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Externalities of Pesticide Application on Apple in Kashmir Valley§

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Abstract

This study has investigated the pesticide-use practices in relationship with external costs on health/ environmental hazards in apple-dominated areas of Kashmir valley. The study has revealed unscientific/ indiscriminate application of pesticides on apple; on an average, the apple orchards are sprayed 9 times, though few farmers even go beyond 12 sprays. Pesticides which are more costly and not recommended for a particular stage of fruit development are also sprayed in the study area. It is surprising that only one farmer has sprayed summer oils on his apple orchard. The use of unidentified/unlabelled pesticides has been found prevalent in the study area. There are huge technological gaps in the use of pesticides; dormant oils, fungicides and insecticides/acaricides are used 61 per cent, 32 per cent and 36 per cent more than the recommendations, respectively. The gaps have been found wider at the farms of farmers who purchase pesticides on cash or credit from contractors-cum-traders who are known for their misguiding roles. The study has provided an account of various environmental externalities of pesticide-use and has estimated costs (damage cost and damage abatement cost) associated with them, employing actual expenditure at market price and contingent valuation procedures. Pesticide health risk models have been specified for quantifying the probability of falling sick of health disorders, viz. dermatological, gastro-intestinal, neurological, respiratory and ophthalmological. The logit regression estimates ascertained that the use of more toxic pesticides significantly increase the probability of falling sick. The study has put forth a few policy suggestions for encouraging scientific application of pesticides and reducing the negative externalities arising from pesticide-use.

Key words: Pesticide-use, environmental externalities, external costs, pesticide-health risk models, apple, Kashmir Valley

JEL Classification: Q12, O18, D62

Introduction

Pesticides have been an essential ally in the farmers' struggle to control different pests and constitute one of the important inputs in agricultural production. The application of pesticides has a number of benefits in addition to improved yield and crop protection (Cooper and Dobson, 2006). The potential benefits are particularly important in developing countries where crop losses contribute to hunger and malnutrition (Anon, 2004). However their benefits are accompanied by disutility of negative externalities that arise from continuous use of pesticides (Lipton and De Kadt, 1988; Pimentel *et al*., 1992). The pesticides are more likely to affect the human health because of their intrinsically toxic properties (WHO, 1990). The exposure to pesticides may result in various mild and serious ailments or even deaths (Wilson and Tisdell, 2001; FAO, 2008). The number of pesticide-poisoning

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cases shows a rising trend (Rosenstock *et al.,* 1991; WRI, 1998). Studies have even highlighted hidden health costs of these chemicals (Waibel, 1994; Rola and Pingali, 1993; Antle *et al*., 1998). Besides, the excessive use of pesticides can pose serious irreversible environmental risks and adversely affects any organism having physiological functions similar to the target organism (Mclaughlin and Mineau, 1995) and may cause a decline in the number of beneficial pest predators (Pimentel and Greiner, 1997). Certain pesticides applied to crops seep down in water bodies and affect fishery (Pimentel *et al*., 1992).

In India, pesticides coupled with other input technologies have resulted in enormous increase in the agricultural productivity over the years (Shetty, 2007). However, indiscriminate use of pesticides has increased not only the cost of production but also many human health hazards and environmental contaminations. The major victims are the most vulnerable sections of the population who are the most exposed owing to occupational factors (Devi, 2009). Pesticide consumption has not been uniform in the country; it varies with the intensity of pests and diseases, cropping patterns and agro-ecological regions. The Kashmir region of Jammu & Kashmir is a major apple-producing region in India, producing 1.62 million tonnes at an average productivity of 11.32 t/ha. Apple hosts a number of pests which if left unattended, would devastate the entire produce. It is observed that pesticides are applied on apple without adequate understanding of pest ecology, economic injury level, formulation/methods and safety measures during pesticide application (Baba *et al*., 2015). The intensive use of pesticides had significantly prevented losses to the tune of 40 per cent of apple by saving its quantity or quality. However, these benefits were offset to a considerable extent by costs imposed in mitigating environmental hazards, including health problems (Baba *et al.*, 2015). The extent of this risk among apple growers and farm labourers in the region still remains largely non-documented. In this back drop, this study seeks to fill some of the gaps by conducting an analysis on the pesticide-use practices and associated externalities in apple-growing areas of Kashmir region of Jammu & Kashmir.

Study Area and Data

The study has used the primary data collected under an ongoing DST-sponsored research project in the year 2015-16 from a sample of respondents selected by employing multi-stage stratified sampling procedure. Four community development blocks were selected, two each from Baramulla and Shopian, the two major apple producing districts of Kashmir. In each selected block, 50 farm households from village cluster were randomly selected, thus making a sample of 200 farmers. Besides, an appropriate number of specialized respondents, viz pathologists, entomologists, toxicologists, environmentalists, skilled pesticide applicators, etc were also selected for obtaining data on various aspects of pesticides and associated externalities.

Pesticide-Health Risk Model: Specification and Structural Form

The health risk may be cardiac, gastro-intestinal, ophthalmologic, neurological, dermatological, respiratory, etc. Some respondents experienced no health disorder due to pesticide pollution after pesticide treatments, while other households did and incurred some costs. The dependent variable of the health risk incidence function thus takes a binary form. We preferred to use logit model owing to its simplicity of estimation/interpretation (Kennedy, 1992). The logit regression explains the relationship between a binary response variable (Yi) and a vector of explanatory variables (Xs) that may also be discrete or continuous variables (Stokes *et al*., 1995) as specified in the model of following structural form which was estimated by employing logistic procedure:

$$Yi = f\,(AGE, EDU, HBT, PSTlt, PSTmt, PSTht, LND, SFTY, U) \quad \ldots(1)$$

where, Y is the dependent variable (Y = 1 if sick, 0 otherwise) which explains incidence of 'ith' health disorder after the application of pesticides, AGE is the age of family-head (years), EDU is the education level of family-head (0 for illiterate, 1 for education up to high school, 2 for education up to higher secondary and 3 for education for bachelors and beyond), HBT is the habitual of smoking (1 for habitual, 0 for not habitual), PSTlt, PSTmt, PSTht denote the quantity of less toxic, moderately toxic and highly toxic pesticides, respectively used in the season, LND is the average holding size (ha), SFTY is the safety measures adopted while pesticide application (0 for using no measure, 1 for using 5 measures, 2 for using 7 measures and 3 for using 8 or more safety measures), and U is the error-term.

The long-term use of chemical pesticides can have an effect on respiratory, neurological, dermatologic, ophthalmologic, and gastro-intestinal systems (Pingali *et al*., 1994). It may also affect human cardiac system (Shetty *et al*., 2011). Accordingly, separate models were specified for estimating the probability of different types of health disorders. The model specified above suggests many important hypotheses related to the incidence of a particular pesticide-related health disorder. The model was developed using the farm, farm practice and farmer-specific explanatory variables. Theoretically, it is expected that a farmer with more land area would have more exposure to pesticides than a small farmer. On the other hand, large farmers may be better placed to put safety measures in place and avoid any health symptoms. This variable has been included to ascertain whether landholding has a negative or positive impact on incidence of health disorder. It is expected that an individual with smoking habit is likely to get poisonous effects of pesticides and therefore, this variable was included as one of explanatory variables in the model. The education of respondents has been put as one of the independent variable in the model. The educated respondents are expected to be aware about various safety measures, scientific methods of pesticide formulations/application and are expected to be at a lower risk of pesticide pollution.

On the basis of lethal dose values different pesticides have been categorized into highly toxic, moderately toxic and less toxic chemicals. Generally higher the toxicity of pesticide, the more hazardous it is to human health. We expect a positive sign for all category chemicals and quantity of these three categories of pesticides has been included as three explanatory variables to capture their effect empirically. Safety measure adopted while pesticide application (SFTY) has been put as one of the independent variables in the model to quantify the effect of safety measures adoption. It is hypothesized that when the applicator adopts more safety measures (out of selected ten measures), there will be less incidence of health disorder.

Valuation of Externalities

Over the past two decades, many attempts have been made to valuate pesticide risks. Florax *et al*. (2005) and Travisi *et al*. (2006) have provided willingness to pay (WTP) estimates for not only various human health risks, but also for environmental risks. There is a wide variation in the WTP estimates, as some studies have found higher WTP for human safety than environmental quality (Foster and Mourato, 2000), while others have shown higher WTP for environmental quality than for food safety and human health (Balcombe *et al*., 2007). Khan *et al*. (2002) have valuated environmental externalities through market price and contingent evaluation approaches. In light of the literature, we preferred to follow a mixed approach, viz. we used actual information obtained from respondents on human/animal poisoning and associated cost at market price and employed contingent valuation method for estimation of cost of rest of environmental externalities. An appropriate number of specialized respondents like pathologists, entomologists, toxicologists, environmentalists, skilled pesticide applicators, etc were selected and asked about their willingness to pay for avoiding environmental externalities which included damage cost and damage abatement cost.

Besides, technology adoption indices were estimated to classify the farmers on the basis of their adoption level of insecticides, dormant sprays, and fungicides by using following formula (2):

$$TAI = 1/n*[\Sigma(A_i/R_i)]*100 \qquad \ldots(2)$$

where, TAI is the technology adoption index of pesticides (dormant sprays, insecticides/acaricides and fungicides), A_i is the actual concentration of ith pesticide used, R_i is the recommended concentration of 'ith' pesticide, n is the number of pesticides applied, and i is the ith pesticide which ranges from 1 to n.

Results and Discussion

Description of Few Socio-economic Indicators

The majority of farmers (70%) belonged to either small or marginal farm category (Table 1), with average holding size of 1.36 ha, though the holding size was relatively more in the Shopian district. The important crop grown in the study area was apple to which farmers have allocated over 60 per cent of total sown area. Rice and vegetables were grown under irrigated conditions while maize and legumes were also grown in some area. The sex ratio (999) indicated a favourable pattern and male members were found relatively more than

Table 1. Socio-economic features of sample households

Particulars	Baramulla district	Shopian district	Average
Total area sown (ha)	1.56	1.88	1.72
Small farms (%)	74.0	69.0	71.5
Large farms (%)	26.0	31.0	28.5
Area under apple (%)	59.8	64.2	62.0
Amount spent on pesticides (% of total working costs)	54.1	52.2	53.4
Age of household-head	67	73	70
Illiterate household-heads (%)	18.0	21.0	19.5
Average household size (No.)	8.0	9.0	8.5
Sex ratio	994	1003	999
Main occupation for household members (%)			
Farming	52.1	58.1	55.1
Service	30.2	27.0	28.6
labour	2.9	3.5	3.2
Business	10.9	7.0	9.0
Dependents	3.8	4.4	4.1

Source: Computed by authors based on information collected through field survey, 2015-16

females in Shopian district. About 55 per cent members of farm households had agriculture as the main occupation. About 29 per cent members were employed in serving corporate/government offices and 4 per cent were completely dependents. The proportion of agricultural labourers among members of farm households was low, about 2 per cent only and it was really a concern for sustainable farming. There are many activities in apple cultivation that require huge investment; the variable cost on inputs for managing one kanal of average age orchard was estimated approximately at ₹ 5000 (Baba *et al*., 2012a); in which pesticides alone comprised 53.41 per cent. As far as literacy of household-heads was concerned, only 19.5 per cent of them were illiterate while rest had acquired education up to primary standard.

Indiscriminate Pesticide Use and Technological Gaps

Since apple constitutes more than 85 per cent of area under all fruits in the valley, it receives considerably high quantity of pesticides. The scientific spray schedule, developed by SKUAST-Kashmir in collaboration with concerned Development Department of Government of Jammu & Kashmir, for apple recommends only 6 essential fungicides to be sprayed at various stages of fruit development. Contrary to this, farmers had adopted diverse spraying system and the majority of them had sprayed their crops 8 or 9 times, 6 per cent of them had even treated apple crop with more than 12 sprays (Table 2). Despite the fact that the season under reference was a normal one, their crops received on average 01 spray of insecticides, 07 sprays of fungicides and 01 dormant spray. Only one farmer was found to have sprayed summer spray oil. Further, pesticides were applied on apple without the consideration of stages of fruit development and even a good proportion of farmers were found repeating same chemicals up to 3 or 4 sprays.

Table 2. Average number of pesticide application in the study area

Sprays (No.)	Farmer	
	No.	% of total
Up to 5	0	0.0
6	13	6.5
7	27	13.5
8	40	20.0
9	49	24.5
10	31	15.5
11	17	8.5
12	11	5.5
>12	12	6.0
Total farmers	200	100.0

Source: Computed by authors based on information collected through field survey, 2015-16

The scientific spray schedule has recommended chemicals with alternatives on the basis of their cost effectiveness for dormant and other stages of fruit development. Accordingly, Duratek dormant spray oil has been recommended as the first choice to the farmers owing to its less cost, however, only 2.5 per cent of the farmers had used this oil despite its availability in the markets (Table 3). About 9 per cent of the farmers had used diesel oil which was estimated to be almost double in cost than Duratek or Mac. Few farmers (1.5%) had been sprayed their orchards with some unidentified oil.

Table 3. Choice of chemicals for dormant spray (Ist spray) by farmers

Chemicals	Farmers		Technological gap (%)
	No.	% of total	
Diesel	17	8.5	-
Duratek	5	2.5	80.0
HP	101	50.5	50.0
Mac	71	35.5	40.0
Others*	3	1.5	60.0-75.0
Unidentified	3	1.5	-
	200	100.0	-

Note: *include Arbofine, ATSO, etc.

Source: Computed by authors based on information collected through field survey, 2015-16

Similarly, there was no uniformity among different orchards with respect to the spray of fungicides and insecticides in the study area. About 17 per cent and 10 per cent of orchardists had sprayed their apple orchards ten times and more than 10 times, respectively (Table 4). Scientific plant protection schedule for apple recommends spray of Mencozeb with alternative choice 'Captan' as second spray at green tip stage. In practice, only 29 per cent farmers had applied these two chemicals at this stage and the rest used other 7 chemicals which are even not mentioned in schedule for this stage. As third spray only 1 per cent of farmers had treated their crop with Captan + Hexoconazole, a most cost effective recommended fungicide and 99 per cent had chosen other fungicides. At this stage, no insecticidal spray was made by the sample respondents which are contradictory to the scientific recommendation which has advised an essential spray of Dimethoate insecticide. Even the use of unlabelled chemical by few of the farmers was seen in the apple growing belt of the valley. Moreover, there was a repeated application of same chemicals at different stages of fruit development and this scenario has put a question mark at the performance of extension agencies serving the valley.

If a new pesticide is found efficacious at evaluation, SKUAST-Kashmir recommends it for application on apple in Kashmir at specific concentration beyond which its negative externality (ies) would supposedly multiply. It is worth to note that none of the pesticides used in the study area was applied at the recommended concentrations. Among dormant sprays, technological gap in the use of Duratek was estimated at 80 per cent as farmers had put this oil and water in the ratio of 3.6:100 litres, respectively, instead of recommended level of 2:100 litres. On average, dormant oils were used 61 per cent more than scientific recommendations though gap was relatively lower in the application of Mac dormant spray oil (Table 3). In fungicidal sprays, the technological gap ranged from 5.5 per cent in Metirum+Pyroclostrobin to as high as 87 per cent in Hexaconazole (Table 4). In the case of insecticides, the maximum gap was observed in application of Fenzaquin, though the average gap among all the insecticides was estimated at 36 per cent. It was observed that the technological gap in the formulation/concentration of newly released pesticides was relatively lower. It is suspected that once the newly-introduced pesticides make their markets, a reasonable proportion of sub-standard/spurious chemicals of them are also pumped into the distribution system, particularly through unauthorized traders. The poor performance of pesticides and availability of substandard/spurious pesticides was found one of the reasons farmers use chemicals in more concentrations (Baba *et al*., 2015).

Since source of pesticides has been perceived as an important element to determine the concentrations/formulation of pesticides at field, a technology adoption index was accordingly developed, a measure of catch-all pesticide treatments by the farmers and was equated with source from where farmers obtained them. It was observed that the source of pesticides showed a sharp connect with technological gaps (Table 5). The farmers in apple-growing areas of the state are guided by trader-cum-contractors or unlicensed dealers and their choice/brand preference of chemicals is steered by these players. Even farmers formulate and apply pesticides as directed by these dealers (Baba *et al*., 2012a). About 57 per cent farmers procure pesticides either on cash or credit from contractors/traders and the majority (89.5%) of them falls within only 0-50 per cent adoption level category. Only 10 per cent of farmers, who purchased pesticides from contractor, adopt pesticide recommendation between 50 and 75 per cent. Easy credit availability from contractors-cum-traders (as kind in the form of fertilizers and pesticides which are often suspected for their quality) made majority of farmers to purchase pesticides from this source (Baba

Table 4. Choice of chemicals for fungicidal/insecticidal/acaricidal sprays by farmers

(in per cent)

Chemicals	Spray										Technological gaps (%)
	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	>10th	
Captan	9.0	2.0	11.0	7.0	10.0	10.0	3.0	3.0	-	-	14.3
Carbondazime+ Mancozab	-	1.0	-	-	9.0	3.0	-	-	-	0.5	7.0
Dodine	31.0	15.0	6.0	7.0	-	1.0	8.0	1.0	-	-	21.7
Fenaramol	-	3.0	3.0	2.0	4.5	6.0	4.0	-	-	-	38.4
Flusilazole	3.0	7.0	11.0	3.0	5.5	4.0	-	-	-	-	37.5
Hexaconizole	2.0	5.0	7.0	11.0	7.0	6.0	4.0	3.0	4.0	-	87.0
Mencozeb	25.0	19.0	10.0	19.0	2.0	3.0	2.0	-	1.0	1.0	13.3
Difenconazole	1.0	11.0	13.0	19.0	4.0	13.0	3.0	2.0	-	1.0	78.5
Metirum+ Pyroclostrobin	-	-	2.0	-	3.0	12.0	4.0	2.0	-	-	5.5
Propeneb	-	6.0	5.0	6.0	6.0	-	5.0		-	-	10.7
Ziram	-	-	-	4.0	-	1.0	7.0	1.0	1.0	1.0	21.8
Myclobutanil	12.0	11.0	5.0	-	-	-	-	1.0	-	0.5	26.0
Captan+Hexaconazole	-	1.0	5.0	1.0	3.0	-	-	-	-	-	71.2
Trifloxystrobin + Tebuconcazole	-	1.0	0.0	3.0	2.0	-	-	-	-	2.0	17.8
Chloropyriphos	9.5	9.5	10.5	6.0	7.5	1.5	3.0	1.5	1.5	3.0	30.0
Fenzaquin	7.5	5.5	6.5	4.0	8.0	1.0	-	-	-	1.0	68.3
Others*	-	3.0	5.0	8.0	9.0	10.0	12.0	5.0	10.0	-	13.1-32.7
No spray	-	-	-	-	19.5	28.5	45.0	80.5	82.5	90.0	-

Source: Computed by authors based on information collected through field survey, 2015-16
Note: *includes indentified/unlabelled pesticide also

Table 5. Adoption of scientific spray schedule and source of pesticides

Source	Pesticides purchased by farmers (%)	Adoption level (%)		
		0-50	50-75	75-100
Dealer	21.55	67.79	22.11	10.10
Sub-Dealer	6.50	61.64	26.25	12.11
Retailer	12.38	76.59	16.11	7.30
Key farmer	3.07	90.25	9.40	0.35
Contractor/trader	56.50	89.50	10.00	0.50

Source: Computed by authors based on information collected through field survey, 2015-16

et al., 2012b). Since dealer and sub-dealers are franchisees of pesticide company and they shall have to abide by the company terms and conditions that prevent them from market malpractices and misguidance of customers. Accordingly, a good proportion (10-12%) of farmers, who purchased pesticides directly from these sources, fell within even 75-100 per cent adoption level category. Institutions should intervene to check the malpractices in the pesticide distribution system.

Externalities of Pesticide Use

The aforesaid discussion on malpractices in pesticide distribution system and resultant deviation from scientific recommendations drew our attention to pesticide-related externalities. As positive externality, the intensive use of pesticides had significantly prevented apple yield losses to the tune of 40 per cent in either quantity or quality; however, the benefits of pesticides were offset to some degree by the costs imposed by them in mitigating negative externalities (environmental hazards including health problems). The unscientific formulation/method of application of pesticides, poor adoption of safety measures in handling chemicals and existence of pesticide residues above the maximum tolerance limits add to the severity of negative externalities.

Farmers/applicators were not found using all safety measure while handling chemicals. None of them had used any protective clothing during spraying. Only 60 per cent of applicators had adopted 1 or 2 measures out of 10 selected safety measures together (Field Survey, 2015-16). The majority of them had tied a piece of cloth or handkerchief as mask on their mouth. Only 23 per cent of the respondents had put on full-sleeve shirts, though many of them had even folded up their sleeves while operating. Only 1 per cent wore gloves or eye goggles. Most of the respondents kept empty containers and pesticide-smeared items unattended within the reach of children, poultry and animals.

The residue analysis of different pesticides in apple samples conducted at the Centre for Toxicology and Residue Analysis, SKUAST-Kashmir, showed that a high proportion of these samples contained residues in excess of maximum residual level (MRL). The samples of apple collected from different districts had residues of insecticide/acaricides like Fenzaquin, Phosalone and Chlopyriphos and fungicides like Myclobutanil, Difenconazole, etc. pesticides much above the permitted safe limit (Sheikh *et al*., 2015). Besides, the issues of phytotoxicity were also reported for apple-growing areas of the state (SKUAST-K pesticide surveillance team).

Regarding health risks, many minor poisoning cases were not reported to the doctors and even few of the severe cases were not brought out due to unsystematic monitoring system in these regions. However, the various pesticide-related health risks which accrued either due to direct exposure to pesticides or use of improper and inadequate safety measures while spraying included occupation poisoning and pesticide residues, as reported by farmers and labourers. The occupational poisoning may be dermatological, ophthalmological, gartro-intenstinal, neurological, cardiac, respiratory and other problems (Table 6). The majority of farmers (58.5%) and labourers (68.0%) reported incidence of neurological health disorders (which included headache, vomiting, behavioural problems, dizziness, giddiness, etc.), followed by gastro-intestinal (including diarrhoea, dehydration, impaired peristaltic movement, etc.), and respiratory health problems associated with pesticides.

Only 1 and 2 per cent of farmers and labourers, respectively had reported cardiac disorders (including sinus tachycardia, sinus bradycardia, depression, etc.). The respondents had shown common response to the occurrence of ophthalmic (including eye irritation, etc.) and dermatological (including hives, itching, rash, etc.) disorders. Since the labourers were hired for spraying by a number of orchardists, their response to various health problems was more compared to farmers. Skin and eye irritation problems were regarded as minor ailments that were often managed at home by the respondents, however, there were symptoms which were more severe and required medical check-up or hospitalization. The cost of occupational poisoning (which included consultation fee, transport, blood/ tissue test, loss of working day/efficiency, etc.) was calculated by using information obtained from farmers and workers. The total amount spent in a season on occupational poisoning was found to be ₹ 2211/ household, of this, maximum amount was spent on neurological and gastro-intestinal problems (Table 6). About ₹ 86/household was spent on the treatment of cardiac problems and per case cost on this problem was more owing to costly treatment of the ailments. The studies have shown an incidence of deadly ailments like brain cancer among population exposed to lethal pesticides (Bhat *et al*., 2010), though no such case was seen among sample respondents.

The externalities due to the existence of pesticide residues may be in the form of possibility of rejection of produce and contamination of water, etc. About 38 per cent farmers and 71 per cent of scientific group reported this problem due to pesticide residues. The cost associated with the problem was estimated on the basis of information, from farmers and sample specialists, on opportunity cost of bring safe water for drinking, monitoring/analysis for residues which together with the cost of overcoming effects of pesticide residues valued as WTP by the respondents amounted to ₹1517/farm.

Within production externalities, there were few cases of animal/poultry poisoning reported by respondents though they prevented them, particularly cattle from entering into pesticide-sprayed orchards. On an average, a farm household spent ₹376/farm on account of treatment of animals/poultry and loss in their yield. Since bees play an important role of pollinator, their poisoning not only result in loss of honey and bee colonies but also loss of apple productivity. The loss in this way was reported by 55 and 78 per cent of farmers and specialized respondents, respectively. The part of specialized respondents who had not responded to this problem remarked that we definitely have to face this problem in future. The cost of these losses was estimated at ₹3550/farm. Another important negative externality of pesticides was the pest resistance and resurgence. This possibility was reported by 46 per cent of scientists and we expected that farmers would be ignorant to this, though 3.5 per cent farmers showed concern about such problems and the associated cost of this problem came to be ₹5500/farm.

The pesticide-related environmental externalities result in the loss of natural balance of ecosystem and warrant huge external costs. The pesticide runoffs that reach the nearest water bodies have detrimental effect on fish, and aquatic plants, which are a part of the food web and play an important role in maintaining the eco-balance. The evidence of bio-magnification of poisonous chemical further aggravates this problem. It has been observed that on an average insecticidal spray led to 30-40 per cent mortality of predators (Anonymous, 2015). About 60 per cent of the farmer-respondents reported a significant decline in populations of beneficial organisms like pollinators, ladybird beetles, spiders, other parasitoids and in particular populations of birds and earthworms. Overuse of pesticides had brought about a decline in the bio-diversity of non-target organisms in these regions. About 20.5 per cent of the sample cultivators reported a significant loss of biodiversity and damage to the components of ecosystem. Relatively a higher

Table 6. Externalities associated with pesticide treatment on apple

Particulars	No. of farmers (N=200)	No. of specialized respondents* (N=50)	External cost (₹/farm)
1. Human health			
a) Occupational poisoning			
Respiratory	40.5	62.0	433
Neurological	58.5	68.0	880
Cardialogical	1.0	2.0	86
Dermotological	39.5	52.0	151
Ophtholomological	37.0	52.0	269
Gastro-intestinal	42.5	58.0	687
Others	0.0	1.0	5
b) Pesticide residues			
Contamination of water, fodder, produce, etc.	37.5	71.0	1517
2. Production externality			
Animal/poultry poisoning	10.0	16.0	376
Honey bee loss	54.5	78.0	3550
Pest resistance and resurgence	3.5	46.0	5500
3. Environmental externality			
Loss of beneficial insects and birds	60.5	80.0	460
Loss of biodiversity and other components of ecosystem	20.5	38.0	530
Campaign and knowledge networking, etc	4.5	40.0	540

Source: Computed by authors based on information collected through field survey, 2015-16; *As discussed in methodology proportion of specialized persons reported these externalities. These problems also impair soil health and involve cost in the form of reduced crop productivity. There is a need of knowledge networking of different stakeholders as a mission and reformation of policies towards resilient and balanced ecosystem to which a significant amount of costs are involved. The contingent valuations of the costs associated with direct environmental problems amounted to ₹1530/ farm. In this way, the unscientific application of different pesticides on apple involved a total cost of ₹14984/farm (or ₹8514/ha) to be incurred on environmental damage costs and damage abatement costs which had significantly reduced the benefits of pesticide-use in the region.

Estimates of Pesticide Health Risk Model

Separate functions were specified for estimating the probability of 5 pesticide-related health ailments, viz. dermatological, neurological, respiratory, gastro-intestinal and ophthalmological. The estimates of the logit pesticide-health risk regression models presented in Table 8 revealed that models for pesticide-related disorder have 90 or higher percentage of correct predictions. Further the chi square estimates for all equations have turned out statistically significant, indicating models as best fit. The coefficients of all functions revealed almost common behaviour of various explanatory variables. The results revealed that the aged respondents were more vulnerable to pesticide-related health disorder though its coefficient is statistically insignificant in dermatological and neurological disorders. This is in line with the fact that as the age advances, the level of immunity decreases and the elderly farmers should not be permitted to attend spray activities or allowed with safety measures only. The education level held a significant relationship with non-occurrence of health disorder. The educated pesticide-applicators or farm attendants may be more conscious of putting on safety gadgets that help reduce probability of occurrence of any health problem.

The higher quantity of pesticide-use was found to increase the probability of a particular disorder, though the relation was more significant with pesticide of moderate and high levels toxicity. It was seen that respondents who considered the price of produce as an important factor, were not aversive of health risk and instead, they were willing to spray more pesticides, even higher than the scientific recommendations. Even such households were most likely to have a higher threshold (higher acceptance level) for health symptoms before they decided to take special care that involved costs. Respondents who had long duration of pesticide exposure were more exposed to pesticides and their probability of falling sick was higher.

Table 7. Logit estimates of incidence of pesticide-related health disorders in Kashmir valley

Variable	Dermatological		Respiratory		Neurological		Gastro-intestinal		Ophthalmological	
	Coef.	Z	Coef.	Z	Coef.	Z	Coef.	Z	Coef.	Z
Intercept	-7.351		-3.195		-17.738		-21.99		-5.612	
AGE	0.037	0.089	0.042*	2.870	0.022	0.001	0.162*	2.121	0.109*	2.078
EDU	0.074	0.105	-0.015*	2.022	-0.022*	1.922	-0.080*	2.059	-0.121*	1.976
PSTl	-0.014	0.031	0.117	0.132	0.033*	1.992	0.015	0.099	0.184*	1.955
PSTm	0.019*	1.898	0.099*	2.033	0.061*	2.903	0.052*	2.131	-0.093	0.197
PSTh	0.034*	1.999	0.132*	3.832	0.170*	3.202	0.182*	1.871	0.632*	2.919
LND	-0.024	0.256	0.063	0.256	0.022*	2.126	0.032*	3.059	0.134*	2.125
SFTY	-0.159*	2.101	-0.065*	2.201	-0.163*	1.897	-0.127*	1.958	-0.099*	3.051
DUR	0.010*	2.915	-0.101*	2.002	0.222*	2.112	-0.055	0.025	0.210*	3.215
HABs	-0.347	0.123	0.078*	0.009	0.265	0.001	0.068*	1.899	0.702	0.001
Max. livelihood ratio	42.087		59.953		64.211		38.586		64.099	
Correct prediction (%)	89.91		90.01		90.15		92.22		91.00	
Chi square estimate	93.44		79.12		111.12		140.74		89.93	

Note: *Denotes significance at 0.05 or better probability level

The regression estimates for the variable in all the models, except respiratory disorder, lent support to these expectations. The duration of exposure could be longer due to the size of holding and this variable turned out to be a significant contributor of the probability of advent of a particular disorder. Supposedly, the adoption of safety measures during pesticide sprays was associated with probability of respondent to be free from health risks. The logit estimates of this variable emphasized upon the diffusion of various safety measures among farmers and applicators in particulars if decline in the probability of health disorder was sought. Except for respiratory and gastro-intestinal health problems, the estimates of smoking habit were not statistically significant. To conclude the maximum likelihood ratio for all the equations with specified variables have been found statistically significant.

Conclusions and Policy Options

The study has revealed that the majority of farmers belong to small farm category, though they allocate a major proportion of their total sown area to apple cultivation and spend as high as 53.41 per cent of working capital on pesticides. Orchards receive on average 9 sprays, although few even go beyond 12 sprays. The repeated use of single pesticide for 3 or 4 sprays without consideration of stages of fruit development and chemicals which do not even appear in scientific spray schedule has been found common in the study area. Further, there are huge technological gaps in formulation of pesticides as more concentrated sprays are being applied in the fields. Contractors/traders are the important sources of pesticides-supply to farmers and they even misguide them in choosing, formulating and spraying pesticides which lead to huge technological gaps in pesticide application at their farms. The study has further revealed that though the application of pesticides saves the apple crop in both quantity and quality terms, their benefit is being offset by the huge amount, they need to incur to mitigate the damage to environment. Estimates of pesticide risk model have ascertained that the quantity of more toxic pesticides significantly increases the probability of falling sick, while use of safety measures during handling pesticide bring down the probability of respondent falling sick of a particular pesticide-related ailment. Following policy options has emerged out of the findings of the study:

- The state government should ensure the availability of pesticides listed in the scientific spray schedule and enforce a check on spurious/sub-standard pesticides in the market. Enhanced institutional credit, testing of pesticides on fast track basis, labelling of pesticides and information regarding handling, formulation and methods of spray printing in local language would be of immense importance.
- Surveillance and forecasting system for monitoring/identifications of pests, diseases and assessing pesticide-related externalities needs to be put in place, as a step towards enriching environmental quality, in collaboration with different stakeholders. There is a need of knowledge networking regarding various externalities of pesticide application and measures to reduce the pesticide use and damage abatement costs. Strengthening of extension agencies and capacity development of stakeholders in this direction would have better pay off.
- Effective measures are required for dissemination of IPM modules to prevent the disease and insect/pest incidence in apple wherein pesticide companies find an important role, especially through product development in bio-pesticides. Moreover, IPM may be taken as a farming system approach rather than a commodity approach. The pesticide industries should regularly check the incursion of any unauthorized/unlicensed trader to prevent the selling of spurious pesticides and in turn to retain market share.
- An effective response is required to various WTO negotiations like sanitary/phytosanitary measures to become globally competitive which emphasize upon production of better quality produce with pesticide residues much below MRLs. The same effect can be generated by a concerted effort to reduce the dose of most toxic category of chemicals and by bridging technological gaps.
- The scientists and agricultural extension workers should have regular interactions with R&D wing of pesticide companies to become familiar with the upcoming products. They should conduct research on contemporary issues of pesticides and externalities and may collaborate with them in the required endeavours.

- Farmers and skilled workers should be encouraged to adopt various safety devices during pesticide mixing, formulation of solution and spraying. Innovation in the form of location-specific light weight and easy to carry safety devices may enhance its adoption by the applicators.

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