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# Monitoring and analysis of the distribution of pests of major exportable herbs in Nepal

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## ABSTRACT

The inhabitants of Nepal's hilly and Himalayan regions heavily depend on herbs and medicinal plants as a primary source of livelihood. In rural hilly and mountainous areas, the collection and trade of herbs remain the predominant source of income for a significant portion of the Nepalese population. Despite the economic importance of herb collection and trade, there has been limited systematic work on pest identification for exportable herbs in Nepal. This lack of study results in restricted options for effectively controlling diseases and insect pests affecting these herbs and their export. To address this gap, a comprehensive survey of major exportable herbs—Amla (*Phyllanthus emblica*), Pakhanved (*Bergenia ciliata*), and Nagbeli (*Lycopodium clavatum*)—was conducted from October 2021 to July 2022 in these herbs-producing major districts (Gorkha, Kaski, Dailekh, Salyan, Dhankuta, Dhading, Baglung, and Dolakha) in Nepal. The survey aimed to assess the distribution and occurrence of common diseases and pests in Nepal. The survey findings indicated that certain pathogens and pests were widespread, while others exhibited a more localized distribution. Specifically, the survey identified a total of 7 diseases, 8 insects, and 15 weeds affecting Amla, 4 diseases, 3 insects, and 3 weeds affecting Pakhanved, and 3 diseases, 5 insects, and 19 weeds affecting Nagbeli. These results offer valuable insights into the national status of pest issues related to exportable herbs in Nepal. These findings provide a localized perspective on the specific diseases and pests affecting the surveyed regions, offering valuable insights for targeted management and control strategies.

**Keywords:** Diseases, Insect pests, Weeds, Surveillance

## INTRODUCTION

Nepal is rich in plant diversity because of altitudinal variation, diverse geography, and the presence of different climatic zones. It has been estimated that there are more than 7000 species of flowering and about 4000 species of non-flowering plants (MoFSC, 2002; MoFSC, 2014). Out of the total plants recorded from Nepal, about 1500-1800 species are being used by local communities to treat various ailments, and more than 100 species are annually traded in and outside Nepal as herbs and medicinal and aromatic plants. Medicinal and aromatic plants (MAPs) have been used since ancient times for healthcare. It has been estimated that about 80% of the population in developing countries still rely on medicinal plants for their healthcare (Gurung and Pyakurel, 2017). Medicinal plants are traded commercially to produce pharmaceuticals, dietary supplement products, natural health products, cosmetics and other personal care products, and culinary products (Medicinal Plants Specialist Group, 2007). An estimated 480–2500 tons of alpine and subalpine medicinal plants are traded annually in Nepal, with a total harvester value of US$0.8–3.3 million; an average harvester value of US$66.0 ± 99.0 is estimated. 1600 tons of trade were conducted in 1997–1998; the harvester value was valued at US$2.3 million, and the export value accounted for 2.5% of Nepal's overall export earnings. Harvesting medicinal plants was discovered to be an integrated aspect of community livelihood plans, accounting for 3 to 44% (on average, 12%) of yearly household income (Olsen and Larsen, 2003). Studies revealed that about 7000 to 27000 tons of medicinal plants are collected and traded annually from Nepal. The total export value is expected to be about US$ 60 million, of

which most of the collected medicinal plants are exported to India and China in raw form (Gurung and Pyakurel, 2017).

Amla (*Phyllanthus emblica*), pakhanved (*Bergenia ciliata*), and Nagbeli (*Lycopodium clavatum*) are potential exportable herbs that have a significant contribution to the herbal trade in Nepal. Amla, also known as gooseberry, is an important herb used as a medicinal plant since ancient times. It is grown from an altitude of 150 m to the mid-hills (1800m) of Nepal. Its fruit and seeds are used for medicinal purposes. The fruits are harvested from September to April. Similarly, Pakhanved is one of the most demanding herbs in Nepal, and root is the major part used for medicinal purposes. It is also known as rock foil. It is a high-altitude herb found from east to west in Nepal at an altitude of 1000-3200 m. Dailekh, Bajhang, and Baitadi districts are major districts for the collection of this herb which is collected from October to April. Nagbeli is also known as common club moss. It is found from east to west in Nepal at an altitude of 1800-2400 m. Dhankuta, Sindhupalchok, Makawanpur, Dhading, and Baglung are major districts for the collection of Nagbeli. Its fruits and leaves are the major parts used. It is collected during September and October.

With rising global demand, people engaged in collection and trade are getting significant economic returns. The collection and trade of herbs is still the major source of income for the majority of the Nepalese population residing in rural, hilly and the mountainous regions. These herbal plants and plant products are transported from the source to Terai and Kathmandu for export outside the country, mostly in crude form. However, pest surveillance of these plants (Amla, Pakhanved, and Nagbeli) in a systematic way is lacking in Nepal. Nepal's accession to the World Trade Organization (WTO) in 2004 offers significant opportunities for the country to foster trade and good trade governance. As a member country of WTO, Nepal possesses a genuine right to export home-produced herbs and MAPs to foreign countries. However, these commodities must meet the International Standard for Phyto-Sanitary Measures (ISPMs) issued by the International Plant Protection Convention (IPPC). Pest information in export and import plant and plant products is vital to implementing phytosanitary measures. Therefore, this study was conducted for pest survey and surveillance of these exportable herbs to generate a national pest database and facilitate herbal trade in Nepal and abroad with the support of Plant Quarantine and Pesticide Management (PQPMC), Nepal.

## MATERIAL AND METHODS

To conduct a pest survey and surveillance of three major exportable herbs (Amla, Pakhanved, and Nagbeli), we conducted both desk and field studies to collect quantitative and qualitative data using various methods and tools. The primary data and relevant information were collected mostly through the field visit. Different methodologies and procedures were adopted for conducting pest surveys and surveillance. More specifically, surveillance was carried out by following ISPM 6 and national standards related to surveillance from October 2021 to July 2022.

The areas for pest surveillance were selected based on the volume of production of respective herbs, problems of pests, and agroecological conditions. Proper representation of the specific herbal plants and areas for documentation were considered during the study. The survey was carried out by trained technical personnel under the direct supervision of the experts to determine pest status in an area by following the survey protocol approved by the NPPO. The study districts **(Figure 1)** with additional information **(Table 1)** for survey and surveillance of pests (diseases, insects, and weeds) on three herbal plants were as below**.**

**Table 1.** Selected districts of pests of exportable herbs in Nepal

| S. N | Herbs | District | Municipality | Locality | Latitude | Longitude | Altitude (masl) |
|---|---|---|---|---|---|---|---|
| **1.** | Amla | Gorkha | Gorkha | Gorbung | 27°56.3190'N | 84°30.1680'E | 700 |
| | | Kaski | Lekhnath | Ghachok | 28°18.6410'N | 83°55.3500'E | 1149 |
| | | Salyan | Kapurkot | Dhanwang | 28°14.6620'N | 82°21.0860'E | 1492.2 |
| | | Dhankuta | Pakhribas | Muga | 27°2.8480'N | 87°14.6660'E | 1401 |
| **2.** | Pakhanved | Dailekh | Gurans | Piladi | 26°30.3340'N | 87°28.3940'E | 2208.1 |
| | | Salyan | Kapurkot | Dhanwang | 28°14.6620'N | 82°21.0860'E | 1489 |
| | | Dhading | Galchi | Papre | 27°8.8480'N | 85°14.6660'E | 1986.4 |
| | | Baglung | Kathekhola | Baur | 28°19.4420'N | 83°29.7850'E | 2405 |
| **3.** | Nagbeli | Dolakha | Bhimeshwor | Hiledada | 27°40.2010'N | 86°2.7280'E | 2084 |
| | | Baglung | Kathekhola | Baur | 28°13.0920'N | 83°33.0670'E | 2048 |
| | | Dhankuta | Pakhribas | Naagidada | 27°3.2470'N | 87°17.6410'E | 1983.2 |

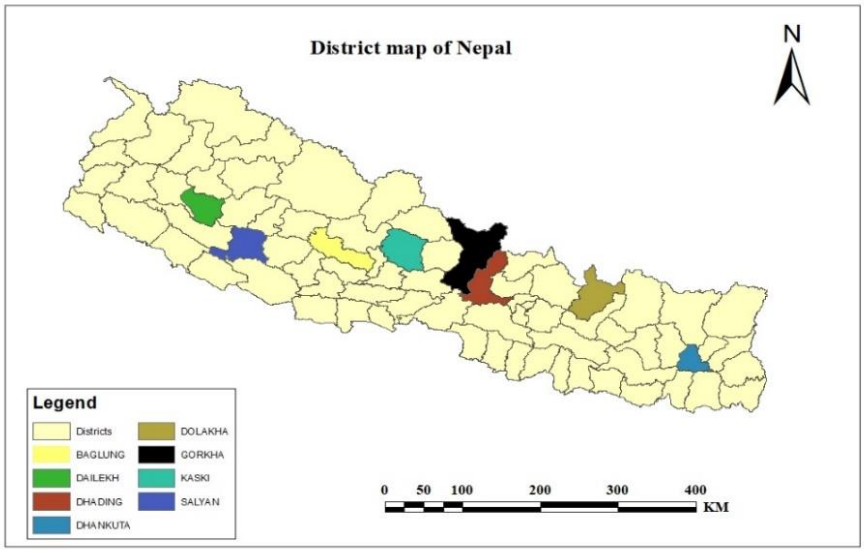



**Fig. 1.** Study sites of pest and weeds of major exportable herbs of Nepal

Data collection was done during vegetative, flowering, and seed/fruit maturity stages at 25 to 30 days intervals. Pests were tried to identify in the field; however, the final diagnosis was done in labs (Plant pathology, Entomology, and Agronomy) of Agriculture and Forestry University, Rampur, Chitwan, Nepal.

**Samples collection:**

**Insect sampling:**

Adult insects were collected from plants by sweep nets and/or by hand picking. Killing jars were used for "small-scale fumigation" to kill collected insects as rapidly as possible using liquid fumigant (ethyl acetate). The insect specimens collected from the field were transported as wet (in 70 percent alcohol) or dry (pinned up). For wet specimens, screw-capped vials with a capacity of 5-10 ml were used for large insects, such as beetles, and 1-2 ml for thrips with 90% ethanol. The well-labeled specimens were preserved in the lab of Agriculture and Forestry University (AFU), Rampur, Chitwan for further processing and identification. Hand-picked-up eggs, larvae, and nymphs were preserved in plastic Petri dishes of size 100mm and let to grow into adults. The adult insects were spread on a tray, pinned up, and preserved in an insect box with proper labelling. Soft-bodied insects, such as aphids and mealy bugs were preserved in small vials with 90% ethyl alcohol and thereafter these specimens were cautiously taken out from the vial using standard camel hairbrush and identified using stereo-microscope. The insects were classified as major, and minor based on the frequency of occurrence during the visit and the severity of damage caused by the insects in the field.

**Disease sampling:**

Based on plant parts infected, leaves, flowers, fruits, twigs, stems, and roots with initial to severe symptoms were collected from the field. For root diseases, soil and crown (lower stem) tissues with root samples were collected. Leaves and flowers were pressed into desiccant papers, and stems, fruits, and roots were placed into zip-lock plastic bags with proper labeling. The samples were delivered to the lab and stored in a refrigerator at 2–5 °C until use. For nematode sampling, soil samples were taken from a depth of 15 cm near the root zone, and affected roots were also sampled and placed in zip lock bags with proper labelling Diseases were also classified as major and minor based on the incidence and severity of the disease in the field.

**Weed sampling:**

Stems, leaves, flowers, fruits/seeds, roots, and/or whole plants of the herbaceous plants and twigs, leaves, and flowers of trees and shrubs were collected. The samples were assigned a unique collection number and they were placed in zipper plastic bags. For preservation, each sample was pressed into a 45 cm*30 cm cardboard sheet, checked daily, and later arranged on the mounting paper.

**Identification of the samples:**

Insect pests and weeds with typical characteristics and diseases with typical symptoms were identified in the field and those unidentified in the field were identified in labs of AFU, Rampur, Chitwan.

The dry-transported specimens to the AFU laboratory were placed on white paper and sorted out according to the insect orders. In the case of the wet specimen, the specimen was taken out and the alcohol content was dried using blotting papers. The specimen was pinned by a standard insect pin and kept for three

days for complete drying. The dried and pinned specimens were kept in the standard insect box at the AFU laboratory. Insect pests were identified by observing the morphology of the adult insects under a stereo microscope and with the help of reference materials. Diseases were tried to identify in the field by observing fresh, typical symptoms. Undiagnosed samples in the field were identified in lab with the help of spore, hyphae, and / or colonial morphology in fungi, cellular and colonial characters in bacteria, with symptoms and juvenile characters in nematodes, and with only typical symptoms in viruses. Weeds were identified based on the morphological character of the plants. Helps of references was taken properly in each case.

## RESULTS

**Amla:**

**Diseases:**

In Gorkha, the predominant diseases were rust (*Ravenelia emblicae*) and leaf spot (*Pestalotiopsis* spp.) **(Table 2)**. Additionally, anthracnose exhibited higher disease severity across all surveyed districts, posing a significant problem, particularly during the fruiting stage **(Figure 2).** From the survey, it was also found that lichen infection in the stems was also numerous in fields in both Kaski and Gorkha.

**Table 2.** Diseases appeared in Amla in different districts.

| S.N. | Common name | Scientific name | Plant parts affected | Occurrence | District |
|---|---|---|---|---|---|
| **1.** | Pestalotiopsis leaf spot | *Pestalotiopsis* spp. | Leaf, Fruit | Major | Gorkha |
| **2.** | Anthracnose | *Coletotrichum gloeosporoides* | Leaf, Fruit | Major | Gorkha, Kaski, Salyan, Dhankuta |
| **3.** | Lichen | *Strigula* spp. | Bark/ Stem | Major | Gorkha, Kaski, Dhankuta |
| **4.** | Rust | *Ravenelia* emblicae | Leaf, Fruit | Major | Gorkha, Salyan |
| **5.** | Gray mold | *Penicillium* spp. | Fruit | Minor | Gorkha, Kaski, Salyan |
| **6.** | Fruit rot | *Phomopsis vexans* | Fruit | Minor | Kaski |
| **7.** | Leaf spot | *Alternaria* spp. | Leaf, Fruit | Minor | Kaski |

(a) Pestalotiopsis Leaf spot (b) Leaf rust (c) Gray mould (d) Fruit rot (e) Anthracnose

(f) Leaf spot (g) Lichen

**Fig. 2.** Symptoms of various diseases in Amla appeared in various districts.

**Insects:**

Substantial damage was caused by mealy bug (*Nipaecoccus viridis)*, bark-eating caterpillar *(Indarbela tetraonis)*, and apical twig gall maker (*Betousa stylophora*) in the majority of surveyed districts **(Figure 3)**, while remaining other insects appeared as minor pests **(Table 3).**

**Table 3.** Insects appear in Amla in various districts.

| S.N. | Common name | Scientific name | Order | Family | Occurrence | District |
|---|---|---|---|---|---|---|
| **1.** | Apical twig gall maker | *Betousa stylophora* | Lepidoptera | Thyrididae | Major | Gorkha, Kaski |
| **2.** | Mealy bug | *Nipaecoccus viridis* | Hemiptera | Pseudococcidae | Major | Gorkha, Kaski |
| **3.** | Bark eating caterpillar | *Indarbela tetraonis* | Lepidoptera | Cossidae | Major | Gorkha, Kaski, Dhankuta |

| | | | | | | |
|---|---|---|---|---|---|---|
| **4.** | Short-horn grasshopper | *Hieroglyphus banian* | Orthoptera | Acrididae | Minor | Gorkha |
| **5.** | Short-horn grasshopper | *Heteropternis* spp. | Orthoptera | Acrididae | Minor | Kaski, Dhankuta, |
| **6.** | Metallic shield bug | *Scutellera nepalensis* | Hemiptera | Scutelleridae | Minor | Dhankuta, Gorkha |
| **7.** | Rice skipper | *Pelopidas mathias* | Lepidoptera | Hesperiidae | Minor | Kaski |
| **8.** | Tiger moth | *Nyctemera* spp. | Erebidae | Lepidoptera | Minor | Kaski, Dhankuta |

(a) Short-horned grasshopper

(b) Short horn grasshopper

(c) Metallic shield bug

(d) Rice skipper


(e) Apical twig gall maker (damage)


(f) Mealy bug


(g) Bark eating caterpillar (damage)

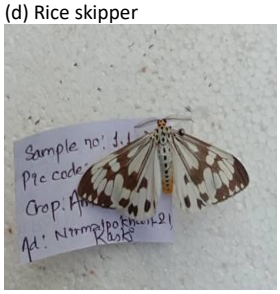

(h) Tiger moth

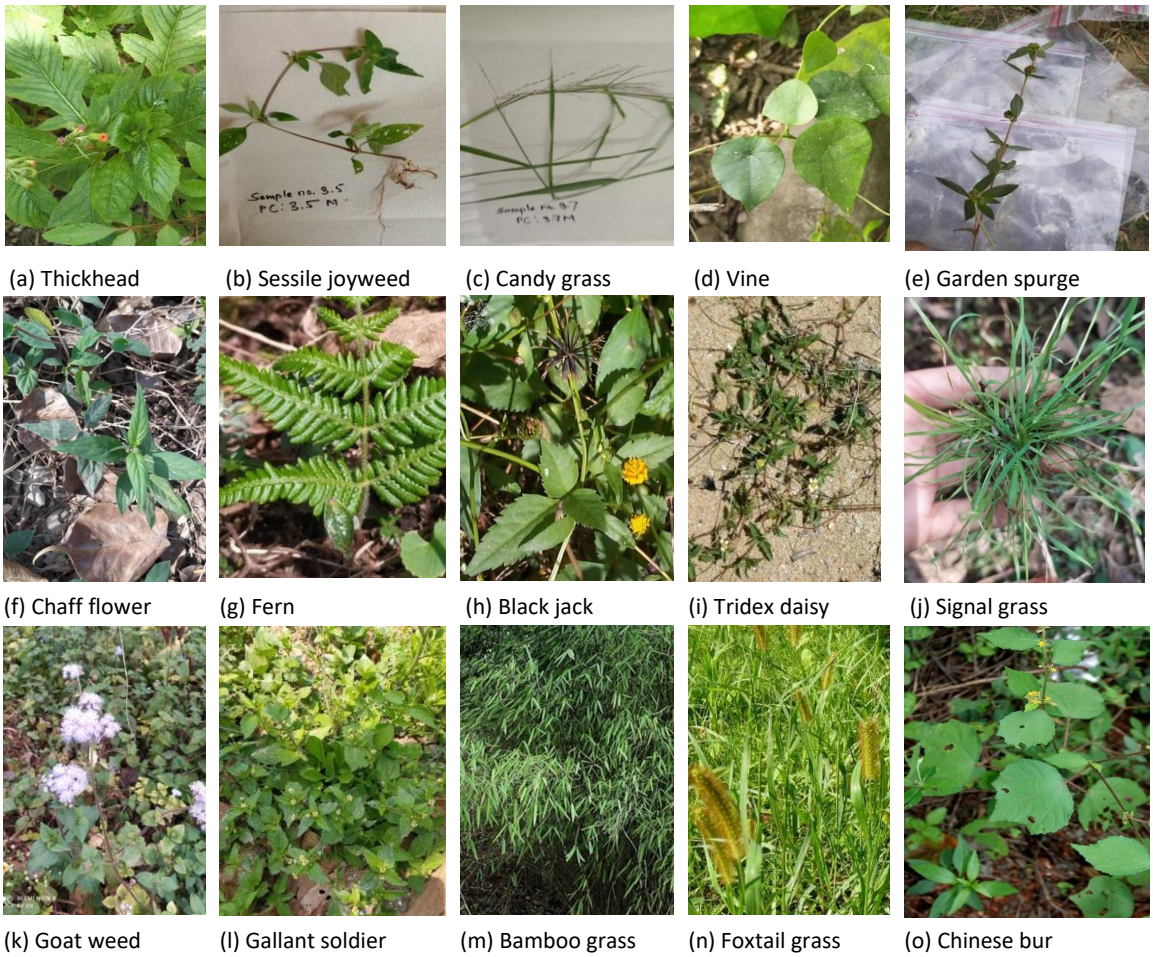
**Fig. 3.** Insects appeared in Amla in various districts.

**Weeds:**

A total of 22 weed species were identified from the Amla field. The most important families according to the number of represented species were Amaranthaceae, Asteraceae, and Euphorbiaceae in descending order **(Table 4)**. The most frequent and dominant weeds were *Ageratum* spp., *Galinsoga* spp. and *Alternanthera* spp in Gorkha and Kaski and *Brachiaria* spp and *Eragrostis spp* in Dhankuta and Salyan as shown in **Figure 4**.

**Table 4.** Weeds found in Amla in different districts.

| S.N. | Name of weed | Scientific name | Family | District |
|---|---|---|---|---|
| 1. | Goat weed | *Ageratum* spp. | Amaranthaceae | Gorkha, Kaski |
| 2. | Chaff flower | *Achyranthus* spp. | Amaranthaceae | Gorkha |
| 3. | Gallant soldier | *Galinsoga* spp. | Asteraceae | Gorkha, Kaski, Salyan |
| 4. | Black jack | *Bidens pilosa* | Asteraceae | Gorkha, |
| 5. | Tridax daisy | *Tridexpro cumbens* | Asteraceae | Gorkha, Salyan |
| 6. | Thickhead | *Crassocephalum* spp. | Asteraceae | Gorkha |
| 7. | Sessile joyweed | *Alternanthera* spp. | Euphorbiaceae | Gorkha, Kaski |
| 8. | Garden spurge | *Euphorbia hirta* | Euphorbiaceae | Kaski |
| 9. | Chinese bur | *Triumfetta* spp. | Malvaceae | Gorkha |
| 10. | Vine | *Stephania* spp. | Menispermaceae | Kaski |
| 11. | Candy grass | *Eragrostis nigra* | Poaceae | Gorkha |
| 12. | Foxtail grass | *Setaroa glauca* | Poaceae | Gorkha, Kaski, Dhankuta, Salyan |
| 13. | Bamboo grass | *Fargessia* spp. | Poaceae | Kaski |
| 14. | Signal grass | *Brachiaria* spp. | Poaceae | Dhankuta, Salyan |
| 15. | Love grass | *Eragrostis* spp. | Poaceae | Kaski, Dhankuta, Salyan |



(a) Thickhead (b) Sessile joyweed (c) Candy grass (d) Vine (e) Garden spurge

(f) Chaff flower (g) Fern (h) Black jack (i) Tridex daisy (j) Signal grass

(k) Goat weed (l) Gallant soldier (m) Bamboo grass (n) Foxtail grass (o) Chinese bur

**Fig. 4.** Weeds observed in Amla in various districts.

**Pakhanved:**

**Diseases:**

A comprehensive pest survey focused on Pakhanved was conducted across four districts. The survey revealed four diseases affecting Pakhanved. Leaf blight (caused by *Alternaria* spp.) was found to be the most important disease in Dailekh, Dhading, and Baglung mainly at the vegetative stage, and leaf spot (unknown pathogen) **(Figure 5)** was found to be the most damaging disease in Dailekh, Dhading, and Salyan at the vegetative stage of plants **(Table 5).** Sooty mold and Crown rot appeared as a minor disease.

**Table 5.** Diseases appeared in Pakhanved in different districts.

| SN | Common name | Scientific name | Parts affected | Order | Occurrence | District |
|---|---|---|---|---|---|---|
| **1** | Leaf blight | *Alternaria* spp. | Leaf | Moniliales | Major | Dailekh, Dhading , Baglung |
| **2.** | Unidentified | Unknown | Leaf | Unknown | Major | Dailekh, Dhading, Salyan |
| **3** | Sooty mold | *Capnodium* spp. | Leaf | Dothidiales | Minor | Salyan |
| **4** | Crown rot | *Fusarium* spp. | Root, Stem | Tuberculariales | Minor | Dailekh, Dhading |

(a) Crown rot (b) Leaf blight (c) Unidentified

**Fig. 5.** Diseases observed in Pakhanved in various districts

**Insects:**

Leaf beetle, red cotton bug, and spring azure appeared were collected in Pakhanved **(Table 6)**, with leaf beetle reported as the predominant pest with the highest frequency of occurrence in Dailekh and Salyan. Spring azure was not found to be directly associated with the host crop as it was collected from a sweeping net, so, it might be the non-host insect **(Figure 6)**.

**Table 6.** Insects recorded in Pakhanved fields in various districts

| SN | Common name | Scientific name | Order | Family | Condition | District |
|---|---|---|---|---|---|---|
| 1 | Leaf Beetle | *Monocesta coryli* | Coleoptera | Chrysomelidae | Major | Dailekh, Salyan |
| 2 | Spring Azure | *Celastrina ladon* | Lepidoptera | Lycaenidae | Minor | Dailekh |
| 3 | Red Cotton Bug | *Dysdercus cingulatus* | Hemiptera | Pyrrhocoridae | Minor | Salyan, Dhading |

(a) Leaf beetle (b) Spring azure (c) Red cotton bug

**Fig. 6.** Insects appeared in Pakhanved in various districts.

**Weeds:**

In all of the districts surveyed, a total of 3 weed species were found to be associated with Pakhanved plant **(Figure 7).** Clubmoss (*Sellaginella* spp.) and fern (*Tracheophyta* spp.) were the most frequent and dominant weed species observed in most of the locations surveyed in Dailekh, Dhading, Baglung, and Salyan **(Table 7)**.

**Table 7.** Weeds observed in Pakhanved fields in various districts.

| S.N. | Common Name | Scientific Name | Family | Location |
|---|---|---|---|---|
| 1. | Fern | *Tracheophyta* spp. | Aspidiaceae | Dailekh, Dhading, Baglung, Salyan |
| 2. | Moss | *Bryopsida* spp. | Funariaceae | Dailekh, Dhading, Baglung, Salyan |
| 3. | Clubmoss | *Sellaginella* spp. | Sellaginellaceae | Dailekh, Dhading, Baglung, Salyan |

(a) Fern (b) Moss (c) Clubmoss

**Fig. 7.** Weeds observed in Pakhanved fields in various districts.

**Nagbeli:**

**Diseases:**

In Nagbeli, three diseases were identified **(Figure 8).** Root rot and stem blight caused by *Rhizoctonia solani* and root rot caused by *Fusarium* spp. were found as major diseases and Leaf blight caused by *Alternaria* spp., was a minor disease in Dhankuta, Baglung and Dolakha regions **(Table 8)**.

**Table 8.** Disease found in Nagbeli in various districts.

| SN | Common name | Genus | Parts affected | Order | Occurrence | District |
|---|---|---|---|---|---|---|
| 1 | Root rot and stem blight | *Rhizoctonia solani* | Leaf, root, stem | Agonomycetales | Major | Dhankuta, Baglung |
| 2 | Root rot | *Fusarium* spp. | Leaf, root, stem | Moniliales | Major | Baglung |
| 3 | Leaf blight | *Alternaria* spp. | Leaf and stem | Moniliales | Minor | Dhankuta, Baglung, Dolakha |

(a) Root and stem blight

(b) Leaf blight

**Fig. 8.** Symptoms of two diseases in Nagbeli in various districts.

**Insects:**

The survey reported the presence of five insects associated with Nagbeli **(Figure 9)**. These insects were minor pests, causing low or no damage to the crop (**Table 9**). All of these insects were captured by sweep netting in the Nagbeli field, so these might be non-insect pests of the crop.

**Table 9.** Insects recorded in Nagbeli fields in various districts

| SN | Common name | Scientific name | Order | Family | Occurrence | District |
|---|---|---|---|---|---|---|
| **1** | Short- horned grasshopper | *Oxya hyla* | Orthoptera | Acrididae | Minor | Dhankuta, Dolakha |
| **2** | Pea blue | *Lampides boeticus* | Lepidoptera | Lycaenidae | Minor | Dhankuta, Dolakha |
| **3** | Indian fritillary | *Argynnis hyperbius* | Lepidoptera | Nymphalidae | Minor | Dhankuta, Baglung |
| **4** | Brush-footed butterfly | *Cethosia biblistis amena* | Lepidoptera | Nymphalide | Minor | Dhankuta, Dolakha |
| **5** | Clouded yellow | *Colias croceus* | Lepidoptera | Pieridae | Minor | Dhankuta |

(a) Short horned grasshopper

(b) Indian fritillary

(c) Clouded yellow

(d) Pea blue

(e) Brush footed butterfly

**Fig. 9.** Insects observed in Nagbeli in various districts.

**Weeds:**

The weed species prevalent in Nagbeli fields represented 10 families from the surveyed area. Among which Asteraceae family had the highest number of weed species (5), followed by Poaceae (4), Ericaceae (2), and Aspidiaceae (2). *Ageratina adenaphora, Artemisia vulgaris, Anaphalis* spp., *Conyza* spp., and *Imperata cylindrica*, were the most frequent weeds in Nagbeli in most of the fields visited in Dhankuta, Dolakha, and Baglung **(Figure 10).** The survey documented a total of 19 weeds associated with Nagbeli as in **Table 10**.

**Table 10.** Weeds recorded in Nagbeli fields in various districts

| S.N. | Name of weed | Scientific name | Family | Collected from |
|---|---|---|---|---|
| **1.** | St. John wort | *Hyperi cumurulum* | Aspidiaceae | Dhankuta, Dolakha |
| **2.** | Fern | *Tracheophyta* spp. | Aspidiaceae | Dhankuta, Dolakha, Baglung |
| **3.** | Pearly everlasting plant | *Anaphalis* spp. | Asteraceae | Dhankuta, Dolakha |
| **4.** | Devil plant | *Ageratina adenaphora* | Asteraceae | Dhankuta, Dolakha |
| **5.** | Horseweed | *Conyza* spp. | Asteraceae | Dolakha |
| **6.** | Mugwort | *Artemisia vulgaris* | Asteraceae | Dhankuta, Dolakha, Baglung |
| **7.** | Black jack | *Bidens pilosa* | Asteraceae | Dhankuta |
| **8.** | Barberry | *Berberis erythroclada* | Berberidaceae | Dhankuta |
| **9.** | Tailapatra | *Gaultheria fragrantissima* | Ericaceae | Dhankuta, Dolakha |
| **10.** | Fetterbush | *Lyoniao valifolia* | Ericaceae | Dolakha |
| **11.** | Melastome | *Melastoma malabathricum* | Melastomataceae | Dolakha |
| **12.** | Woodsorrel | *Oxalis* spp. | Oxalidaceae | Dolakha, Dhankuta |
| **13.** | Gooseberry | *Phyllanthus niruri* | Phyllanthaceae | Dhankuta, Dolakha |
| **14.** | Bamboo grass | *Fargessia* spp. | Poaceae | Dhankuta, Dolakha |
| **15.** | Candy grass | *Eragrostis* spp. | Poaceae | Baglung |
| **16.** | Signal grass | *Brachiaria* spp. | Poaceae | Baglung |
| **17.** | Cogon grass | *Imperata cylindrica* | Poaceae | Baglung, Dolakha |
| **18.** | Himalyan strawberry | *Potentilla* spp. | Rosaceae | Baglung, Dhankuta |
| **19.** | Clubmoss | *Sellaginella* spp. | Sellaginellaceae | Dhankuta, Dolakha, Baglung |
| | | | | |

(a) Pearly everlasting plant

(b) Mugwort

(c) Tailapatra

(d) Devil plant

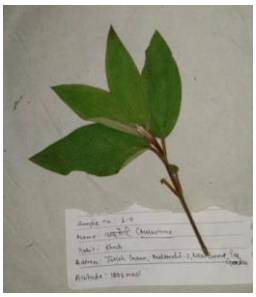
(e) Barberry

(f) Candy grass

(g) Woodsorrel

(h) Fern

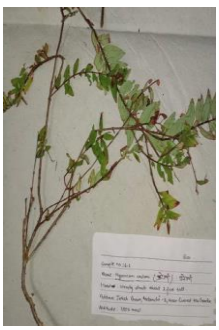
(i) Horseweed



(j) Melastoma

(k) Goosebery

(l) Clubmoss



(m) St. John wort

(n) Cogon grass

(o) Fetterbush

(p) Signal grass (q) Black jack (r) Himalayan strawberry (s) Bamboo grass

**Fig. 10.** Weeds observed in Nagbeli fields in various districts

## DISCUSSION

In our study, we surveyed 8 districts in different agroecological regions from October 2021 to July 2022 to document the major insect pests infesting the main exportable herbs of Nepal, including Amla, Pakhanved, and Nagbeli. We found that rust (*Ravenelia emblicae*) and leaf spot (*Pestalotiopsis* spp.) were the major diseases affecting Amla. At the same time, the mealy bug and bark-eating caterpillar were the predominant insects reported during the survey. Bharpoda (2009) reported similar results, indicating that damage caused by bark-eating caterpillars and mealybugs was prevalent throughout the year, peaking in July. Three diseases were found to be infecting Pakhanved. Leaf blight, caused by *Alternaria* spp., and an unknown disease were the most prevalent in the surveyed fields. Additionally, fern and clubmoss were the most frequently occurring and predominant weeds in the surveyed locations.

Moreover, in Nagbeli, 3 diseases, 5 types of insects, and 19 kinds of weeds were identified. The major diseases were root rot and stem blight caused by *Rhizoctonia solani*, as well as root rot caused by *Fusarium* spp. The other insect species reported were considered minor as they were not found frequently. The most common weeds in Nagbeli included *Ageratina adenaphora*, *Artemisia vulgaris*, *Anaphalis* spp., *Conyza* spp., and *Imperata cylindrica,* and these were observed in most of the surveyed districts. Additionally, there were no reported findings specifically addressing the diseases, insects and weeds affecting Pakhanved and Nagbeli in Nepal. In the majority of the surveyed locations, there was little documentation of management practices to control insects and pests, the overall condition of the herbs was found to be below the optimum level. This study aims to offer insights for future research on the conservation of medicinal herbs with respect to insect and pest.

## CONCLUSION

This survey encompasses a range of diseases, pests, and weeds affecting key herbs exported from Nepal. The identified issues vary from broad-spectrum to specific and from widespread to region-specific organisms. The findings offer insights into the prevalence and distribution of common diseases and pests affecting major exportable herbs such as Amla, Pakhanved, and Nagbeli in Nepal. These insights not only assist in guiding to growers but also establish a foundation for future national research prioritization and regulatory efforts. In the context of Integrated Pest Management (IPM), this survey is crucial for anticipating potential harm to plants. To ensure the sustainable management of Nepal's significant herbs, it is imperative to conduct focused research on pest and disease control. Regular surveys and surveillance covering extensive areas are essential for pest risk analysis and the adoption of effective control practices in sustainable management.

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## REFERENCES

Bharpoda, T. M., Koshiya, D. J., Korat, D. M. (2009). Seasonal occurrence of insect-pests on aonla (*Emblica officinalis* Geartn) and their natural enemies. *Karnataka Journal of Agricultural Sciences*, *22*(2), 314-318.

Gurung, K., Pyakurel, D. (2017). *Identification Manual of Commercial Medicinal and Aromatic Plants of Nepal*. Nepal Herbs and Herbal Products Association (NEHHPA). Teku, Kathmandu, Nepal.

IPPC. (1997). International Plant Protection Convention. Rome, IPPC, FAO.

ISPM 10. (1999). Requirements for the establishment of pest free places of production and pest free production sites. Rome, IPPC, FAO.

ISPM 2. (1995). Guidelines for pest risk analysis. Rome, IPPC, FAO. [Published 1996] [Revised; now ISPM 2: 2007]

ISPM 2. (2007). Framework for pest risk analysis. Rome, IPPC.

ISPM 22. (2005). Requirements for the establishment of areas of low pest prevalence. Rome, IPPC, FAO.

ISPM 27. (2006). Diagnostic protocols for regulated pests. Rome, IPPC, FAO.

ISPM 3. (2005). Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms. Rome, IPPC, FAO.

ISPM 6. (1997). Guidelines for surveillance. Rome, IPPC, FAO.

ISPM11. (2001). Pest risk analysis for quarantine pests. Rome, IPPC, FAO. [Revised; now ISPM 11:2004]

Medicinal Plant Specialist Group. (2007). International Standard for Sustainable Wild Collection of Medicinal and Aromatic Plants (ISSC-MAP). Version 1.0. BundesamtfürNaturschutz (BfN), MPSG/SSC/IUCN, WWF Germany, and TRAFFIC, Bonn, Gland, Frankfurt, and Cambridge (BfN-Skripten 195).

MoFSC, (2014). Nepal National Biodiversity Strategy and Action Plan: 2014-2020. Ministry of Forest and Soil Conservation (MoFSC), Kathmandu, Nepal

MoFSC, (2002). Nepal Biodiversity Strategy. Ministry of Forest and Soil Conservation (MoFSC), Kathmandu, Nepal.

Olsen, C. S., Larsen, H.O. (2003). Alpine medicinal plant trade and Himalayan mountain livelihood strategies. *The Geographical Journal*, *169*(3), 243-254.

Plant Protection Directorate Hariharbhawan, Lalitpur (2071). Pest surveillance protocols for citrus pest surveillance.

WTO. (1994). Agreement on the Application of Sanitary and Phytosanitary Measures. *Geneva:* World Trade Organization.