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Emerging trend in host utilization and dispersal capacity of flea beetles in ecologically disturbed population

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Abstract
Flea beetles are major common pests of many vegetable crops. They usually damage flowers, shrubs and trees. The small plants and seedlings are particularly susceptible. Flea beetles are confronted with an arsenal of constitutive and inducible chemical plant defenses in which the plants serve as their source of food (Host). To maintain host utilization, it avoids deleterious effects from plant toxins, by developing biochemical adaptation which allows them to deal with these metabolites. Most adult flea beetle damage is unique in appearance. They feed by chewing a small hole (often smaller than 1/8 inch) in a leaf, moving a short distance, then chewing another hole and so on. The flea beetles usually move by walking or flying but when in ecologically disturbed population if alarmed they can jump to a considerable distance (i.e. dispersal capacity). Possible challenges of the control of these flea beetles were reviewed especially the behavioral and biochemical adaptation developed by flea beetle in the process of host utilization and also various ways of improving the situation. To manage flea beetle effectively, producers should use an integrated pest management (IPM).

Keywords: flea beetle, host utilization, biochemical adaptation, behavioral adaptation

1. Introduction
Flea beetles are major common pests of many vegetable crops. They usually damage flowers, shrubs and even trees. Crenshaw (2013) reported that the Adult beetles, which causes most plant injuries, are typically small, often shiny, and have large rear legs that allow them to jump like a flea when disturbed. Flea beetles causes a characteristic injury known as "shot holing." The adults chew many small holes or pits in the leaves, which make them look as if they have been damaged by fine buckshot. Crenshaw (2013) also find out that "The small plants and seedlings are particularly susceptible. Growth may be seriously retarded and plants even killed. Leaf feeding also damages plant appearance. This can be important among certain ornamentals and for leafy vegetable crops. Although there is some overlap of tastes, each type of flea beetle has a decided preference for certain plants. For example, some flea beetles feed only on potatoes, tomatoes and other members of the nightshade family. Others have a taste for broccoli, cabbage and other cole crops (Crenshaw, 2013). Flea beetles execute their most severe attacks during dry weather and are most active on sunny days. The larvae are known to chew roots, according to Squire, Dvid (2007) [23].

1.1 Ecologically disturbed population
Ecologically disturbed population is a temporary change in environmental conditions that causes a pronounced change in an ecosystem. Disturbances often act quickly and with great effect, to alter the physical structure or arrangement of biotic and abiotic elements. Disturbance can also occur over a long period of time and can impact the biodiversity within an ecosystem. Major ecological disturbances may include fires, flooding, windstorms, insect outbreaks and trampling. Earthquakes, various types of volcanic eruptions, tsunami, firestorms, impact events, climate change, and the devastating effects of human impact on the environment (anthropogenic disturbances) such as clear cutting, forest clearing and the introduction of predator species can be considered major disturbances (Dale *et al*., 2001) [8].

2. Overview
Phytophagous insects are confronted with an arsenal of constitutive and inducible chemical plant defenses, (Mithöfer and Boland, 2012) [21]. To avoid deleterious effects from plant toxins, herbivores require appropriate biochemical adaptations allowing them to deal with these metabolites, for example, by developing insensitive target sites or by enzymatic detoxification. Many specialized insects are able to sequester plant defense compounds and exploit them for their own protection against natural enemies and/or as semiochemicals in interspecific communication, according to (Nishida R, 2002) [22]. Foster and Obermeyer (2017) [10] observed that the flea beetles usually move by walking or flying but when in site of a predator for instance they can jump to a considerable distance because of the possession of the large hind legs, for instance the ragwort flea beetle can easily leap 1 m (i.e. dispersal capacity).

2.1 Classification of the different forms of disturbance
There are various form of disturbance of which only the few major ones will be discussed base on the stated topic
1. Deleterious effects from plant toxins
2. Introduction of predators into the population
3. Climatic change (humidity, temperature, rainfall, etc

2.1.1 Deleterious effects from plant toxins
For example crucifer plants (Brassicales) that are defended by the glucosinolate-myrosinase system, the so-called "mustard-oil bomb." Tissue damage caused by insect feeding brings glucosinolates into contact with the plant enzyme

myrosinase, which hydrolyzes them to form toxic compounds, such as isothiocyanates, (ITC). However, it was previously observed that *Phyllotreta striolata* beetles themselves produce volatile glucosinolate hydrolysis products and also In some studies with *Phyllotreta striolata* (Coleoptera: Chrysomelidae), it was detected several unexpected ITCs in the volatile emission of adults feeding on different *Brassica* host plants, (Beran F, 2011) [3] for example, alkenyl ITCs was identified to be present in the headspace of adult *P. striolata* feeding on *Brassica oleracea* var. *italic.* Flea beetles of the genus *Phyllotreta* (Coleoptera: Chrysomelidae) are closely associated with glucosinolate-containing plants in the Brassicaceae, Resedaceae, Tropaeolaceae, and Capparaceae on which they feed throughout their life cycle, (Vig K, 2004) [26]. In fact, the only confirmed exception is *Phyllotreta vittula*, which prefers Poaceae but also accepts crucifers as food plants, (Vig K, 1998). As specialized herbivores, *Phyllotreta* flea beetles are expected to be adapted to the glucosinolate-myrosinase system, but the mechanism for such tolerance is not known for any crucifer-feeding Coleoptera to date. *P. striolata* adults not only selectively sequester intact glucosinolates from their host plants but also express their own myrosinase, a member of the β-glucosidase family capable of hydrolyzing glucosinolates to form toxic degradation products in other to utilizes plant host and this factor has no much effect on the carrying capacity of flea beetle

2.1.2 Introduction of predators into the population

Predators, contribute to lowering populations but is limited because the establishment of them is not very successful and research is minimal on their effect on flea beetle populations. Flea beetles emerge in large numbers over a short period of time and can overwhelm the predators and parasites. With this predation has little or no effect on the flea beetle carrying capacity. For example a native parasitoid wasp, *Microctonus vittatae*, is found throughout North America and can kill adult flea beetles, although the rate of parasitization is low (Knodel and Olson, 2002) [17]. Generalist predators such as lacewing larvae (*Chrysoperla* spp.), big eyed bugs (*Geocoris* spp.), and damsel bugs (*Nabis* spp.) have also been known to feed on adult stages of flea beetles (Knodel and Olson, 2002) [17]. Flowering plants such as anise, dill, chamomile, marigold, or clover can be grown around the host plants to enhance floral resources and encourage the native parasitic wasp and other generalist predators (Gredler, 2001).

2.1.3 Climatic change (humidity, temperature, rainfall, etc.

It is expected that insect herbivores and their interactions with host plants might be affected if temperatures increase (Kocmánková *et al*., 2011). A changing climate has a major impact on processes influenced by temperature such as insect developmental time (Keena and Moore, 2010) [16], spatial distribution (Gutierrez *et al*., 2008) [13], behavior, survival and reproduction of insects (Bale *et al*., 2002) [2]. Recent studies surveyed the effects of a changing climate on insects and biological control of insects, (Gerard *et al*. 2013) [11]. In the case of flea beetle it readily fly when temperatures exceed (17.8 °C) and will move quickly into the field's interior, (behavioral adaptation). Flea beetles feed actively during a sunny, warm part of the day (Knodel *et al*. 2017) [18].

2.2 Host plant interaction

Most adult flea beetle damage is unique in appearance. They feed by chewing a small hole (often smaller than 1/8 inch) in a leaf, moving a short distance, and then chewing another hole and so on. The result looks like a number of "shot holes" in the leaf. While some of the holes may meet, very often they do not (Foster *et al*., 2017) [10].

Foster and Obermeyer (2017) [10] stated that Flea beetles eggs is lay on plants or in soil around the base of plants. The tiny larvae feed on the roots of the plant, causing only minor damage to edible plants. Generally, flea beetles are not difficult to control, but often they will have already seriously injured crops before they are detected. Therefore, it is very important to regularly check susceptible plants, especially when they are in the seedling stage. Most species of flea beetles emerge from hibernation in late May and feed on weeds and other plants, if hosts are not available. Keeping fields free of weed hosts will help reduce flea beetle populations. Flea beetle damage often can be observed on weed hosts before it becomes apparent on crops. Also, flea beetles tend to become more numerous when susceptible crops are grown in the same area year after year. For commercial growers, crop rotation may help reduce flea beetle damage.

Foster and Obermeyer (2017) [10] stated that the following flea beetles are the major pest of plants and use behavioral as well as biochemical adaptation to utilize the host plants.

2.2.1 Potato Flea Beetle (*Epitrix cucumeris* (*Harris*); is black and 1/16 inch long and is one of the most common and destructive flea beetles, attacking potatoes, tomatoes, green pepper, eggplant, and other siliceous plants. Adults emerge from the soil in mid-spring and feed on young foliage of these crops. They also may feed on sunflower, morning glory, jimson weed, and lambs quarter. Larval feeding on potato tubers may cause roughness, pits, and trails on the surface or in the tuber itself. These pits show up as black spots on peeled potatoes. Potato flea beetles are also vectors of several diseases of potato.

2.2.2 Spinach Flea Beetle (*Disonycha xanthomelas*) is easily recognized and is one of the largest among the species. It is almost 1/4 inch long, has dark, greenish-black wing covers, a yellow-orange thorax, and a dark head. Unlike other species, the spinach flea beetle lays its eggs in clusters on leaf surfaces. Larvae feed on the undersides of leaves. In addition to spinach, adults will feed on beets, chickweed, lambsquarter, and many other weeds. There are usually two generations of spinach flea beetles per year, the first developing on weeds and the second developing on spinach and beets.

2.2.3 Striped Flea Beetle *(Phyllotreta striolata* (Fabricius) commonly attacks cruciferous plants such as cabbage, broccoli, turnip, radish, and mustard in most areas of tropics and Indiana. It will also feed on shepherds purse, wild mustard, and other weeds. The adult is shiny black, about 1/12 inch long, with a longitudinal, wavy yellowish stripe on each wing cover. Injury done by the adults appears as pits or holes in the leaves. Larvae may seriously injure the roots of plants, particularly turnips and radishes.

2.2.4 Pale striped Flea Beetle (*Systena blanda* (Melsheimer) feeds on cabbage, beans, tomatoes, corn, peas, strawberries, and other crops. Weed hosts are ragweed, pigweed, and lambsquarter. The adult is about 1/8 inch long but ranges in color, from shiny reddish to brownish-yellow. A straight, broad, yellow stripe runs down each wing cover.

2.2.5 Sweet potato Flea Beetle *Chaetocnema confinis* (Crotch) is common in the southernmost parts of Indiana. The adults are small (only about 1/16 inch long), bronze-black with yellowish legs and antennae. Feeding damage by the adult sweet potato flea beetle is somewhat different than other species. Feeding injury on early sweet potato foliage, appears as narrow grooves in the upper and lower leaf surfaces. Badly damaged leaves turn brown and die. Adults also may feed on morning glory and other plants. By mid-June they have usually left the sweet potatoes to lay their eggs near the roots of bindweed.

2.2.6 Mint Flea Beetle (is about 1/12 inch long, pale brownish yellow, with a darker brown head and black eyes. The larvae, which are the primary damaging stage, feed in the soil on roots. Feeding by the adults, which is usually not serious, may cause leaves to dry up and fall from the plants, especially in hot years. Commercial mint producers may use Malathion at 1-1/2 pints per acre after cutting and removal of crop from the field for control of adults to prevent oviposition. The 7-day harvest restriction should be observed if applied before cutting.

2.2.7 Grape Flea Beetle (*Altica chalybea* (Illiger) is almost 1/5 inch long and dark, shining steel-blue. They feed on the developing buds of grape vines in late April or early May, often causing considerable injury. The eggs are laid under bark on the vines. After hatching, the brown larvae with black spots, feed extensively on the leaves. Larval damage resembles that done by corn rootworm beetles. After feeding 3-4 weeks larvae drop to the ground and pupate in the soil. In 1-2 weeks, the new adults emerge and feed for the remainder of the summer before going into hibernation.

2.2.8 Corn Flea Beetle (*Chaetocnema pulicaria* (Melsheimer) is a black, pinhead-sized (about 1/16 inch) insect that feeds on all types of corn. It can be a serious pest when growing conditions are poor and plants are making slow growth. Damage is generally confined to plants less than 6 inches tall. Corn flea beetle feeds by stripping the green top layer from the leaves, resulting in irregular brown or grey lines. Most importantly, corn flea beetle can transmit a bacterium that causes Stewart's wilt.

2.3 Host Utilization and Dispersal Capacity of Flea beetles

Insects go through several phases in finding a host plant as described by Health 2017) [14]. Firstly, they must search for the host. This requires the insect to move towards and contact or at least remain near a host plant. Ultimately, it must select an appropriate host. This involves multiple sensory cues and short-term memory of the insect to recall previous choices in order to decide which host to accept. Prolonged feeding and/or oviposition indicates acceptance of the host plant. Herbivorous insects use multiple mechanisms and strategies to determine host plant selection. The strategies or mechanisms depend upon the insect's geography, ultimate goal and options available to it. For long range searches (greater than 1m), visual and olfactory cues direct an insect towards a host plant. When closer than one meter, short range mechanisms are used to determine the plant's suitability as a host. This includes evaluation of physical and/or chemical properties of the host plant by the insect, including preference to specific plant geographies such as upper and lower leaf surfaces (Health, 2017) [14].

Dispersal is more simply defined as a movement that results in an increase in the mean distance between individuals (Sujiyanand *et al*., 2016). Sujiyanand *et al*. (2016), also reported that Insects are among the groups of organisms which are most likely to be affected by climate change because climate has a strong direct influence on their development, reproduction, and survival.

The sudden climate change which has effect on insect as reported by Sujiyanand *et al*., (2016), which also made insect population to migrate due to negative impact of climate change against the insect and at the same time made their habitat stressful to thrive in, make the insect population density to be determined using captured recaptured technique difficult and cumbersome, as such insect that has been captured marked and release will migrate due to climate change which makes the researcher not to recapture them again for population estimates due to abovementioned reasons, made captured marked recapture technique unsupported in an ecologically stressed habitats.

3. Challenges of Flea beetles Control

Mani and Pal (2013) [20] found out that the use of high-breed varieties of crops and increased use of agrochemicals favour the build-up of crop pests in which species of flea beetles is not exception with the result that the intensity of several pests have increased, many minor pests have assumed the status of major pests.

In addition, the climate change exerts a profound effect on the intensity of pest problems. Flea beetle causes damage by making round holes on the leaves which get skeletonized under heavy infestation. Sometimes flowers and developing fruits are also attacked. About 60% holes are found on the newly formed leaves. It attacks the crop from seedling to harvest stage affecting the vigour and resulting in drastic reduction in yield (Mani *et al*., 2013) [20].

Another challenge is the biological control of flea beetle play a minor role in controlling flea beetles. For example, The flower beetle, *Collops vittatus* (Say), Gerber, G. and C. Osgood; (1975) [12]. Big-eyed bug, *Geocorus bullatus* (Say), Burgess, L. (1977b).

The native braconid wasp (Microctonus vittatae Muesebeck) parasitizes flea beetle adults and is widespread across the prairies, however, parasitism by the wasp usually averages less than 5% of the flea beetle population, Wylie, H.G. (1981) [21].

Factors that increase the risk of flea beetle damage (Canola Council of Canada)

i) Low seeding rates Crop damage is exacerbated when flea beetles can only feed on a few plants. When you have fewer plants, it's more important to protect each one. Monitor fields more closely.

ii) Poor crop vigour if the weather turns cold or very dry and growth stalls, or if the plants do not have good early-season vigour, they remain smaller for a longer period and are more vulnerable to flea beetle damage

iii) Conventional tillage Flea beetles are less active under minimal and zero-till conditions. The thatch left by the crop stubble is cool, shaded and more difficult for the beetles to navigate. In conventional tillage systems, flea beetles are more active and can cause more damage.

3.1 Solutions/ Way out

Knodel Olson and Lubenow (2017) [18] observed that in the spring, overwintering flea beetle adults emerge, locate, feed on and damage emerging plants. To manage flea beetles effectively, producers should use an integrated pest management (IPM) program.

Field monitoring for flea beetle activity should begin in newly emerged fields during May and June when air temperatures reach (14°C). Yellow sticky traps can be used for monitoring beetle emergence and population levels, but they do not indicate the need for control actions. Monitor fields for the presence of flea beetles and their feeding injury (defoliation) during the first 14 days after crop emergence, or until plants have reached the four- to six-leaf stages. Fields should be checked daily to identify damage early and make timely management decisions. The amount of defoliation is used as an action threshold. Injury occurs first at the field edges, particularly where a shelterbelt or grassy area borders a field. are feeding actively in the field. Watch fields closely in hot, dry weather, when flea populations can increase rapidly. Foliar treatments must be made quickly if defoliation exceeds 20 to 25 percent. Under high beetle densities, a delay of one to two days can result in the loss of entire fields. Apply insecticides during the sunny, warm part of the day when beetles are feeding actively on the plants. Canola plants that have reached the four- to six-leaf vegetative growth stage or beyond can tolerate more feeding injury unless flea beetles are feeding on the growing point (Knodel *et al*. 2017) [18].

Kansas State University Research and Extension in (2018) identified the following stages in cultural method of controlling flea beetles population

- Weed control in and around planting sites to deprive larvae of food sources needed for successful development.
- Removal of old crop debris and other surface trash to deprive overwintering beetles protective cover.
- The use of later planting dates when warmer temperatures assist plants in outgrowing or overcoming flea beetles feeding damage.
- The rotation or isolation of current-year plantings from those of the previous year.

3.2 Conclusion

It is found out that flea beetles species are classified based on their feeding nature as polyphagous insect that feed on different groups of host plant as well as monophagous insect that feeds only on one group of host plant, Behavioral and biochemical adaptation is developed by flea beetle in the process of host utilization, possession of well-developed hind limbs help flea beetle during dispersal capacity when disturbed in an ecological population, some of these factors that cause ecological disturbance in flea beetle population are introduction of predators, climate change and deleterious effect from plant toxins.

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