- Antifeedant

When *Spodoptera litura* infested crops were treated to neem products, due to presence of azadirachtin, salanin, and melandriol, it cause vomiting like sensation and the insect does not feed on the neem-treated surface (Jeyasankar et al., 2010; Vijayalakshmi et al., 1985).

- Growth Regulation

The neem components, azadirachtin, suppresses the activity of ecdysone so that the larva fails to molt and ultimately dies. It also causes malformation and sterility in emerging adult or inhibition of chitin formation (Vijayalakshmi et al. 1985).

Effectiveness of neem products

Neem products are found effective against more than 350 species of arthropods, 12 species of nematodes, 15 species of fungi, 3 viruses, and two species of snails and one crustacean species (Nigam et al., 1994), 200 species of insects (Uchegbu et al., 2011).

Neem leaf extracts, seed extract (seed cake), bark extract, neem oil can be used widely to control Blattodea pests (Ibrahim & Demisse, 2013) Hemipteran pests (Degri et al., 2013) Lepidopteran pests (Okrikata et al., 2016), Thysanopteran pests (Dougoud et al., 2019) and Coleopteran insect in storage condition (Kemabonta & Falodu, 2013; Khan et al., 2016)

Neem products have low toxicity to mammals (Boeke et al., 2004; El-Wakeil, 2013) although some non-target species may be particularly susceptible.

Neem products were found profitable(benefit/cost) for the control of the green leafhopper *Nephotettix virescens* in rice (Rajappan et al., 2000) , the aphid *Lipaphis erysimi* in mustard (Gupta, 2005) , the whitefly *Bemisia tabaci* and the pod borer *Maruca testulalis* in black gram (Gupta & Pathak, 2009) ,the pod bug *Clavigralla gibbosa* in pigeon pea (Narasimhamurthy & Keval, 2013), and the *Sesamia calamistis* stem borers in sorghum (Okrikata & Anaso, 2016).

A study on the effect of Azatrol 1.2% (Azadiractin A and B) and triple action neem oil (70% neem oil) and pure neem oil against aphid in greenhouse condition showed that aphid colonization is reduced by 50-75% after 1 week of application and 2nd application at 1 week of 1st application cause total elimination of aphid. It has shown that Feeding was suppressed but Neem couldn't achieve complete inhibition of food intake (Shannag et al., 2015). The cold extract after soaking of leaves for 1 week is found to have effective insecticidal properties against the storage insect pests (Vimala et al., 2010) . Neem seed kernel powder mixture can be used for the control of Okra Cotton leafhopper (Neupane, 2000).

3.5.2 Asuro (Justicia adhatoda)

Justicia adhatoda linn is a shrub widespread throughout the tropical regions of Southeast Asia (Chakraborty & Brantner, 2001). It was found that the leaves and flowers of Asuro contain a significant amount of phenols, flavonoids, and alkaloids in addition to protein and carbohydrate. The presence of these bioactive secondary metabolites in the leaves and flower of *Justicia adhatoda* Linn are correlated with their medicinal applications (Sarangthem, 2014).

Extracts of Asuro showed antifeedant (76.33), larvicidal (62.33%), pupicidal (22.05%), and ovicidal (58.86%) effect. On the contrary, the extracts of *Vitex negundo* and *Justicia adhatoda* prolonged the larval and pupal duration of *S. litura*. This indicates that the selected medicinal plants may be a potent source of natural antifeedant, ovicidal and larvicidal activities against selected important agricultural lepidopteran polyphagous field pest *Spodoptera litura*. *Justicia adhatoda* was found to be effective in reducing the feeding rate of larvae of *Spodoptera litura* with maximum antifeedant activity in ethanol extracts of *Justicia adhatoda* at 5% extract concentration (Sukanya Rajput, 2018).

Sadek (2003) reported the extract of Asuro leaves to exhibit feeding deterrent properties when applied on the leaf disc method against *Spodoptera littoralis* (Sadek, 2003). Anuradha et al. (2010) reported the deterrent effect of Asuro leaves extract on the last instar of *Spodoptera litura* at various concentrations (25, 50, 75 and 100%). Due to the toxic effect of plant extracts, the maximum number of treated larvae died in spite of less food consumption (Anuradha, 2010).

3.5.3 Tobacco (Nicotiana tabacum)

Tobacco (*Nicotiana tabacum*) contain nicotine and other alkaloids which are synaptic poisons, they mimic neurotransmitter acetylcholine and exhibits agonistic effects on most nicotinic acetylcholine receptors (Brack, 2018). Rizvi and his team concluded that tobacco extract @ 2 % showed the control of cotton mealybug when the infestation is at the initial stage (Rizvi et al., 2015). Tobacco decoction (@250 g tobacco + 30 g liquid soap + 4 liters of water boiled for 30 minutes), sprayed @ 1:4 parts water was found effective to control Tobacco caterpillar(*Spodoptera litura F.*), mustard sawfly(*Athalia lugens proxima*) and leaf miners(*Phytomyza horticola*) on vegetable crops (Mainali et al.). According to Ubina et al. (1994) Tobacco spray reduced bean fly and bean aphid population by 89% and 97% , respectively. Tobacco dust reduced tomato cutworm and bean fly populations by 89% and 79%, respectively. Leafhopper, thrips and corn earworm were also reduced by 50-69%.

3.5.4 Sweet flag (Acorus calamus)

Sweet flag *(Acorus calamus),* native to India, central Asia, and Eastern Europe is found today in many temperate and sub-temperate areas of the globe. In Nepal, the herb is available up to 2000-meter altitude. Bojho are found in sedge meadows that are prone to flooding, edges of small lakes and ponds, marshes, swamps, seeps and springs, and wetland restorations. The plant contains β-asarone in stolons which is considered the main substance that acts as an insecticide (Giri et al., 2013). Acorus calamus stolon dust at 5 g/kg of potato tubers showed high efficacy to protect potato tubers against potato tuber moth for about three to four months in farmer's rustic potato stores (Giri et al., 2013). Bulb of the sweet flag can be used as an insecticide, insect repellent, and contact poison (Dahal, 1995).

3.5.5 Garlic (Aliium sativum)

Garlic (*Aliium sativum*) is herb that contains numerous vitamins, minerals, and trace elements. Many research have shown that garlic can be used as repellent to some plant pests and diseases (Ramasasa, 1991). Sulfur compounds such as DAS, DADS, DATS, methylallyl disulfide, methylallyl trisulfide, 2-vinyl-4H-1, 3-dithinin, and (E, Z)-aioenes are present in essential garlic oil (Aggarwal et al., 2013). These constituents could be used for the control of serious fruit and vegetable pests (Upadhyay, 2016). Two of the major constituent's methyl allyl disulfide and DATS, were found against Motschulsky and *Tribolium castaneum* (Herbst). Similarly, essential oils of garlic repelled and caused lethality in *Sitophilus zeamais* L. (Coleoptera) adults and also reduced their progeny production (Meriga et al., 2012).

3.5.6 Ginger (Zingiber officinale)

Ginger (*Zingiber officinale*) is one of the most common herbs used as pesticides. Prophylactic and therapeutic cadmium detoxification effects of ginger have been reported in many studies (Egwurugwu et al., 2007). 6-dehydroshogaol, zingerone, and 3-hydroxy-1-(4-hydroxy-3-methoxyphenyl)butane extracted from ginger showed moderate insect growth regulatory (IGR) and antifeedant activity against *Spilosoma obliqua* , and significant antifungal activity against *Rhizoctonia solani* (Agarwal et al., 2001). Extract of ginger can help in the control of American bollworm, aphids, planthoppers, thrips, whitefly, root-knot nematodes, brown leaf spot on rice, mango anthracnose, and yellow vein mosaic (Sridhar et al., 2002). Higher concentrations of ginger residue were found effective for the protection of crops against *C. maculatus* adult emergence (Amuji et al., 2012).

3.5.7 Sichuan pepper (Xanthoxylum armatum.)

Timur (*Zanthoxylum armatum*) is commonly used in daily life for condiments and therapeutic remedies. Different plant parts of the *Z. armatum* also has insecticidal potential. However, potential has not been yet determined against many agricultural pests, including leaf worm. In study done by (Kaleeswaran et al., 2018), n-hexane pericarp extract of *Z. armatum* has strong antifeedent, ovicidal and larvicidal properties against *Spodoptera litura*. Some research shows that it have insecticidal properties against *Plutella xylostella* (Kumar et al., 2016) and *Pieris brassicae* (Kaleeswaran et al., 2019). In a case study made in some parts of the country, Timur was found to be used by farmers for the preparation of botanical pesticides (Kaphle & Bastakoti, 2016).

3.5.8 Chinaberry (Melia azedarach)

Chinaberry (*Melia azedarach*) is highly recognized for its insecticidal properties. Biologically active triterpenoids with an alimentary effect are responsible for this property. They inhibit the feeding and also cause death and malformations of subsequent generations (Vergara et al., 1997). *M. azedarach* senescent leaf extract proved to be lethal to 100% of the larval

population of *Spodoptera frugiperda* (Bullangpoti et al., 2012). Similarly in a study conducted on Diamond Black Moth extracts of chinaberry was found to be toxic to larvae they died due to failure in molting (Chen et al., 1996).

3.5.9 Lantana (Lantana camara L.)

Lantana Camara L. is a perennial shrub, exotic to Nepal, due to its adverse growth it is also called unwanted shrub (Vaidya et al., 2005). In Nepal, *Lantana Camara* extract and its powder widely used to check the plant diseases whether it is bacterial or fungal as well as to increase the fertility of the soil and also used to cure human diseases (Vaidya & Bhattarai, 2009). Lantanolic acid and Lantic acid are the active principles present in Lantana, which shows growth inhibition and repellent activity against insect pests (Nirmal et al.). Chopped leaves and tender stem of *Lantana camara* mixed with potato tubers @ 300-330 gm/8 kg was found effective to control potato tuber moth in storage(Pradhan, 1987). It contains a variety of chemical substances such as triterpenes, iridoid, and phenylethanoid, glycosides, naphthoquinones, and flavonoids (Ghisalberti, 2000). (Rajashekar et al., 2014) reported lantana to be effective against storage pests, while (Muzemu et al., 2011) reported that different plant extracts are biopesticidal against rape aphids(*Brassica napus*). *L. camara* contains camaric acid and olenolic acids which may have larvicidal or ovicidal properties (Ghimire et al., 2015). Research of Ghimire found that 50% concentration of *L. camara* leaf extract at 48 hrs and above was found deleterious to root-knot nematode (Ghimire et al., 2015).

3.5.10 Basil (Ocimum tenuiflorum)

More than 200 chemicals in basil oil have been reported. The chemical constituents include monoterpenes, sesquiterpenes, triterpenes, flavonoids, and aromatic compounds. Major components in basil oil include linalool, estragole (methyl chavicol), anethole, eugenol, and methyl eugenol (Li & Chang, 2016). Tulasi leaf extract is used as a seed treatment(10 ml/kg) along with foliar sprays(10ml/lit) thrice at tillering, booting and panicle initiation stage was found effective in reducing rice blast (Hossain, 2000). 2.5 gm of Tulasi leaf powder showed high repellency against post-harvest pests *Sitophilus zeamais L.* and *Callosobruchus macullatus L.* (Iloba & Ekrakene, 2006). Basil oil at 2% showed significant mortality, repellency, and anti-reproductive effects to rice weevil (Popović et al., 2006). Basil leaf powder @0.5gm/100g of cowpea was found effective to control *Callosobruchus maculates* on cowpea and chickpea (Paneru & Shivakoti, 2001).

3.5.11 Titepati (Artemisia Vulgaris)

It is distributed throughout Nepal at 300 - 2500 m, common along sideways and in margins of cleared forest (Rai et al., 2012). *Artemisia vulgaris L.*, a perennial aromatic shrub with a bitter taste, is considered as a medicinal plant and water extract of it consists of active components like psilostachyin A, psilostachy C, Exiguaflavanone A, Maackiain, fernenol with both anti-bacterial and medicinal value (Rai et al., 2012). *Artemisia vulgaris* leaves chopped pieces (20 g /kg potato) were also effective in reducing potato tuber moth damage levels (Giri et al., 2013). Fresh leaves extract of artemisia kept in water for one hour (1:4 parts) and sprayed @ 25,50, and 100g/liter water was found effective to control red pumpkin beetle in summer squash (Neupane, 1993). Chopped foliage of Titepati @ 5 mt/ha mixed in soil controlled red ant in potato field (Gc et al., 1997).

3.5.12 Mint (Mentha arvensis)

Essential oils and chemical constituents derived from different species of the *Mentha* were found to be effective against fungal and bacterial plant pathogens including storage insects like Callosobruchus and Tribolium species (Singh & Pandey, 2018). An aqueous extract of Mentha arvensis @2oo gm/ 1.33 liter of water applied on cauliflower foliage prevents the attack of mustard aphid (*Lipaphis erysimi*) (K Vaidya, 2000). Vaidya, (2000) found that field intercropped with Mentha arvensis effectively control Red ant (*Dorylus orientalis*) problem (Kaminee Vaidya, 2000). Chopped and shade dried Mentha leaves with stem @ 300-330 g/8 kg of Potato controlled Potato tuber moth(*Pthoremia operculella*) on storage (Pradhan, 1987).

3.5.13 Pire ghas (Polygonum sps.)

Pire ghas (*Polygonum sps*.) is one of the most common weeds of Nepal. Traditionally it is used to cure gastrointestinal diseases, neurological disorders, diarrhea (Sharma, 2003) and leaf paste is used to cure swelling (Parihaar et al., 2014), According to Ayaz et al. (2016), in addition to the medicinal property, 124 compounds were identified among which several bioactive antibacterial, antifungal, and insecticidal compounds were found.

3.5.14 Sajiwan (Jatropha curcas)

Sjiwan (*Jatropha curcas)* is considered a multipurpose plant because of its multiple uses. It is used as live fences as it can prevent or control erosion and also reclaim land (Openshaw, 2000). Seed oil is used to make biodiesel while Twigs are used to brush teeth to cure gum problems and latex are mixed with mustard oil and used for itches in the body. Along with other uses, sajiwan can also be used as biopesticides and in laboratory insecticidal activity of seed extracts of *Jatropha curcas* against Homopteran (peach aphid), Lepidopteran (cabbage butterfly), and Coleopteran (rice weevil) insect pests were observed (Li et al., 2006).

3.5.15 Drum-stick (Moringa Oleifera)

Moringa Oleifera belongs to the family Moringaceae which possesses an additional 13 species. Moringa, considered as one of the world's most useful trees (Ojiako et al., 2012). According to Fugile (2000), the many uses for *M. Oleifera* include fertilizer, biopesticide, medicine, etc., (Fuglie, 2000). Prabhu et al. (2011) had recorded that the phytochemicals derived from *M. oleifera* seeds extracts are effective mosquito vector control agents (Prabhu et al., 2011). Also, Ojiako et al., (2013) had found that *M. oleifera* seed extracts reduced the number of *Megalurothrips sjostedti* and *A crassivora* (Frank et al., 2013*)*. Also, *M. oleifera* extracts had a 62 % reduction of *Phyllotreta Cruciferae* (Alao et al., 2015). Methanolic extracts of aqueous extract of moringa seeds exhibited larvicidal action against *Aedes aegypti* (Kamaraj & Rahuman, 2010).

4. Conclusions

Traditionally, farmers have identified and used variety of the plant products and extracts for pest control. As an alternative to synthetic pesticides, ecologically safe methods must be developed to control insect pests of field crops and stored food products. Organic pest management appears to be a more attractive alternative with lower economic costs. Combined use of botanicals with microbial pesticides increases efficacy and reduces cost per application and delays the development of resistance. Although botanical pesticides are safe to the environment, human health and natural enemies, they can't completely replace the synthetic pesticides. It will be quite logical to use existing technical knowledge and skill with scientific technologies. In several research, botanical pesticides have shown better activity than synthetic pesticides. Such many studies should be done on various effects of these botanicals against several harmful insect pests. To make botanicals more versatile, more formulations should be developed. Identification, documentation, conservation, and promotion of the existing indigenous knowledge and skill should be done to protect the intellectual right and put them into formal research for effective technology development. Networking and coordinated effort of all stakeholders is a crucial need to harness the abundant in-house resources available on pest management.

Acknowledgement

First and foremost, praises and thanks to god, the Almighty, for his showers of blessings to us. The completion of this study could not have been possible without continuous support, valuable time and guidance from our respected teacher, Mr. Subodh Khanal. Besides him we would also like to thanks Mr. Arun GC sir for motivating and suggesting us. We are really thankful to our dear friend miss Sabina Regmi for technical guidance. Last but not least we would like to thank our beloved parents for supporting us in each and every situations of our life.

Abbreviations

DADS- Diallyl Disulphide

DAS- Diallyl Sulphide

DATS- Diallyl Trisulphide

GDP- Gross Domestic Product

IGR- Insect Growth Regulatory

IPM- Integrated Pest Management

PPD- Plant Protection Directorate

PQPMC- Plant Quarantine and Pesticide Management Center

PRMD- Pesticide Registration and. Management Division

UNEP- United Nations Environment Programme

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