**Farmer Perspectives and Usage Patterns of Insecticides in Chilli Cultivation in Bhabhar Region of Uttarakhand, India**

**Abstract**

A comprehensive field survey was conducted across seven blocks *viz.,* Jaspur, Kashipur, Bajpur, Gadarpur, Rudrapur, Sitarganj and Khatima of Udham Singh Nagar district in Uttarakhand to assess chilli cultivation practices, pest incidence, and farmer knowledge regarding pest management and pesticide safety. The study revealed that most farmers were marginal cultivators, with 66 % growing chilli on less than 0.5 acres. Thrips and other insect pests, including root grubs, tobacco caterpillars, and pod borers, posed significant threats, with 56.29 % of farmers reporting damage from non-thrips insects. Leaf curling assessments showed no immune chilli varieties, and over 41 % of crops were classified as susceptible to thrips, especially in areas with intensive cultivation and pesticide use. Thrips primarily affected growing shoots and older leaves, while fruit and stem damage were less prevalent. Most farmers relied on formal sources such as university experts and agricultural departments for plant protection advice, although regional disparities existed. Chemical mixing was widely practiced (75.14%), and 72.28 % of farmers applied two or more pesticide sprays per crop, often at 5- to 10-day intervals. While 83.14 % of farmers used protective clothing during spraying, 15.43 % still prepared spray solutions with bare hands, and only half were aware of CIBRC guidelines. These findings highlight the urgent need for integrated pest management, development of resistant varieties, safety education, and enhanced regulatory outreach to ensure sustainable and safe chilli cultivation in the region.

**Key words:** Thrips, varieties, pesticides, plant protection source, protective clothing, CIBRC

**INTRODUCTION**

Chilli (*Capsicum annuum* L.) is a member of the Solanaceae family and is an economically important crop cultivated as both spice and vegetable, especially throughout tropical and subtropical areas **(Naveena *et al.* 2020).** The fruit serves in various culinary cultures, being consumed as fresh green chilli or dried red chilli. They are used in diets through raw consumption in salads, prepared as cooked vegetables, preserved by pickling, or utilization as flavour enhancers in numerous culinary preparations **(Zanwar *et al.,* 2022)**. Given its extensive applications across food, pharmaceutical, and cosmetic sectors, chilli holds a considerable economic importance. India dominates global chilli production with 2.78 million tonnes from 8.52 lakh hectares in 2023-24 **(Horticulture Statistics Division, 2024)**, primarily from Andhra Pradesh, Telangana, Madhya Pradesh, Karnataka, and Odisha **(Spice Board India, 2023)**. While Uttarakhand contributes modestly with 10.88 thousand tonnes of capsicum from 1.95 thousand hectares in 2024-25 following a peak of **16.54 thousand tonnes** in 2022 **(CEIC Data, 2024; DA&FW, 2024)**. This underscores India's global leadership in chilli production and Uttarakhand's role in preserving unique cultivars for sustainable agroecosystems.

Insect pests cause significant chilli yield losses, with 25-26 species affecting various parts of the plant **(Girish, 2012).** Key pests include sucking insects like thrips (*Scirtothrips dorsalis*), white mites (*Polyphagotarsonemus latus*), and aphids (*Aphis gossypii*, *Myzus persicae*). Important foliage feeders include tobacco caterpillar (*Spodoptera litura*) and pod borer (*Helicoverpa armigera*) **(Ali *et al.,* 2006; Priyadarshini *et al.,* 2019)**.Chilli thrips (*S. dorsalis*) order Thysanoptera poses the greatest threat potentially causing yield losses exceeding 75 % under favourable conditions **(Sarkar *et al.,* 2015; Ballal *et al.,* 2022)**, making it the most economically damaging pest in chilli cultivation.

Chilli's soft, succulent tissues make it vulnerable to pests and diseases, worsened by selective breeding that reduced genetic diversity while accelerating growth **(Weerakkody and Mawalagedera, 2020).** Growing global population demands increased food production through sustainable strategies, especially with declining yields and shrinking farmlands. This has driven industrial farming practices involving widespread use of agricultural chemicals including fertilizers, insecticides, nutrients, and growth enhancers in crop systems **(Alhamza and Osman, 2024).** Pesticides are vital for crop protection against pests, fungi, weeds, and rodents, making them indispensable in commercial agriculture, especially for vegetables like chilli **(Tudi *et al.,* 2021).** However, excessive and improper pesticide use by farmers has created serious environmental threat and health risks, highlighting the need for better application practices and sustainable pest management approaches **(Weerakkody and Mawalagedera, 2020).** India has registered 392 pesticides for crop protection as of March 2025. During 2023-24, the country used 67,964.97 metric tonnes of chemical pesticides, with Uttarakhand contributing 147.08 metric tonnes (0.22%) **(DPPQS, 2025).** National pesticide application rates increased from 0.29 kg/ha in 2021-22 to 0.40 kg/ha in 2023-24 **(Reddy *et al.,* 2024).** Jammu and Kashmir leads in pesticide intensity at 2.097 kg/ha, followed by Punjab at 1.3 kg/ha, while Uttarakhand ranks 12th with moderate usage of 0.3 kg/ha (**Janaki *et al.,* 2025)** indicating regional variations in pesticide dependency across Indian states.

Pesticide usage patterns and farmers' attitudes toward chemical pest control are influenced by multiple interconnected factors including demographics, geography, weather, ecology, and government regulations **(Ali *et al.,* 2020).** Additionally, crop cultivation techniques, management practices **(Van Hoi *et al.,* 2009)**, and crop types significantly affect both pesticide application decisions and overall farmer perceptions regarding chemical pest control methods. With this background, the present study was undertaken to understand the status of farmers’ perspectives and usage patterns of insecticides against chilli thrips across various chilli growing areas of bhabhar region of Uttarakhand.

**MATERIALS AND METHODS**

Using the roving survey method, data on pesticide usage patterns among farmers in from random villages of major chilli growing areas across various seven blocks of Udham Singh Nagar district of Uttarakhand state in the bhabhar region was gathered. Details regarding pesticide usage patterns were obtained from chilli growers from five random villages from every block/taluka through direct interactions using a structured schedule or questionnaire. Information was collected from a representative sample of 10 farmers from every village *i.e.,* 50 farmers from each block regarding the pesticides applied to chilli crops during the previous or current season/year.

The primary aim of the survey was to examine the patterns of insecticide use and perspectives among farmers for managing thrips in chilli cultivation. This was achieved through a comprehensive questionnaire that addressed various aspects of pesticide application. Information was collected via one-on-one personal interviews with the farmers, covering topics such as land holdings, pest and disease occurrence, alternative chemical use, method of application, frequency of sprays, safety precautions, adherence to pre-harvest intervals, and various other aspects at their farm levels. The collected data were compiled across different categories and analysed to assess pesticide usage trends in the chilli cropping systems of major chilli growing regions bhabhar region of Uttarakhand.

**RESULTS AND DISCUSSION**

The survey conducted over seven different blocks of Udham Singh Nagar district of Uttarakhand *viz.,* Jaspur, Kashipur, Bajpur, Gadarpur, Rudrapur, Sitarganj and Khatima in bhabhar region showed varied results according to the data collected and analysed. The results are represented according of different criteria

**CULTIVATION AND FARMERS KNOWLEDGE ABOUT INSECT PESTS IN CHILLI**

The survey results on various cultivation practices and farmers knowledge about insect pests in chilli in various blocks of Udham Singh Nagar are presented in **Table 1**.

**Area under chilli cultivation:**

A survey on chilli cultivation in various blocks of Udham Singh Nagar revealed that most farmers were marginal cultivators, growing chilli on less than 0.5 acres. In Rudrapur, about 92 % of farmers cultivated chilli on under 0.5 acres, compared to only 20 % in Kashipur. In contrast, 58 % of Kashipur farmers had 0.5 to 1 acre under chilli, while only 6 % in Rudrapur fell in this category. Gadarpur had the highest proportion (24%) of farmers cultivating chilli on more than 1 acre, whereas Rudrapur had the lowest in this category. Overall, across all blocks, 66 % of farmers grew chilli on less than 0.5 acres, 21.71 % on 0.5 to 1 acre, and only 12.31 % on more than 1 acre. These findings highlight significant regional differences in land holdings dedicated to chilli cultivation. Similar results were discovered by **Hazari and Kalita (2022)**, who reported that most of the respondents were small and marginal farmers and that all of them were from farming families. Additionally, **Swami *et al.* (2022)** revealed that 41.50 % of chilli growers had less than 0.5 acres of growing land, while 31 % had between 0.5 and 1 hectares. With an average cultivation area of roughly 0.86 ha per farmer, 27.30 % of chilli producers supplied more than 1.0 ha.

**Damage Percentage:**

The survey assessed insect damage in chilli cultivation across different blocks, categorizing pest infestations into thrips and other insects. Results showed varying damage patterns across surveyed areas. Thrips damage was not severe overall in the region. In Gadarpur, 72 % of farmers reported thrips as the primary pest damaging their crops, while only 24 % of Khatima farmers experienced thrips damage. This stark regional variation highlights the localized nature of thrips infestations. Other insects, including root grubs, tobacco caterpillars, and pod borers, showed contrasting distribution patterns. Khatima experienced significantly higher damage from these pests, with 92 % of farmers affected, compared to only 28 % in Gadarpur. This inverse relationship between thrips and other insect damage across locations suggests different environmental conditions or management practices influence pest prevalence. Regional analysis revealed that thrips affected 43.71 % of farmers overall, while other insects impacted 56.29 % of the farming community. The findings demonstrate that root grubs, tobacco caterpillars, and pod borers collectively posed a greater threat to chilli cultivation than thrips in the bhabhar region. More than half of farmers experienced damage from these alternative pest species, suggesting the need for integrated pest management strategies targeting multiple insect threats rather than focusing solely on thrips control in chilli production systems. Recent research highlights the considerable impact of thrips and various insect pests on chilli. The invasive species, *Thrips parvispinus* has inflicted substantial harm in several Indian regions, with documented cases of complete crop destruction in specific areas **(Veranna *et al.,* 2022).** Field surveys reveal that farmers universally regard thrips and mites as primary pest threats in chilli in certain locations **(Mannan *et al.,* 2020)**.

**Curling Percentage of Leaves:**

Chilli varieties were assessed for thrips damage response and categorized as immune, resistant, moderately resistant, susceptible, and highly susceptible based on leaf curling percentages as per the scale given by **Niles (1980)**. No varieties showed immunity to thrips infestation across the surveyed areas. Regional variations in variety resistance were significant. Sitarganj demonstrated superior resistance patterns with 38 % resistant varieties compared to only 4 % in Gadarpur. Moderately resistant varieties were predominantly cultivated in Sitarganj (54%) versus 10% in Gadarpur. Susceptibility patterns varied considerably across blocks. Khatima showed high susceptibility with 52 % of varieties affected, while only 4 % of Sitarganj varieties were susceptible. Gadarpur exhibited the highest vulnerability, with 36 % of varieties being highly susceptible to thrips, whereas Khatima recorded no highly susceptible varieties. Overall analysis revealed that 41.71 % of cultivated varieties across all blocks were susceptible to thrips. This increased susceptibility was attributed to intensive cultivation practices and excessive insecticide application, which enhanced thrips' tolerance capacity and consequently

**Table 1. Cultivation and farmers knowledge about insect pests in chilli**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Farmers’ Response** | | | | | | | |
| **Jaspur** | **Kashipur** | **Bajpur** | **Gadarpur** | **Rudrapur** | **Sitarganj** | **Khatima** | **Overall** |
| **Area (acre)** | | | | | | | | |
| <0.5 | 35  (70) | 10  (20) | 32  (64) | 29  (58) | 46  (92) | 44  (88) | 35  (70) | 231  (66) |
| 0.5 – 1 | 10  (20) | 29  (58) | 14  (28) | 9  (18) | 3  (6) | 6  (12) | 5  (10) | 76  (21.71) |
| >1 | 5  (10) | 11  (22) | 4  (8) | 12  (24) | 1  (2) | - | 10  (20) | 43  (12.29) |
| **Damage %** | | | | | | | | |
| thrips | 20  (40) | 28  (56) | 19  (38) | 36  (72) | 23  (46) | 15  (30) | 12  (24) | 153  (43.71) |
| other insects | 30  (60) | 22  (44) | 31  (62) | 14  (28) | 27  (54) | 35  (70) | 38  (76) | 197  56.29) |
| **Curling of leaves (%)** | | | | | | | | |
| 0 - 0% = immune | - | - | - | - | - | - | - | - |
| 1 - 1-25% = resistant | 7  (14) | 4  (8) | 9  (18) | 2  (4) | 5  (10) | 19  (38) | 8  (16) | 54  (15.43) |
| 2 - 26-50% = moderately resistant | 13  (26) | 10  (20) | 15  (30) | 5  (10) | 11  (22) | 27  (54) | 16  (32) | 97  (27.71) |
| 3 - 51-75% = susceptible | 24  (48) | 21  (42) | 25  (50) | 25  (50) | 23  (46) | 2  (4) | 26  (52) | 146  (41.71) |
| 4 - >75% = Highly susceptible | 6  (12) | 15  (30) | 1  (2) | 18  (36) | 11  (22) | 2  (4) | - | 53  (15.14) |
| **Plant part damaged by thrips** | | | | | | | | |
| Growing shoot | 23  (46) | 22  (44) | 20  (40) | 26  (52) | 23  (46) | 21  (42) | 18  (36) | 139  (39.71) |
| Older leaves | 18  (36) | 17  (34) | 19  (38) | 20  (40) | 18  (36) | 20  (40) | 21  (42) | 100  (28.57) |
| Flower | 7  (14) | 8  (16) | 10  (20) | 3  (6) | 9  (18) | 8  (16) | 10  (20) | 75  (21.43) |
| Fruit | 2  (4) | 3  (6) | 1  (2) | 1  (2) | - | 1  (2) | 1  (2) | 36  (10.29) |

N = 50, Data represented in parenthesis is the percentage of farmer respondents of respective categories during the survey

increased host plant vulnerability. The findings suggest that current pest management strategies may be inadvertently contributing to reduced plant resistance against thrips infestations.

**Part of plant damaged:**

Survey data from seven regional locations revealed distinct thrips damage patterns across different plant parts. Growing shoots were the primary target, affecting 139 farmers (39.71%), with consistent damage rates of 36-52 % across all locations. This pattern reflects thrips' preference for soft, developing tissues. Older leaves ranked second, impacting 100 farmers (28.57%) with uniform damage distribution (34-42%) across regions. This consistency suggests thrips attack mature foliage when populations are high or preferred feeding sites become limited. Flower damage affected 75 farmers (21.43%), showing significant regional variation. Khatima reported minimal damage (6%) while Gadarpur experienced the highest incidence (20%). These differences likely reflect varying crop varieties, growth stages, or local thrips population dynamics. Fruit damage was minimal, affecting only 36 farmers (10.29%). Most locations showed low percentages (2-6%), with Rudrapur reporting no fruit damage. This pattern aligns with thrips feeding behavior, as fruits are tougher and less palatable than other plant tissues. Regional variations were notable, with Gadarpur displaying the most diverse damage pattern across multiple plant parts, while other locations showed typical distributions favouring growing shoots and older leaves. These differences may result from regional farming practices, crop varieties, or environmental factors influencing thrips behavior. Effective thrips management should prioritize protecting young foliage and growing shoots while considering broader impacts on mature leaves and developing flowers and fruits. The current results were also reported across studies where thrips were found to be significant pests in various crops, causing damage to different plant parts. They primarily target growing shoots and young foliage, but also affect mature leaves, flowers, and fruits **(Visschers *et al.,*2023).** Thrips species composition and distribution vary across plant parts and growth stages. For instance, *Frankliniella fusca* dominates on cotton seedlings, while *F. tritici* is more prevalent on terminals, squares, and flowers **(Reay-Jones *et al.,* 2017).**

**KNOWLEDGE ABOUT PLANT PROTECTION PRACTICES**

The survey results on knowledge about plant protection practices among chilli farmers in various blocks of Udham Singh Nagar are presented in **Table 2**.

**Source of Plant Protection Advice**

Survey data from seven blocks in Udham Singh Nagar district showed university experts as the primary plant protection advice source for 191 farmers (54.57%), followed by department personnel (68 farmers, 19.43%), pesticide shops (59 farmers, 16.86%), and fellow farmers (32 farmers, 9.14%). Regional variations were pronounced. Rudrapur demonstrated highest university expert reliance at 78 % (39 farmers), followed by Kashipur at 70 % (35 farmers). Gadarpur showed contrasting patterns with only 20 % (10 farmers) consulting university experts, instead relying heavily on pesticide shops at 46 % (23 farmers) and department personnel at 22 % (11 farmers). Khatima exhibited highest dependence on department personnel at 30 % (15 farmers). Rudrapur farmers showed zero reliance on fellow farmers. Overall, 74 % of farmers depend on formal institutional sources, indicating effective agricultural extension service penetration. However, Gadarpur's divergent pattern suggests potential gaps in university extension services or distinct local practices requiring investigation to optimize advisory service delivery across the district. Current research supports the varied and changing nature of agricultural extension systems across India. Although university specialists and government officials continue to serve as valuable sources of plant protection guidance in certain areas **(Sahu *et al.,* 2024)**, private sector entities, especially input suppliers, have become the favoured information channels for numerous farmers **(Rao *et al.,* 2009).**

**Mixing of Chemicals**

The results on farmers' responses regarding mixing of chemicals across seven blocks in Udham Sigh Nagar district shows that a significant majority of 263 farmers (75.14%) engage in chemical mixing practices, while 87 farmers (24.86%) do not mix chemicals. Regional analysis reveals that Gadarpur has the highest proportion of farmers mixing chemicals at 88% (44 farmers), followed closely by Kashipur at 82 % (41 farmers) and Rudrapur at 80 % (40 farmers), while Khatima shows the lowest adoption of chemical mixing at 62 % (31 farmers), followed by Sitarganj at 68 % (34 farmers) and Bajpur at 72 % (36 farmers). The overall pattern indicates widespread adoption of chemical mixing practices across the region, with three-quarters of farmers employing this approach, though notable regional variations suggest differing local agricultural practices, knowledge levels, or extension service influence in chemical application methods. Current research supports the practice of mixing of chemicals that more than two-thirds of farmers (69.7%) mixed only needed pesticides, with a small percentage spreading them to other crops (15.8%) and disposing of them in the field (11.7%) **Sachan *et al.* (2022).** Althoughparticipant farmers had an average of 19.6 years of farming experience, women were mostly involved in pesticide mixing and other agricultural tasks other than spraying **Pandiyan *et al.* (2023)**.

**Total number of sprays per crop**

Survey data from seven blocks in Udham Singh Nagar district revealed varying spray application patterns across farmers. The majority (156 farmers, 44.57%) applied more than two

**Table 2. Knowledge of farmers about plant protection practices**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Farmers’ Response** | | | | | | | |
| **Jaspur** | **Kashipur** | **Bajpur** | **Gadarpur** | **Rudrapur** | **Sitarganj** | **Khatima** | **Overall** |
| **Plant protection advice** | | | | | | | | |
| University expert | 25  (50) | 35  (70) | 32  (64) | 10  (20) | 39  (78) | 23  (46) | 27  (54) | 191  (54.57) |
| Dept. personnel | 10  (20) | 5  (10) | 8  (16) | 11  (22) | 10  (20) | 9  (18) | 15  (30) | 68  (19.43) |
| pesticide shop | 6  (12) | 6  (12) | 7  (14) | 23  (46) | 1  (2) | 10  (20) | 6  (12) | 59  (16.86) |
| fellow farmers | 9  (18) | 4  (8) | 3  (6) | 6  (12) | - | 8  (16) | 2  (4) | 32  (9.14) |
| **Mixing of chemicals** | | | | | | | | |
| Yes | 37  (74) | 41  (82) | 36  (72) | 44  (88) | 40  (80) | 34  (68) | 31  (62) | 263  (75.14) |
| No | 13  (26) | 9  (18) | 14  (28) | 6  (12) | 10  (20) | 16  (32) | 19  (38) | 87  (24.86) |
| **Total number of sprays per crop** | | | | | | | | |
| 0 | - | - | - | - | - | - | - | - |
| 1 | 14  (28) | 8  (16) | 14  (28) | 9  (18) | 13  (26) | 20  (40) | 19  (38) | 97  (27.71) |
| 2 | 15  (30) | 15  (30) | 16  (32) | 10  (20) | 13  (26) | 15  (30) | 13  (26) | 97  (27.71) |
| >2 | 21  (42) | 27  (54) | 20  (40) | 31  (62) | 24  (48) | 15  (30) | 18  (36) | 156  (44.57) |
| **Interval between two sprays** | | | | | | | | |
| 5 days | 32  (64) | 38  (76) | 31  (62) | 40  (80) | 35  (70) | 31  (62) | 29  (58) | 236  (67.43) |
| 10 days | 12  (24) | 9  (18) | 13  (26) | 8  (16) | 8  (16) | 13  (26) | 14  (28) | 77  (22.00) |
| 15 days | 6  (12) | 3  (6) | 6  (12) | 2  (4) | 7  (14) | 6  (12) | 6  (12) | 36  (10.29) |
| > 15 days | - | - | - | - | - | - | 1  (2) | 1  (0.29) |

N = 50, Data represented in parenthesis is the percentage of farmer respondents of respective categories during the survey

sprays per crop, while equal proportions used either one spray or two sprays (97 farmers each, 27.71%). No farmers reported zero sprays. Regional analysis showed Gadarpur with highest spray intensity at 62% (31 farmers) using more than two sprays, followed by Kashipur at 54 % (27 farmers) and Rudrapur at 48 % (24 farmers). Sitarganj and Khatima demonstrated more conservative practices with only 30 % (15 farmers) and 36 % (18 farmers) respectively applying multiple sprays. Single spray application was most common in Sitarganj (40%, 20 farmers) and Khatima (38%, 19 farmers), while Kashipur had the fewest single-spray users at 16 % (8 farmers). Two-spray application showed uniform distribution ranging from 20 % in Gadarpur to32 % in Bajpur. Overall, 72.28 % of farmers applied two or more sprays per crop, indicating intensive chemical practices. Gadarpur and Kashipur showed most intensive applications while Sitarganj and Khatima adopted moderate approaches.

Current research supports the practice of number of sprays taken per crop which shows that pesticide use patterns vary across regions in India, with higher usage in plains compared to hilly areas. In Udham Singh Nagar district, most farmers apply multiple sprays per crop, indicating intensive chemical practices **(Miglani *et al.,* 2019).** Nationwide, pesticide consumption trends show fluctuations, with some states experiencing increased usage while others demonstrate declining trends **(Devi *et al.,* 2017).**

**Interval between two sprays**

Survey data from seven blocks in Udham Singh Nagar district revealed intensive spray scheduling patterns among farmers. The majority (236 farmers, 67.43%) maintained 5-day intervals between sprays, followed by 77 farmers (22.00%) using 10-day intervals, 36 farmers

**Table 3: Frequently used pesticides in chilli crop in bhabhar region of Uttarakhand**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Pesticide** | **Trade name** | **Class of Pesticide** | **Colour on the Label** | **Toxicity Class** | **Used against** |
| 1 | **Imidaclorprid** | Confidor | Neonicotinoid |  | II | Sucking insects |
| 2 | **Chlorpyrifos** | Terminator | Organophosphate |  | II | Soil dwelling insects |
| 3 | **Cypermethrin** | Cymbush | Synthetic Pyrethoids |  | II | Borers and Foliage feeders |
| 4 | **Phorate** | Thimet | Organophosphate |  | Ia | Soil dwelling insects |
| 5 | **Dimethoate** | Rogor | Organophosphate |  | II | Sucking insects |

(10.29%) employing 15-day intervals, and only one farmer (0.29%) in Khatima extending beyond 15 days. Regional analysis showed Gadarpur with highest adherence to 5-day intervals at 80 % (40 farmers), followed by Kashipur at 76 % (38 farmers) and Rudrapur at 70 % (35 farmers). Khatima demonstrated lowest adoption at 58 % (29 farmers). For 10-day intervals, Khatima led with 28 % (14 farmers), followed by Bajpur and Sitarganj at 26 % each (13 farmers), while Gadarpur and Rudrapur showed lowest usage at 16 % each (8 farmers). Fifteen-day intervals were least popular, ranging from 4 % in Gadarpur to 14 % in Rudrapur, with most areas maintaining around 12 %. Results indicate overwhelmingly intensive spray schedules, with nearly 90 % of farmers applying insecticides at 10-day intervals or less, suggesting high pest pressure, intensive farming practices, or excessive chemical dependency. Gadarpur and Kashipur demonstrated the most intensive frequency patterns.

The studies revealed diverse pesticide application practices across regions. In Switzerland, 36 per cent of farmers apply fungicides earlier than recommended due to economic risks and disease uncertainty **(Mohring *et al.,* 2020).** In India and Nepal, most farmers (93% and 90% respectively) rely on chemical control, with 73 per cent in India and 86 per cent in Nepal initiating treatment at first pest appearance **(Rao *et al.,* 2009).**

**KNOWLEDGE OF FARMERS ABOUT SAFE USAGE OF INSECTICIDES**

The survey results on knowledge about safe usage of insecticides among chilli farmers in various blocks of Udham Singh Nagar are presented in **Table 4**.

**Safety period from last spray and harvest**

Survey data from seven blocks in Udham Singh Nagar district revealed concerning patterns in waiting periods. The majority of farmers (149, 42.57%) maintained 7-day waiting periods, followed closely by 135 farmers (38.57%) using 10-day periods. Smaller proportions observed 15-day waiting periods (32 farmers, 9.14%) and 3-day waiting periods (34 farmers, 9.71%), with no farmers extending beyond 15 days of waiting periods. Regional analysis showed Gadarpur with highest 7-day waiting period adoption at 52 % (26 farmers), followed by Kashipur at 48% (24 farmers) and Rudrapur at 46 % (23 farmers). Sitarganj demonstrated lowest adoption at 32 % (16 farmers). For 10-day waiting periods, Sitarganj and Khatima led with 48 % (24 farmers) and 46 % (23 farmers) respectively, while Gadarpur showed lowest usage at 26 % (13 farmers). The concerning 3-day waiting period was highest in Gadarpur at 18 % (9 farmers) and Kashipur at 16 % (8 farmers), compared to only 4 % (2 farmers each) in Sitarganj and Khatima. Fifteen-day waiting periods showed low adoption, ranging from 4 % in Gadarpur to 16 % in Sitarganj. Overall, over 80 % of farmers maintained waiting periods of 10 days or less, with nearly half observing only 7-day intervals, suggesting potential food safety concerns and inadequate adherence to recommended waiting period, particularly in Gadarpur and Kashipur.

Recent studies regarding the present findings highlight concerning patterns in pesticide use and food safety practices among farmers. Many farmers, especially in plain regions, adopt short pre-harvest intervals of 3-7 days, potentially leading to unsafe residue levels. However, some positive practices were observed, with farmers in hilly regions maintaining longer pre-harvest intervals **(Vinothkumar *et al.,* 2025).** Furthermore, a study found that 90 per cent of horticulture farmers showed moderate to high awareness of practices to minimize pesticide residues, including using branded green pesticides and observing 7-10 day waiting periods **(Ghanghas *et al.,* 2023)**. This aligns with findings that some farmers harvest vegetables within a week of pesticide application, violating recommended waiting periods **(Mitku, 2021).**

**Preparation of Spray Solution**

Survey data from seven blocks in Udham Singh Nagar district revealed varying spray solution preparation practices. Nearly half the farmers (168, 48.00%) used bamboo sticks, followed by 128 farmers (36.57%) using gloves, while 54 farmers (15.43%) prepared solutions with bare hands. Regional analysis showed Sitarganj with highest bamboo stick usage at 54% (27 farmers), followed by Bajpur, Gadarpur, and Khatima at 50 % each (25 farmers), while Kashipur showed lowest usage at 42 % (21 farmers). For glove usage, Kashipur and Gadarpur led with 44 % (22 farmers) and 40 % (20 farmers) respectively, along with Rudrapur at 40 % (20 farmers). Jaspur showed lowest adoption at 28 % (18 farmers). The concerning bare-hand practice was most prevalent in Jaspur and Khatima at 18 % each (9 farmers), followed by Bajpur, Sitarganj, and Rudrapur at 16 % each (8 farmers). Gadarpur showed lowest rate at 10 % (5 farmers). While 84.57 % employed protection during preparation, 15.43 % still engaged in unsafe direct contact practices, highlighting the need for enhanced safety awareness and training programs. **Rakesh *et al.* (2017)** also revealed that 39 percent of the 98 farmers interviewed mixed the chemicals with their bare hands, one-third disposed of empty agrochemical sacs or tins in the open, and 43% reused containers/sacks to keep supplies at home. **Sai *et al.* (2019)** also reported that 118 males and 53 females participated in the study, with a median age of 40 years. Approximately 61 % of farmers were aware of the adverse consequences of pesticides. However, 22 % were mixing insecticides with their bare hands. The habit of storing, mixing, and applying agrochemicals without personal protective equipment, as well as the unsafe disposal of pesticide containers, appears to be widespread in the study communities.

**Table 4. Knowledge about safe usage of insecticides**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Farmers’ Response** | | | | | | | |
| **Jaspur** | **Kashipur** | **Bajpur** | **Gadarpur** | **Rudrapur** | **Sitarganj** | **Khatima** | **Overall** |
| **Safety period from last spray and harvest** | | | | | | | | |
| 3 days | 4  (8) | 8  (16) | 3  (6) | 9  (18) | 6  (12) | 2  (4) | 2  (4) | 34  (9.71) |
| 7 days | 21  (42) | 24  (48) | 20  (40) | 26  (52) | 23  (46) | 16  (32) | 19  (38) | 149  (42.57) |
| 10 days | 20  (40) | 15  (30) | 23  (46) | 13  (26) | 17  (34) | 24  (48) | 23  (46) | 135  (38.57) |
| 15 days | 5  (10) | 3  (6) | 4  (8) | 2  (4) | 4  (8) | 8  (16) | 6  (12) | 32  (9.14) |
| > 15 days | - | - | - | - | - | - | - | - |
| **Preparation of spray solution** | | | | | | | | |
| Bare hands | 9  (18) | 7  (14) | 8  (16) | 5  (10) | 8  (16) | 8  (16) | 9  (18) | 54  (15.43) |
| With gloves | 18  (28) | 22  (44) | 17  (34) | 20  (40) | 20  (40) | 15  (30) | 16  (32) | 128  (36.57) |
| With bamboo sticks | 23  (46) | 21  (42) | 25  (50) | 25  (50) | 22  (44) | 27  (54) | 25  (50) | 168  (48.00) |
| **Use of protective clothes during spraying** | | | | | | | | |
| Yes | 41  (82) | 44  (88) | 40  (80) | 46  (92) | 43  (86) | 38  (76) | 39  (78) | 291  (83.14) |
| No | 9  (18) | 6  (12) | 10  (20) | 4  (8) | 7  (14) | 12  (24) | 11  (22) | 59  (16.86) |
| **Knowledge about CIBRC guidelines** | | | | | | | | |
| Yes | 24  (48) | 29  (58) | 23  (46) | 26  (52) | 30  (60) | 21  (42) | 20  (40) | 173  (49.43) |
| No | 26  (52) | 21  (42) | 27  (54) | 24  (48) | 20  (40) | 29  (58) | 30  (60) | 177  (50.57) |

N=50, Data represented in parenthesis is the percentage of farmer respondents of respective categories during the survey

**Use of protective clothing during protection**

Survey data from seven Uttarakhand locations revealed that 291 farmers (83.14%) used protective clothing during spraying, while 59 farmers (16.86%) did not employ safety measures. Regional analysis showed Gadarpur with highest protective clothing adoption at 92 % (46 farmers), followed by Kashipur at 88 % (44 farmers) and Rudrapur at 86 % (43 farmers). Sitarganj demonstrated lowest usage at 76 % (38 farmers), followed by Khatima at 78 % (39 farmers) and Bajpur at 80 % (40 farmers). Correspondingly, Sitarganj had highest non-compliance at 24 % (12 farmers), followed by Khatima at 22 % (11 farmers) and Bajpur at 20 % (10 farmers). Gadarpur showed best safety compliance with only 8 % (4 farmers) not using protective gear. The pattern indicates strong safety awareness, with over four-fifths recognizing protective clothing importance. However, location variations suggest Sitarganj and Khatima need enhanced safety training, while Gadarpur and Kashipur demonstrate exemplary safety consciousness serving as potential models for other areas. Similar findings were reported by **Banerjee *et al.* (2014)** also investigated the personal protection measures adopted by farmers during spraying and discovered that covering the nose and mouth with a handkerchief and bathing after spraying was the most common practice (27%). **Rakesh *et al.* (2017)** also found that just 28 % of the 98 farmers interviewed employed appropriate personal protection equipment when applying agrochemicals. **Sai *et al.* (2019)** where 26 % of pesticide sprayers did not use protective clothes and approximately 67 % were irresponsibly disposing of pesticide residue in open fields.

**Knowledge about CIBRC guidelines**

Survey data from seven Uttarakhand locations revealed nearly equal distribution in CIBRC (Central Insecticides Board and Registration Committee) guideline awareness, with 173 farmers (49.43%) having knowledge while 177 farmers (50.57%) lacked awareness. Regional analysis showed Rudrapur with highest awareness at 60 % (30 farmers), followed by Kashipur at 58 % (29 farmers) and Gadarpur at 52 % (26 farmers). Khatima demonstrated lowest awareness at 40 % (20 farmers), followed by Sitarganj at 42 % (21 farmers) and Bajpur at 46 % (23 farmers). Correspondingly, Khatima had highest unawareness at 60 % (30 farmers), followed by Sitarganj at 58 % (29 farmers) and Bajpur at 54 % (27 farmers). Rudrapur showed best regulatory awareness with only 40 % (20 farmers) lacking knowledge. The studies on awareness about CIBRC (Central Insecticides Board and Registration Committee) guidelines among chilli farmers across studies revealed a concerning lack of awareness among farmers regarding proper pesticide use and regulatory guidelines. In Himachal Pradesh, no farmers were familiar with CIBRC guidelines, with 57.33 per cent relying on pesticide dealers for advice **(Singh *et al.,* 2016).** Similarly, in Aligarh, farmers were unaware of CIBRC's roles and guidelines **(Ali *et al.,* 2022).** A nationwide survey found that only 20 per cent of farmers obtained plant protection information from agricultural extension officers **(Shetty *et al.,* 2010).** This suggests urgent need for comprehensive extension programs and regulatory education initiatives, particularly in Khatima, Sitarganj, and Bajpur where awareness levels fall significantly below regional average, while Rudrapur and Kashipur could serve as dissemination models.

**Conclusion**

A comprehensive survey across seven blocks in Udham Singh Nagar district in the bhabhar region of Uttarakhand examined chilli cultivation practices among farmers. The study found that more than half of farmers were marginal, with significant regional variations. Thrips affected nearly half of the farmers, with a significant number of varieties grown being susceptible due to intensive cultivation and excessive insecticide use. University experts were the primary advisory source to more than half of respondent farmers, though many relied heavily on pesticide shops. Chemical usage was intensive, with around two-thirds of farmers mixing different chemicals during spray and applying multiple sprays per crop, concerningly following a short gap of just five days between sprays. While majority of farmers used protective clothing and followed waiting periods for safety before harvest, institutional knowledge of insecticide usage guidelines was not prominent among farmers. The survey reveals urgent need for sustainable pest management strategies, enhanced safety training, and localized extension approaches combining resistant variety development and strengthened extension services to improve productivity and farmer safety.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

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**Appendix**

**Appendix 1: Questionnaire of the survey regarding pesticide usage patterns in bhabhar region of Uttarakhand**

|  |  |
| --- | --- |
| **Activity** | **Remarks** |
| Cultivation and knowledge about insect pests | |
| Area (acre) | <0.5 / 0.5-1.0 / >1.0 |
| Damage % | Thrips / other insects |
| Curling of leaves (%) | Immune / resistant / moderately resistant / susceptible / highly susceptible |
| Plant part damaged by thrips | Growing shoots / older leaves / flower / fruit |
| Knowledge about plant protection practices | |
| Plant protection advice | University expert / department personnel / pesticide shop / fellow farmers |
| Mixing of chemicals | Yes / No |
| Total number of sprays per crop | 0 / 1 / 2 / >2 |
| Interval between two sprays | 5 days / 10 days / 15 days / >15 days |
| Knowledge about safe usage of insecticides | |
| Safety period from last spray and harvest | 3 days / 7 days / 10 days / 15 days / >15 days |
| Preparation of spray solution | Bare hands / gloves / bamboo sticks |
| Use of protective clothes during spraying | Yes / No |
| Knowledge about CIBRC guidelines | Yes / No |

**Appendix 2: Details of surveyed locations in Udham Singh Nagar district in bhabhar region of Uttarakhand**

|  |  |
| --- | --- |
| **Block/taluka** | **Villages** |
| **Jaspur** | Bahadarpur, Murliwala, Meghawala, Puranpur, Nedahi, |
| **Kashipur** | Dhakia No. 2, Bhimnagar, Firojpur, Nandrampur, Kundeshwari, |
| **Bajpur** | Bannakhera, Bidumpur, Haripura, Rainta, Shivpuri |
| **Gadarpur** | Sakainiya, Junni Majra, Ram Yuman Pur No. 2, Rajpura No. 1, Teja khoja |
| **Rudrapur** | Gadaria Bang, Sirali Kalan, Laxmipur, Gangoli, Pantpura |
| **Sitarganj** | Sirsa, Gaganpur, Gaurikhera, Sisona, Karghatiya |
| **Khatima** | Kumrah, Banusa, Dewari, Sujaya Maholiya, Naugavataggu |