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ARTICLES

Economic Analysis of Leaf Rust Management by Chemical Controls: Evidence and Implications for Household Coffee Farmers in India

M.R. Narayana*

ABSTRACT

Coffee Leaf Rust (CLR) is a disease that affects the production of Arabica coffee. Its management is essential to improve the production, income and livelihood of household Arabica coffee farmers. This paper develops a simple methodology to calculate the economic costs, gross returns and net economic gains of CLR management by adopters of chemical controls at the national, state and district levels in India. Chemical controls are distinguished by application of recommended and non-recommended combinations and spray schedules of Bordeaux mixture and Systemic fungicides. The methodology is implemented by using a newly collected sample survey data of 575 household Arabica coffee farmers in the traditional coffee growing regions (Karnataka, Tamil Nadu and Kerala) and comprising more than 90 per cent of small farmers. In general, empirical results offer evidence for higher gross returns and positive net economic gains for all adopters of chemical controls with remarkable inter-state and inter-district variations. Though total cost shows remarkable variations between chemical controls and across regions, the composition of total cost shows higher chemical input cost than labour cost for all chemical controls and in all regions. These results have implications for design of a public promotional policy of CLR management by chemical controls for small farmers on empirical economic grounds. Subject to the comparability of CLR by chemical controls, the methodology, empirical results and policy implications are applicable and relevant for other coffee growing and developing countries of Asia and Africa.

Keywords: Arabica coffee, Coffee leaf rust, Bordeaux mixture, Systemic fungicides, Small farmers/ farmers

JEL: Q12, Q19

I

INTRODUCTION

Coffee Leaf Rust (CLR) is an important disease which affects coffee production. According to the Coffee Board (2009 a), when the disease is severe, loss of foliage can occur up to 50 per cent and berries up to 70 per cent. Uncontrolled CLR disease, among other factors, has negative impacts on coffee production, especially Arabica coffee that is more susceptible to CLR than Robusta.[1]

*Professor of Economics, Centre for Economic Studies and Policy, Institute for Social and Economic Change, Bangalore-560 072, (Karnataka).

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Management of CLR refers to all those practices which are directly or indirectly applied to prevent the future occurrence, and control the spread of and cure the existing leaf rust disease. Broadly, these practices include chemical controls, cultivation of resistant varieties, intercropping, weeding, and pruning, shade regulation, topping and de-suckering. Chemical controls for management of CLR refer to application of scientific combinations and spray schedules of Bordeaux mixture and systemic fungicides. Application of chemical controls are economically costly in terms of recurring labour and chemical inputs' costs, because they are required to be applied in all coffee seasons. Other things being the same, focus on CLR management by chemical controls raises many policy-relevant research questions such as the following. What are the chemical controls and their recommended/scientific applications for management of CLR? What are the economic costs of adoption and how do they differ between labour and non-labour costs and by regions? What are the economic gains for adopters or losses for non-adopters? How do the gains and losses differ by chemical control practices and regions? What are the reasons for non-adoption of recommended controls or non-adoption of any controls? What are the implications of these economic analyses for promotion of recommended chemical controls? The first motivation for the focus on management of CLR by chemical sprays in this paper is to find plausible answers to these questions.

India’s coffee farming is known for its dominant share of small farmers with estate size of less than 10 hectares. For instance, the small farmers accounted for 70 per cent of 0.184 million estates in India in 2007-08. Within the small farmers, the smallest farmers with estate size of less than 2 hectares constitute 56 per cent [Coffee Board (2011)]. Narayana (2013a) found that the occurrence of CLR is historical and universal in India’s coffee farming by all estate sizes. Given the smallness of scale and size of production, Narayana’s (2013a) finding implies that management of CLR by chemical controls is of special importance for small farmers because of its implications for improvements in production, income and livelihood of the small farmers by effective and affordable management through promotional public support measures. The second motivation for this paper is to argue for such a public promotion policy to be targeted at small farmers on economic grounds.

To our knowledge, many international studies have taken up CLR but not its economic analysis of management by chemical controls. These studies include Schieber (1972) for Latin American countries (i.e., Panama to Mexico), Phiri *et al*. (2001) for Malawi, Staver *et al*. (2001) for Nicaragua, Sato-Pinto *et al*. (2002) for Mexico, Avelino *et al*.(2006) for Honduras, and Lopez-Bravo *et al*. (2012) for Costa Rica. In the same way, research studies on the economic analysis of CLR management by chemical controls are not available for India. This research gap is evident, for instance, in the studies on cost of cultivation of coffee by Babu Reddy *et al*. (2003), Babu Reddy (2004) and NABARD (2011). Babu Reddy *et al*. (2003) estimated the cost of Arabica coffee cultivation for Chikmagalur region in Karnataka in 2001-02 including the plant protection chemical cost, which may be related to pest and disease management. This cost per hectare of cultivation was about 22 per cent of total expenditure on the cultural practices.[2] Babu Reddy (2004) estimated the cost of cultivation of Arabica coffee in Kodagu region in Karnataka State in 2001-02. The plant protection chemical cost per hectare of cultivation was about 18 per cent of total expenditure on the cultural practices. NABARD's (2011) estimates included two methods of plant protection: (a) Pest management through spraying neem kernel extract and application of neem cake. (b) Disease (brown eye spot disease causing defoliation) management through providing adequate shade, mulching and spraying Bordeaux mixture. The estimated cost of plant protection (includes manuring) per acre was about 12 per cent of the total labour costs; 24 per cent of total material costs; and 13 per cent of total costs from the 1st year to the 4th year. However, plant protection chemical costs in all the above studies are not separable by management CLR by chemical controls.[3] However, this paper fills in this research gap by focusing on the economic analysis of CLR management by chemical controls by household coffee farmers in India.

The main objective of this paper is to present a simple economic framework for calculation of cost, returns and net economic gains by recommended and non-recommended CLR management by chemical controls by household Arabica coffee farmers in India. In the absence of data on household coffee farmers' adoption of CLR management by chemical controls, however, a new survey data is collected from a sample survey of 575 household Arabica coffee farmers in traditional coffee growing regions in 2010. The representativeness of sample is ensured by drawing the sample farmers from all traditional coffee growing states/major coffee growing regions within each state/district/all Liaison Zones of Coffee Board within each region. The data thus collected is used for all calculations and analyses to answer the research questions and draw policy implications with special reference to small farmers.

The rest of the paper is organised as follow. Section II describes the methodology for collection of new primary data, and framework for calculation of economic cost, returns and gains of CLR management by chemical controls. The empirical results are analysed in section III. Major conclusions and policy implications are summarised in the final section.

II

METHODOLOGY

This section describes the methodology for collection of primary data on household coffee farmers' management of CLR by chemical controls and a framework for calculation of economic cost, return and economic gains by chemical controls at the national and sub-national levels.

2.1. *Collection of Primary Data*

Primary data was collected from 575 sample farmers in the traditional Arabica coffee growing regions from 23 February 2010 to 31 August 2010. Household was the unit of analysis and, hence, corporate coffee sector is not included in the sample.[4] The sample design in terms of selection and allocation of sample farmers/farmers was based on multi-stage and simple random sampling method. The multi-stage sample design was distinguished by three stages. In Stage I, the total sample was allocated to three states in proportion of their average share by five variables: (a) Planted area (Arabica) in 2007-08, (b) Planted area (Arabica) in 2008-09, (c) Production of coffee (Arabica) in 2007-08, (d) Production of coffee (Arabica) in 2008-09 and (e) Production of coffee (Arabica) in 2009-10. In Stage II, the sample size in Stage I in each state was allocated in proportion to the distribution of the farmers by estate size of planted area under Arabica coffee. In Stage III, the sample farmers were ultimately drawn from all the Liaison Zones of the Coffee Board of India. In the absence of a complete household listing of coffee farmers, however, the entire fieldwork was undertaken with the guidance of the officials and staff in the extension services of the Coffee Board. Structured questionnaire was the instrument of collection of primary data. Trained investigators canvassed the questionnaire by direct personal interview with farmers in their estates.

Of the total 575 sample farmers, 73 per cent (or 417 farmers) were from Karnataka, 18 per cent (or 103 farmers) from Tamil Nadu and the rest 9 per cent (or 54 farmers) from Kerala. Of the 417 sample farmers within Karnataka, 44 per cent were from Chikmagalur district, 31 per cent from Kodagu district and 25 per cent from Hassan district.

Further, the small farmers (having less than 10 ha or about 25 acres) constituted the highest share of sample farmers: 91 per cent at all India level and in each state. Within Karnataka, this share varied from about 86 per cent in Chikmagalur to 94 per cent in Hassan and to 94 per cent in Kodagu district. In particular, the sample was dominated by the smallest farmers with less than 5 acres or 2 hectares or smaller farmers with less than 10 acres or 4 hectares of estate size. For instance, the share of smallest (or smaller) farmers was equal to about 43 (or 24) per cent in Karnataka, 81 (or 7) per cent in Kerala, 64 (or 14) per cent in Tamil Nadu and 51 (or 21) per cent at the all India level. Thus, the results of this paper, based on the above data, are of special relevance for these vulnerable sections of coffee farmers in India.

The questionnaire included questions on coffee production, application of chemical controls and cost details of chemical controls. The respondent farmers provided all the details of application of chemical controls but not the cost details for reasons including lack of memorisation of cost composition and indivisibility of labour input between CLR management practices and other farming activities. This precludes the direct computation of cost of CLR management from the survey data.

Thus, in what follows, an indirect approach is developed to calculate the cost of chemical controls.

2.2. *Calculation of Cost of Management of CLR by Chemical Controls*

Total cost of CLR management by chemical controls is equal to sum of chemical and labour costs, which are specific to regions. Calculation of this cost draws from the experiences of experimental farms at the Central Coffee Research Institute as well as the informal discussions with farmers during the fieldwork.

2.2.1. *Chemical Costs*

Application of fungicides is the most important chemical control for CLR management practice for Arabica coffee. Fungicides are of two types: Bordeaux mixture and Systemic fungicides [i.e. Bayleton (*Triadimeton*) and Contaf (*Hexaconazole*)]. Cost of fungicides is calculated as follows. First, the required/recommended dosages and input combinations of fungicides per acre of bearing area of Arabica coffee are obtained. That is, preparation of 0.5 per cent of Bordeaux mixture requires one kilogram of copper sulphate and one kilogram of lime, each dissolved in 50 litres of water. The combined mixture of dissolved copper sulphate and lime water is ready for spray as Bordeaux mixture at 5 barrels per acre. Systemic fungicide (Bayleton) is prepared with 160g of Bayleton per barrel for the required spray of 3 barrels per acre. Systemic fungicide (Contaf) is prepared with 400ml of Contaf per barrel for the required spray of 3 barrels per acre. Second, unit price of these fungicides are constructed by using market price of chemical inputs at different regions in 2009-10 (Table 1). Third, using the recommended spray schedules and fungicides combinations (Table 2), annual cost of chemical inputs are calculated for adopters in each coffee growing state/district

Throughout, a farmer is considered to follow the recommended practices if he/she adopts any one or more of the spray schedule by fungicides combinations as given in Table 2. Any other practice of a farmer other than in this table is considered a non-recommended practice. A non-adopter is a farmer who does not adopt either a recommended or non-recommended practice.

2.2.2. *Labour Cost*

Labour cost is the product of total man-days required for applying chemical controls and wage rate per man-day. Labour input requirements are approximated by three man-days per one round of chemical spray per acre. The wage rate per man-day at all India level is the average of the official minimum wage rate per man-day in Karnataka, Kerala and Tamil Nadu.[5] The official minimum wage rates by states are published in the Database on Coffee [Coffee Board (2011)]. This minimum wage in

TABLE 1. COST OF FUNGICIDES BY COFFEE STATIONS IN 2009-10

Region	Input prices (Rs. at current prices)			
	Copper sulphate (per kg)	Spray lime (per kg)	Contaf (per litre)	Bayleton (per kg)
(1)	(2)	(3)	(4)	(5)
All India	103	7	520	2115
States and districts				
1. Karnataka	127	10	367	2363
1.1. Chikmagalur	125	8.50	510	2425
1.2. Hassan	132	10.25	350	2300
1.3. Kodagu	125	12	240	2363
2. Tamil Nadu	128	7	380	2115
2.1. Thandigudi (Pulneys)	125	5.60	480	2115
2.2. Yercaud (Shevroys)	130	8	279	2115
3. Kerala	103	7	520	2115

Source: Computed by the author.

Notes: (i) All input prices for (a) Karnataka and Tamil Nadu are the average of respective prices in districts/coffee regions and (b) Kerala refers to national level prices. (ii) Price of spray lime for Hassan refers to the average of prices of spray lime in Chikmagalur and Hassan districts. (iii) Price of Bayleton for Kodagu is the average of Bayleton prices in Chikmagalur and Hassan districts. (vi) Price of Bayleton for Thandigudi and Yercaud refers to the national level prices of Bayleton.

TABLE 2. RECOMMENDED CHEMICAL CONTROLS BY SPRAY SCHEDULE AND FUNGICIDES COMBINATIONS

Spray schedule	Fungicides' combinations
(1)	(2)
1. Two rounds of Bordeaux mixture (BM)	BM + BM
2. Two rounds of systemic fungicides	Contaf + Contaf
	Bayleton + Bayleton
3. Three rounds of systemic fungicides	Contaf + Contaf+ Contaf
	Bayleton + Bayleton + Bayleton
4. Two rounds of systemic fungicides and one round of BM	Contaf + BM+ Contaf
	Bayleton + BM + Bayleton
5. One round of BM and one round of systemic fungicides	BM+ Contaf
	BM + Bayleton

Source: Compiled by the author.

2009-10 was equal to Rs. 119 in Karnataka, Rs. 132 in Kerala and Rs. 122 in Tamil Nadu. These minimum wages were applicable within the entire state. Hence, district and state level minimum wages were equal to the minimum wage rate of Karnataka state.

2.3. *Calculation of Gross Returns for Adopters and Non-Adopters of Chemical Controls*

Gross value of output is treated equal to gross returns to Arabica coffee for all adopters and non-adopters of chemical controls. Self-reported output by sample farmers may be subject to measurement errors due to under or over reporting of coffee output, especially when both Arabica and Robusta are grown, and the quantity of clean coffee output is not clearly remembered by cherry and parchment. These data limitations of self-reporting call for field experiences to arrive at plausible estimates of coffee output. First, clean coffee is considered equal to 80 per cent of the parchment (i.e., 40 kg clean coffee from 50 kg bag parchment) and 50 per cent from cherry (i.e., 25 kg clean coffee from 50 kg bag cherry). Accordingly, physical quantities of clean Arabica coffee are obtained by individual farmers in each region. Second, value of clean coffee is computed by multiplying the selling price and the above computed quantity of clean Arabica coffee. The selling price is as reported by the farmers during the survey.

2.4. *Calculation of Economic Gains of Management of CLR by Chemical Controls*

Other things being equal, the difference in gross returns per acre of bearing area of Arabica coffee between the adopters and non-adopters of a chemical control is defined as the total economic gains. Net economic gains for adopters of a chemical control are calculated by subtracting the cost of that chemical control from its total economic gains.

III

EMPIRICAL RESULTS

Cost, gross returns and net economic gains per acre of bearing area of Arabica coffee is calculated by adopters of three recommended chemical controls: (a) two-rounds of Bordeaux mixture; (b) two-rounds of Systemic fungicides (Contaf); and (c) one-round of Bordeaux mixture and two- rounds of Systemic fungicides; and three non-recommended chemical controls: (i) one-round of Bordeaux mixture; (ii) one-round of systemic fungicides; and (iii) two-rounds of Bordeaux mixture and one-round of systemic fungicides.

Table 3 presents the results on total cost, gross returns, ratio of total cost to gross returns and net economic gains as a percentage of gross returns for six chemical controls of CLR management at the national, state and district levels. In addition, gross value of output per acre of bearing area by non-adopters is separately calculated for comparison purposes as well as for calculation of economic gains. That is equal to Rs. 25099 at all India; Rs. 18720 for Karnataka; Rs. 14421 for Kerala; and Rs. 32634 for Tamil Nadu. These results are analysed by national, state and district level in order to highlight the essential similarities and unique differences by recommended and non-recommended chemical controls across regions.

3.1. *Results at the National Level*

Of the recommended chemical controls, total cost is higher for adopters of one-round of Bordeaux mixture and two-rounds of systemic fungicides. Higher total cost is due to higher chemical input and labour costs for more rounds of fungicides applications. Across regions, higher cost for a given fungicide application is due to

TABLE 3: ECONOMIC COSTS, GROSS RETURNS AND NET ECONOMIC GAINS TO ADOPTERS OF CLR MANAGEMENT PRACTICES OF ARABICA COFFEE IN INDIA, 2009-10

	Adopters of recommended chemical controls			Adopters of non-recommended chemical controls		
Cost, returns and net economic gains by coffee regions (1)	Two-rounds of Bordeaux mixture (2)	Two-rounds of Systemic fungicides (3)	One-round of Bordeaux mixture and Two-rounds of Systemic fungicides (4)	One-round of Bordeaux mixture (5)	One-round of Systemic fungicides (6)	Two-rounds of Bordeaux mixture and One-round of Systemic fungicides (7)
1. All India						
• Total cost (INR)	1842	1956	2872	916	978	2810
• Labour cost as per cent of total cost	39.74	37.42	38.23	39.96	37.42	39.07
• Gross returns (INR)	41666	40599	44376	42302	39220	39572
• Net economic gains as per cent of gross returns	35.34	33.36	36.97	38.50	33.51	29.47
2. Karnataka						
• Total cost (INR)	2084	1595	2637	1042	797	2524
• Labour cost as per cent of total cost	34.26	44.76	40.61	34.26	44.79	28.29
• Gross returns (INR)	44347	43265	44451	48515	45648	39639
• Net economic gains as per cent of gross returns	53.09	53.05	51.95	59.27	57.24	46.41
2.1. Chikmagalur						
• Total cost (INR)	2044	1938	2960	1022	969	3013
• Labour cost as per cent of total cost	34.93	36.84	36.18	34.96	36.84	35.55
• Gross returns (INR)	43794	43450	45994	53365	50563	36938
• Net economic gains as per cent of gross returns	60.13	60.06	60.04	69.19	67.59	50.10
2.2. Hassan						
• Total cost (INR)	2037	1554	2572	1081	777	2814
• Labour cost as per cent of total cost	35.05	45.95	41.64	35.07	45.95	38.06
• Gross returns (INR)	36034	34056	43585	38612	35523	37548
• Net economic gains as per cent of gross returns	63.27	62.55	68.40	68.36	66.28	62.68
2.3. Kodagu						
• Total cost (INR)	2104	1290	2342	1052	645	2749
• Labour cost as per cent of total cost	33.94	55.35	45.73	33.94	55.35	38.96

Table 3 (Contd.)

TABLE 3 (Concld.)

• Gross returns (INR)	50174	47154	42442	44525	42305	48599
• Net economic gains as per cent of gross returns	55.20	54.06	46.48	51.88	50.32	52.42
3. Kerala						
• Total cost (INR)	1902	2016	NA	946	1008	NA
• Labour cost as per cent of total cost	41.64	39.29	NA	41.86	39.29	NA
• Gross returns (INR)	32990	27446	NA	13961	14940	NA
• Net economic gains as per cent of gross returns	50.52	40.11	NA	-10.07	-3.27	NA
4. Tamil Nadu						
• Total cost (INR)	2046	1608	NA	1023	804	NA
• Labour cost as per cent of total cost	34.02	43.28	NA	34.02	43.28	NA
• Gross returns (INR)	40741	41954	NA	42229	60005	NA
• Net economic gains as per cent of gross returns	14.88	18.38	NA	20.30	44.27	NA

Source: The author.

Notes: (a) Figures in parentheses in column 2 (or column 3) refer to the adopters of one-round of Bordeaux mixture (or systemic fungicides). (b) NA refers to not applicable.

higher chemical inputs and/or labour costs. The share of labour cost varies from about 37 per cent to 40 per cent across regions and the rest of the total cost is directly accountable for chemical inputs. This shows the significance of chemical input prices for all adopters of the chemical controls.[6]

The ratio of total cost to gross returns is higher for adopters of one-round of Bordeaux mixture and two-rounds of systemic fungicides because gross returns are highest to the adopters of this practice (Rs. 44376) as compared to the gross returns of adopters of two-rounds of Bordeaux mixture (Rs. 41666 or systemic fungicides (Rs. 40599). Most importantly, gross returns of adopters of all recommended practices are remarkably higher than non-adopters (Rs. 25099). Net economic gains are positive for adopters of all practices and vary from 34 per cent to 37 per cent. Highest net economic gains are evident for adopters of the recommended control of one-round of Bordeaux mixture and two-rounds of systemic fungicides.

Of the adopters of non-recommended chemical controls, gross returns as well as net economic gains are the highest for the adopters of two-rounds of Bordeaux mixture. On the other hand, adopters of two-rounds of Bordeaux mixture and one-round of systemic fungicides have the higher cost and lower gross returns as compared to the adopters of one-round of Bordeaux mixture or systemic fungicides. Consequently, the ratios of total cost, input cost and labour cost to gross returns are higher; and economic gains are lower for the adopters of two-rounds of Bordeaux mixture and one-round of systemic fungicides.

As in the case of adopters of recommended practices, the gross returns of adopters of non-recommended practices are higher than the non-adopters. This implies that all adopters of the chemical controls have positive net economic gains. These results offer a strong empirical support for promotion of chemical controls for management of CLR management among the non-adopters.

It is important to emphasise that the adopters of one-round of Bordeaux mixture and two-rounds of systemic fungicides have the highest gross returns and net economic gains as compared to all the adopters of recommended and non-recommended practices. This implies that adoption of one-round of Bordeaux mixture and two-rounds of systemic fungicides is strongly justifiable on both empirical and economic grounds. These adopters show an implicit optimising behaviour in terms of maximising the gross returns, if not the minimisation of total cost.

3.2. *Results at the State Level*

Tamil Nadu has a single sample farmer who adopted (a) one-round of Bordeaux mixture and two-rounds of systemic fungicides and (b) two-rounds of Bordeaux mixture and one-round of systemic fungicides. Kerala state has no sample farmers who adopted these mix of Bordeaux mixture and systemic fungicides. Hence, calculation of costs and returns of these chemical controls is not applicable for farmers in Tamil Nadu and Kerala.

Input cost is different between the states because of variations in input prices as shown in Table 1. Variations in labour cost is directly attributable to differential minimum wage rates, because the number of man-days per acre of bearing areas required for CLR management is assumed to be the same for all farmers in all the states. As a combined consequence of the above inter-state variations in chemical inputs and labour costs, the total cost of chemical controls is different across states. For instance, total cost for application of one-round or two-rounds of Bordeaux mixture is highest in Karnataka (Rs. 2084) and total cost for application of one-round or two-rounds of Systemic fungicides is highest in Kerala (Rs. 2016). It is important to note that in all the states, the ratio of labour cost to total cost is less than 50 per cent. Thus, chemical input prices account for largest share in total cost in all states.

Of the recommended practices, gross returns are the highest for farmers who adopt the one-round of Bordeaux mixture and two-rounds of systemic fungicides in Karnataka; two-rounds of Bordeaux mixture in Kerala; and two-rounds of Systemic fungicides in Tamil Nadu. On the other hand, of the non-recommended practices, the adopters of one-round of Bordeaux mixture in Karnataka and two-rounds of Systemic fungicides in Tamil Nadu have the highest. Thus, gross returns show remarkable inter-state variations across chemical controls.

In all the states, net economic gains are positive for farmers in all the states except for adopters of non-recommended chemical controls in Kerala. Net economic gains are the highest for adopters of all recommended and non-recommended chemical controls in Karnataka. Of the chemical controls adopted by Karnataka farmers, net economic gains are the highest (59.27) for adopters of one-round of Systemic fungicides which is a non-recommended practice.

Using the empirical evidence in Narayana (2013b), low adoption of chemical controls by farmers in Tamil Nadu and Kerala may be explained by varieties of coffee and altitude at which coffee is grown. First, demand for chemical controls in general, and for recommended chemical controls in particular, is more for farmers who cultivate the CLR-tolerant varieties than who cultivate the CLR-resistant varieties. About 73 per cent of the sample farmers in Karnataka cultivated CLR-tolerant varieties (e.g., S.795) as compared to about 30 per cent of the farmers in Kerala and 59 per cent in Tamil Nadu. The important CLR-resistant varieties of coffee grown in Kerala and Tamil Nadu include Selection.9 and Cauvery. For instance, 87 per cent of the farmers in Kerala and 80 per cent of the farmers in Tamil Nadu cultivated Selection.9 variety. This explains why a large number of farmers use chemical controls in Karnataka as compared to farmers in Kerala and Tamil Nadu. Second, the agro-climatic conditions for cultivation have important implications for less adoption of chemical controls in Kerala and Tamil Nadu. For instance, Chandragiri variety is best suited for cultivation at higher altitude (1006 meters and above). At this elevation, it is highly resistant to CLR and the farmers who cultivate this variety at higher altitudes demand less of chemical controls. Overall, 12 per cent of the sample farmers in Karnataka had cultivated coffee at altitude above 1006 meters (or 3300 feet). In contrast, 87 per cent of the farmers in Kerala and 96 per cent of the farmers cultivated coffee above 1006 meters. This explains why a large number of farmers do not use chemical controls in Kerala and Tamil Nadu as compared to farmers in Karnataka.

Higher gross returns and net economic gains for non-recommended practices in Karnataka and Kerala are particularly relevant for those farmers who grow resistant varieties because the potential coffee yield is comparable across varieties. For instance, Coffee Board (2009b) distinguished the yield potential (green beans per hectare) by 2000 kg for S.795, 1200-2000 kg for Selection.6; 1700 kg for Selection.9; 2000 kg for Selection.12; and 1156-1875 kg for Chandragiri.

The negative net economic gains for adopters of non-recommended practices (i.e. one-round of Bordeaux mixture or one-round of Systemic fungicides) in Kerala are the surprising results. In particular, negative net economic gain is stronger for adopters of one-round of Bordeaux mixture. This result is the consequence of gross returns of these adopters being less than gross returns of non-adopters and the cost of chemical controls. These non-adopters are the typical example of coffee grown at higher altitude.

3.3. *Results at the District Level*

Cost, gross returns and net economic gains of adopting the chemical controls are different between the three coffee growing districts in Karnataka state. Variation in inputs prices account for differences in total cost because of uniformity of labour cost across districts. Gross returns of adopters have strong inter-district variations in Karnataka. In general, gross returns are higher for one-round of adopters than two-rounds of Bordeaux mixture or systemic fungicides in Chikmagalur and Hassan. This result is mixed in Kodagu. Of the recommended chemical controls, the highest gross returns and net economic gains are evident for adopters of two-rounds of Bordeaux mixture. Of the non-recommended practices, the highest gross returns and net economic gains are evident for adopters of two-rounds of Systemic fungicides and one-round of Bordeaux mixture. This mixed result for Kodagu is attributable for the present of the largest number of farmers of CLR-resistant coffee varieties (e.g., 68 per cent by Selection.6) along with CLR-tolerant varieties (e.g., 60 per cent by S.795).

The calculated gross returns of non-adopters of chemical controls are equal to Rs. 15418 in Chikmagalur, Rs. 11200 in Hassan, and Rs. 20374 in Kodagu. These returns are unambiguously lower as compared to the gross returns of any of the recommended or non-recommended adopters of chemical controls in Table 2. This result is consistent with the national and state level results.

IV

MAJOR CONCLUSIONS AND IMPLICATIONS

This paper has developed an economic framework for calculation of the costs, gross returns and net economic gains for adopters of the recommended and non-recommended chemical controls at the national, state and district levels in India. The framework is implemented for the sample survey data of 575 Arabica coffee farmers in 2010. The results lead to the following conclusions and implications.

First, the adopters of chemical controls have unambiguously higher gross returns and net economic gains than the non-adopters. This conclusion is relevant for all farmers at the national, state and district level coffee regions in India. A notable exception to this general result is the adopters of non-recommended practices who grow CLR resistant varieties and grow coffee at higher altitude in Kerala. Second, chemical input cost is higher than the labour cost when labour cost is calculated at official minimum wages and man-days required for application of fungicides is at the minimum. This implies that a strategy to reduce the total cost of CLR management by chemical controls should target at chemical input prices, which are determined by market mechanisms. Public subsidies for chemical inputs, especially for small farmers, are one plausible way to reduce this input cost. Third, gross returns and net economic gains may vary between the states and districts and by farmers of CLR resistant and tolerant varieties. This is an important insight from the disaggregate calculations at the state and district levels. Fourth, the output gains by adopting chemical controls are higher than the cost of management of CLR in terms of positive net economic gains. This empirical result provides with the economic justification for promotion of chemical control practices for management of CLR. Fifth, all results and their implications are mainly relevant for the small and very small farmers whose livelihood depends on the production and income from coffee farming. This captures the distributive effects of CLR management by chemical controls and supports for design of a public promotional policy of recommended chemical controls for this vulnerable group of coffee farmers.

The farmers of non-recommended chemical controls in Tamil Nadu state and Kodagu district have higher gross returns and net economic gains than the farmers of recommended chemical controls. This surprising result may be due to a myopic behaviour towards short run maximisation of the gross returns by ignoring the long run consequences of CLR on coffee farming. In the long run interest of the Arabica coffee production, however, the myopic behaviour of farmers may be corrected through information, education and communication activities as they are related to recommended CLR management practices. Scientifically, management of diseases may have positive spillover effects on the management of pests in coffee farming. These spillovers may provide with additional justifications for stronger promotional activities of recommended CLR management by chemical controls.

CLR is widespread in Arabica coffee growing countries in Asia and Africa. Subject to the comparability of management of CLR by chemical controls, however, the methodology, empirical results and policy implications of this paper are applicable and relevant for other coffee growing developing countries in Asia and Africa.

The results, conclusions and implications of this paper are based on the assumption that all farming practices are uniformly practiced by all farmers except the management of CLR by chemical sprays. Accordingly, difference in gross returns between adopters and non-adopters is attributed to the adoption or non-adoption of CLR management by chemical controls. Further, calculation of gross returns and labour cost are approximated and applied to all farmers due to lack of information from individual farmers. These limitations underline the need for extending this study in future by relaxing these assumptions and improving the database to generate more general and stronger supportive evidence for results, conclusions and implications of this paper.

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NOTES

1. Scientific details of CLR are available in Central Coffee Research Institute (2009a). These details include symptoms, favourable factors for spread of disease, disease development phases, period of extension, intensification, defoliation and inactivity. In addition, this source provides with technical details of CLR management.

2. Expenditure on cultural practices includes weeding, fertilizer applications, FYM/Compost applications, liming, plant protection, bush management, shade regulation, soil cultivation, harvesting, processing, wathe/fence/fire path, supply planting, fuel for farm vehicles and equipment and interest on working capital.

3. It is well known that the Report of the Commission for Agricultural Costs and Prices recommends the minimum support prices for 25 commodities to be fixed by the Government of India [see, for instance, Government of India (2011)]. These commodities do not include plantation crops including coffee and have no relevance for the CLR. Nevertheless, the cost estimates of the Commission may be useful for a general comparison of cost of cultivation of coffee with these commodities.

4. Corporate coffee sector include those public and private companies which are registered under the Indian Companies Act 1956. CMIE-Prowess Database includes company-wise corporate annual data (as available from the companies' annual reports) on coffee sector (under non-food crops) in India. For instance, 9 registered coffee companies (out of 31 total companies) data are available under non-food crops for Karnataka. Corporate coffee sector is not included in the paper for three reasons. First, CMIE data on coffee sector includes no information on CLR management. Second, in terms of size and scale of production, corporate coffee sector is not comparable with the household coffee sector. Third, during the fieldwork, we contacted the estate managers of corporate coffee estates but no details of their management practices were informed to us due to occupational secrecy or for lack of permission from the corporate office. However, informal discussions with a plantation consultant of a corporate estate revealed that their CLR management practices were generally in line with the recommended practices except for advantages of economy of scale.

5. The minimum wage for adult labourer is fixed by the Department of Labour of the respective State Government and is applicable to all plantation labour (non-staff) within the State. The minimum wage includes variable dearness allowances and varies across the states. The current (applicable from 1st April 2011 to 31 March 2012) minimum wage rate for an adult coffee plantation labourer in Karnataka is equal to Rs. 130.08. This includes the variable dearness allowances of Rs. 45.58.

6. If the actual/market wages are higher than the minimum wages, and other things being the same, share of labour cost would be higher than calculated in this paper. Thus, labour cost in Table 3 may be considered as a lower limit.

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