Bean Stem Maggots of Ethiopia: Their Species Composition, Geographical Distribution, Importance and Population Dynamics

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Abstract

Results of ecological studies carried out in Ethiopia between 1990 and 1993 showed that three species of bean stem maggots (BSM): *Ophiomyia phaseoli* (Tryon), *O. spencerella* (Greathead) and *O. centrosematis* de Meijere occur on haricot bean (*Phaseolus vulgaris*) in various parts of Ethiopia. *Ophiomyia phaseoli* and *O. spencerella* were the most widely distributed and abundant of the three species; *O. centrosematis* occurred rarely and represented less than 2 percent of the total BSM population in most instances. BSM intensity and the resulting seedling mortality were more severe at altitudes ranging between approximately 1700-1900 m above sea level; most of these areas lie in the vicinities of Areka, Wolaita Sodo, Awassa and Arsi-Negele in southern and south-central Ethiopia. BSM did not appear to be important at altitudes below 1600 m and above 2000 m.

Incidence of BSM species was found to be influenced by one or a combination of environmental factors and cultural practices including altitude, sowing date, and growth stage and type of the host plant. *Ophiomyia phaseoli* and *O. centrosematis* were more prevalent at altitudes below 1800 m and warmer climatic conditions whereas *O. spencerella* was dominant at higher altitudes and cooler, wetter environments. *Ophiomyia phaseoli* was more abundant in early sown bean whereas *O. spencerella* became more common later in the season; within the same sowing date, proportions of *O. centrosematis* and *O. spencerella* declined and those of *O. phaseoli* increased with the progress in the growth stage of the host plant. The incidence of *O. phaseoli* was more frequent on thin-stemmed, narrow-leaf, small-seeded, pea bean types whereas *O. spencerella* and *O. centrosematis* showed preference for more succulent, broad-leaf, large-seeded, navy bean types.

INTRODUCTION

Bean stem maggots (also known as bean fly), *Ophiomyia* spp. (Diptera: Agromyzidae), are the major pest of haricot bean (*Phaseolus vulgaris* L.) in Ethiopia and elsewhere in Africa where this crop is grown mostly by smallholder farmers. Although limited previous observations have revealed the existence of three species of BSM in Ethiopia (Abate et al. 1990), little is known about their ecology, population dynamics, relative importance and geographical distribution in this country.

Ophiomyia phaseoli (Tryon) has been considered to be the only species that attacks haricot bean in Africa until Greathead (1969) showed that there are three species, viz. *O. phaseoli*, *O. spencerella* (Greathead), and *O. centrosematis* de Meijere in the then East Africa (Kenya, Tanzania and Uganda). Recent preliminary observations from Ethiopia (Abate et al. 1990), and reports from Burundi (Autrique 1989), Mozambique (Davies 1990) and Zambia (Sithanantham 1989) also confirm occurrence of the three species in these countries.

Several reports from eastern and southern Africa and elsewhere indicate that BSM infestation level is influenced by sowing date, plant density, cropping pattern, crop variety, soil fertility, and climatic factors (Abate 1990,

Autrique 1989, Davies 1990, Letourneau n.d., Oree et al. 1990, Sithanantham 1989, Slumpa & Ampofo 1990). For instance, Davies (1990) in Mozambique, Letourneau (n.d.) in Malawi, and Oree et al. (1990) in Tanzania reported that BSM infestation increased with late sowing. On the other hand, earlier work in Ethiopia suggests that BSM response to sowing date is site-specific (Abate 1990). Integrated pest management (IPM) is accepted to be the most appropriate approach to manage BSM in smallholder agriculture (Abate 1990), where the bulk of haricot bean is grown. A thorough understanding of the ecology and population dynamics of BSM is crucial in the development of a sound IPM programme. This paper reports results of studies on the ecology, geographical distribution, species composition, population dynamics, and significance of BSM in Ethiopia.

MATERIALS AND METHODS

Surveys

Intensive surveys were conducted at farmers' fields and research centres between 1990 and 1993 in the major bean growing regions of Ethiopia (Fig. 1). Samples from farmers' fields were collected only once for each location whereas repeated sampling was done at research centres at Areka, Awassa, and Arsi-Negele from various nurseries, agronomic trials, and production fields. Samples for Melkassa were obtained from 36 non-replicated seed multiplication plots each 4 m long and 7.2 m wide, 60 cm between rows and 10 cm between plants, consisting of nearly 350 segregating nursery lines (264 thin-stemmed pea bean types and 168 thick-stemmed navy bean types). These were sown on 28 September 1992 and grown under irrigation. Dead seedlings were collected at approximately 6, 7, 8, and 10 weeks after sowing and BSM numbers were determined as in the population dynamics experiments described below.

Altitude for each site was recorded from altimeter readings, and sampling dates were noted. Sowing dates for each sample were also recorded wherever possible. From each location up to 100 dead plants or plants showing BSM damage symptoms (stunting, wilting and dying) were uprooted, put into plastic bags and taken to the laboratory. These were dissected and the number of puparia and larvae were counted and recorded for each plant; the puparia were sorted into shining black, with a grey ventral surface (*O. spencerella*) and brown (consisting of *O. phaseoli* and *O. centrosematis*) specimens. The brown pupae were further separated into the two species using the keys provided by Greathead (1969), Allen and Smithson (1986), Talekar and Chen (1986), Karel and Autrique (1989), Ismay (1989), with the characteristics of posterior spiracles as the main criteria (these are somewhat bifurcated and have 8-9 lobes in *O. phaseoli*, and blunt with 3 lobes in *O. centrosematis*).

Population Dynamics Experiments

Experiments to determine seasonal changes in BSM numbers were conducted at Awassa in 1991 and 1992 and at Areka in 1992 and 1993. Seeds of the moderately susceptible local variety 'Red Wolaita' were sown at 2-week intervals between 9 May and 23 August in 1991 and between 1 May and 9 August in 1992 at Awassa. In a similar fashion, the same variety was sown at Areka between 22 April and 5 September 1992 and 26 February and 2 July 1993. These dates were chosen on the basis of farmers' production practices where haricot bean is planted both in the *belg* (March/April) and *meher* (June/July) seasons at both locations.

Plots for each planting were 6 m long and 4 m wide, 40 cm between rows and 10 cm between plants, replicated twice. Plant stand counts were recorded at 2-3 weeks after sowing. Dead seedlings due to BSM were recorded at least twice a week for about 4 weeks, following stand counts. Percent seedling mortality was thus calculated from the dead plant totals. Twenty plants were uprooted from each plot by walking in an "X" pattern (across diagonals) and picking one plant per row at 30-45 days after sowing. These samples were taken to the laboratory and the numbers of BSM (larvae + puparia) were counted per plant and species separated as for the survey data described above.

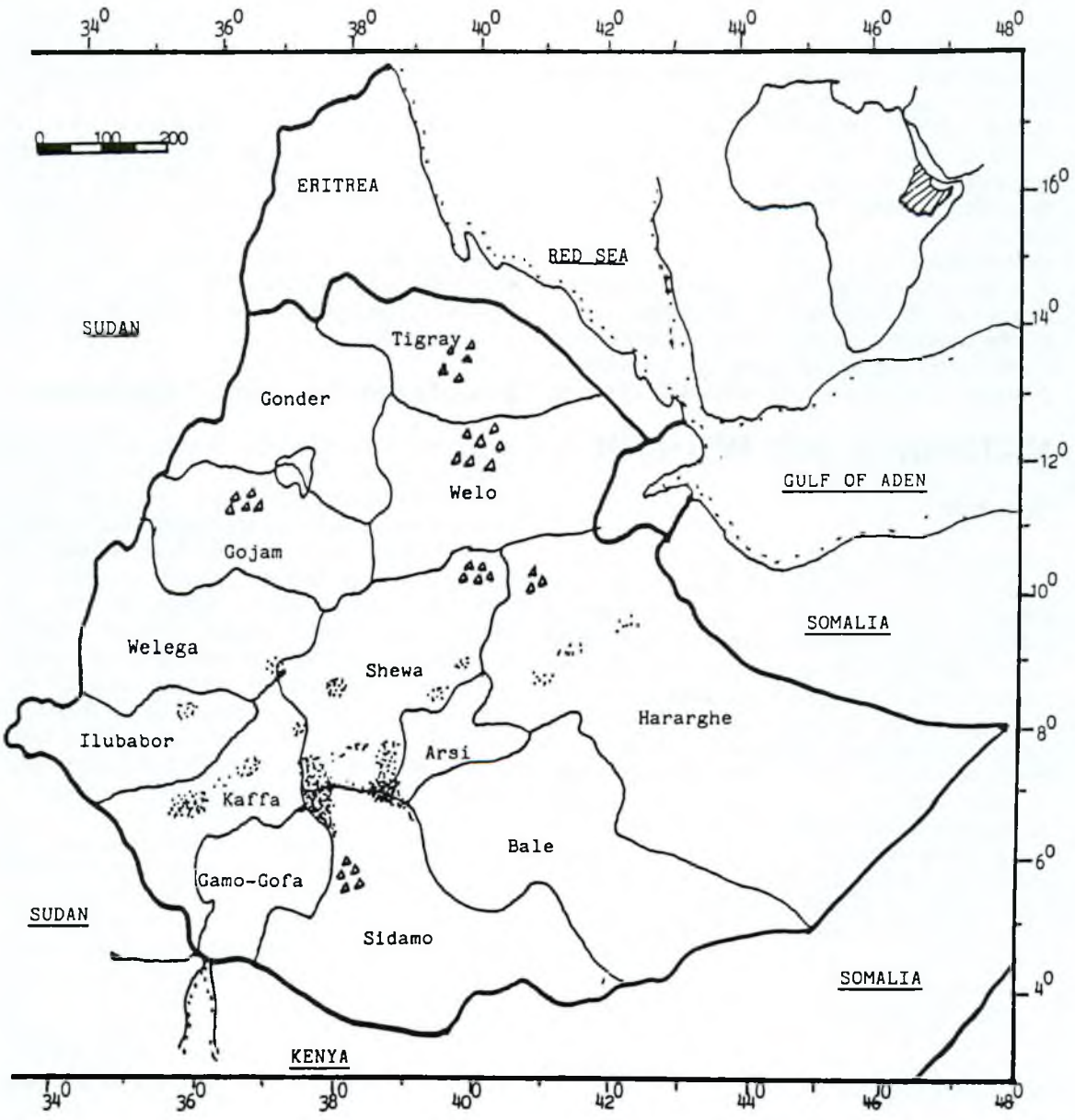

Fig. 1. Distribution of bean stem maggots in Ethiopia (previous records are indicated by diamond signs; records based on current survey are shown by solid dots).

RESULTS

Surveys

The occurrence of BSM species and their intensity in the major bean growing regions of Ethiopia covered in the survey are presented in Table 1 (samples from farmers' fields) and Table 2 (repeated sampling from research centres). BSM intensity (as measured by BSM per 10 plants) and species composition varied with location and sampling date (or sowing date). Samples of bean plants collected at Welenchiti, Bulbula, Ambo (Shewa); Hirna, Chelenko, Kobo, Kunie, Kulubi (Hararghe); and Abelti and Seka (Kaffa) did not yield BSM although they showed characteristic symptoms of damage caused by this insect (stunting, yellowing and dying). BSM intensity at some localities, such as Kersa, Wakmolie, Yabete Anbessa (Hararghe); Melkassa, Shashemene (Shewa); Metu (Ilubabor); and Bonga, Jimma (Kaffa) was relatively low, suggesting that these insects may not be a limiting factor in haricot bean production in these areas.

By contrast, high intensities were observed in southern and south-central Ethiopia. These included Areka (Sidamo) and its vicinities (Waraza-Soho, Damot-Woide, Gurmu-Woide, Gurmu-Koisha, Gurmu-Ledisa); the Awassa (Sidamo) area; the Wolaita Sodo (Sidamo) area (Bedessa, Shakiso-Shone, Dola); and the Shashemene area (Awara, Yeyi, Arsi-Negele), all of which represent the major concentration of haricot bean production in Ethiopia. The highest intensity of 340 BSM per 10 plants from August 1 sample at Areka is the record number known so far; here, it was observed that the plants (sown in April) were vigorous and had heavy pod load in spite of sustaining such a high BSM intensity. Overall, BSM was particularly important in areas lying between 1700-1900 m above sea level; it did not seem to be important at altitudes below 1600 m and above 2000 m.

One or more of the three species of BSM: *O. phaseoli*, *O. spencerella* and *O. centrosematis*, were found in different parts of Ethiopia. *Ophiomyia phaseoli* and *O. spencerella* were by far the most widespread and most abundant of the three species found in this country. *Ophiomyia centrosematis* was rare; it was recorded from Jimma (Table 1), Arsi-Negele, Awassa and Melkassa (Table 2). This species accounted for less than 2 percent of the total BSM numbers at Awassa and Arsi-Negele whereas it represented nearly 17 and 9.4 percent at Jimma (sampled on 28 August 1990) and Melkassa (average of 4 sampling dates, 11 November to 6 December 1992), respectively.

Ophiomyia phaseoli was more abundant at altitudes below 1800 m above sea level whereas *O. spencerella* occurred in large numbers mostly at altitudes above 1800 m (Fig. 2). However, there were obvious exceptions. For example, *O. phaseoli* accounted for 100% in the Shashemene area (1880-1900 m) whereas *O. spencerella* constituted about 88 and 67% at Bonga (1650 m) and Jimma (1750 m), respectively. These exceptions can be due to the temperature regimes in the respective areas. Although Bonga and Jimma are medium altitude areas, they are surrounded by tropical forest vegetation and have much cooler temperatures and higher rainfall than the corresponding locations with similar altitudes. It is possible that temperature may be the key factor determining the distribution of BSM species, rather than altitude *per se*. Further research is needed to establish the relationship between temperature and distribution of BSM species.

Another important factor in determining the abundance and composition of BSM species appeared to be the time of planting. For instance, nearly 100% of BSM sampled in June at Awassa was *O. phaseoli* whereas this species accounted for just over 25% when sampled in late August at the same location (Table 2). Similarly, at Areka, *O. phaseoli* consisted of 14-20% and 1-3% in plants sampled in April and July/August, respectively. Furthermore, *O. phaseoli* (and *O. spencerella*) constituted approximately 41 (57) percent in plots sown in June and 0 (100) percent in those sown in July at Arsi-Negele.

Results of repeated samples collected from Melkassa showed that the proportion of *O. phaseoli* increased and that of *O. centrosematis* and *O. spencerella* decreased at later growth

stages of the plant (Table 2). It can be seen from the table that *O. phaseoli*, *O. spencerella* and *O. centrosematis* constituted 41, 33 and 26%, respectively, at 5 weeks after emergence (wae) and 82, 13 and 5% at 10 wae. Here, BSMper dead plant in thin-stemmed pea bean types was about 2.5 while the more robust, thick–stemmed and broad-leaved navy bean types contained nearly 4.5. It also appeared that *O. phaseoli* preferred thin-stemmed genotypes whereas this situation was reversed in *O. spencerella* and *O. centrosematis*. For example, the species composition of *O. phaseoli*, *O. spencerella* and *O. centrosematis* in thin- (and thick- stemmed) genotypes was 82.3 (68.7), 12.4 (17.8), and 5.3 (13.5) percent, respectively. Our previous report (Abate et al. 1995) also showed the influence of crop variety and soil fertility on BSM intensity and species composition.

Table 1. Intensity (insects per 10 plants) and species composition (percent) of bean stem maggot at various altitudes in major bean growing areas of Ethiopia, 1990-1992

Locality	Alt.(m)	Date sampled	Intensity	Composition*		
				phas	spen	cent
Welenchiti	1450	3.9.90	0.0	-	-	-
Melkassa	1550	18.10.90	3.3	100.0	0.0	0.0
Bako	1650	23.8.90	5.8	91.7	8.3	0.0
Bonga	1650	26.8.90	8.9	11.8	88.2	0.0
Bulbula	1650	26.8.90	0.0	-	-	-
Damot-Woide	1680	23.6.90	35.5	23.7	76.3	0.0
Abelti	1685	27.8.90	0.0	-	-	-
Awara	1700	1.7.90	44.0	16.7	83.3	0.0
Metu	1700	27.8.90	2.3	85.7	14.3	0.0
Seka	1700	26.8.90	0.0	-	-	-
Jimma	1750	26.8.90	2.7	16.7	66.6	16.7
Moto-Chokorsa	1750	26.8.90	14.5	77.8	22.2	0.0
Diri	1760	26.8.90	25.7	50.0	50.0	0.0
Dola	1770	15.6.92	45.0	4.2	95.8	0.0
Shakiso-Shone	1780	16.6.92	62.4	0.0	100.0	0.0
Gurmu-Woide	1800	21.4.92	18.0	34.6	65.4	0.0
Bedessa	1850	23.6.92	42.2	2.7	97.3	0.0
Gurmu-Koisha	1860	15.6.92	52.5	0.0	100.0	0.0
Yeyi	1880	1.8.90	14.0	100.0	0.0	0.0
Shashemene	1900	9.5.91	1.4	100.0	0.0	0.0
Waraza-Soho	1900	23.6.90	92.4	0.7	99.3	0.0
Waraza-Soho	1900	1.8.90	59.7	8.9	90.6	0.0
Hirna	1900	2.9.90	0.0	-	-	-
Gurmu-Ledisa	1910	15.6.92	23.3	0.0	100.0	0.0
Chelenko	2000	2.9.90	0.0	-	-	-
Kobo	2000	2.9.90	0.0	-	-	-
Wakmolie	2050	2.9.90	1.0	0.0	100.0	0.0
Ambo	2100	22.8.90	0.0	-	-	-
Kersa	2150	2.9.90	3.6	0.0	100.0	0.0
Yabete-Anbessa	2250	2.9.90	1.0	0.0	100.0	0.0
Kunie	2350	2.9.90	0.0	-	-	-
Kulubi	2450	2.9.90	0.0	-	-	-

*phas=O. phaseoli; spen=O. spencerella; cent=O. centrosematis.

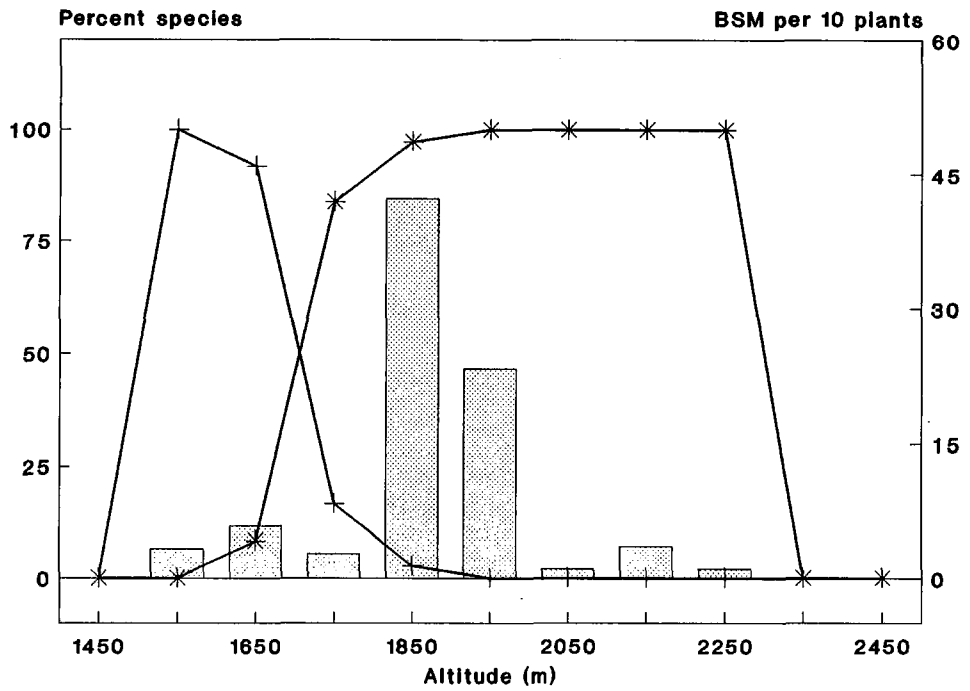

Figure 2. **Relationship between BSM intensity (bars) and composition of two major species of BSM (lines; x---x=*Ophiomyia phaseoli*, *——*= *O. spencerella*) at various altitudes in Ethiopia**

Table 2 Seasonal changes in bean stem maggot intensity (insects per 10 plants) and percent species composition at four locations in Ethiopia, 1990-1993

Site & date sampled	Intensity	Percent *Ophiomyia*		
		phaseoli	*spencerella*	*centrosematis*
Areka				
April 4	27.6	14.1	85.9	0.0
April 21	20.0	20.0	80.0	0.0
May 31	10.0	1.0	99.0	0.0
June 7	23.6	3.5	96.5	0.0
June 15	45.8	2.4	97.6	0.0
July 21	44.2	1.0	99.0	0.0
August 1	340.0	3.2	96.8	0.0
Awassa				
June 2	22.9	100.0	0.0	0.0
June 17	23.8	99.0	1.0	0.0
July 23	25.4	88.2	11.8	0.0
July 31	36.7	59.4	40.6	0.0
August 2	86.7	79.6	20.4	0.0
August 25[a]	61.4	54.3	44.3	1.5
August 25[b]	42.4	25.5	73.3	1.2
Melkassa				
November 11	35.1	41.4	32.8	25.9
November 18	43.3	70.8	15.7	13.4
November 26	37.9	79.1	13.4	7.6
December 8	29.0	83.9	11.2	4.9
Arsi-Negele				
July 30[c]	23.5	41.1	57.1	1.8
July 30[d]	27.5	0.0	100.0	0.0
Sept 5	15.7	26.1	73.9	0.0

[a,b,c,d] *sown late June, late July, early May, and early July, respectively.*

Population Dynamics Experiments

Figure 3 depicts seasonal changes in the proportions of the two major BSM species at the two locations where the population dynamics experiments were conducted for two seasons each. At Awassa, *O. phaseoli* was the dominant species on haricot bean planted before July and August; it accounted for 93 to 100% of the two species in bean plots sown between early May and mid June. By contrast, *O. spencerella* constituted 60 to 100% in plots sown during the cooler and wetter months of July and August (Fig. 3). At Areka, *O. spencerella* ranged between 73 and 100% in 1992 and between 57 and 100% in 1993 (Fig. 3). Here, *O. phaseoli* was found in appreciable numbers only in plots sown during the warmer and relatively drier months of February to May. Relationships between BSM intensity and seedling mortality at Awassa are presented in Figure 4. BSM intensity (i.e. BSM per 10 plants) tended to be higher in plots sown in May whereas seedling mortality peaks were observed in plots sown in late May and early August. Although BSM intensity and seedling mortality followed similar trends, they were not significantly correlated.

Figure 5 shows the relationship between BSM intensity and seedling mortality in haricot bean sown at different dates at Areka during 1992 and 1993. It can be seen that BSM intensity was lower in the early sown plots than in the late sown ones during both years; seedling mortality also followed a similar trend. Although correlations between BSM intensity and seedling mortality were not significant in the 1992 experiment ($r=0.315$, $P=0.372$), there was a highly significant positive correlation ($r=0.829$; $P=0.002$) between the two parameters in 1993.

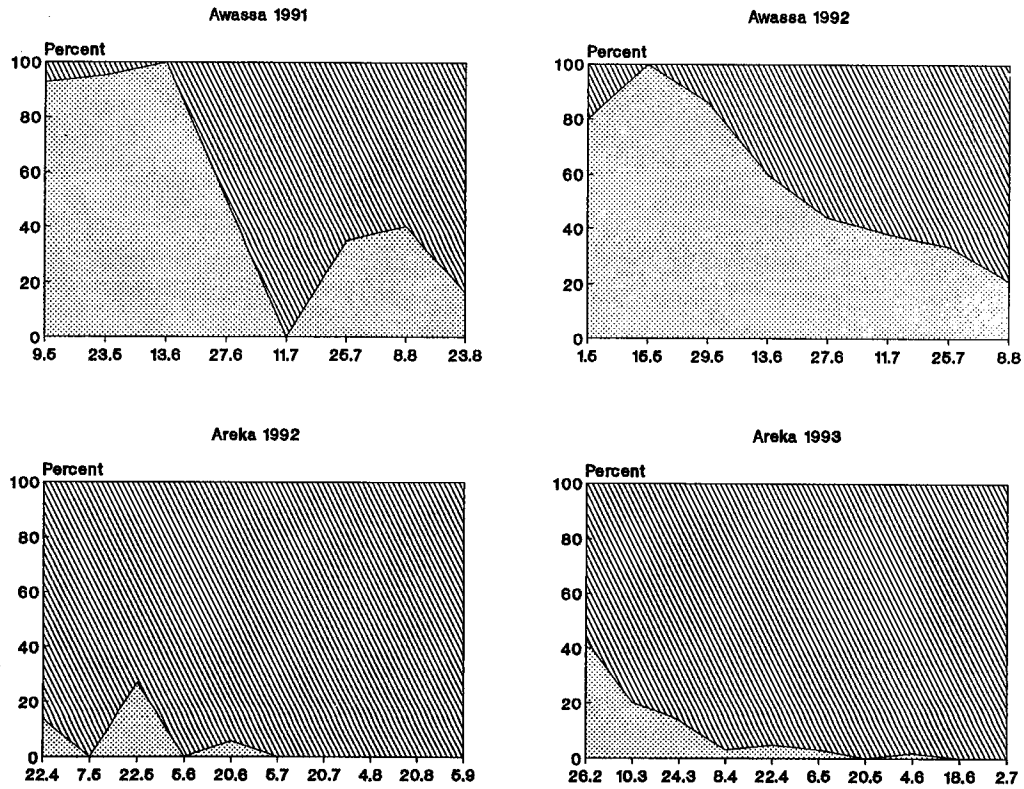

Figure 3. Seasonal changes in proportions of *Ophiomyia phaseoli* (dotted area) and *O. spencerella* (hatched area) at different sowing dates and seasons at two locations in Ethiopia

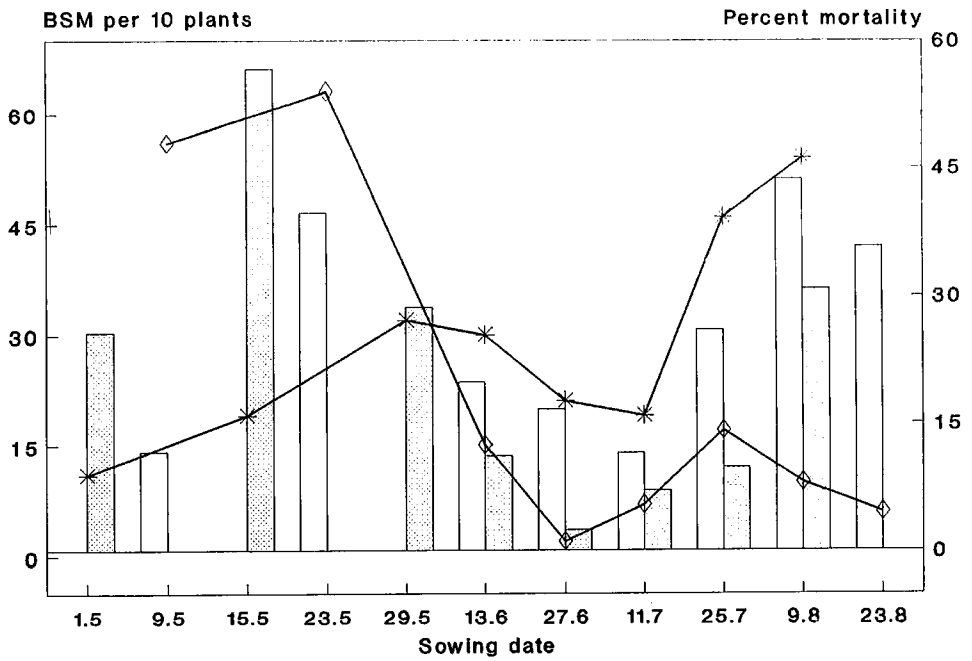

Figure 4. Relationship between BSM intensity (bars; unshaded=1991, shaded=1992) and percent seedling mortality (lines; solid=1991, broken=1992) at Awassa, Ethiopia.

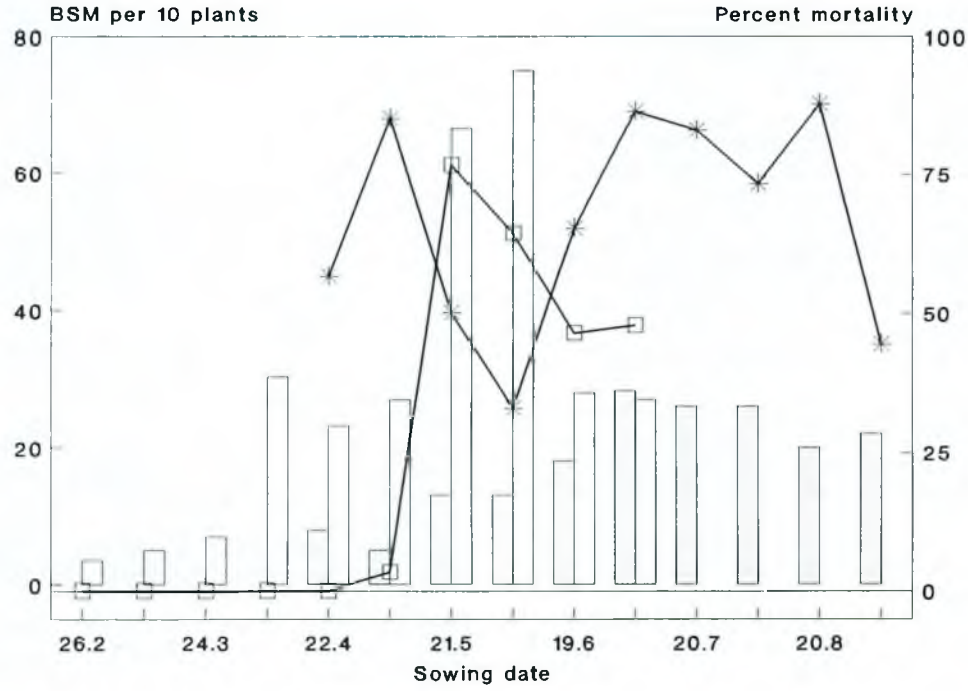

Figure 5. **Relationship between BSM intensity (bars; shaded=1992, unshaded=1993) and percent seedling mortality (lines; asterisk=1992, square=1993) at Areka, Ethiopia.**

Discussion

It has been reported previously (Crowe et al. 1977, Abate 1991) that *O. phaseoli* was the only major pest of beans and cowpea (*Vigna unguiculata*) in most haricot bean growing regions of Ethiopia, including the areas in the vicinities of Hagere-Mariam, Sidamo; Shewa-Robi, northern Shewa; Mekele, Tigray; Pawe, Gojam; Kobo, Welo; and Mieso, Hararghe.Our present study elucidated the species composition and geographical distribution of BSM in Ethiopia and some of the environmental factors affecting their numbers. All three species of BSM, viz. *Ophiomyia phaseoli*, *O. spencerella* and *O. centrosematis* occur in this country, with the first two being the most important. Unpublished data from other recent surveys also confirm the presence of *O. phaseoli* and *O. spencerella* at Pawe.

Although, in Burundi, Autrique (1989) showed that *O. spencerella* was practically the only species at altitudes of 1400-2000 m while *O. phaseoli* and *O. centrosematis* were more common at lower altitudes, our findings suggest that BSM intensity, species composition and distribution are influenced not only by altitude but also by other factors, including cultural

practices (such as sowing date and crop husbandry), environmental conditions, crop variety and growth stage of the host plant.

Our observations that *O. phaseoli* is more common at lower altitudes and early sown beans, and *O. spencerella* is more important at higher altitudes and in late sown bean are consistent with reports from other parts of Africa (Davies, 1990; Sithanantham, 1989; Oree et al. 1990, Slumpa et al. 1990). Although *O. centrosematis* has been reported to constitute no more than 0-4 percent of the total BSM numbers in other countries (Autrique 1989, Sithanantham 1989), our experience from repeated sampling at Melkassa shows that its proportion can range from 5-26 percent, depending on the growth stage of the crop and time of planting.

The findings that BSM intensity in more robust, thick-stemmed bean types was greater than that in thin-stemmed pea bean types is also consistent with previous reports from Ethiopia (Abate 1990) and elsewhere (Letourneau n.d.). However, it should not be interpreted to mean that thick-stemmed genotypes or plants made more vigorous through improved soil fertility are more susceptible than thin-stemmed or less vigorous plants. What it actually means is that it will take more BSM to kill a vigorous plant than its thin-stemmed counterpart. It is possible that there is association between the nutritional quality of the plant and survivorship of BSM (Letourneau n.d.). The record high intensity of 34 BSM per plant from August 1 sample at Areka also supports this point.

Acknowledgements

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