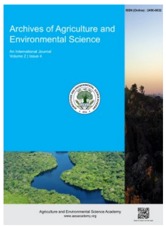
Archives of Agriculture and Environmental Science 7(2): 278-287 (2022)
https://doi.org/10.26832/24566632.2022.0702018

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



REVIEW ARTICLE

CrossMark

Understanding farmers' knowledge, attitudes and practices of pesticide use in Nepal: synthesis of a systematic literature review

Kishor Atreya[1,2*], Kanchan Kattel[3], Samikshya Pandit[4], Prashant Chaudhary[4] and Pragati Sipkhan[5]

[1]School of Forestry and Natural Resource Management, Institute of Forestry, Tribhuvan University, Kathmandu, NEPAL
[2]Department of Watershed Management and Environmental Science, Pokhara Campus, Institute of Forestry, Tribhuvan University, Pokhara, NEPAL
[3]Southasia Institute of Advanced Studies (SIAS), Kathmandu, NEPAL
[4]Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, NEPAL
[5]Agricultural Technology Centre (ATC), Kathmandu, NEPAL
[*]Corresponding author's E-mail: k.atreya@gmail.com

ARTICLE HISTORY

Received: 03 April 2022
Revised received: 21 May 2022
Accepted: 16 June 2022

Keywords

Awareness
Framework
Knowledge, Attitude and Practice (KAP)
Pesticides
Nepal

ABSTRACT

Literature suggests a deeper understanding of farmers' knowledge, attitude and practice (KAP) of pesticide use in agriculture, especially in developing countries, to identify interventions to reduce pesticide use in agriculture. In this paper, we thus performed a systematic review of literature on KAP of farmers on chemical pesticide use in Nepal through a systematic literature search on Scopus web repository published between 2000 and 2021. We got 114 publications initially, and with a well-defined inclusion and exclusion criteria, we finally reviewed 29 articles for data extraction. The results indicate (i) an inadequate KAP of farmers on pesticide use. For example, three in four farmers were found to wash their clothes after pesticide spray. One in four farmers wore boots and only one in ten farmers wore glasses during pesticide spray. Approximately 54% of farmers take a shower after pesticide spray and just one in four farmers bury empty pesticide containers in the soil. Prior studies identified that the lack of awareness and training on the handling practices is the major cause of pesticide misuse; and through formal education and introducing integrated pest management strategies for controlling pests could reduce pesticide misuse. Another notable finding is the lack of KAP theoretical understanding in the prior publications. Many studies in Nepal studied much less on 'attitude" but much higher on "practice" of pesticide usage. We thus propose a new KAP study framework for future research to understand ground-level behavioral change and improve the effectiveness of the KAP-related programs and interventions.

Citation of this article: Atreya, K., Kattel, K., Pandit, S., Chaudhary, P., & Sipkhan, P. (2022). Understanding farmers' knowledge, attitudes and practices of pesticide use in Nepal: synthesis of a systematic literature review. *Archives of Agriculture and Environmental Science*, 7(2), 278-287, https://dx.doi.org/10.26832/24566632.2022.0702018

INTRODUCTION

With agricultural commercialization, use of chemical pesticides has increased worldwide (Sharma *et al.*, 2019), including Nepal (Khanal *et al.*, 2021). Compared to other countries, the average application rate may not be a major issue in Nepal. However, pesticide use is extremely high in its road and river corridors, where vegetable farming is heavily intensive. A national survey shows 0.396 kg a.i./ha of average pesticide application in Nepal (MountDigit Technology, 2014). However, for certain types of vegetables, location-specific studies have reported significantly higher application (e.g., dichlorovos, 23.12 kg a.i/ha for brinjal) (Bhandari *et al.*, 2018). Studies indicate that over 90% of the total pesticides consumed in Nepal are used solely in vegetable farming. National import data also indicates an increasing import of pesticides, and over 3037 pesticides by trade name and 172 pesticides by common name are presently registered for use in Nepal (Khanal *et al.*, 2021). The pesticide application pattern varies according to the ecological belts and the type of cultivated crops (Bhandari *et al.*, 2018). Further, the emergence of new diseases and pests and increasing resistance of insect pests to pesticides leave farmers with no other choice than to apply highly toxic chemical pesticides. The major issue with pesticide use is the nonexistence of proper handling during pesticide application, and is more prominent in developing countries (Bagheri *et al.*, 2021; Isgren & Andersson, 2021). Unsafe handling, mixing pesticides with bare hands, minimal use of personal protection equipment (PPE) during application, unsound disposal of empty pesticide containers after use, mixing pesticides nearby the water sources, and cocktails applications are the major concerns of pesticide misuse, leading to ecological and health hazards. Farmers' occupational exposure to pesticides, especially in the areas of intensive agriculture, is supposedly increasing the economic and environmental health burden for themselves and for the nation. Every effort by government and development sectors to eliminate the misconception of farmers about chemical pesticide use is insufficient and near to ineffective.

An excessive and improper use of pesticide may cause serious health burdens, including cancer and other chronic health-related problems. Fetal death, birth defects, altered growth, dermatological concerns, acute and chronic neurotoxicity are some health effects linked to pesticide misuse (Rani *et al.*, 2021). In recent years, awareness of the negative impacts of pesticides is expected to be increasing among farmers. On some occasion, even in highly intensified areas, a few farmers are producing pesticide free vegetables for household consumption. Most farmers are, however, reluctant to limit pesticide use in their field crops, because of the lack of viable alternatives. In Nepal, the government has been promoting and recommending integrated pest management (IPM), a major system-based practice of farming, as an option to minimize the use of chemical pesticides since 1997, through a FAO developed farmer field school (FFS) extension approach. The IPM farmers use locally available resources to make biopesticide and controlling pests. This practice has produced some promising results in crop disease and pest management, albeit limited. For example, "*Jholmol*", a biopesticide prepared through mixing locally available herbs in cow urine, has been developed for cost-effective plant nutrition and plant protection (ICIMOD, 2020). However, it is not used much on the ground, despite several organizations, both private and public, taunting its importance as an option for minimizing pesticide use. Awareness and educational interventions on KAP of pesticide use should seek a way to transform practice through delivered knowledge. Literature suggests a deeper understanding of farmers' KAP of pesticide use in agriculture, especially in developing countries, to identify interventions to reduce pesticide use in agriculture. A critical analysis of the KAP studies is what this calls for. Because, many studies in Nepal and elsewhere report consistently poor KAP of farmers despite several good "green" efforts by numerous organizations, including FAO's IPM-FFS. In many developing countries with similar farming contexts, this exists. Thus, finding intervention to reduce pesticide use in agriculture could be an universal application. In this paper, we systematically reviewed literature on KAP of farmers on chemical pesticide use, and found that prior studies lacked a definite theoretical concept of KAP. We thus suggest a new KAP study framework explicitly for better understanding pesticide usage in Nepal and beyond.

METHODOLOGY

This study systematically reviewed literature related to the knowledge, attitude and practice of farmers on the use of chemical pesticides in Nepal. Second, it found a theoretical limitation of the existing studies, and finally it proposed a new KAP study framework for future research. While doing so, literature have been retrieved from Scopus web repository published between 2000 and 2021. We used the following combination of words in the "keyword section" of the Scopus website to search for articles: "Nepal" AND "pesticide" AND ("knowledge" OR "attitude" OR "practice" OR "safety" OR "behavior"). The search resulted in 114 publications published between 2000 and August 2021. We developed several inclusion and exclusion criteria for review (Table 1), and data was extracted from 29 articles. The third and fourth co-authors extracted the information, and others thoroughly cross-checked it. According to SCImago Journal Rank (https://www.scimagojr.com/), we found three of the total publications in "Quartile 1" (Q1) and seven in Q2 ranked journals, showing a minimum number (34%) of articles published in the indexed journals. Two-third of the publications (66%) appeared in either national journals or other publications. The number of publications in the subject area is slowly increasing, notably in recent years (Figure 1).

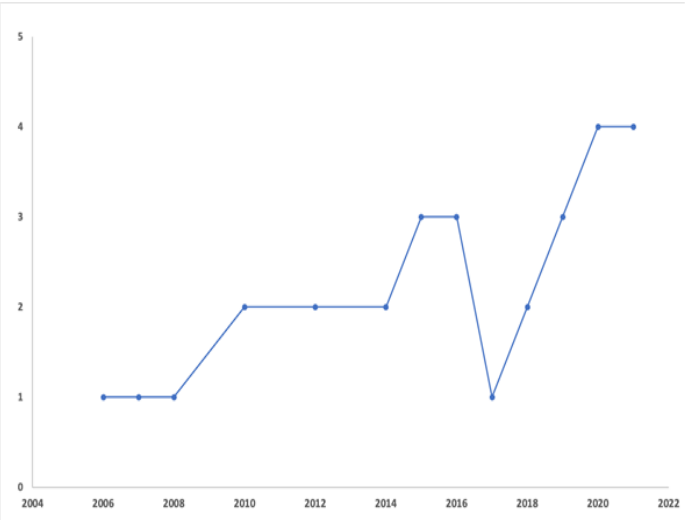


Figure 1. *Publications over years on the subject.*

Table 1. Inclusion and exclusion criteria used for screening publications.

Inclusion criteria	"Nepal" and "Pesticide(s)" in the title, published between 2000 to August 2021.
Exclusion criteria	Duplicates, thesis and dissertation, working paper, literature review-based study, pilot study, non-English papers, medical/hospital-based studies, laboratory-based pesticides analysis, studies on national import and use of pesticides, and "unrelated" to our study objectives. We extracted information (explicitly % data) over 35 KAP variables, and here "unrelated" means no data in all those information.

Table 2. Farmer's knowledge, attitude and practices of pesticide use in Nepal.

S.N.	Variables	Number of studies reported	Average percentage (%) of farmers who stated "yes" to the "variables"		
			Min	Max	Average
1	Wear gloves while spraying	18	2	60	19.2
2	Wear masks while handling pesticides	17	10	85	52.0
3	Read color code of pesticides during purchase	14	6	92	49.2
4	Wear boots/shoes while spraying	14	1	100	33.7
5	Know pesticide's potential harm on human health	13	10	100	62.4
6	Consider wind direction while spraying	13	4	100	59.9
7	Bath after pesticide spray	13	6	91	53.5
8	Burn empty pesticide containers after spray	13	3	61	28.1
9	Bury empty pesticide containers	12	1	75	25.5
10	Wear full sleeves shirt while spraying	11	14	100	53.5
11	Know the color codes of pesticides	11	25	92	53.3
12	Wash clothes after spray	10	31	100	75.4
13	Throw away empty pesticide containers	10	2	65	34.3
14	Use of PPE (complete set)	10	10	70	31.1
15	Wear full pants while spraying	9	12	78	34.1
16	Wear hat while spraying	9	9	49	24.8
17	Store pesticides inside house	8	6	98	53.4
18	Wear glass while spraying	8	1	17	7.9
19	Know about waiting period	7	17	92	50.6
20	Follow IPM techniques (at least one)	7	4	53	27.0
21	Know pesticide's harm on environment	6	9	100	69.8
22	Read expiry date before application/buy	5	41	85	59.2
23	Know biopesticides	5	2	28	13.4
24	Use of biopesticides	5	1	20	9.4
25	Think "pesticides use" needs a reduction	4	21	88	59.8
26	Spray in the morning/evening	4	40	71	58.5
27	Know banned pesticides in Nepal	4	13	34	22.0
28	Apply pesticide after disease development	4	1	48	20.0
29	Know the routes of pesticides entering human body	3	29	94	71.0
30	Check sprayer condition for leakage before use	3	42	66	55.0
31	Apply pesticide after the incidence of disease pest	3	38	60	50.7
32	Spray in the afternoon	3	9	60	33.7
33	Store pesticides inside animal shed	3	3	43	27.3
34	Apply pesticide before the incidence of disease pest	2	18	52	35.0
35	Blow clogged nozzle of sprayer	1	5	5	5.0

Data extraction and variables

We extracted information regarding farmers' knowledge, attitudes and practices on chemical pesticide use from 29 publications. All publications contained an analysis of primary data collected through surveys, which studied 5,620 households altogether (ranged 23 to 790 households), majorly from the Bagmati Province (20 studies), of which 11 studies were from Kavrepalanchowk district. In total,16 studies had an average of 36% female respondents. Likewise, 15 studies mentioned literate individuals in their sample population, and we found that two-third of the respondents were literate. We extracted information on 35 variables, which are directly or indirectly related to either the knowledge, or attitudes or practices of farmers on pesticide use. The publications had used no standard data collection format (i.e., no clear KAP theoretical framework), nor had they defined "knowledge", "attitude" and "practice", and thus, for these reasons, we enlisted all 35 variables as presented in Table 2. The lack of a theoretical framework for data collection in the study warrants a need for the development of a theoretical framework. Such a framework seems essential/applicable to similar kinds of studies in the future. We found a varied KAP of farmers on the use of chemical pesticides throughout the studies reviewed. Thus, comparison of findings across studies and variables requires serious caution. Only 18 studies reported data regarding the usage of gloves while applying pesticides. On average, we estimate that 19% of the farmers (average of 18 studies) in Nepal wear hand gloves during pesticide application. This, by any standard, is unsatisfactory. Likewise, through a synthesis of 17 studies, we conclude that more than half of farmers in Nepal wear face masks during pesticide spraying. Some studies reported that 100% of farmers used boots and full-sleeved shirts, took care of wind direction during pesticide sprays, knew the health and environmental problems of pesticide, and washed clothes after spray. It is ideal to achieve a similar KAP for farmers, but the ground realities are different. For example, only three in four farmers were found to wash their clothes after pesticide spray. Likewise, one in four farmers wore boots and only one in ten farmers wore glasses during pesticide spray. Similarly, only 54% of farmers take a shower after pesticide spray and just one in four farmers bury empty pesticide containers in the soil. Examining all these 35 KAP variables, we conclude that the KAP of farmers on the use of chemical pesticides in agriculture is poor and inadequate by international standards. This entails that the prior efforts of the government and development sector to reduce chemical pesticide use and to make farmers aware of the danger of chemical pesticides are insufficient. Among many developmental and educational programs associated with agriculture and reducing chemical pesticides in agriculture, introduction of IPM through the FFS approach is the most popular. In our case, 12 studies reported IPM trainings for the sampled population. We calculated an average of 20% of the total sample population (2322 throughout selected studies) had attended IPM trainings. Likewise, 7 studies observed IPM practices at farms. On average, we found that 27% of the total 779 sampled farmers had practiced at least one IPM practice on their farms.

KNOWLEDGE SYNTHESIS AND DISCUSSION

Here, we provide an overall synthesis of our understanding through critical analysis of the literature reviewed, and the data presented in Table 2. We present our major findings in the following bullet points, and then a new KAP framework has been proposed.

Farmers lack knowledge of the risk posed by chemical pesticides. Because of this, they perceive pesticides as 'medicine' rather than 'poison' (Thapa *et al.*, 2015). Using pesticides is a 'part of agricultural life' (Atreya, 2008; Atreya *et al.*, 2012; Khanal *et al.*, 2016) for farmers. They lack knowledge on the hazard of pesticides (Thapa *et al.*, 2021). Also, the lack of adequate knowledge of storage, handling and application of pesticides is common among the farmers (Karmacharya, 2012; Sharma, 2015; Bhandari *et al.*, 2020). Thus, they undervalue pesticide risk and are more concerned about farm income and economic returns (Atreya *et al.*, 2012). Farmers report an increase in yield with pesticide application (Karmacharya, 2012; Thapa *et al.*, 2015) and they perceive that the cultivation of vegetables without its application is nearly impossible (Karmacharya, 2012). They do not even understand the significance of waiting periods. They believe that the use of pesticides can aesthetically enhance their produce and its market value. For example, the use of carbendazim and mancozeb has been reported before harvesting tomato fruits (Thapa *et al.*, 2015; Bhandari *et al.*, 2020). Indifference and perception of the associated risks may be a reason why farmers use inadequate safety measures while handling chemical pesticides. Studies state a higher risk of pesticide use to farmers because of low adoption of personal protective equipment (PPE) and extreme misuse of pesticides (Lamichhane *et al.*, 2018); but the understanding of the socio-economic dimension that causes farmers to misuse the poisonous pesticides is very limited. Descriptive studies on short-term pesticide-associated illness (frequency tabulation, for example) are plenty. However, empirical studies are almost nonexistent as of now. Studies highlight that long-term chronic illness could be linked to intensive farming and high use of hazardous pesticides (Atreya *et al.*, 2020). Farmers in developing countries are less aware of the health risks of pesticides. Neither do they know about the lethal composition of the pesticides nor do they understand their mode of action on pests (Afsheen, 2021). So, they have little idea about the interaction of pesticides with the environment and its effects on it; even less about its impacts on human health (Mohanty *et al.*, 2013). We argue that improper use and disposal of poisonous chemical pesticides is not solely because of the ignorance of the farmers regarding the health and the surrounding ecosystem, but because of ineffective policies and programs. The targeted interventions by the concerned authorities are unable to instill the level of risk in their attitude or even help achieve the lifelong behavioral change of farmers.

Farmers lack knowledge of the long-term negative impact of chemical pesticide use on their health and surroundings. Farmers relate the loss of bees and fishes from their surroundings to the high application of chemical pesticides (Atreya *et al.*, 2012). It shows that farmers who regularly use chemical pesticides for a long time are aware of the environmental degradation nearby. Most farmers perceive pesticides to be useful and safe for their health and the environment (Thapa *et al.*, 2015). Some farmers do not even realize that certain health issues arise because of unsafe pesticide use (Khanal *et al.*, 2016; Sharma *et al.*, 2021), and medication for the illness associated with pesticide use is rare because the illnesses go unnoticed (Khanal *et al.*, 2016). There are cases of reduction in pesticide use because of health issues (Shrestha *et al.*, 2010). Studies report a shift from intensification in vegetable farming to the realization of pesticide hazards. Some farmers in Nepal have either reduced the area for vegetable cultivation or completely abandoned commercial vegetable farming because of the health issues they experience (Basnet and Chidi, 2019). But farmers only feel and react to the acute symptoms and they do not know about the chronic complications that arise because of excessive and improper pesticide use (Sharma, 2015; Thapa *et al.*, 2015). The chronic health impact of pesticide use is not visible to farmers; and for illiterate farmers, the government and NGO initiatives can only be the means of awareness of the negative impact of pesticides. However, it is the long-term impact that adds up to creating a bigger cumulative burden on health and the environment. Therefore, lack of knowledge on these aspects is perhaps one reason for the unsafe use of pesticides.

Farmers are less likely to read information and understand toxicity labels given in the pesticide containers. The meaning of different color labels in the pesticide is less known to most farmers. There are several reasons behind this. The most important are: farmers' low level of literacy (more education, more reading habits), less interest of youth in agriculture (youths diverging from farming as a profession), limited farming experience (less experienced farmers read less frequently) and geography (farmers in high mountains and mid-hills read more frequently the color label than in the plains). Using international language on pesticide containers makes them unreadable to the farmers (Adhikari *et al*., 2019; Sapkota *et al*., 2020). Farmers who cannot read and write often use obsolete pesticides with no mention of expiry date (Neupane *et al*., 2014). Illiterate farmers also misuse pesticides (Sainju, 2015). Comparatively, literate farmers are more likely to be careful while buying pesticides (Kafle *et al*., 2021). The result says a 1% increase in the year of schooling decreased the use of pesticides by 3% (Maharjan, 2020). Old age is associated with misuse and sometimes even the abuse of chemical pesticides (Lamichhane *et al*., 2019). For example, people below 41 years are more aware of health hazards, thus they adopt relatively safe pesticide use practices (Neupane *et al*., 2014). Experienced farmers state a higher number of health issues (Lamichhane *et al*., 2019). Many studies report that only a few farmers read the labels and most follow instructions provided by agrovets (Giri *et al*., 2006; Pudasaini *et al*., 2016; Lamichhane *et al*., 2018; Thapa *et al*., 2021). However, agrovets often cannot provide farmers with adequate guidance concerning pesticide selection and use (Giri *et al*., 2006; Pudasaini *et al*., 2016; Adhikari *et al*., 2019; Sapkota *et al*., 2020; Bhandari *et al*., 2021). Farmers are sometimes misguided by agrovets based on their limited technical knowledge (Rijal *et al*., 2018). It indicates that capacity building of the agrovets is urgent. With developing countries with infrequent extension services to their farmers (Afsheen, 2021), it is mostly the agrovet personnel, whom the farmers regard as their guides and experts. If only farmers were trained to interpret the instructions on pesticide labels, there would be less impact of pesticide use on their health. Agrovet personnel require adequate additional training so that they can provide the farmers with instructions.

Farmers lack knowledge of proper disposal of pesticide containers/packets/sachets/bottles. Studies show the used bottles, packets and sachets of pesticides thrown haphazardly into the environment (Koirala *et al*., 2013; Lamichhane *et al*., 2018; Sapkota *et al*., 2020; Bhandari *et al*., 2021; Sharma *et al*., 2021). Collecting and burning of such containers was found as a rare practice among farmers. Reuse of pesticide bottles for other uses at home is not common. However, unused and leftover pesticide is kept in storage near the ceiling, food storage room, kitchen and bedroom (Neupane *et al*., 2014; Khanal and Singh, 2016; Lamichhane *et al*., 2018; Koju *et al*., 2020; Sapkota *et al*., 2020). The leftover pesticides are wrapped in a polythene bag and placed inside the home. No extra precautions are taken while storing leftover pesticide. Storage is such that anyone can have access to it. Most farmers lack adequate knowledge of storage and disposal of the leftover pesticides (Sharma, 2015). The overall waste management system is a failure in many developing countries like Nepal, where all biodegradable, non-biodegradable and hazardous wastes get dumped into open spaces. Safe waste disposal infrastructure is out of reach for the average farmers.

Farmers use inadequate PPE during pesticide application on their farms (Atreya, 2007; Atreya *et al*., 2012; Neupane *et al*., 2014; Khanal *et al*., 2016; Basnet and Chidi, 2019). Common practice includes wearing a full-sleeved shirt and pants during application. Use of gloves, goggles and a mask is not common. Wearing protective gears during mixing and preparation of pesticides in pumps is rare (Karmacharya, 2012). Likewise, the use of locally made brooms is also common in the absence of a sprayer. Pesticide dust is sprayed by hand in the absence of a pesticide duster (Karmacharya, 2012). Gender wise, males know more about safety precautions as compared to females (Atreya, 2007). It is the low level of education, lack of training, low income, limited awareness and discomfort that influences minimal use of safety precautions (Atreya *et al*., 2012; Sapkota *et al*., 2020). Because of the limited knowledge and understanding of pesticide use effects, adoption of safety measures during pesticide application is minimal, resulting in complex health conditions (Khanal *et al*., 2016; Basnet and Chidi, 2019). Weak financial status is a major cause that limits smallholders from using proper PPE even when they totally understand its importance.

Farmers lack adequate knowledge of the interaction between crops, pests, and their environment. Because of the limited knowledge and information on crop-pest interaction and economic thresholds, farmers apply chemical pesticides prior to pest infestation (Rijal *et al*., 2018; Sapkota *et al*., 2020). Likewise, farmers lack adequate knowledge of the interaction between weather and pesticide use. They are often found to apply chemical pesticides on windy days. Those farmers who do not consider wind direction during pesticide spraying are more likely to report higher health problems (Lamichhane *et al*., 2019). This concern can only be addressed by creating awareness among farmers about the crop-pest-environment interaction and the levels of risks associated. This is because most farmers do not consider the potential effects of chemical pesticides on non-target beneficial insects and pollinators (Rijal *et al*., 2018). Farmers are unaware of the pesticide resistance issues because of the repetitive application of the same chemicals in a season (Rijal *et al*., 2018).

Farmers have limited knowledge of and access to biopesticides. Farmers prefer chemical measures to pest problems because they are easy to use and show knock-down effects (Bhandari *et al*., 2020). However, accessibility and availability of alternative measures to control pests, for example, biopesticides and IPM techniques, are extremely limited (Atreya *et al*., 2012; Bhandari *et al*., 2020). Farmers ask about biopesticides but use chemicals because of the lack of biopesticide access (Adhikari *et al*., 2019). Use of botanical pesticides is also uncommon; in fact, few subsistence farmers apply them (Kafle *et al.*, 2021). Agrovets and pesticide dealers are demotivated in trading biopesticides because of inadequate storage facilities, less demand, limited availability, high cost, and slim profit margins (Adhikari *et al.*, 2019). Agrovets are the sole guidance to farmers and they themselves perceive biopesticides as fewer effective alternatives than chemicals (Adhikari *et al.*, 2019). The biopesticide programs and training are sporadic and are often directed by project goals rather than a common goal of establishing them as standard alternatives. Farmers are oriented towards crop yield, economic returns and short-term results for making their living. As long as commercial agrovets are the only guidance to farmers, biopesticide will always remain underrated despite being a low-cost, low-risk alternative for farmers.

Gender gaps exist in understanding pesticide use and associated risk. There is a serious gender gap in scientific understanding concerning pesticide use and its associated risks among the Nepali agricultural population (Atreya, 2007). Compared to men, women are less educated (Atreya, 2007; Sainju, 2015), their participation in IPM training is low (Atreya, 2007), and they have a higher tendency to keep empty pesticide containers for home use (Atreya, 2007) as a homemaker. Women are far behind in reading and understanding the color code of the pesticide labels (Atreya, 2007). Thus, all these factors contribute to a higher risk of pesticide exposure for women (Atreya, 2007). Among smallholders, women purchase pesticides, however, men engage the most among the large farm holders (Bhandari *et al.*, 2020). Men are relatively more careful while buying pesticides (Kafle *et al.*, 2021). It is the men who are involved in the purchase, preparation and application of chemical pesticides in Nepal (Thapa *et al.*, 2021). This may not be the case in women-headed households where women take charge of both household chores and farm activities. Because of male labor out-migration in search of better livelihood opportunities, female-headed households are increasing, hence increasing chances of women's involvement in pesticide purchase and use.

Training on the safe handling practices of pesticides is the most recommended for enhancing skills and technical knowledge of farmers (Shrestha *et al.*, 2010; Vaidya *et al.*, 2017). Such training enhances the rates of adoption and proper use of PPE (Koirala *et al.*, 2013; Sharma *et al.*, 2021; Thapa *et al.*, 2021). Farmers who never received training on the safe use of pesticides were found to use absolute and banned pesticides (Shrestha *et al.*, 2010). However, provision of training does not essentially translate to good practice. Trained farmers seldom use adequate safety gear and 99% of them use pesticides without accounting for the recommended dose (Khanal and Singh, 2016). Likewise, educating farmers could reduce pesticide use. For example, Maharjan *et al.* (2020) stated that a 1% increase in years of schooling was associated with a 3% decrease in pesticide use. However, Sainju (2015) found no significant association between (i) knowledge about the route of exposure and use of mask/mouth cover (ii) education and knowledge about the route of exposure, and (iii) knowledge about health effects of pesticides and their storage practices. Although studies (Koju *et al.*, 2020) recommend provision of adequate training and access to formal education for reducing pesticides, empirical studies on the contribution of formal education and training on knowledge, attitude and practice of pesticide use are lacking. It is just a naive assumption that farmers change their pesticide use practices through surficial knowledge provided in training, which cannot be the sure case considering their deep-rooted perceptions, previous experience, ease of practice, attitude to behavior change and much more. The attitude and behavior change are controlled by a farmer's "mindset", which largely depends on psychosocial factors and not solely on educational interventions. Interventions to change farmers' behavior in relation to pesticide use are recommended for their effectiveness (Lamichhane *et al.*, 2018), however we could not find the field application of such interventions in relation to pesticide use.

Farmers are aware of IPM but are unwilling to adopt IPM practices. For example, Thapa (2017) showed that out of 1057 IPM-FFS trained rice farmers between 1998 and 2015 in Rupandehi district, only 5% of them were practicing at least one IPM technique. Low adoption is probably because of the labor-intensive IPM practices (Thapa *et al.*, 2015), that are more hectic for smallholders, who receive lower gain from farming. Also, large farm holders are more likely to receive IPM training (Bhandari *et al.*, 2020) and have better pesticide handling practices (Khanal and Singh, 2016). Most farmers do not practice IPM because chemical pesticides are cheaper (Thapa *et al.*, 2015) and their neighbors use chemicals (Thapa *et al.*, 2015). Studies claim that adequate training on IPM could change farmers' behaviors towards the safe use of pesticides and its handling (Atreya, 2008). A few studies (Atreya, 2007; Atreya, 2008; Khanal and Singh, 2016) have reported that IPM trained farmers are more aware of the color codes and spray chemical pesticides considering weather, but they seldom wear complete safety PPE (Khanal and Singh, 2016).

Finally, we propose a new conceptual framework for KAP studies on pesticides. This is because, as we already stated in the "data extraction and variables" section, that prior studies had no defined framework for data collection (Figure 2) and almost all studies outlined KAP variables without a conceptual base. For example, Vaidya *et al.* (2017) enlisted 16 knowledge variables under the "knowledge and attitude" table. Similarly, Kafle *et al.* (2021) included "check manufacture and expiry date", for example, in both the knowledge and practice section. Likewise, the lead author of this paper had presented "knowledge", "attitude" and "practice" of pesticide usage into a single heading in his prior publication (Atreya, 2007), doctoral study (Atreya, 2013) and doctoral supervision (Bhandari *et al.*, 2018; Bhandari, 2021). It warrants a deeper understanding of and disentangling KAP variables in pesticide usage behavioral research in Nepal. Comparison of data across studies and variables, now and even in the future, thus requires attention and standardization. A theoretical framework connects scholars to existing knowledge guided by specific theory, and helps them to articulate their study assumptions, and to propose new broader knowledge on the study topic. This would contribute to the development/revision of the

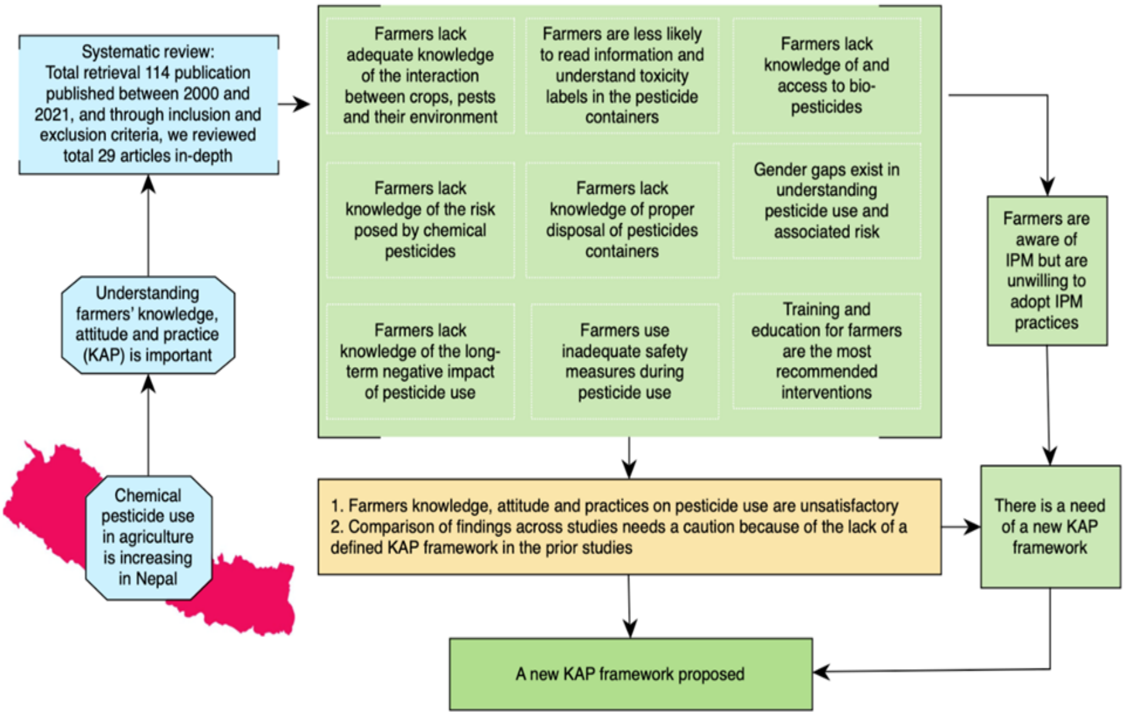


Figure 2. *Summary of the systematic review of literature.*

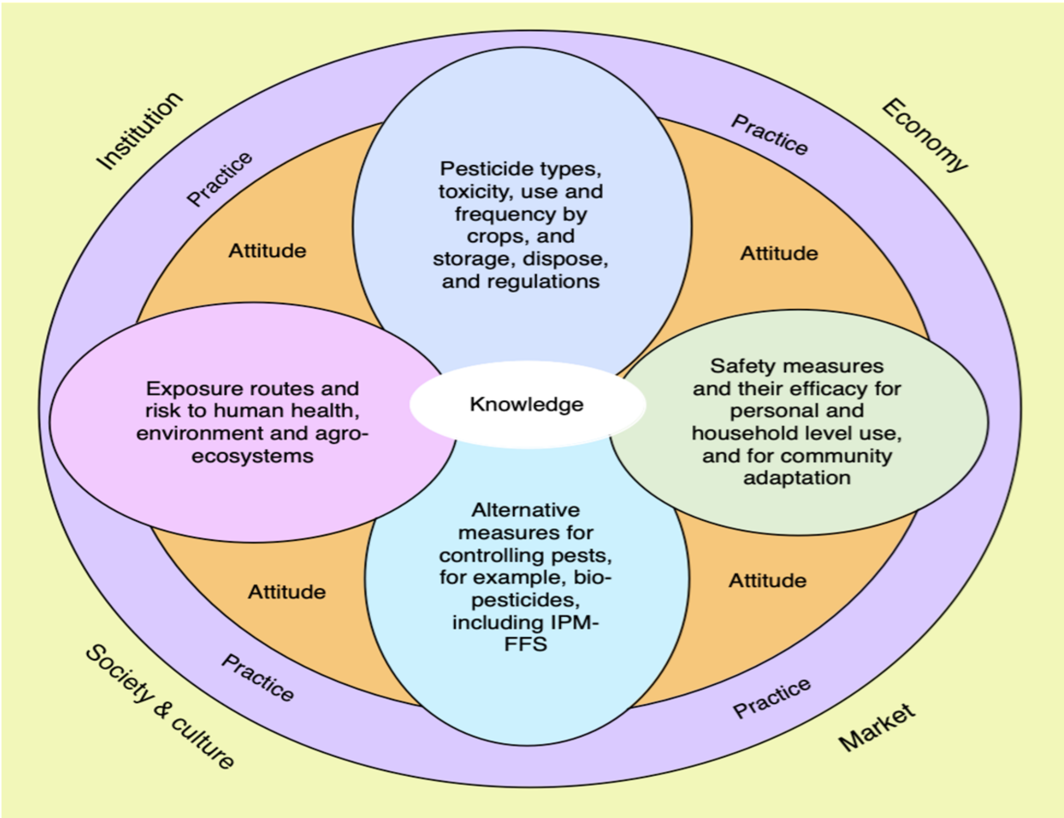


Figure 3. *The proposed KAP framework for the pesticide-related studies.*

theory considered. Simply, frameworks not only explain, predict, and understand a phenomenon under existing knowledge system, but also challenge and extend existing knowledge systems. KAP studies are popular in health-related behavioral studies, including pesticide usage. Therefore, designing and conducting a KAP study needs a defined guideline, which we did not find in the prior studies conducted in Nepal. Henceforth, we propose a new KAP framework (Figure 3). The KAP theory divides the process of human behavioral change into three: acquiring knowledge (what we know and what we want to know), generating attitudes/beliefs (what we believe), and practice/behavior (what we do). Prior studies considered much less on "attitude" but much higher on "practice" variables of the KAP of pesticide usage.

With the pesticide-associated health behavior change, we suggest collecting KAP data on four principal thematic areas: (i) pesticide use pattern and intensity, (ii) associated risk to humans and agroecosystems, (iii) safety measure effectiveness and community adaptation, and (iv) alternate control measures including IPM-FFS. Knowledge is all about farmers' understanding of these areas. Knowledge is objective. Attitude is the way farmers believe and feel a need for change, either positive or negative, for the knowledge they acquire. In other words, it is the subjective take on the knowledge perceived. In our case, once the knowledge variables are identified under the four thematic areas, the attitude, in fact, is interlinked within it. For example, "knowledge" is about understanding the meaning of the toxicity color code present in the pesticide containers, whereas "attitude" is whether the individual considers the implications of the color codes while purchasing/spraying chemical pesticides. Similarly, "yellow" label in the container means "highly toxic" (it is knowledge), but how an individual evaluates it, positive (good attitude) or negative (bad attitude), depends on individual's perception and feelings (it is an attitude). More on this, positive in a sense, individual avoids purchasing by seeing the highly toxic level; and negative in a way, individual purchases it instantly by seeing the highly toxic level with a belief that pesticide will work effectively to control disease/pest. Attitude is subjective, based on experience and biased knowledge. Henceforth, data needs of "attitude" in the pesticide-associated studies would be in line with the four principal thematic areas. However, the way we design the questions will vary. Finally, "practice" is all about the "action" that individuals perform through processing knowledge. However, individual "knowledge" does not guarantee a good "action", because individual's attitude to the knowledge along the process influences the last action. Here, we mean to say that an action is the outcome of the interaction between knowledge and attitude. For more clarification, we go back to the earlier example. When a farmer knows "yellow" labeled pesticides are "highly toxic" (knowledge) and perceives their dangers to human health and surroundings (attitude), then the farmer may not buy the "yellow" labelled pesticides (good action). Likewise, when the farmer perceives "yellow" labeled pesticides as "non-toxic" (knowledge, negative), there is a high possibility that the farmer will buy those pesticides (dangerous action). Likewise, when the farmer evaluates "yellow" labelled pesticides are "safe for use" (attitude, negative) despite knowing about their toxicity (knowledge), it is likely that the farmer will buy those "yellow" labeled pesticides (dangerous action). Henceforth, data needs of "practice" in our framework would be like data needs of the four thematic areas of knowledge and attitude, but the way we inquire questions will be different. Other factors, including social, cultural, economic, institutional and access to markets, affect farmer's knowledge, attitude and practices on pesticide use, therefore, we suggest collecting additional information on these aspects as well. This proposed KAP study framework can be used standalone in future research related to pesticide usage. It can be merged into the FAO's IPM-FFS cycle for the regular feedback evaluation.

Conclusion

Overall, almost every article we reviewed has indicated that the lack of awareness and training is the major cause of pesticide misuse. Studies done in Nepal consistently report poor knowledge, attitude and practice of farmers on the use of chemical pesticides and safety. However, those findings are not surprising because similar situations in some other developing countries are well reported. The situation is extremely worrisome from the environmental ethics perspective, though. It is the fate of the developing world that many projects and programs are mostly guided by the objectives of a donor and the effectiveness is rarely measured in terms of the long-term impact of any programs. Despite numerous organizations spending their time and budget in that regard, it is clearly visible that there is still a long way to go to reach a point where chemical pesticide use is practically discouraged, and used properly if necessary. Prior efforts of the government and development sector to reduce pesticide use are insufficient. There is a need for both the research and practice-based organizations in Nepal to reflect on the approach of the programs and assess the effectiveness based on the extent of long-term behavioral change that the initiatives lead to. There is an evidence gap between knowledge and practice regarding safe pesticide use, which can be bridged by using the proposed KAP framework in future research and in the IPM-FFS educational and awareness intervention, so that farmers act upon the urgency of minimizing the pesticide's risk to both humans and the environment.

ACKNOWLEDGEMENT

The authors are highly indebted to two anonymous reviewers for their academic work, helpful comments and suggestions. This paper is an outcome of a research grant to faculty members appointed through a research excellence-based open competition (HERP-DLI-7B) of Tribhuvan University, Nepal. The authors are thankful to the Higher Education Reform Project, Project Implementation Unit, Tribhuvan University, Nepal.

REFERENCES

Adhikari, S. R., Pandit, V., Sharma, D. R., & Subedi, R. K. (2019). Perception on biological pesticide by various levels of stakeholders in Nepal. *Journal of Biological Control*, *33*(3), 173–177, https://doi.org/10.18311/jbc/2019/22690

Afsheen, S. (2021). A cross sectional survey of knowledge, attitude and practices related to the use of insecticides among farmers in industrial triangle of Punjab, Pakistan. *PLoS ONE*, *16*(8 August). https://doi.org/10.1371/journal.pone.0255454

Atreya, K. (2007). Pesticide use knowledge and practices: A gender differences in Nepal. *Environmental Research*, *104*(2), 305–311, https://doi.org/10.1016/j.envres.2007.01.001

Atreya, K. (2008). Health costs from short-term exposure to pesticides in Nepal. *Social Science and Medicine*, *67*(4), 511–519, https://doi.org/10.1016/j.socscimed.2008.04.005

Atreya, K. (2013). Pesticide use in Nepal: Health effects and economic costs for farmers in the central mid-hills Nepal [Norwegian University of Life Sciences, Aas, Norway]. In *Norwegian University of Life Sciences*. http://www.umb.no/statisk/noragric/PhD/defences/Kishor_cover.pdf

Atreya, K., Kumar Sitaula, B., Overgaard, H., Man Bajracharya, R., & Sharma, S. (2012). Knowledge, attitude and practices of pesticide use and acetylcholinesterase depression among farm workers in Nepal. *International Journal of Environmental Health Research*, *22*(5), 401–415, https://doi.org/10.1080/09603123.2011.650154

Atreya, K., Rijal, C., & Neupane, P. (2020). Pesticide use in agriculture and chronic health conditions: A survey-based cross-sectional study in Nepal. *Archives of Agriculture and Environmental Science*, *5*(4), 489–497, https://doi.org/10.26832/24566632.2020.050409

Bagheri, A., Emami, N., & Damalas, C. A. (2021). Farmers' behavior towards safe pesticide handling: An analysis with the theory of planned behavior. *Science of the Total Environment*, *751*, https://doi.org/10.1016/j.scitotenv.2020.141709

Basnet, N., & Chidi, C. L. (2019). Impact of Pesticide and Fertilizer on Human Health: A Case Study in Godawari Area, Lalitpur, Nepal. *The Geographic Base*, *6*, 65–76, https://doi.org/10.3126/tgb.v6i0.26168

Bhandari, G. (2021). *Pesticide use in Nepal: The assessment of residues and risks* [Wageningen University, Wageningen, the Netherlands]. https://doi.org/10.18174/536691

Bhandari, G., Atreya, K., Vašíčková, J., Yang, X., & Geissen, V. (2021). Ecological risk assessment of pesticide residues in soils from vegetable production areas: A case study in S-Nepal. *Science of the Total Environment*, *788*(147921), https://doi.org/10.1016/j.scitotenv.2021.147921

Bhandari, G., Atreya, K., Yang, X., Fan, L., & Geissen, V. (2018). Factors affecting pesticide safety behaviour: The perceptions of Nepalese farmers and retailers. *Science of the Total Environment*, *631–632*, 1560–1571, https://doi.org/10.1016/j.scitotenv.2018.03.144

Bhandari, S., Paneru, S., Pandit, S., Rijal, S., Manandhar, H. K., & Ghimire, B. P. (2020). Assessment of pesticide use in major vegetables from farmers' perception and knowledge in Dhading district, Nepal. *Journal of Agriculture and Natural Resources*, *3*(1), 265–281, https://doi.org/10.3126/janr.v3i1.27180

Giri, Y. P., Aryal, S., Paneru, R. B., & Adhikari, J. R. (2006). Recent use and distribution pattern of pesticides in Nepal. *Journal of the Environment*, *10*(June), 49–62.

ICIMOD. (2020). *Jholmal: a nature-based solution for mountain farming systems*. https://doi.org/10.13140/RG.2.2.27756.69761

Isgren, E., & Andersson, E. (2021). An Environmental Justice Perspective on Smallholder Pesticide Use in Sub-Saharan Africa. *Journal of Environment and Development*, *30*(1), 68–97, https://doi.org/10.1177/1070496520974407

Kafle, S., Vaidya, A., Pradhan, B., Jørs, E., & Onta, S. (2021). Factors associated with practice of chemical pesticide use and acute poisoning experienced by farmers in Chitwan district, Nepal. *International Journal of Environmental Research and Public Health*, *18*(8), 4194, https://doi.org/10.3390/ijerph18084194

Karmacharya, S. (2012). Pesticide Use In Agriculture And Its Socio- Economic Contexts, A Case Study of Panchkhal Area, Kavre, Nepal. *International Journal of Scientific & Technology Research*, *1*(9), 17–20.

Khanal, D., Neupane, S., Poudel, S., & Shrestha, M. (2021). An overview of chemical pesticide Import in Nepal. *The Journal of Agriculture and Environment*, *22*(June), 121–134.

Khanal, G., & Singh, A. (2016). Patterns of Pesticide Use and Associated Factors among the Commercial Farmers of Chitwan, Nepal. *Environmental Health Insights*, *10*, 1–7, https://doi.org/10.4137/EHI.S40973

Khanal, G., Singh, A., & Dhungana, G. (2016). Pesticide Poisoning Among Commercial Vegetable Farmers of Chitwan, Nepal. *Primary Prevention Insights*, *6*, 19–25, https://doi.org/10.4137/ppri.s40531

Koirala, P., Tamrakar, A. S., Bhattarai, B. P., Yadav, B. K., Humagain, S., & GC, Y. D. (2013). Use and Handling Practice of Pesticides in Vegetables: A Case Study on Some Selected Districts of Nepal. *Journal of Food Science and Technology Nepal*, *6*, 105–109, https://doi.org/10.3126/jfstn.v6i0.8270

Koju, P., Shakya, P. R., Shrestha, A., Karmacharya, B. M., Shrestha, S., & and Lindsay, M. J. (2020). Pilot educational intervention to promote safe pesticide use practices among farmworkers in Nepal. *Annals of Work Exposures and Health*, *64*(8), 866–875, https://doi.org/10.1093/ANNWEH/WXAA054

Lamichhane, R., Lama, N., Subedi, S., Singh, S. B., Sah, R. B., & Yadav, B. K. (2018). Health Risk Behavior and Use of Safety Precaution among Pesticide Handling Farmers of Duhabi-Bhaluwa Region, Sunsari, Nepal. *International Journal of Clinical and Experimental Medicine Research*, *2*(3), 37–43, https://doi.org/10.26855/ijcemr.2018.03.001

Lamichhane, R., Lama, N., Subedi, S., Singh, S. B., Sah, R. B., & Yadav, B. K. (2019). Use of Pesticides and Health Risk among Farmers in Sunsari District, Nepal. *Journal of Nepal Health Research Council*, *17*(01), 66–70, https://doi.org/10.33314/jnhrc.v17i01.1204

Maharjan, S. (2020). Pesticides Use Pattern and Handling Practices among Cucumber (Cucumis sativus L.) Growing Farmers of Parsa District of Nepal. *International Journal of Agriculture Environment and Biotechnology*, *13*(2), 155–162, https://doi.org/10.30954/0974-1712.02.2020.6

Mohanty, M. K., Behera, B. K., Jena, S. K., Srikanth, S., Mogane, C., Samal, S., & Behera, A. A. (2013). Knowledge attitude and practice of pesticide use among agricultural workers in Puducherry, South India. *Journal of Forensic and Legal Medicine*, *20*(8), 1028–1031, https://doi.org/10.1016/j.jflm.2013.09.030

MountDigit Technology. (2014). Study on national pesticide consumption statistics in Nepal.

Neupane, D., Jørs, E., & Brandt, L. (2014). Pesticide use, erythrocyte acetylcholinesterase level and self-reported acute intoxication symptoms among vegetable farmers in Nepal: A cross-sectional study. *Environmental Health: A Global Access Science Source*, *13*(1), 98, https://doi.org/10.1186/1476-069X-13-98

Pudasaini, R., Thapa, R. B., & Tiwari, S. (2016). Farmers Perception on Effect of Pesticide on Insect Pollinators at Padampur and Jutpani Vdcs, Chitwan, Nepal. *International Journal of Applied Sciences and Biotechnology*, *4*(1), 64–66, https://doi.org/10.3126/ijasbt.v4i1.14575

Rani, L., Thapa, K., Kanojia, N., Sharma, N., Singh, S., Grewal, A. S., Srivastav, A. L., & Kaushal, J. (2021). An extensive review on the consequences of chemical pesticides on human health and environment. *Journal of Cleaner Production*, *283*(124657), https://doi.org/10.1016/j.jclepro.2020.124657

Rijal, J. P., Regmi, R., Ghimire, R., Puri, K. D., Gyawaly, S., & Poudel, S. (2018). Farmers' knowledge on pesticide safety and pest management practices: A case study of vegetable growers in Chitwan, Nepal. *Agriculture (Switzerland)*, *8*(1), 16, https://doi.org/10.3390/agriculture8010016

Sainju, R. (2015). Farmers Knowledge , Practices and Perceived Health Symptoms Associated with Pesticides used in Thimi , Bhaktapur , Nepal. *International Journal of Medicine & Biomedical Sciences*, *1*(1), 23–27.

Sapkota, K. R., Sapkota, S., Sapkota, S., & Katuwal, K. (2020). Pesticides handling practices among potato growers in Kavrepalanchok, Nepal. *Journal of Agriculture and Natural Resources*, *3*(1), 77–87, https://doi.org/10.3126/janr.v3i1.27093

Sharma, A., Kumar, V., Shahzad, B., Tanveer, M., Sidhu, G. P. S., Handa, N., Kohli, S. K., Yadav, P., Bali, A. S., Parihar, R. D., Dar, O. I., Singh, K., Jasrotia, S., Bakshi, P., Ramakrishnan, M., Kumar, S., Bhardwaj, R., & Thukral, A. K. (2019). Worldwide pesticide usage and its impacts on ecosystem. *SN Applied Sciences*, *1*(11), 1–16, https://doi.org/10.1007/s42452-019-1485-1

Sharma, B., Ojha, B. R., Ojha, A., Sapkota, B., Adhikari, G., & Gautam, S. (2021). Assessment of Pesticide Application Pattern in Major Vegetables of Palpa District, Nepal. *International Journal of Social Sciences and Management*, *8*(1), 292–298, https://doi.org/10.3126/ijssm.v8i1.32694

Sharma, D. R. (2015). Use of pesticides and its residue on vegetable crops in Nepal. *Journal of Agriculture and Environment*, *16*, 33–42, https://doi.org/10.3126/aej.v16i0.19838

Shrestha, P., Koirala, P., & Tamrakar, A. S. (2010). Knowledge, Practice and Use of Pesticides among Commercial Vegetable Growers of Dhading District, Nepal. *Journal of Agriculture and Environment*, *11*, 95–100, https://doi.org/10.3126/aej.v11i0.3656

Thapa, A., Tamrakar, A. S., & Subedi, I. P. (2015). Pesticide Use Practices Among Tomato Growers in Kavre District, Nepal. *Nepalese Journal of Zoology*, *3*(1), 17–23, https://doi.org/10.3126/njz.v3i1.30861

Thapa, C. B. (2017). Survey of Integrated Pest Management (IPM) Practice in Vegetable Crops of Rupandehi District, Western Nepal. *International Journal of Applied Sciences and Biotechnology*, *5*(2), 237–242, https://doi.org/10.3126/ijasbt.v5i2.17628

Thapa, S., Piras, G., Thapa, S., Goswami, A., Bhandari, P., & Dahal, B. (2021). Study on farmers' Pest management strategy, knowledge on pesticide safety and practice of pesticide use at Bhaktapur district, Nepal. *Cogent Food and Agriculture*, *7*(1), https://doi.org/10.1080/23311932.2021.1916168

Thapa, S., Thapa, B., Bhandari, R., Jamkatel, D., Acharya, P., Rawal, S., Bista, S., Singh, R., Prasai, A., Bharati, S., & Basnet, A. (2021). Knowledge on Pesticide Handling Practices and Factors Affecting Adoption of Personal Protective Equipment: A Case of Farmers from Nepal. *Advances in Agriculture*, *2021*, 5569835. https://doi.org/10.1155/2021/5569835

Vaidya, A., Gyenwali, D., Tiwari, S., Pande, B. R., & Jørs, E. (2017). Changes in Perceptions and Practices of Farmers and Pesticide Retailers on Safer Pesticide Use and Alternatives: Impacts of a Community Intervention in Chitwan, Nepal. *Environmental Health Insights*, *11*, https://doi.org/10.1177/1178630217719270