* = (I - \tilde{A}_n)^{-1}(A_n - \tilde{A}_n)$, so that

$$A^* = \begin{bmatrix} 0 & 0 & (I - A_{11})^{-1} A_{13} \\ A_{21} & 0 & 0 \\ (I - A_{33})^{-1} A_{31} & (I - A_{33})^{-1} A_{32} & 0 \end{bmatrix} \quad (8)$$

From equation (8) it can be observed that the pattern of zero and non-zero cells of A^* corresponds to a circular permutation matrix. Accordingly, if y_n is partitioned compatibly with A_n, then the structure of equation (7) implies that the partitions of y_n are related to each other as points on a closed loop. In Supplementary Fig. 1, these points are shown schematically as the corners of a triangle (y_1, y_2, and y_3). Matrix A^* represents the mapping from one partition of y_n to another, as also shown in Supplementary Fig. 1. This can be represented by the following equations:

$$y_1 = (I - A_{11})^{-1} A_{13} y_3 + (I - A_{11})^{-1} x_1, \quad (9)$$

$$y_2 = A_{21} y_1 + x_2, \quad (10)$$

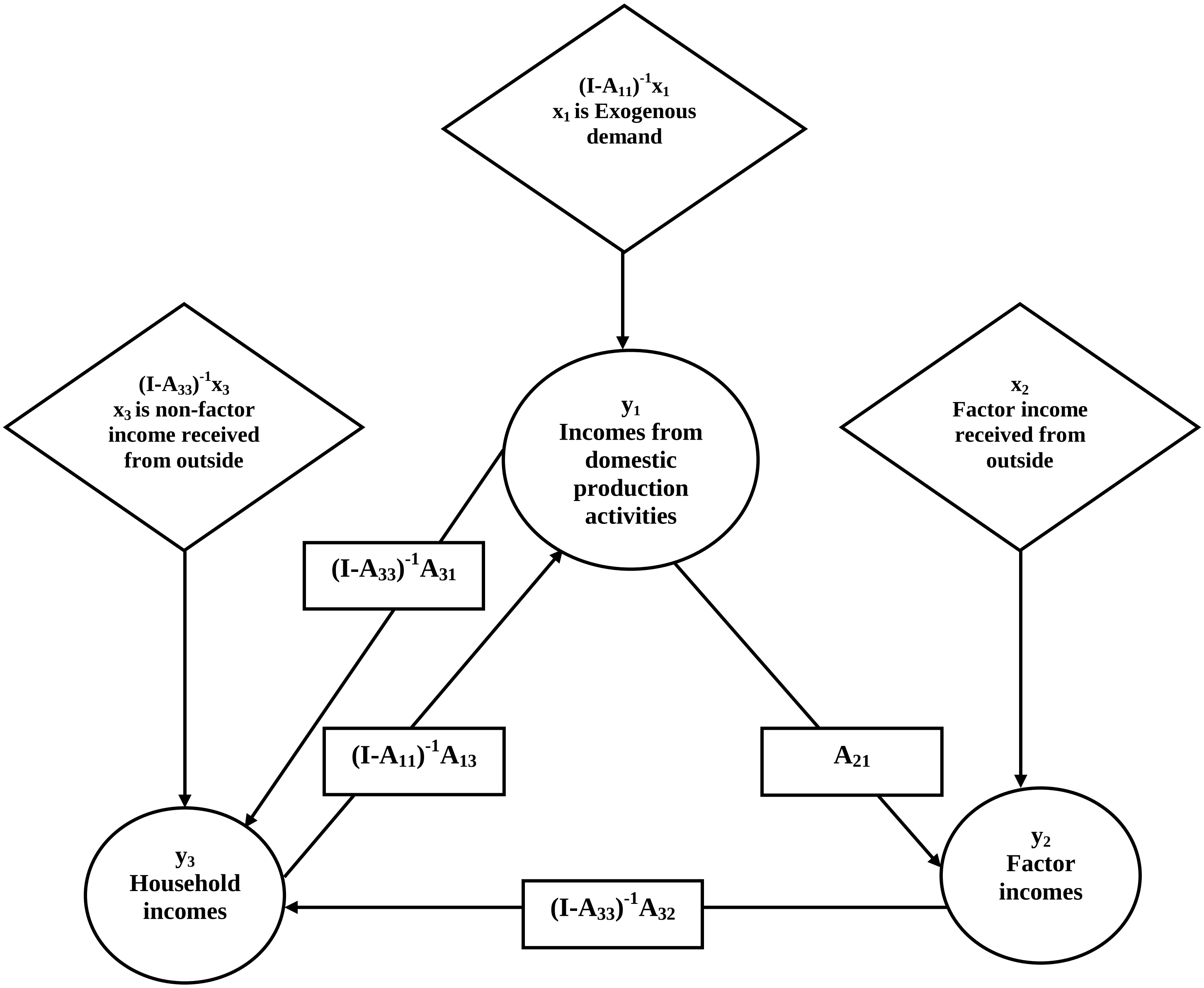
$$y_3 = (I - A_{33})^{-1} A_{31} y_1 + (I - A_{33})^{-1} A_{32} y_2 + (I - A_{33})^{-1} x_3, \qquad (11)$$

where $(I - A_{11})^{-1}$ and $(I - A_{33})^{-1}$ are transfer multipliers, and the formulation in the equations represent a closed-loop system, which is the algebraic statement of the circular flow of income from activities to factors to institutions, and then back to activities in the form of consumption demand.

Simulations

Our two simulation experiments consider an expansion of the village crop area by 10 acres, either grown with Bt or conventional cotton. These 10 acres are additional to the crop area already cultivated in Kanzara. For the essence of the results, the magnitude of the area expansion does not matter. Based on the existing structure of the village economy, the multiplier model simply simulates the direct and spillover effects resulting from the increase in a specific economic activity, in our case either Bt or conventional cotton production. All the resulting effects are proportional to the assumed area expansion, such that income distribution is not influenced by the choice of the concrete acreage. We used the disaggregated Supplementary Table 1 to calibrate the insecticide and yield differences between Bt and conventional cotton in the simulations.

Technically, the assumed expansion in the village cotton area is implemented as an exogenous increase in cotton demand (initial injection) by the value produced on the additional 10 acres. The injection generates a rise in cotton output of $(I - A_{11})^{-1} x_1$, which creates demand also for factors other than land (e.g., labor and capital). These factors are assumed to be available at given price levels, and their employment leads to the generation of additional value added $A_{21}y_1$. Equations (9) to (11) and Supplementary Fig. 1 show the mechanisms through which the multiplier process operates. Apart from labor income, equation (10) also includes any exogenous factor income received from government and the rest of India. The households receive profit income $(I - A_{33})^{-1} A_{31} y_1$ and labor income $(I - A_{33})^{-1} A_{32} y_2$ based on their resource endowment (A_{31} and A_{32}) and transfer system (A_{33}) as well as income $(I - A_{33})^{-1} x_3$ based on exogenous transfers from the rest of India. The loop in Supplementary Fig. 1 is closed through the pattern of household expenditures on commodities, which translates into new production and corresponding additional flows of income accruing to production activities given by equation (9).



Supplementary Figure 1 Schematic representation of the multiplier process among endogenous accounts

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