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Stem fly, *Ophiomyia phaseoli* (Tryon) (Insecta: Diptera: Agromyzidae) a major insect: A review

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Abstract
The present study was conducted on Stem Fly or bean fly (*Ophiomyia phaseoli* Tryon. their biology, damage, identification and management with the objectives of arriving at the crucial conclusion on the most suitable techniques to decrease pest infestation for high potential yield and productivity with least damage to the environment and also need to develop a reliable technique that would help to positively identify resistant lines.

Keywords: Stem fly, *Ophiomyia phaseoli*, Insecta: Diptera: Agromyzidae

Introduction

The Stem Fly or bean fly (*Ophiomyia phaseoli* Tryon.) is a major pest insect in different countries across the globe. The extent of damage varies from crop to crop and season to season, being especially severe to seedlings. The adult stem fly deposit their eggs in puncture of the leaf tissues, the first pair of leaves of bean seedlings being favourite sites for oviposition and cause extensive tunneling to young plants. If the attacked plant survives, the effect of the injury may be manifested later, in the older plants. In severe attacks infested leaves initially hang down, then wilt and may even drop. The stems can crack and yield is low. Overall plant growth is stunted and it may die; yield losses in some east-Asian countries can come to 30-50% and even to 100%. (Tengecho *et al*. 1988) [54]. It is a major pest of most edible legumes, such as beans and peas. A survey was carried out during two seasons showed that the bean fly (BF), *Ophiomyia phaseoli* (Tyron), is widely distributed in Ethiopia and caused economic damage to bean. (Abate, 1991) [3].

The stem fly incidence was observed on blackgram and soybean from July to November and on cowpea from July to October (Agarwal and Pandey, 1996) [6]. Bean fly (*Ophiomyia phaseoli* Tryon) is one of the most important insect pests of beans in major bean growing areas of eastern Africa (Ampofo and Massomo, 1998) [7]. Since farmers have limited land, they continue to cultivate the same areas over the years, using limited or no application of pesticides or fertilizer, which leads to a build-up of pests and reduction in soil fertility (Letourneau, 1994). Under such farming conditions, bean fly becomes the most important insect pest, causing significant yield losses (Greathead, 1968, [16] Letourneau, 1995) [27]. Overall plant growth is stunted and it may die; yield losses in some east-Asian countries can come to 30-50% and even to 100%.

It was recorded from different countries viz., Asia, Africa, North America and Brazil There are estimated 110 species are known to occur on cultivated plant. Therefore, it is desirable to develop alternative methods for pest management which are safe to both human and ecology (Sakomoto *et al*., 2003) [41]. In our country a cost effective and efficient management of the stem fly is the need of the hour. Stem fly population is still susceptible to available insecticides. But most of the insect-pests have developed resistance against several conventional synthetic insecticides in different growing areas. Therefore, it is need to find out other alternative management of insect-pest through bio-rational and botanical insecticides with high potency, selectivity and different mode of action for stem fly. The researchers, mostly coming from the academe, conduct efficacy trials in experimental plots and also at farmer's fields while the Local Government Units (LGUs) conduct farmer training in collaboration with the academe and product developers (Gautam *et al*., 2018) [15].

Distribution of bean fly, *Ophiomyia phaseoli*

There are three main bean fly species that have been reported to attack beans in various parts of the world namely, *Ophiomyia phaseoli* Tyron, *Ophiomyia spencerella* Greathead, and *Ophiomyia centrosematis* de Meijere (Greathead, 1968,[16] Letourneau, 1995 [27] Songa and Ampofo, 1999) [48]. The distribution of *Ophiomyia phaseoli* and *Ophiomyia centrosematis* extend throughout tropical and subtropical Africa, Asia, and Australia, but *Ophiomyia spencerella* has not been recorded outside Africa (Abate *et al*., 2000). In eastern and southern Africa, bean fly infestation is extensive, and has been established in nearly all the countries in the region. However, in different species then, *Ophiomyia phaseoli* and *Ophiomyia spencerella* are the most important, because the *Ophiomyia centrosematis* occurs rarely only and in small numbers (Abate and Ampofo, 1996) [4]. Within a growing season, *Ophiomyia phaseoli* is known to attack the earlier planted crops compared to *Ophiomyia spencerella* which damage the late planted crops. A study on the relative abundance of bean fly species and their population dynamics in semi-arid eastern Kenya revealed that the dominant species in this region are *Ophiomyia phaseoli* and *Ophiomyia spencerella* (Songa and Ampofo, 1999) [48].

Identification of Stem Fly, *Ophiomyia phaseoli*

The adult fly is metallic black with their size of 2-2.5mm and having hyaline wings having a distinct notch in the coastal regions. In early stage maggots are initially white, but later they turn into yellowish brownish color. They are small in size (0.5- 1mm). Pupae are barrel shaped and brown in color. Female are larger than males, with their wing expense of an average of 5mm (TNAU Agritech Portal) [55].

Damage Symptoms of Stem Fly, *Ophiomyia phaseoli*

Stem fly, *Ophiomyia phaseoli* (Tryon) is one of the most serious pest of bean crop. The infestation of stem fly maggot occurs at seedling stage. The affected plants in the early stage show thickening or cracking of the stem at or just above the ground level. The heavily infested area can easily be distinguished by the rusty red appearance of the basal portion of the stem. The plant becomes stunted and yellow and finally dries. The maggots feed by boring into the stem. The leaves of infested plants turn yellow while adults also cause damage by puncturing the leaves, and the injured parts turn yellow (Yadav and Patel, 2015) [60]. The incidence of this pest was observed in the field from seedling to vegetative stage of crop. Spring crop suffers less than the late summer crop. The attacked plants bear fewer pods which are mostly empty or having very small seeds. In most of the cases stem is swollen below the ground level and the plant that can survive, contains small seeds (Pandey, 1962) [34]. Under heavy infestation of stem fly it causes wilting of the plant up to the extent of 99.3 per cent. The crop is most susceptible in the seedling stage against this pest. The date of sowing may affect the incidence of the pest. The infestation is progressively increased in early sowing crop (Kooner *et al*., 1977) [21].

Life cycle of Stem fly, *Ophiomyia phaseoli*

Stem fly are active during summer and mate 2-6 days after emergence. The female lays an average of 100-200 elongate, oval and white eggs in clusters on the host leaf tissue with the help of their elongated ovipositor. The incubation period of eggs is 2-4 days after hatch the young caterpillars feed on green tissues of leaves, later they web leaves together and feed within the folds and move into the stem and mine down to soil level, into the taproot (Songa, 1999) [49]. They passes through three instars and the larval development period is completed in 12-15 days. The larva pupates within its gallery and the pupal period lasts 5-7 days. The pest fecundity and longevity differ according to the specific host plant. The adult flies feed on plant secretions and on sap exuding from feeding holes. The adult flies live for 8-22 days whereas the adult male survives for 11 days. The pest completes 8-9 generations from July to April and shifts from one host plant to the other in various seasons. It passes winter as larva or as pupa.

Savde *et al*., (2018) [42] also reported the life cycle of stem fly in pigeon pea and said that Stem Fly were always laid their eggs on the undersurface of the young leaves of pigeon pea and were also deposit their eggs near the midrib or primary vein or in between the veins into the tissue of the leaf by penetrating through ovipositor into the leaf tissue under the epidermal layer. The freshly laid eggs are oval shaped with smooth round ends. The incubation period ranged from 3 to 5 days. The larval period was ranged from 6 to 12 days. The fully grown larva pupates inside the stem, but first mines a hole to the epidermis to aid in the emergence of the adult. The pupal period ranged from 7.00 to 10.00 days. The longevity of the male fly varied from 5.00 to 13.00 days, whereas female ranged from 8.00 to 16.00 days. Pre-oviposition period ranged from 3.00 to 6.00 days and oviposition period lasted for 2.00 to 4.00 days. The fly laid with an average of 65.00 to 90.00 eggs throughout its life span when food was provided whereas the total life cycle of stem fly ranged from 21-37 days. These observations are similar and in close agreement with the studies made by Taleka *et al.*, (1988) [51].

Genetics, mechanisms and sources of resistance

The genetics of insect resistance or tolerance in common bean is usually quantitative and polygenic (Miklas *et al*., 2006) [30]. Less information exists on the inheritance of resistance to bean fly. A report from a genetic study indicated the significance of additive gene effects over the non-additive gene effects for percent plant survival of beans under natural infestation of bean fly (Mushi and Slumpa, 1998) [32]. However, a detailed study that would consider more resistance parameters would be necessary in order to provide more comprehensive results. Similar investigations in soybean revealed that the inheritance of resistance to agromyzid bean fly (*Melanagromyza sojae* Zehntner) was controlled by one major gene along with minor genes (Wang and Gai, 2001) [57].

Plant structural and chemical defense can depress feeding by the herbivorous pests (antixenosis), by suppressing their growth and development (antibiosis), or by reducing the damage symptoms (tolerance) (Clement *et al*., 1994) [13]. Studies on the mechanism of resistance to bean fly have mainly carry out in soybean (Talekar and Hu, 1993 [52], Taleker and Tengkano, 1993) [53] and in mungbean Talekar *et al*., 1988) [53], where it observed that both morphological and chemical components present in certain soybean plants and reduce the fecundity of bean fly. Different sources of resistance to the bean fly in common bean germplasm have been reported (Greathead, 1968) [16]. Abate *et al*., (1995) [1] identified sources of resistance to bean fly among agreement obtained from the CIAT. Distant from common beans, host plant resistance against bean fly and related agromyzid has been found in other leguminous crops such as mungbean, cowpea, soybean etc.

Table 1: Examples of sources of resistance in common bean genotypes with high levels of resistance to bean fly.

Landrace/ Variety	Source	Crop species	Reference
G5773,	CIAT	*Phaseolus vulgaris*	Abate (1990) [2], Abate *et al*. (1995) [1], Mushi and Slumpa, (1996) [31].
G35023, G35075	CIAT	*Phaseolus coccineus*	Kornegay and Cardona, (1991a) [22].
A429, TMO	CIAT	*Phaseolus vulgaris*	Abate *et al*. (1995) [1].
Mlama 49, Mlama 127, G22501	CIAT	*Phaseolus vulgaris*	Hillocks *et al*. (2006) [18].
G2472, EMP 81, G3844, BAT 16	CIAT	*Phaseolus vulgaris*	Mushi and Slumpa (1996) [31], Mushi and Slumpa (1998) [32].
G21212, CIM 9314-36	CIAT	*Phaseolus vulgaris*	Mushi and Slumpa (1996) [31].

Effect of abiotic factor on population buildup of Stem Fly, *Ophiomyia phaseoli*

This study was confirmed with the observation made by (Kumar *et.al*, 2018) [25], they observed the incidence of *O. phaseoli* started during the 3rd week of November i.e. 14 days after sowing (two weeks after emergence) and also they observed the maximum infestation in the fourth SMW i.e. 84 days after sowing.

The mean larval population was gradually increased towards the progress of weeks as the temperature decreases i.e. up to 4th SMW and further the larval population had started declining gradually as the temperature increases. This result was in accordance with Mangang, (2012) [29] who also reported that minimum temperature had favoured the development of stem fly. Similar study was observed by Yadav *et al*., (2019) [59] recorded that during, third week of November and reached the peak in the last week of January (4th SMW) as the temperature decreases and further the larval population had started declining gradually as the temperature increases.

Effect of biotic factor on population buildup of Stem Fly, *Ophiomyia phaseoli*

It was found that two species of parasitoids, i.e. eulophid and braconid, emerged from bean fly pupae and the number of parasitoids fluctuated at different mungbean growth stages and in different growing seasons. The higher parasitism rate was 58.33%. The longevity of the eulophid parasitoid was 9.89±0.64 days. Konishi, (2004) [20] also said that there are 26 eulophid and four braconid parasitoids of leaf mining agromyzid pests. The braconid *Opius* spp. was recorded as an important parasitoid in Thailand. Riek, (1979) [39] also found that the Eulophidae is a large family of very diverse forms and habitats. Most of the parasitoids obtained in the present study were eulophids and it seemed to be important parasitoid as a biological control agent for bean fly in Yezin. Greathead, (1975) [16] reported that braconids *Opius phaseoli* and *Opius importatus* were introduced from East Africa to Kauai and Maui islands in Hawaii in 1971. It was reported that one of the major natural enemy of bean fly, the braconid *Opius phaseoli*, in East Africa also occurs in India (Waterhouse, 1998) [58].

Integrated management of Stem Fly, *Ophiomyia phaseoli*

Cultural Practices

Pre-season cleanup

Avoid sowing of the crop earlier than mid-October to check the attack of the pest. Remove and destroy all the affected branches during the initial attack. Sown the crop in the second week of October to escape the damage of the pest (Singh 1970 [45] and Kooner *et al*. 1977) [21]. Remove all unwanted plant debris and weeds from the field. For this reason, it is important to avoid growing other crops next to the field and to prevent heavy growths of broadleaf weeds around the outside edges of the field.

Balanced use of fertilizer

Fertilization schedules based on the balanced use of nutrients should be followed. Application of nitrogen should be applied only as required for optimal growth. Irregular heavy applications set up nitrogen surpluses that cause heavy growth, which favor the population growth of other pests. Application of potash applies at desired levels and has been found to reduce the incidence of insect-pests.

Monitoring

Seedlings are to be examined for pest symptoms, such as oviposition marks on the leaves, and for the small and shiny black flies with clear wings. The presence of swollen and cracked stems at the plant base also indicates pest infestation (Bandara *et al*., 2009) [9]. The plant debris should be placed immediately in a covered container before being disposed-off. This practice can be helpful in reducing the pest population of all the targeted pests.

Horticultural methods

Removal of crop residues with symptoms of damage and removal of any wild legumes around the crop area. Covering the seedlings with straw to protect them against oviposition by the pest (Letourneau, 1994) [28].

Plant tolerance

Pest-tolerant varieties of bean and other legumes have been bred and are available at AVRDC (the Asian Vegetable Research and Development Center, now known as the World Vegetable Center). Such type of tolerance is associated with high trichome density on leaves and stems, purplish and smaller diameter stems, and smaller unifoliate leaves. (Nasar and Halin, 1966) [5].

Effect of date of sowing against Stem Fly, *Ophiomyia phaseoli*

The present findings are in confirmation of (Singh, 1970) [45] and (Kooner *et al*., 1977) [21] who also found less damage in later part of November and early December as compare to October. However, these findings are further confirmed by (Brar *et al*., 1996) [10] who also reported that early sown crop suffered more as compared to late sown crop against stem fly. However, present findings are contradicted by the findings of (Nderitu *et al*,. 1990) [33] who found more infestation in late season crop as compared to early season crop. Likewise, (Prodhan *et al*., 2000) [36] also reported that the incidence of pea stem fly in black gram was increase with the expansion of season.

Bali and Qureshi (1988) [8] observed lesser infestation in late sown crop and obtained higher pea yield against stem fly. These results are in agreement with the present findings. Similarly, (Prodhan *et al*. 2008) [37] worked on incidence of stem fly on black gram at different dates of sowing from August 7th to September 11th 2007, at an interval of 7 days and found 100 per cent infestation of stem fly in early sown crop.

The damage was gradually decreased when observed on late sown crops

Screening of genotypes against Stem Fly, *Ophiomyia phaseoli*

Kumar and Sharma (2002) [24] screened 25 germplasms of vegetable pea against *O. phaseoli*. Out of 25 germplasm Azad P-1 was the common germplasm taken for consideration by this scientist as well in present findings, the other germplasm were totally different when comparison in between the germplasm, in present findings Azad P-1 was observed as moderate susceptible variety Kumar and Sharma (2002) [24], also found that least harboring stem fly damage as comparison in different germplasm as well as they have conducted experiment in *rabi*, 1998-99 which is of long back shows that the variety has come up as moderate susceptible in present findings. However least infestation in present finding was observed in Pusa pragati, Kashi udai and Punjab-88 varieties of pea. Singh and Mishra (1977) [44] screened 12 varieties out of which Asauji was found most resistant variety against stem fly, and Alaska was more susceptible against pea stem fly.

Application of host-plant resistance

Host-plant resistance is a component of integrated pest management approach that can be used to contain field pest populations below economic threshold levels. When a known pest is constantly present and happens to be the single most limiting factor in successful cultivation of a crop in a wide crop area, then the host-plant resistance has comparative advantage over other control strategies (Shanower *et al*., 1998) [43]. An example of such insect pest is the bean fly, because the development of bean varieties with reasonable levels of resistance to bean fly can help to reduce direct cost to the small-scale farmers. Miklas *et al*., (2006) [30] also observed that improving bean varieties for resistance to insect pests can help reduce the dependence on pesticides to allow stable bean production across varied and unfavorable environments.

Botanical insecticide for Stem Fly, *Ophiomyia phaseoli*

The present findings corroborates with findings of Kumar and Sharma (2003) [26] they found that dimethoate and nimbecidine as significantly superior treatment against stem fly on pea. However, the present findings are supported by findings of Purwar and Yadav (2004) [38] where they observed that NSKE 4% have considerably reduced the stem fly infestation. Krishan kant (2005) [23] also observed on synthetic pyrethroids with plant product like neem oil, which also reduced the incidence of stem fly where in present findings, neem oil have also reduced the infestation compared to control. These findings were agreed with, Mittal and Ujjagir (2005) [56] they reported that NSKE 5 per cent as a minimum effective botanical against stem fly, as in the present findings NSKE also showed minimum effect on infestation of stem fly.

Table: List of botanical insecticides

S. No.	Botanical insecticides	Dose (%)
1.	NSKE	5
2.	Azadirachtin 0.03 EC	5.0 ml/ltr
3.	Neem Oil	0.5
4.	Neemarin	3.0 ml/ltr

Chemical insecticide for Stem Fly, *Ophiomyia phaseoli*

The present result corroborates with findings of. Srivastava and Sehgal (2000) [50] evaluated that bio-efficacy of various insecticide against stem fly and found that acephate has given good control of stem fly population, they have also tested nimbecidine for the control of stem fly and found that a comparative good control of pea stem fly. In present findings cartap-hydrochloride proved best in minimizing the stem fly infestation. Purwar and Yadav (2004) [38] further observed that in chemical control acephate 0.1% have recorded less stem fly infestation followed by quinalphos 0.05. Pandey *et al*. (1981) [35] evaluated that basal applications of phorate 1.5 kg a.i. ha^{-1} followed by spraying with 0.03 per cent chlorpyriphos were next in order with basal application of carbofuran 1.5 kg a.i. ha^{-1} followed by spray with 0.03 per cent quinalphos in decreasing the stem fly infestation in pea but at par with increasing the yield. Singh and Singh (1990b) [46] investigated that quinalphos (0.05%) and monocrotophos (0.05%) were found highly effective in checking the plant infestation (36.66 and 46.66%) and stem tunneling (20.69 and 27.36%) caused by the maggots of stem fly as against 100 and 50.28 per cent plant infestation and stem tunneling respectively in the control. Chander and Singh (1991) [11] observed the seed treatment with chlorpyriphos, dimethoate and monocrotophos 10 ml kg^{-1} seed was effective for the control of *Ophiomyia phaseoli* up to 28 days after sowing. Foliar application of 0.04 per cent monocrotophos 30 days after sowing was also effective in reducing population of bean fly.

Seed yield improvement and stability

Progress in breeding for high yield in common bean has been slow (Singh, 1991) [47]. Breeding for seed yield improvement need an understanding of the factors that are important in yield increase (Yan and Wallace, 1995) [61]. Kelly *et al*., (1998) [19] studied that seed yield in common bean can be improved if the developed cultivars are bred to fit within the cropping season in the target environment. Specifically, efficient genotypes that can quickly change from vegetative to reproductive growth phase for specific adaptation to definite local environment are suitable. For the semi-arid areas, farmer fields represent multiple environments and are often very dissimilar to the experimental stations.

Farmer perceptions of bean varieties and pests

In an effort to mitigate some of the crop production constraints experienced by the farmers, a number of improved bean varieties and agronomic packages for management of soil, pests and diseases have been recommended for the semi-aid areas. Apparently, adoption of these technologies has been modest. Despite the adoption of some of the new varieties, self-sufficiency in beans has remained unachievable. Knowledge of farmers and their practices for managing pests is necessary for the development of management strategies that will better serve the farmers (Chitere and Omolo, 1993, Rubia *et al*., 1996) [40, 12].

Research focus

Host plant resistance is one of the sustainable strategies that can be used to contain field pest populations below economic threshold levels; accomplishment in incorporating insect resistance into commercial varieties through breeding has been difficult in many legume crops (Edwards and Singh, 2006) [14]. The lack of progress has been attributed to breeders not having access to a full range of available germplasm resources. Another problem has been the difficulty in achieving pest resistance without reducing agronomic quality (Edwards and Singh, 2006) [14]. The development of bean varieties with improved resistance to insect pests can help reduce the dependence on pesticides in high input systems, minimize yield loss from pests in low- and high-input systems, and enable stable bean production across diverse environments (Miklas *et al*., 2006) [30]. In addition, farmers would be better served if such varieties are further improved for farmer preferred traits such as culinary qualities and market values (seed colour and seed size), which would improve adoption rates by small-scale farmers (Abate *et al*., 1900) [2].

Conclusion

A key challenge in breeding common bean for resistance to bean fly is to develop a systematic screening procedure that would provide a constant bean fly populations to exert uniform pressure on the screening material**.** Most of the screening has been based on open-field tests which has its own disadvantages. For example, low bean fly pressure could arise from high prevalence of natural enemies during certain periods that consequently reduce bean fly populations**.** Therefore, there is need to develop a reliable technique that would help to positively identify resistant lines.

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