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Patterns of pesticide application in district Sangrur, Punjab, and farmers' awareness regarding its health hazards

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Abstract
This study meticulously investigates the patterns of pesticide application among agriculturists in the Sangrur district of Punjab, while also evaluating their awareness regarding the associated health hazards. A cross-sectional survey conducted between January and July 2019 engaged 100 farmers, employing structured interviews to gather data on pesticide usage, safety protocols, and health outcomes. The findings reveal a pervasive dependence on chemical pesticides, accompanied by a limited adoption of protective measures during application. Although a significant majority of farmers acknowledged the potential health risks linked to pesticide exposure, this awareness did not consistently manifest in safe handling practices. Commonly reported acute symptoms encompassed nausea, dermal irritation, and headaches, with a subset of farmers enduring more severe afflictions such as respiratory complications and dermatological disorders. Notably, a considerable proportion of farmers stored pesticides within household premises and disposed of containers improperly, thereby exacerbating exposure risks. The study accentuates the imperative for targeted interventions aimed at enhancing farmers' comprehension of pesticide hazards and fostering safer application practices. Recommendations include the implementation of comprehensive training programs, augmenting access to personal protective equipment, and establishing robust support systems through governmental and non-governmental organizations to facilitate the transition towards safer agricultural practices.

Keywords: Pesticide usage, health hazards, personal protective equipment, farmers' awareness, agricultural residue

Introduction

India is the second most populous nation in the world, following China (NCP 2019). According to the United Nations (World Population Prospects 2017), India's population was recorded at 1,210,854,977 during the 2011 census, accounting for 17.55% of the global population. Consequently, there exists a substantial demand for the production of food and fiber (NCPl 2019). To address these pressing needs, the agricultural productivity of India was significantly enhanced with the advent of the Green Revolution in 1965 (Khush 1999) [10]. The Green Revolution heralded the introduction of innovative farming techniques, as well as synthetic fertilizers, pesticides, and herbicides (Mathur *et al*. 2005) [8].

In India, the pattern of pesticide utilization diverges significantly from global trends. Worldwide, the application of insecticides accounts for approximately 44%, whereas in India, this figure escalates to a substantial 76% (Mathur 1999) [9]. The consumption of pesticides has surged from 154 metric tons in 1954 to an astonishing 88,000 metric tons by the 2000-2001 period (Mathur *et al*. 2005) [8]. In contrast, herbicides and fungicides are employed to a lesser extent than insecticides. The predominant use of pesticides is observed in cotton cultivation, surpassing their application in wheat and paddy (Aktar *et al*. 2009) [2]. According to Sharma and Thaker (2011) [17], pesticide consumption witnessed an increase from approximately 78,000 tons in 1965-1966 to an astounding 26.5 million tons by 2009-2010. The Ministry of Statistics and Programme Implementation (2018-2019) reports that Indian agriculture contributes around 15.4% to the GDP composition.

Among the various states in India, Punjab stands as the epicenter of the Green Revolution, liberating its population from reliance on other states or countries for sustenance (Sidhu and Byerlee 1992) [19]. As per the Statistical Abstract of Punjab (2005) [20], grain production escalated from approximately 3.16 million tons during 1960-1966 to 25.66 million tons by 2004-2005. However, this remarkable increase in production has not been without its drawbacks; the excessive reliance on pesticides is a notable concern (Shiva 1991; Yadav 2006) [18, 23]. Pesticides were originally intended to mitigate the threats posed by harmful pests, weeds, and diseases that jeopardize crop yields. Unfortunately, the indiscriminate application of synthetic pesticides has resulted in significant environmental contamination (Agarwal and Pandey 2017).

Farmers in Punjab utilize a substantial quantity of pesticides to safeguard their crops from pests, diseases, and other threats. The application of pesticides has been recorded at an alarming rate to protect cotton crops from the pest *Helicoverpa armigera* (American bollworm) (Mehrotra and Phokela 1992) [11]. According to the report by Puri *et al.* (1999) [15], pesticide consumption in India was approximately 54% for the cotton crop alone, despite cotton cultivation accounting for a mere 5% of the agricultural area in the country. Due to its prolific agricultural output, particularly in cotton farming, the Malwa region of Punjab is renowned as “Makheon Meetha Malwa” (sweeter than honey). Among the three regions of Punjab—Majha, Malwa, and Doaba—Malwa constitutes the largest portion of the state. Geographically, it is situated between 29°-30’ and 31°-10’ North latitudes and 73°-50 and 76°-50 East longitudes. The districts encompassed within the Malwa region include Moga, Faridkot, Mansa, Bathinda, Patiala, Sangrur, Fazilka, Ludhiana, Ferozpur, Barnala, and Muktsar (Indian Census 2011) (Mittal *et al*. 2014) [13]. As per the

Statistical Abstract of Punjab (2011) [21], a staggering 86.5% of the total area of 30,200 km² in Malwa is designated as agricultural land. The primary crops cultivated in this region comprise rice, wheat, and cotton.

Presently, this region is grappling with severe health hazards stemming from the improper use of conventional pesticide chemicals. Reports indicate contamination of groundwater with heavy metals such as Lead (Pb), Arsenic (As), and Uranium (U) due to inadequate pesticide application. Numerous cases of cancer and reproductive disorders have also been attributed to the excessive use of pesticides (Mittal *et al*. 2014) [13]. Pesticides encompass a diverse array of chemical compounds, including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators, defoliants, and desiccants. Among these, organochlorines (OC) have been effective in managing various diseases such as malaria and typhus. With the advent of advanced technology in the 1960s, organophosphate (OP) insecticides were introduced, followed by carbamates in the 1970s and pyrethroids in the 1980s, along with herbicides and fungicides during the 1970s to 1980s. The inception of pesticides can be traced back to the production of BHC (benzene hexachloride) in 1952 near Kolkata (Aktar *et al*. 2009) [2]. The utilization of pesticides surged during the 1960s, spurred by the adoption of High Yielding Variety (HYV) seeds, which were more amenable to conventional pesticides. Since that time, the practice of pesticide application has escalated significantly (Ranjan 2017) [16].

The primary objective of the present research is to assess the awareness among farmers concerning pesticide usage patterns and their implications for human health as well as the environment.

Materials And Methods

A comprehensive random survey was conducted to collect data on various facets of pesticide utilization, including type, frequency, dosage, and farmers' perceptions regarding associated issues such as health implications and economic considerations, as well as pest management practices.

Study Area: The research was undertaken in Punjab, situated in North West India, which extends from 29°32’ to 32°32’ North and 73°55’ to 76°50’ East. It is bordered by Jammu and Kashmir to the north, Himachal Pradesh to the east, and Haryana and Rajasthan to the south. This region encompasses an area of 50,362 km², making it one of the smallest states in India. The study was executed in five villages within the Sangrur district: Khurana, Kammomajra, Kular Khurd, Kanoi, and Ubhawal (Table 1). The entire study area is situated between latitudes 29°43’25” and 30°41’41” North and longitudes 75°33’09” and 76°12’40” East, covering an expanse of 3,685 km².

Table 1: Location of the Study Area

Villages	Geographical Coordinates	
	Latitudes	Longitudes
Khurana	30.2441° N	75.9063° E
Kammomajra	30.2092° N	75.8759° E
Kular Khurd	30.1931° N	75.8547° E
Kanoi	30.1656° N	75.8578° E
Ubhawal	30.2131° N	75.7764° E

Data Collection

A total of 100 farmers were randomly selected to gather the requisite information for this study. The interviewees were not pre-informed to mitigate biased responses and to attain genuine insights into their farming practices. Interviews were conducted in the local vernacular. Data was amassed through a structured questionnaire, one-on-one interviews, and group discussions, aimed at obtaining information concerning prevalent pests, pathogens, and diseases affecting crops, factors influencing pesticide selection, availability of pesticides, frequency, timing, dosage, and patterns of pesticide application, as well as safety measures adopted and health implications of pesticides on users. Additional information was also collected regarding various related and ancillary factors pertinent to cultivation practices. Overall, the amassed data were categorized into three sections: (i) pesticide use and management practices, (ii) protective measures and health-related issues, and (iii) farmers' perceptions regarding the environmental impact of pesticides. The questionnaire was meticulously designed in both multiple-choice and binary question formats. A comprehensive record of all collected information was maintained for subsequent analysis.

Data Analysis: The gathered data was systematically classified according to the acquired information and analyzed using graphs and pie charts.

Results and Discussion

Table 2: Land Holding in acres of farmers having different ranges of land

Sr.No	Land Holding (in acres)	No. of Farmers					Total
		Khurana	Kammomajra	Kular Khurd	Kanoi	Ubhawal	
1	0-10	19	18	15	17	19	88
2	10-20	1	2	2	0	1	6
3	20-30	0	0	3	1	0	4
4	30-40	0	0	0	1	0	1
5	40-50	0	0	0	0	0	0
6	50-60	0	0	0	1	0	1
Total		20	20	20	20	20	100

According to the results, 88 farmers own land ranging from 0-10 acres, 6 from 10-20 acres, 4 from 20-30 acres, 1 from 30-40 acres, 0 from 40-50 acres, and 1 farmer from 50-60 acres (Table 2). As per Table 3, the prevalent nomenclature of the pesticides employed by farmers, along with their respective chemical compositions and toxicity classifications, is also delineated. Furthermore, it illustrates the specific type of pesticide utilized and the corresponding crop for which the pesticide is applied.

Table 3: A comprehensive overview of various pesticides, detailing their common designations, chemical classifications, and associated toxicity categories

S.No	Trade Name	Common Name	Type of Pesticides	Chemical Class	Toxicity Class	Crop
1	Topik	Clodinafop propargyl	Herbicide	Organochlorine	U	Wheat
2	Melsa	Pinoxaden	Herbicide	Phenylpyrazoline	-	Wheat
3	Padan	Cartap	Insecticide	Carbamate	II	Rice
4	Hexalife	Hexaconazole	Fungicide	Triazole	U	Rice
5	Mission	Sulphossulfuron	Herbicide	Sulfonylurea	-	Wheat
6	Chess	Pymetrozine	Insecticide	Pyridine Azomethines	-	Rice
7	Hindol	Chloripyrophos	Insecticide	Organophosphate	II	Rice
8	Super Knot	Buprofezin	Intecticide	Organophosphate	U	Rice
9	Attack	Metsulfuron Methyl	Herbicide	Sulfonylurea	U	Wheat
10	San Quat	Paraquate dichloride	Herbicide	Bipyridyl	II	Wheat
11	Leader	Lambdacyhalothrin	Insecticide	Pyrethroid	II	Wheat
12	Kay-D 58	2,4-D	Herbicide	Phenoxy-carboxylic-acid	II	Wheat/Rice

***** Toxicity class of pesticides as classified by the World Health Organization. II: moderately hazardous; U: unlikely to present acute hazard in normal use.

Farmers interviewed have employed a variety of pesticides to effectively target specific pests, weeds, and diseases that accompany their crops (Table 4). The column graph depicted in Fig.2 illustrates the number of farmers utilizing different pesticides. Mahmood *et al.* (2016) [7] examined pesticides, encompassing their various types, utility, and detrimental effects on the environment. The authors also explored strategies to mitigate the reliance on pesticides, aiming to avert their adverse consequences for future generations. Mehrotra (1989) [12] conducted an investigation into pest control in India utilizing chemical pesticides such as DDT and HCH, with organophosphates employed to combat diseases and pests. The findings indicated favorable outcomes from the application of these pesticides against various infestations and ailments. Furthermore, the author elucidated strategies to mitigate the deleterious effects of pesticide usage.

Table 4: A diverse array of pesticides employed by agriculturalists across five villages

S.No	Trade Name	Crop	Target Pest/Weed/ Diesease	No. of Farmers					Total
				Khurana	Kammo majra	Kular Khurd	Kanoi	Ubhawal	
1	Moolah	Wheat	Weed (*Phalaris minor*)	5	2	0	0	0	7
2	Pulsar	Rice	Pests (flies, termites, fire ants)	5	1	8	6	0	20
3	Delete	Wheat	Weed (*Phalaris minor*)	5	0	2	0	4	11
4	Melsa	Wheat	Weed (*Phalaris minor* and *Avena ludoviciana*)	0	1	2	4	0	7
5	Hindol	Rice	Pests(stem borer, leaf borer, etc.)	6	0	2	8	0	16
6	Kaiser	Wheat	Weed (*Chenopodium album, Melilotus alba*)	3	2	0	4	6	15
7	Lucifer	Wheat	Weed (*Phalaris minor*)	6	1	0	9	7	23
8	Omega	Wheat	Weed (*Phalaris minor*)	0	0	0	0	0	3
9	Yara Vita	Wheat/ Rice	Disease	0	4	0	4	0	4
10	Lotus Manganese	Wheat	Disease	0	5	3	4	0	12
11	Attack	Wheat/ Rice	Weed	0	4	2	8	0	14
12	San Mast	Wheat	Weed(*Mililotus* sp., *Vicia* sp.)	0	0	0	8	10	18
13	Hexalife	Rice	Fungi	4	1	4	0	0	9
14	San Quat	Wheat/ Rice	Weed	6	0	2	0	8	16
15	Mission	Wheat	Weed	0	5	7	0	0	12
16	Kri-Shan	Rice	Pest(grubs, termite)	0	3	0	0	0	3
17	Kritap	Rice	Pest(stem borer, leaf folder)	0	1	0	4	5	9
18	San Ron	Wheat	Weed (*Chenopodium album, Melilotus alba*)	0	2	4	0	7	13
19	Algrip	Wheat	Weed	0	4	1	6	0	11
20	Padan	Rice	Pest (chewing and sucking insects)	2	4	3	5	8	19
21	Topik	Rice	Weed (Phalaris minor)	20	20	20	20	20	100
22	Leader	Wheat	Pest	20	20	20	20	20	100
23	Chess	Rice	Pest	5	1	4	6	5	21
24	Super Knot	Rice	Pest (*Nilaparvata lugens* and *Sogatella furcifera*)	6	7	8	9	5	35

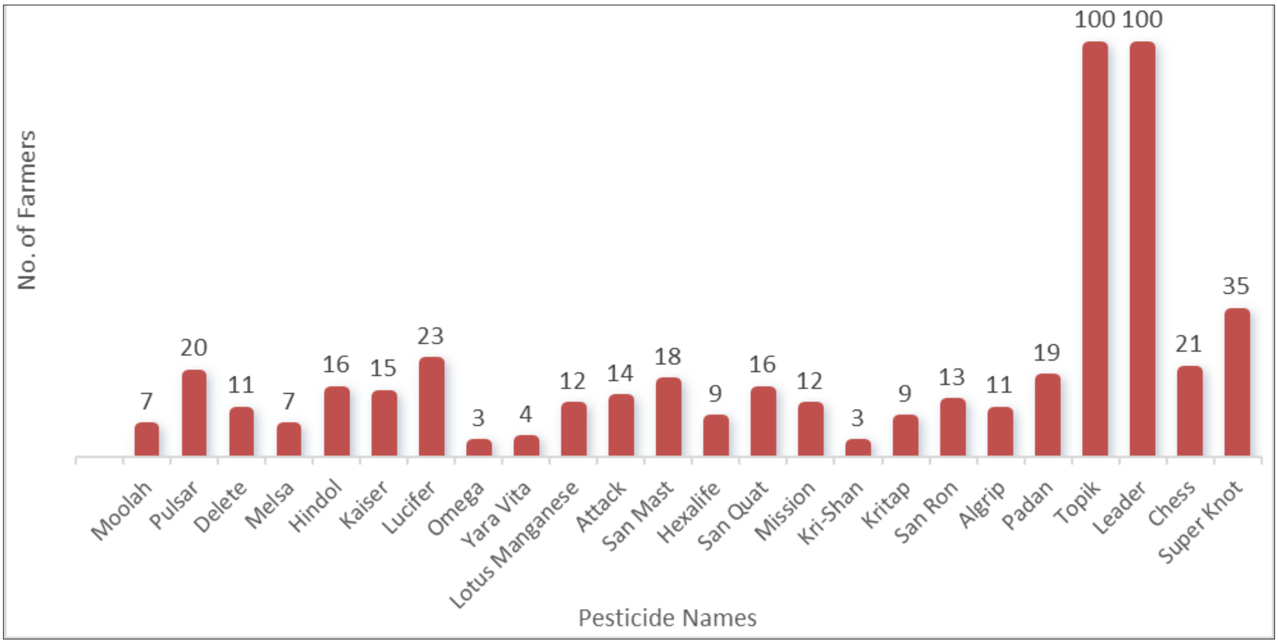

Fig 2: A column graph illustrating the various pesticides employed by the number of agricultural practitioners

After the harvest of both Rabi and Kharif crops, farmers adeptly managed crop residue through various methods, including burning, fodder production, and soil tillage, according to their preferences and convenience. Table 5 illustrates the strategies employed by farmers for crop residue management following the harvest of both Rabi and Kharif seasons. The findings reveal that the predominant method of managing Rabi crop residue is fodder production, utilized by 50% of farmers, while in the case of Kharif crops, soil tillage is the preferred method, adopted by 34% of farmers (Fig. 3).

Table 5: Methods Employed by Farmers to Manage Crop Residue

S.No.	Crop	Method	No. of Farmers					Total
			Khurana	Kammomajra	Kular Khurd	Kanoi	Ubhawal	
1	Rabi	Burning	0	0	0	0	0	0
		Fodder	20	20	20	20	20	100
2	Kharif	Burning	0	0	13	9	10	32
		Soil tillage	20	20	7	11	10	68

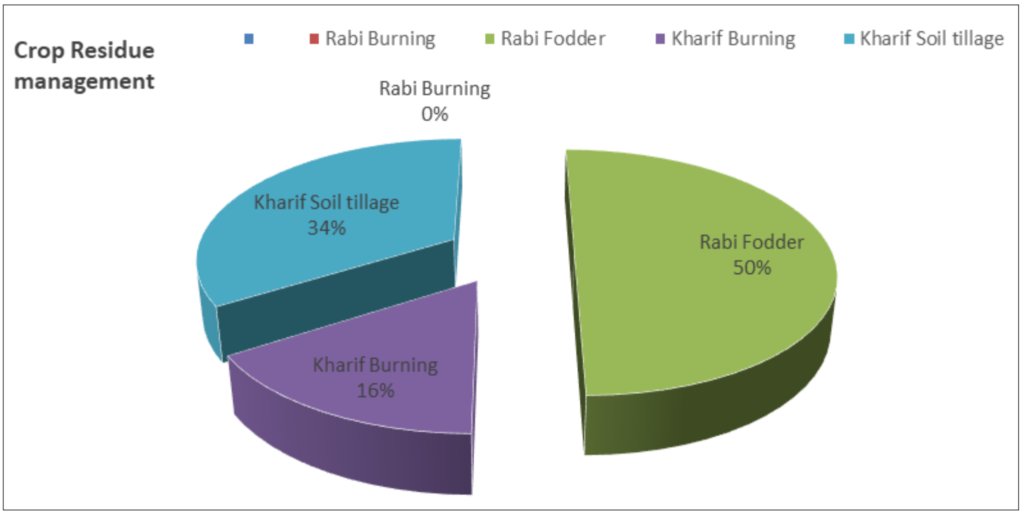

Fig 3: Different methodologies employed by agronomists for the management of crop residues following the Rabi and Kharif seasons, accompanied by their respective percentages.

Six distinct parameters, namely soil analysis, recommended pesticide dosage, pesticide storage locations, post-application container disposal, awareness of the environmental impacts of pesticides, and alternative methods that farmers can adopt to reduce pesticide usage. These elements were incorporated to gather insights from farmers regarding their awareness of human health and environmental implications (Table 6, Fig. 4).

Table 6: Parameters selected to contemplate farmers' cognizance

S.No	Parameters		No. of Farmers					Total
			Khurana	Kammomajra	Kular Khurd	Kanoi	Ubhawal	
1	Soil Testing	Yes	2	2	0	0	1	5
		No	18	18	20	20	19	95
2	Recommended pesticide Dosage	Yes	12	16	14	14	17	73
		No	8	4	6	6	3	27
3	Pesticide Storage Place	Safe	6	6	8	6	7	33
		Unsafe	14	14	12	14	13	67
4	After Use of Pesticides Container	Yes	6	6	8	6	.7	33
		No	14	14	12	14	13	67
5	Awareness regarding the effect of pesticides on the Environment	Moderately Harmful	13	17	15	14	16	75
		Very Harmful	7	3	5	6	4	25
6	Alternative Methods	Crop Rotation	20	20	20	20	20	100
		Organic Farming	8	4	3	6	3	24

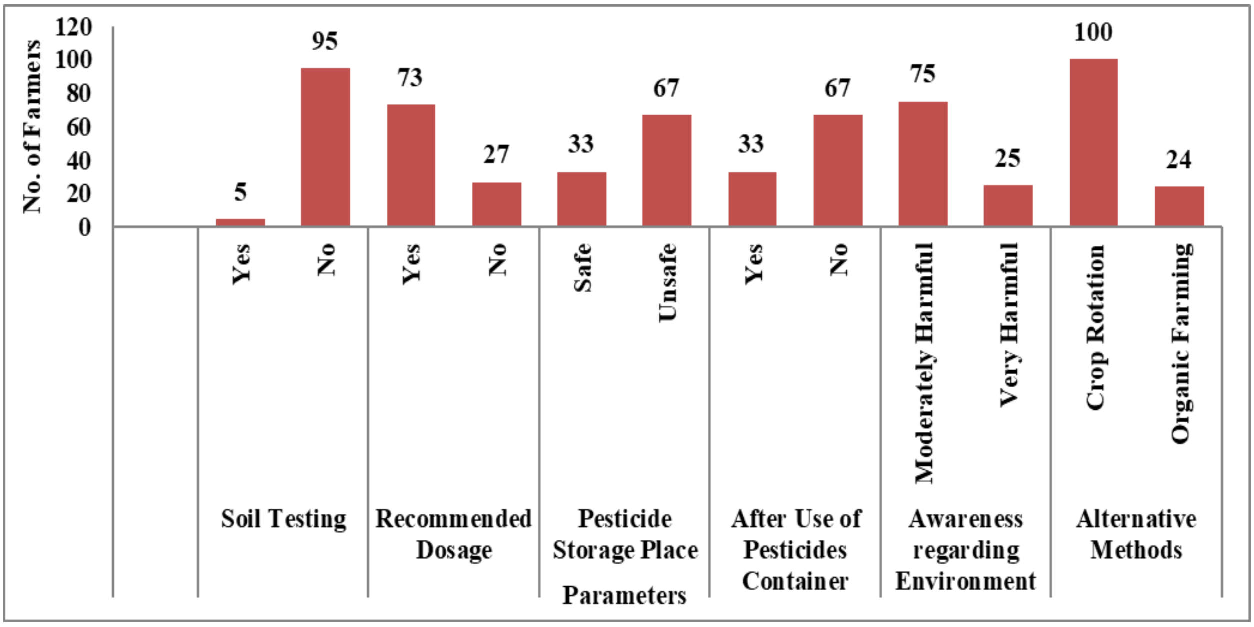

Fig 4: Bar graph illustrating various parameters to assess farmers' awareness.

Survey results regarding the implementation of protective measures have revealed that among the various safety protocols, the most prevalently utilized forms of protection while handling or applying pesticides are gloves (59%) and footwear (27%). Regrettably, there is a notable lack of awareness among farmers concerning the necessity of utilizing face masks and appropriate clothing, such as long pants and long-sleeved shirts (Table 7, Fig.5).Wilson (2005) [22] conducted a comprehensive study on the pesticide exposure experienced by farmers in developing nations, examining both acute and chronic health repercussions, as well as the protective measures implemented by these agricultural workers. The findings indicated that the farmers invested minimally in protective equipment. Kumar *et al.* (2012) investigated the perils associated with the improper application of pesticides on humans, animals, and the environment. The study revealed that the use of Personal Protective Equipment (PPE) can significantly mitigate pesticide exposure. Furthermore, the authors advocated for the consumption of organic food products in preference to conventional alternatives.

Table 7: Personal protective gear used by farmers during pesticide application in the field

S.No.	Protective Measures	No. of Farmers					Total
		Khurana	Kammomajra	Kular Khurd	Kanoi	Ubhawal	
1	Gloves	12	6	17	11	10	56
2	Long Sleeve Shirt	0	0	1	0	0	1
3	Long Pants	5	1	1	3	1	11
4	Boot/shoes	7	0	12	5	1	25
5	Face Mask	0	1	0	0	0	1

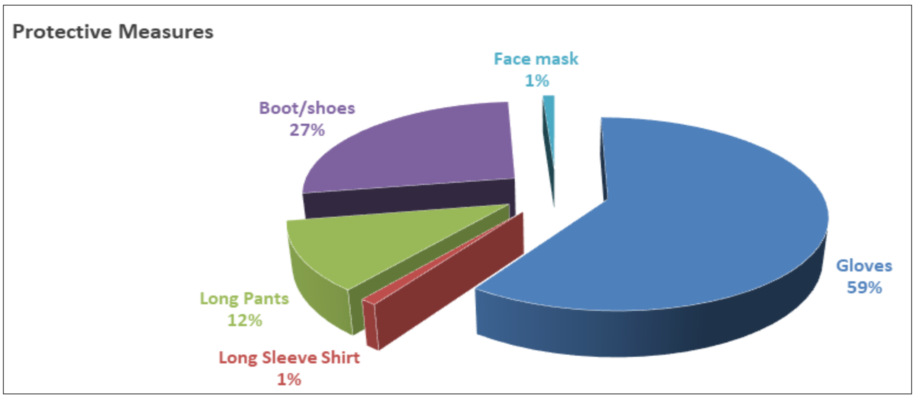

Fig 5: Pie chart illustrating the distribution of farmers utilizing various types of personal protective equipment.

The findings presented in Table 8 and Fig. 6 elucidate the myriad symptoms encountered by farmers during pesticide application. The results indicate that the most significant health consequence of pesticide use is the occurrence of skin rashes, affecting 64% of the individuals surveyed. This may be attributed to insufficient protective clothing. Following skin rashes, the second most prevalent issue identified in the survey is headaches, which can be linked to the absence of face masks. As per Ecobichon (2001) [4] the improper application of hazardous pesticides in developing nations can lead to a myriad of acute and chronic health repercussions for the populace. The author advocated for the implementation of training programs for farmers, aimed at instructing them on the judicious use of pesticides. In a comparable investigation, Jeyaratnam *et al*. (1987) [5] examined the incidence of acute pesticide poisoning among farmers in Indonesia, Sri Lanka, Malaysia, and Thailand. The findings indicated that due to a deficiency in education regarding safety protocols while handling pesticides, farmers in developing nations may encounter significant health challenges. Andersson *et al*. (2014) [3] conducted a comprehensive review regarding the ramifications of pesticides on human health risks and the associated cost-benefit analysis. The findings revealed that pesticides adversely affect individuals through both direct and indirect exposures, exemplified by farmers and consumers, respectively. Another survey by Kumar *et al*. (2017) [6] during the years 2014-2015 examined the patterns of pesticide usage through a questionnaire distributed among farmers cultivating bhindi, with the aim of analyzing their awareness regarding various aspects related to pesticides. The findings indicated that only a small fraction of farmers possessed knowledge about the detrimental effects of pesticides on human health. Numerous health issues were also observed during the application of pesticides, including skin and ocular irritation, headaches, breathlessness, and coughing. Mittal *et al*. (2014) [13] elucidated the myriad factors associated with pesticide utilization in the Malwa region of Punjab, India, encompassing occupational, environmental, and societal dimensions. They also delineated various strategies to mitigate the deleterious effects of pesticides.

Table 8: Symptoms Associated with Pesticide Exposure

S.No.	Symptoms	No. of Farmers					Total
		Khurana	Kammomajra	Kular Khurd	Kanoi	Ubhawal	
1	Headache	2	5	1	1	3	10
2	Skin Rashes	8	11	11	11	4	43
3	Dizziness	3	1	0	1	0	5
4	Difficulty in Breathing	5	1	0	0	1	7
5	Nausea	2	0	0	0	0	2

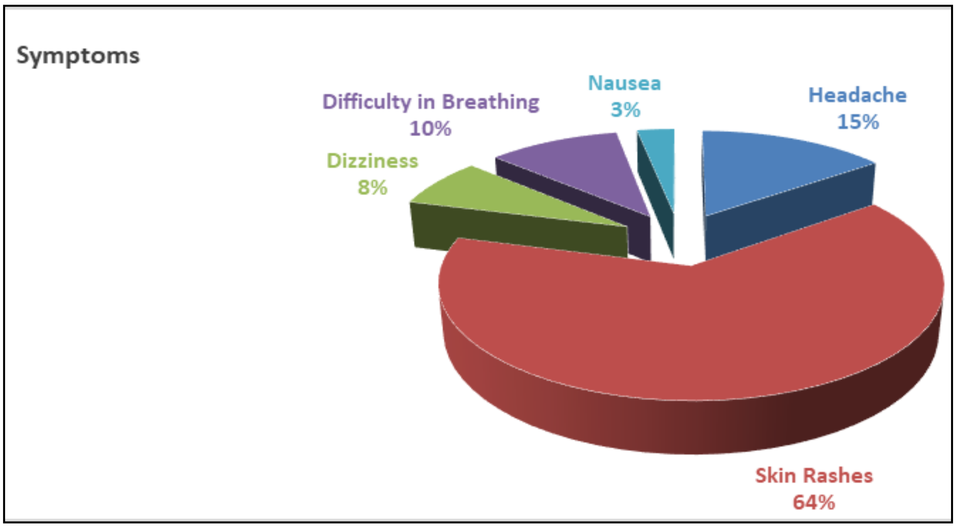

Fig 6: Pie chart illustrating the distribution of various symptoms encountered by farmers upon exposure to pesticides.

The table 9 elucidates the methodologies employed by farmers in the disposal of pesticide packages or containers post-application. A predominant number of them discard the packages as refuse, while others opt to dispose of them in open fields, and some resort to incineration or interment in a pit. Fig. 7 illustrates the percentages associated with various disposal methods utilized by farmers, and regrettably, the most prevalent practice is the indiscriminate disposal of waste in open fields, accounting for a concerning 52%.

Table 9: Site for the disposal of empty pesticide containers

S.No.	Site of Disposal	No. of Farmers					Total
		Khurana	Kammomajra	Kular Khurd	Kanoi	Ubhawal	
1	Put in rubbish/trash	5	9	9	6	11	40
2	Burnt	9	7	3	6	1	20
3	Thrown in Open Field	15	14	11	18	11	69
4	Burried	3	0	1	0	0	4

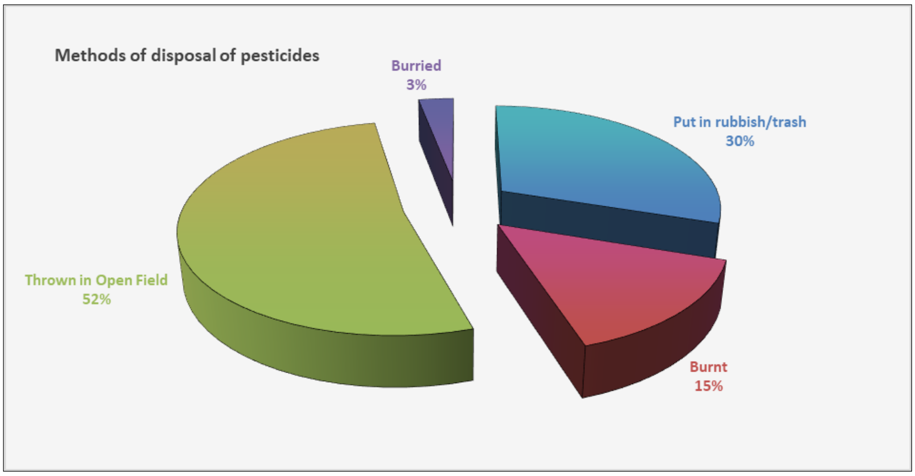

Fig 7: Pie chart illustrating the distribution of various methods employed for the disposal of pesticide containers.

Conclusions

A comprehensive randomized survey was undertaken to amass data on various dimensions of pesticide utilization, encompassing types, frequency, dosage, and farmers' perceptions regarding pertinent issues such as health ramifications and economic implications. Results indicated that farmers employed a diverse array of pesticides to effectively target specific pests. Following the harvest, farmers adopted various methodologies such as residue incineration, fodder production, and soil cultivation to eliminate crop remnants. The predominant strategy for managing Rabi crop residue is fodder production, utilized by 50% of farmers, whereas for Kharif crops, soil tillage emerges as the preferred approach, adopted by 34% of farmers. Six distinct parameters were examined: soil analysis, recommended pesticide dosages, pesticide storage locations, disposal of post-application containers, awareness of the environmental ramifications of pesticides, and alternative strategies that farmers can implement to mitigate pesticide usage, alongside gathering insights regarding their cognizance of human health and ecological implications. Survey results concerning the implementation of protective measures have revealed that among the various safety protocols, the most commonly employed forms of protection while handling pesticides are gloves (59%) and footwear (27%). The findings suggest that the most significant health repercussion of pesticide application is the manifestation of skin rashes, impacting 64% of the individuals surveyed, which may be attributed to inadequate protective attire. Following skin rashes, the second most prevalent issue identified in the survey is headaches, which can be associated with the lack of face masks. A considerable number of respondents discard pesticide packages as refuse, while others choose to dispose of them in open fields, and some resort to incineration or burial in a pit.

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