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Parasitoid Species Diversity and Rates of Parasitism on Maize and Sorghum Stem Borers in the Central Rift Valley of Ethiopia

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Studies were conducted in the Central Rift Valley of Ethiopia to find out stem borer parasitoids species diversity and extent of parasitism, and to determine the stem borer species composition in maize and sorghum. Assessments were done in six districts of eastern Shoa on 120 farmers` fields on maize and sorghum. Observations showed the presence of three stem borer species on maize and sorghum. These were Busseola fusca Fuller (Lepidoptera: Noctuidae), Chilo partellus (Swinhoe) (Lepidoptera: Crambidae) and Sesamia calamistis Hampson (Lepidoptera: Noctuidae). B. fusca and C. partellus were found to be the dominant species consisting of 54% and 45% on maize, and 12.8% and 86.7% on sorghum respectively of the stem borer population. S. calamistis accounted for only less than 0.5%. Larval parasitoids, namely Cotesia flavipes Cameron (Hymenoptera: Braconidae), Dolichogenidea fuscivora Walker (Hymenoptera: Braconidae), and Dolichogenidea polaszeki Walker (Hymenoptera: Braconidae) and pupal parasitoids; Dentichasmias busseolae Heinrich (Hymenoptera: Ichneumonidae) and Pediobius furvus (Gahan) (Hymenoptera: Eulophidae) were recovered from B. fusca and /or C. partellus. Natural parasitism of the above- mentioned parasitoids were assessed at different growth stages of the crops and C. flavipes was found to be the dominant parasitoid species. Exposure of stem borer eggs and recovery of egg parasitoids were made at Melkassa and Arsi Negelle. The results indicated that two egg parasitoids, Telenomus busseolae Gahan (Hymenoptera: Scelionidae) with 62% parasitism and Telenomus thestor (Hymenoptera: Scelionidae) with 76% parasitism were reared from eggs of B. fusca. A hyperparasitoid, Aphanogumus fijiensis was recovered from C. flavipes. Entomopathogens were also isolated from the stem borers.

Key words: stem borer, parasitoids, parasitism, Busseola fusca, Chilo partellus, Cotesia flavipes

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INTRODUCTION

Sorghum (*Sorghum bicolor* L) is an important cereal crop worldwide used for food, feed production of alcoholic beverages and bio fuels. Ethiopia is center of origin and diversity for this crop. Sorghum is the second most important crop for Injera making quality next to tef and it is cultivated in all regions of the country in altitude ranges from 400 and 2500 m above sea level. It is the third most important cereal crop in terms of production and area coverage, with 4.4 million tons produced from 1.85 million hectares of land and with the national average

productivity of 2.4 tons per hectare. It takes a share of 18% of the area covered by cereals and 14.6% of the area covered by grain crops (CSA, 2014). Maize (*Zea mays* L) is the main cereal grown in Ethiopia mainly used for food, feed, fuel, mulching, house and fence construction. About two million hectares of land is under maize production in Ethiopia (CSA, 2014). Maize accounts for about 25.81% of the grain production in the country. Maize is an important food crop in Ethiopia ranking 2nd in terms of acreage and 1st in terms of yield per hectare, respectively (CSA, 2014).

However yield of maize and sorghum are significantly reduced by the infestation of stem borer species. Emana and Tsedeke (1999), Emana *et al.* (2003) reported 10 to 100% yield losses due to stem borers. Six stem borer species were reported on maize and sorghum in Ethiopia out of which *Busseola fusca* Fuller and *Chilo partellus* (Swinhoe) are the key species which cause economic damage sometimes causing total crop loss that needs to be controlled (Emana, 2001).

Although there are effective insecticides for stem borer control, the resource poor farmers cannot afford to buy them. The cryptic feeding nature of stem borers is also another factor, which limit the use of insecticides. The use of insecticides may have negative effect on the environment and also destroy natural enemies. Biological control implies the control of insect pests by natural enemies, under either natural or artificial circumstances. It is an approach under which the survival or activity of the pest population is reduced through the agency of other natural enemies. The result is reduction in the incidence and severity of insect pests. Parasitoids are natural enemies which attack various life stages of maize and sorghum stem borers. The effect of these parasitoids ranges from a temporary or minor effect to the death of the host (stem borers). Parasitoids are assumed to maintain stem borers population density at a lower average than would occur in their absence. The diversity, efficiency and type of natural enemies vary from region to region and from country to country within Africa (Yitaferu and Walker, 1997; Moyal, 1998; Adugna, 2000). Parasitoids have been the most common type of natural enemies introduced for the biological control of insect (Greathead, 1986). Hence, this study was initiated to investigate the status of stem borer species and to determine egg, larval and pupal parasitoids species diversity and their level of parasitism on maize and sorghum stem borers in the central rift valley of Ethiopia.

MATERIALS AND METHODS

Growth stages of the crops and sampling

Observations were carried out in major sorghum and maize growing districts of the Central Rift Valley of Ethiopia (East Shoa) in Dugda Bora, Adami Tullu, Arsi Negelle, Shashemene, Boset and Adama, at different growth stages of maize and sorghum. Vanderlip and Reeves (1972) described sorghum growth stages (G0 up to G9) and the method mentioned here was adopted for this study. Whereby; G0 (emergence), G1 (collar of 3rd leaf visible), G2 (Collar of 5th leaf visible), G3 (Growing point differentiation, approximately eight leaf stage), G4 (Final leaf visible in whorl), G5 (Boot, head extended into flag leaf sheath), G6 (Half bloom, half of the plants at some stage of bloom), G7 (Soft dough), G8 (Hard dough), G9 (Physiological maturity, Maximum dry matter accumulation) were the growth stages and their identifying characteristics. For simplicity G0 to G3 were considered as vegetative, G4 to G6 as flowering, G7 to G8 as seed setting and G9 as maturity stages of the crop. The Growth stages of maize (VE up to R6) were described by Iowa State University of Science and Technology Cooperative Extension Service (1993) and the method was adopted for this study. Whereby; VE Emergence, V1 (1st leaf), V2 (2nd leaf), V3 (3rd leaf), Vn (nth leaf), VT (Tasseling), R1 (Silking), R2 (Blister), R3 (Milk), R4 (Dough), R5 (Dent), R6 (Physiological Maturity) were the growth stage and their identifying characteristics. For simplicity VE to VT were considered as vegetative, R1-R2 as flowering, R3-R4 as seed setting and R5-R6 as maturity growth stages of the crop.

During each observation ten plants were sampled randomly and additionally five infested plants using purposive sampling were destructively sampled for the assessment from each field using zigzag pattern. Sampling was done from 20 fields, in each district. In total 120 farmers` fields were considered. Out of these, 65 fields were maize and 55 were sorghum. Coordinates were recorded using Global Positioning System (GPS).

Parasitoid and host assessment: - The seedling stage was targeted for egg parasitoids while the vegetative, flowering, seed setting and maturity stages were targeted for the larval and pupal parasitoids. Accordingly, in the seedling stage, eggs of stem borers (*B. fusca* and *C. partellus*) were collected and taken to laboratory for egg parasitoids' emergence. From the vegetative stage onwards, larvae and pupae of stem borers and parasitoid cocoons found on sampled plants were taken to laboratory for further rearing in ambient condition (for parasitoid emergence or pathogen development or adult moths emergence). Stem borer larvae were reared separately in Petri dishes by feeding them maize stems disinfected with sodium hypochlorite (5% Naocl) to avoid saprophytic fungal growth. Eggs, pupae and parasitoid cocoons were kept in Petri dishes. The samples in the laboratory were monitored daily. Parasitoid specimens were put in 70% alcohol and sent to International center for Insect Physiology and Ecology (ICIPE) for identification.

Pathogens were isolated and Gram reaction, cultural and cellular morphologies were studied to identify those pathogens associated with mortality of stem borers. To identify bacterial pathogens, the culture of the samples was crushed before centrifuging. Before and after adding antibiotic cocktail the sediments and supernatant were cultured. The samples were subculture to purify it. Gram stained smear from homogeneous colonies were prepared. The smear was observed under microscope to identify the causal agents. To identify viruses, the samples were crushed and diluted with 5 ml of distilled water. Diluted sample of 1.5 ml was taken to 2 ml eppendorf and centrifuged at 1000 rpm for 5 minutes. The supernatant was taken and the sediment was discarded. Antibiotic cocktail of 0.1 ml was added to the supernatant and incubated at room temperature for 24 hours. The supernatant was centrifuged at 1000 rpm for five minutes. Again the supernatant was taken and the sediment was discarded. Giemsa stained smear from the supernatant was prepared and observed under microscope for the presence of viruses.

Exposure of Stem Borer Eggs and Recovery of Egg Parasitoids

As a means of preventing larval damage, there is the need to explore the scope for increasing the egg stage mortality of lepidopteran pests. Egg parasitoids are good natural enemies of pests because they parasitize and kill the pest before it causes damage on the crop (Wajn berg and Hassan, 1994).

Seedling raising

Melkassa-1 (variety of maize) was sown in 20 cm x 20 cm x 10 cm pots in the green house. At two leaf stage, the seedlings were drawn from the green house and put in a rectangular oviposition wooden cage (chamber) with iron mesh used for egg laying (50 cm x 50 cm x 60 cm). There was an opening on top of the chamber for stem borer adults' entrance.

Insect rearing

Larvae of *B. fusca* were reared in the laboratory to get male and female adults for the experiment. Ten newly emerged adult females were released in each oviposition chamber. They were fed with 20% sugar solution by soaking cotton in the solution and suspending it inside the ovipositon chamber. The Seedlings were monitored for two to three consecutive days after releasing moths into cages to check whether they laid eggs or not.

Number of egg batches per plant and number of eggs per batch were recorded. The pots that contained eggs of *B. fusca* were placed in maize plots out in the field at Melkassa and Arsi Negelle. Using a hand lens (magnification 10X), eggs were monitored daily until the fate of all eggs (parasitized, predated or disappeared) was known. According to Van den Berg (1993) and Bonhof (2000) predation refers to when at least part of the chorion is present, but the contents of the egg have vanished, while disappearance refers to the case where both the contents and the chorion of the egg have vanished.

In each pot, the seedlings that contained egg batches of the stem borers were tagged. After three days of exposure the egg batches were placed in separate glass vials (50 mm long x12 mm in diameter) where cotton plugs were used as stoppers for the vials. Days of exposure of egg bathes in the field were determined based on the biology of the insect. Eggs were collected before hatching in the field. Collected eggs of *B*. *fusca* were brought to laboratory for identification and determination of parasitism rate of egg parasitoids.

Observations were made every day to check egg parasitoids emergence. Pupae of egg parasitoids (confirmed by the blackening of the egg chorion of the host) were counted within the host eggs using binocular microscope (magnification 16X) to determine the number of parasitized eggs (Hassan, 1990). The emerged egg parasitoids and first instar larvae of stem borers were recorded. Collected egg parasitoids were sent to ICIPE for identification. Percentage parasitism was calculated as the ratio of parasitized eggs to the total egg density (Van Driesche, 1983). Table 1

Statistical Analysis

General linear model procedure in SAS Computer program was used for the data analysis. Prior to analysis, data were checked for normality. Data which lacked normality were transformed using square root and arcsine transformation. Analysis of variance was done for each data. The means were separated using student-Newman-Keuls (SNK) test.

RESULTS

Abundance of stem borers in the Central Rift Valley of Ethiopia

Stem borer species composition and distribution were assessed in the central rift valley of Ethiopia across localities and growth stages. Density of *C. partellus* ranged between 6.8 and 12.83 per ten plants across the growth stages in maize (Table 2). This was significantly

($F_{3, 15}$=9.81; P= 0. 0.0008) different for growth stages. Significant ($F_{5, 15}$=21.78; P= 0. 0001) number of *C. partellus* in maize was recorded in Dugda Bora (Table 3). In this area maize was more dominantly grown than sorghum. In areas where sorghum plots are very low *C. partellus* can be forced to shift to maize plots where there is much food concentration to support its development. *C. partellus* densities increased from 23.6 to 68.2 per 10 plants in sorghum as growth stage progressed to maturity stage (Table 3). In sorghum growing areas of the central rift valley of Ethiopia the temperature increases and moisture decreases as growth stages progressed. C. partellus is related to high temperature and low precipitation (Emana, 2001). This condition favored the prevalence of *C. partellus.* Hence, the density of *C. partellus* follows such pattern to significantly increase its population as the growing period of sorghum progressed. The highest density of *C. partellus* in sorghum was recorded at Adami Tullu and Boset (Table 2). Boset is a sorghum belt and hot spot area for C. partellus. Consequently, density of C. partellus was more in sorghum than in maize. Significant difference existed in the abundance of *C. partellus* in sorghum among growth stages (Table 3) ($F_{3, 12}$= 3.20; P=0.0622) and among districts ($F_{4, 12}$ = 18.16; P=0.0001) (Table 2). C. partellus was high in sorghum than in maize. This may be explained by the difference of the origin of the crops. Sorghum is indigenous to Ethiopia and less preferred by indigenous stem borers like *B. fusca* than the exotic stem borers like *C. partellus.*

The larval and pupal populations of *B. fusca* in maize ($F_{5, 15}$=16; P=0.0001) and sorghum ($F_{4, 12}$ = 16.51; P=0001) were found significant among districts and the highest population of the insect pest in both crops were obtained from Shashemene (Table 4). Infestation and density of stem borers per plant varied from region to region, from season to season and between crops depending upon temperature, precipitation, elevation, presence and absence of wild hosts and type of parasitoids (Emana, 2001). Seshu reddy *et al*. (1992) and Assefa (1985) strongly underlined the role of elevations in determining species composition of stem borers. In the current study, these factors go with the density and species composition of stem borers and *B. fusca* was abundant in areas like Shashemene with high elevation (1860-1977 m.a.s.l). No significant variation was observed among the growth stage in the density of *B. fusca* attacking both maize and sorghum (Table 3). *B. fusca* prevails and infest in all growing periods of both maize and sorghum almost with constant magnitude. *B. fusca* populations in all districts were several folds high on maize than on sorghum except Boset (Table 5) which indicates maize is the preferred host to *B. fusca* than sorghum.

Importance, species composition and distribution of parasitoids of stem borers

Mainly three Hymenopterous larval parasitoids, *C. flavipes* Cameron (Braconidae), *Dolichogenidae polaszeki* walker (Braconidae) *Dolichogenidae fuscivora* walker (Braconidae) were found parasitizing *B. fusca* and *C. partellus* (Table 5*)*. Other larval Parasitoids such as Phoridae, Chloropidae, *Bracon* sp., *Cotesia sesamiae* and *Euvipio rufa* were also reared from few larvae of *C. partellus* and *B*. *fusca*.

.Of these parasitoids *C. flavipes* was found to be the dominant species accounting for 80% of the total population of parasitoids. *C. flavipes* was the dominant larval parasitoid recorded on *C. partellus,* while *C*. *falvipes*, *Dolichogenidae polaszeki* walker and *Dolichogenidae fuscivora* walker were recorded on *B. fusca* larvae (Table 6, 7, 8 & 9). Both Pupa of *C. partellus* and *B*. *fusca* were parasitized by *Dentichasmias bussealae* Heinrich (Ichneumonidae) and *Pediobius furvus* Gahan (Eulophidae*)* (Table 6). Few eggs of *B. fusca* and *C. partellus* were collected from farmers' fields but no egg parasitoids were recovered from both stem borer species. This might be due to the difficulties to collect high number of eggs of *B. fusca* and *C. partellus* in field conditions. But two egg parasitoids *T. busseolae* and *T. thestor* were recovered from B. fusca eggs by artificial exposure methods.

Level of Parasitism of *C*. *partellus* and *B*. *fusca* by larval and pupal parasitoids at different phenological stages of maize and sorghum was evaluated in different areas of the central rift valley of Ethiopia. In the central rift valley of Ethiopia the most abundant and widely distributed parasitoid was *C*. *flavipes* which plays a vital role for the mortality of stem borer species. Density of parasitized *C*. *partellus* by *C*. *flavipes* in maize ($F_{5, 15}$= 8.73; P=0.0005) and sorghum ($F_{4, 12}$= 8.28; P=0.0019) was significant among districts. Per cent parasitism by *C*. *flavipes* on *C*. *partellus* in maize ranged between 1 to 75.7% where the highest per cent parasitism of 75.7% was found at Boset (Table 4). *C*. *flavipes* parasitism on *C*. *partellus* in sorghum ranged from 1 to 38.8 % where the highest percent parasitism of 38.8% was recorded at Boset (Table 5). *C*. *partellus* was abundant in areas with low elevation, low precipitation and high temperature. Such physical factors exist in Boset. *C. flavipes* required low precipitation, high evapotranspiration, and high temperature which were more or less similar to the requirements of *C. partellus* the most suitable host for *C. flavipes.* Mortality of *C. partellus* in maize by *C. flavipes* seems high as opposed to mortality of *C. partellus* by *C. flavipes* in sorghum. This might be related to the population of *C. flavipes* which was not proportional to the ever increasing population of *C. partellus* in sorghum while the density of *C. flavipes* was proportional to the population of *C. partellus* in maize.

Table 1. Elevations and geoposition of the study areas

Districts	Elevation(m)	Cooridinates	
		Latitude	Longitude
Dugda bora	1665-1671	08^0 00.45`-$08^0$ 07.80`	038^0 43.47`-$038^0$ 48.27`
Adamitullu	1601-1666	07^0 40.99`-$07^0$ 58.66`	038^0 38.64`-$038^0$ 43.27`
Arsi Negelle	1959-1671	07^0 19.69`-$07^0$ 33.07`	038^0 39.62`-$038^0$ 40.61`
Shashemene	1860-1977	07^0 10.10`-$07^0$ 16.90`	038^0 32.88`-$038^0$ 39.11`
Boset	1391-1450	08^0 27.18`-$08^0$ 28.32`	039^0 26.55`-$039^0$ 29.57`
Adama	1473-1681	08^0 28.69`-$08^0$ 37.11`	039^0 17.67`-$039^0$ 23.30`

Table 2

Growth stages	*C. partellus*		*B. fusca*	
	Maize	**Sorghum**	**Maize**	**Sorghum**
Vegetative	*8.71 ± 0.64 a	23.60± 1.04 b	13.71 ± 0.63 a	4.00 ± 0.52 a
Flowering	6.80 ± 0.40 b	42.60 ± 1.31 ba	9.00± 0.62 a	8.60± 0.89 a
Seed setting	8.17 ± 0.51 b	47.60 ± 1.70 ba	15.33 ± 0.72 a	5.60± 0.62 a
Maturity	12.83± 0.53 a	68.20± 1.90 a	18.33± 0.91 a	6.20± 0.66 a

Table 3. Density of stem borer species (mean ± SE) on maize and sorghum in the Central Rift Valley of Ethiopia

Districts	*C. partellus*		*B. fusca*	
	Maize	**Sorghum**	**Maize**	**Sorghum**
Dugda Bora	*28.8± 0.41 a	** --	13.25± 0.36 b	** --
Adami Tulu	17.3± 0.22 b	101.3± 1.7 a	13.00± 0.17 b	1.25± 0.29 b
Arsi Negelle	7.8± 0.55 c	17 ± 0.63 c	17.25± 0.56 b	5 ±0.50 b
Shashemene	1.0± 0.0 d	2.8± 0.48 d	37.50 ± 0.67 a	21.75 ± 0.39 a
Boset	8.5± 0.17 c	65.8± 0.25 ba	1.00± 0.00 c	1.25± 0.17 b
Adama	9.5 ± 0.42 c	40.8± 0.61 bc	3.75± 0.42 c	1.25 ± 0.17 b

Means followed by the same letter (s) are not significantly different from each other at 5 %
* Number of insects (larvae + pupae)/10 plants
**No data recorded

Table 4. Effect of maize and sorghum growth stages on stem borer density (Mean ± SE)

Growth stages	*C. partellus*		*B. fusca*	
	Maize	**Sorghum**	**Maize**	**Sorghum**
Vegetative	*8.71 ± 0.64 a	23.60± 1.04 b	13.71 ± 0.63 a	4.00 ± 0.52 a
Flowering	6.80 ± 0.40 b	42.60 ± 1.31 ba	9.00± 0.62 a	8.60± 0.89 a
Seed setting	8.17 ± 0.51 b	47.60 ± 1.70 ba	15.33 ± 0.72 a	5.60± 0.62 a
Maturity	12.83± 0.53 a	68.20± 1.90 a	18.33± 0.91 a	6.20± 0.66 a

Means followed by the same letter (s) are not significantly different from each other at 5 %
* Number of insects (larvae + pupae)/10 plants

Table 5. Species compositions of parasitoids attacking stem borers of maize and sorghum in the central rift valley of Ethiopia

Stem borer Species	Stage Parasitized	Species of Parasitoids	Families	Maximum % parasitism
B. fusca	Egg	*T. busseolae*	Scelionidae	62
		T. thestor	Scelionidae	76
	Larva	*C. flavipes*	Braconidae	25.1
		D. polaszeki	Braconidae	42
		D. fuscivora	Braconidae	37.5
		C. sesamiae	Braconidae	1
	Pupa	*D. busseolae*	Ichneumonidae	10.4
		P. furvus	Eulophidae	7.6
C. partellus	Larva	*C. flavipes*	Braconidae	75.7
		D. fuscivora	Braconidae	1
	Pupa	*D. busseolae*	Ichneumonidae	2.3
		P. furvus	Eulophidae	11.1

Table 6. Extent of parasitism (mean ± SE) by larval parasitoids on stem borer species in maize in the central rift valley of Ethiopia.

	%parasitism by *C. flavipes* on		%parasitism by *D. fusivora* on
Districts	*C. partellus*	*B. fusca*	*B. fusca*
Dugda Bora	13.7 ± 5.65 bc	8.63 **±** 5.98 a	12.55 ± 7.19 b
Adami Tulu	2.43 ± 1.97 c	18.75 **±** 7.16 a	33.1 ± 8.27 a
Arsi Negelle	2.63 ± 2.54 c	13.93 **±** 7.23 a	30.3 ± 7.77 a
shashemene	1 ± 0.00 c	4.3 ± 2.96 a	7.48 ± 5.12 b
Boset	75.73 ± 12.90 a	1 ± 0 a	2.13 ± 2.20 b
Adama	52.6 ± 13.34 ba	13.5 ± 9.96 a	5.73 ± 4.11 b

Table 7. Extent of parasitism (mean ± SE) by larval parasitoids on stem borer species in sorghum in the central rift valley of Ethiopia.

	%parasitism by *C. flavipes* on	%parasitism by *D. polaszeki* on
Districts	*C. partellus*	*B. fusca*
Adami Tulu	3.73 ± 3.57 b	11.63 ± 6.79 ba
Arsi Negelle	9.08 ± 7.38 b	40.25 ± 19.07 a
shashemene	1.00 ± 0.00 b	30.75 ± 10.91 ba
Boset	38.8 ± 5.11 a	2.25 ± 2.22 b
Adama	23.7 ± 3.27 a	9.50 ± 5.20 ba

Mortality of *C. partellus* by *C. flavipes* persist with more or less constant magnitude in all growth stages in both maize and sorghum without significant variation (Table 6 & 7). As long as there is an infestation of *C. partellus* in maize and sorghum throughout the growing season, *C. flavipes* has complete association to oviposit its eggs inside the host larvae and develop until the mature *C. flavipes* larvae emerges from it to spin cocoons to turn to adult wasp by gradually consume its host contents and eventually kill the insect pest.

The highest percent parasitism of *B. fusca* larva by *C. flavipes* on maize was observed at seed setting of the crop (25.07%) (Table 6). Extent of parasitism of *C. flavipes* by *B. fusca* larval stage in maize was also observed among growth stages ($F_{3, 15}$= 4.97; P=0.0136) where the study was conducted (Table 6). Lower proportions of *B. fusca* larval parasitism by *C. flavipes* were observed at vegetative growth stages of maize (Table 6). During early vegetative stage of Sorghum, mortality of *B. fusca* by *C. flavipes* is very low while it was high (40%) during the maturity stage (Figure 2). This was possibly due to the larval stages of the insect pest. At early vegetative stage of the crop, 1st and 2nd larval instars of *B. fusca* dominates which could not be parasitized by *C. flavipes*. The parasitoid prefer to oviposit on mature larval instars of the insect pest to sustain its development as the 1st and 2nd larval instars die off by the attack of parasitoids before it finish its development. *B. fusca* larvae on maize sustained higher per cent parasitism at Adami Tullu (Table 4).

A larval parasitoid, *D. polaszeki,* was also reared from *B*. *fusca* in maize and sorghum. *D. polaszeki* on *B*. *fusca* in sorghum was recorded at all stages of the crop development but reached its peak at vegetative with 42% parasitism and continued to decline to 29.6% at flowering, to 2.1% at seed setting and 1.8% at maturity growth stage (Table 8). There was a sharp decline of parasitism as sorghum growing season progressed. This perhaps due to the parasitoid requires relatively cool and wet condition. In sorghum, significant difference was observed in *D. polaszeki* parasitism among districts (Table 5) ($F_{4, 12}$= 3.51; P=0.0404) and growth stages (Table 8) ($F_{3, 12}$= 8.2; P=0.0031). Larval mortality of *B. fusca by D. polaszeki* in maize was low. The highest *B. fusca* larval mortality recorded was 3.1 % at maize flowering stage (Figure 2).

Another larval parasitoid, *D. fuscivora* was found in both maize and sorghum infested by *B*. *fusca*. *D. fuscivora* on *B. fusca* infesting maize was highest at maturity with 37.5% parasitism followed by at seed setting stage with 22.88% parasitism (Table 6). The highest parasitism of *D. fuscivora* (33 .1%) on *B. fusca* larvae in maize was recorded at Adami Tullu followed by at Arsi Negelle (30.3 %) (Table 6) with a significant difference from other districts.

D. fuscivora caused 20% *B. fusca* larval mortality on sorghum at maturity growth stage. (Figure 2) and it was recorded only around Shashemene with 18.2% *B*. *fusca* larval mortality rate (Figure 1). *B. fusca* larval mortality rate by D*. fuscivora* in sorghum also increased as growth stage progressed from 8.5% of flowering growth stage to 20% of maturity growth stage (Figure 2).

D. bussealae and *P. furvus* were the pupal parasitoids recorded. No *D. busseolae* was reared from *C*. *partellus* and *B*. *fusca* in Sorghum. This might be due to the volatile emitted from sorghum does not attract the parasitoid. A pupal mortality rate of 10.4% by *D. busseola* was recorded in maize at vegetative stage (Figure 3). This pupal parasitoid was only recorded in Dugda Bora district with an average pupal mortality rate of 3.8% in maize (Figure 4).

Compared with *D. busseolae*, the pupal parasitoid *P. furvus* caused high levels of mortality on *C*. *partellus* in both maize and sorghum. The highest pupal mortality of *C*. *partellus* by *P. furvus* (11.1%) (Figure 3) was observed at seed setting growth stage of maize. Comparable level of pupal mortality of *C. partellus* by *P*. *furvus* (10.4%) (Figure 3) was observed in sorghum at seed setting growth stage. *P*. *furvus* parasitism on *C. partellus* in sorghum was more prevalent in Boset with 15.9% pupal mortality rate and in Adama with 15.4% pupal mortality rate (Figure 4). Mortality of *B*. *fusca* pupae from maize by *P. furvus* was observed only in Dugda Bora with 7.6 % pupal death (Figure 4).The highest rate of parasitism (5.7%) by *P. furvus* on B. fusca in maize was recorded at seed setting growth stage (Figure 3).

As indicated in figure 4 the pupal parasitoids were not recorded at Arsinegelle and Shashemene. These areas are located to an altitude ranges between 1860m to 1977m which is higher than other study areas. The establishment of these pupal parasitoids seems to prefer low elevations.

Exposure of Stem Borer Eggs and Recovery of Egg Parasitoids

Two egg parasitoids; *T. busseolae* and *T. thestor,* were recovered from eggs of *B. fusca* in maize (Table 8). Percent parasitism of *T. busseolae* from *B.fusca* eggs was 62 and 34 at Melkassa and Arsi Negelle, respectively. Parasitism by *T. thestor* to *B. fusca* eggs was 76 in maize at Melkassa. No egg parasitoids were reared from *C. partellus* either on sorghum or maize. Table 10

DISCUSSION

The existence of three species of stem borers have been reported in maize and sorghum agro ecosystems in Ethiopia (Assefa, 1985; Yitaferu and Walker, 1997; Emana and Tsedeke, 1999). Emana *et al.* (2002) reported the existence of six species of stem borers in Ethiopia. The current assessment revealed the presence of three stem borer species of maize and sorghum in the Central Rift Valley of Ethiopia. These were *B*. *fusca*, *C. partellus* and, *S. calamistis*. *C. partellus* and *B. fusca* were the dominant consisting of 45.5 and 54% on maize, and 86.7 and 12.8% on sorghum, respectively. *S. calamistis* was rarely found infesting maize and sorghum, accounting for only less than 0.5%. Emana *et al.* (2002)

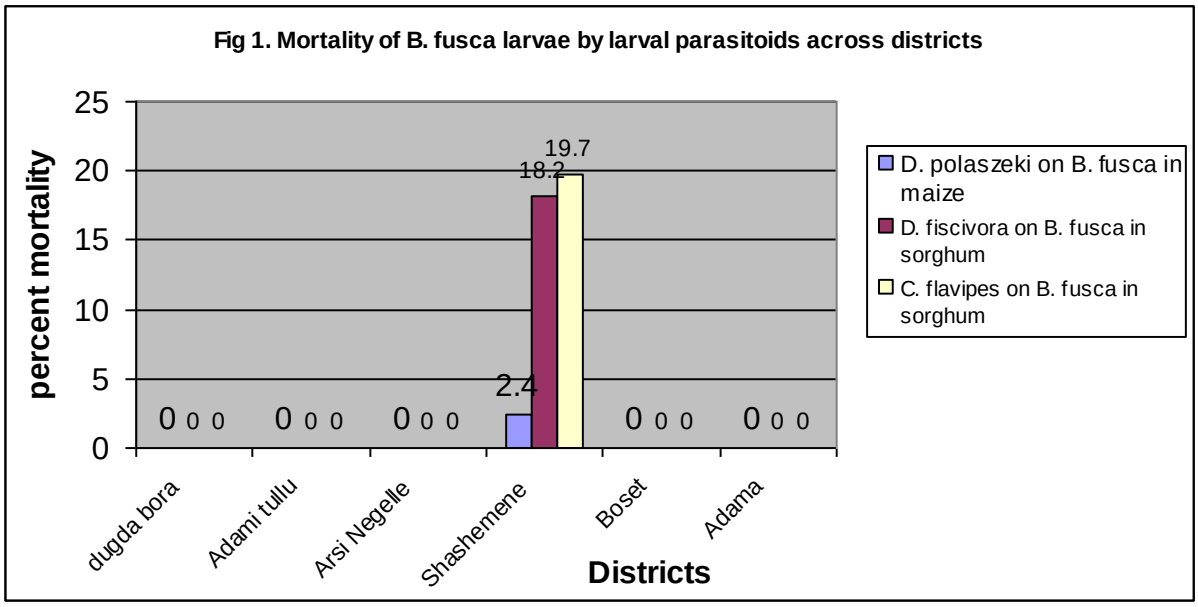

Table 8. Extent of parasitism (mean ± SE) by larval parasitoids on stem borer species in maize at different growth stages of the crop.

	%parasitism by *C. flavipes* on		%parasitism by *D. fusivora* on
	C. partellus	*B. fusca*	*B. fusca*
Growth stages			
Vegetative	23.22 ± 7.74 a	2.5 **±** 1.65 b	3.93 ± 3.37b
Flowering	20.5 ± 8.07 a	3.47 **±** 2.65 b	4.03 ± 2.65 b
Seed setting	22.35 ±13.62 a	25.07 **±** 5.93 a	27.88 ±5.86 a
Maturity	32.67 ±16.17 a	9.03 ± 5.45 b	37.5 ± 6.32 a

Table 9. Extent of parasitism (mean ± SE) by larval parasitoids on stem borer species in sorghum at different growth stages of the crop.

	%parasitism by *C. flavipes*	%parasitism by *D. polaszeki*
	C. partellus	*B. fusca*
Growth stages		
Vegetative	18.22 ± 8.55 a	42.00 ± 13.43 a
Flowering	10 ± 5.70 a	29.6 ± 7.41a
Seed setting	16.94 ± 6.48 a	2.1 ± 1.36 b
Maturity	15.88 ± 7.92 a	1.8 ± 1.56 b

reported that sorghum is the most preferred host by *C. partellus* while maize is the preferred host by *B. fusca*, which is in line with the current findings.

In all districts the most abundant and widely distributed parasitoid was *C*. *flavipes*. The current findings are in agreement with previous investigations Emana *et al.* (2002); Emana *et al*. (2003) that indicate *C. flavipes* as the dominant parasitoid of stems borers mainly *C. partellus* and *B. fusca*. *C. flavipes* is an Asian origin endolarval parasitoid of Pyralid stem borers (Mohyddin, 1971). It was not introduced to Ethiopia. However, it was introduced and released in 1993 in Kenya, Uganda, Somalia, Mozambique and other eastern and southern African countries for the control of *C. partellus* (Overholt, 1998). The presence of *C. flavipes* in Ethiopia was speculated as crossed over to the country from Somalia release (Emana *et al.,* 2001).

Ngi-Song *et al*. (2001) reported that *C. flavipes* would

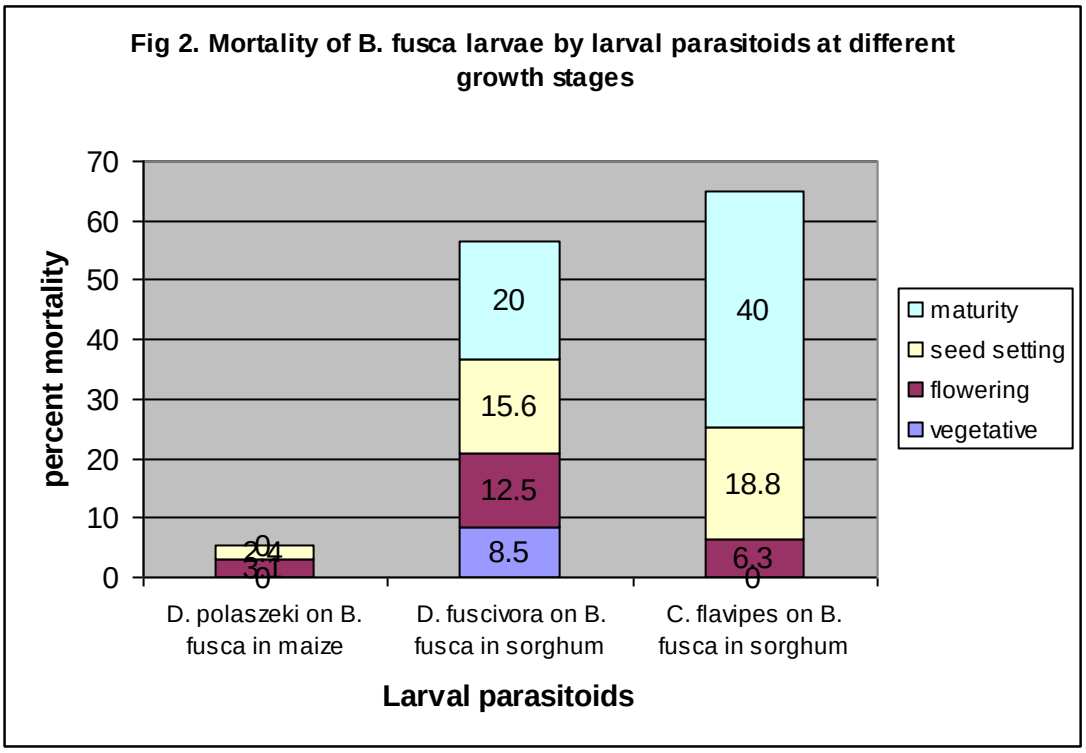
Fig 2. Mortality of B. fusca larvae by larval parasitoids at different growth stages
percent mortality
70
60
50
40
30
20
10
0
20
15.6
12.5
8.5
40
18.8
6.3
0
maturity
seed setting
flowering
vegetative
D. polaszeki on B. fusca in maize
D. fuscivora on B. fusca in sorghum
C. flavipes on B. fusca in sorghum
Larval parasitoids

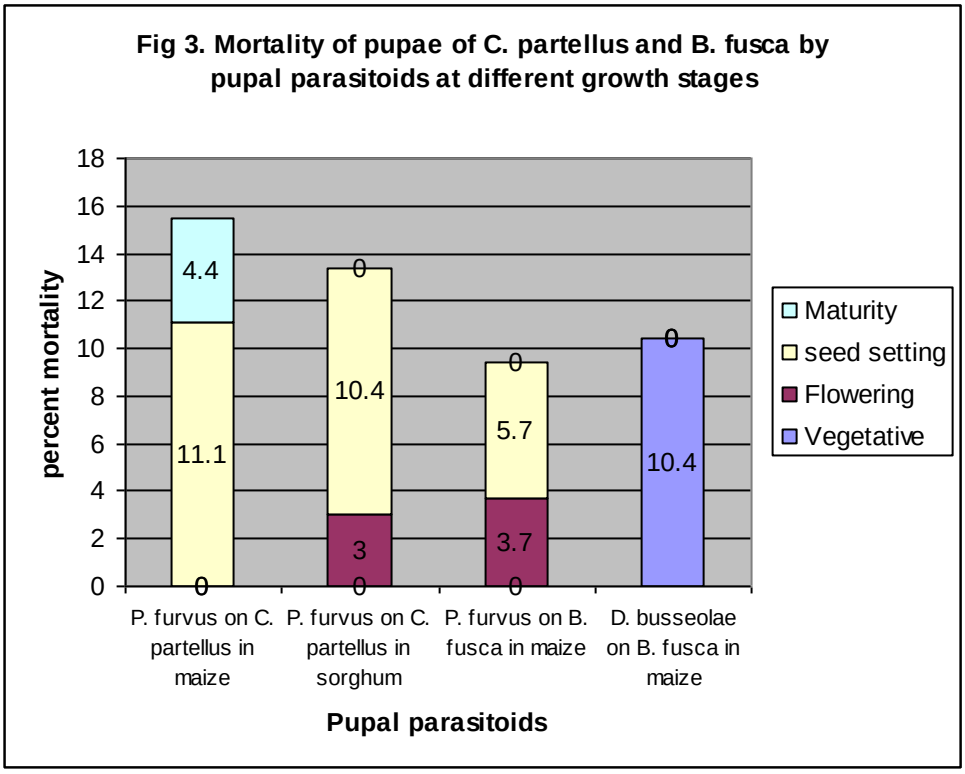
Fig 3. Mortality of pupae of C. partellus and B. fusca by pupal parasitoids at different growth stages
percent mortality
18
16
14
12
10
8
6
4
2
0
4.4
11.1
0
0
10.4
3
0
0
5.7
3.7
0
0
10.4
Maturity
seed setting
Flowering
Vegetative
P. furvus on C. partellus in maize
P. furvus on C. partellus in sorghum
P. furvus on B. fusca in maize
D. busseolae on B. fusca in maize
Pupal parasitoids

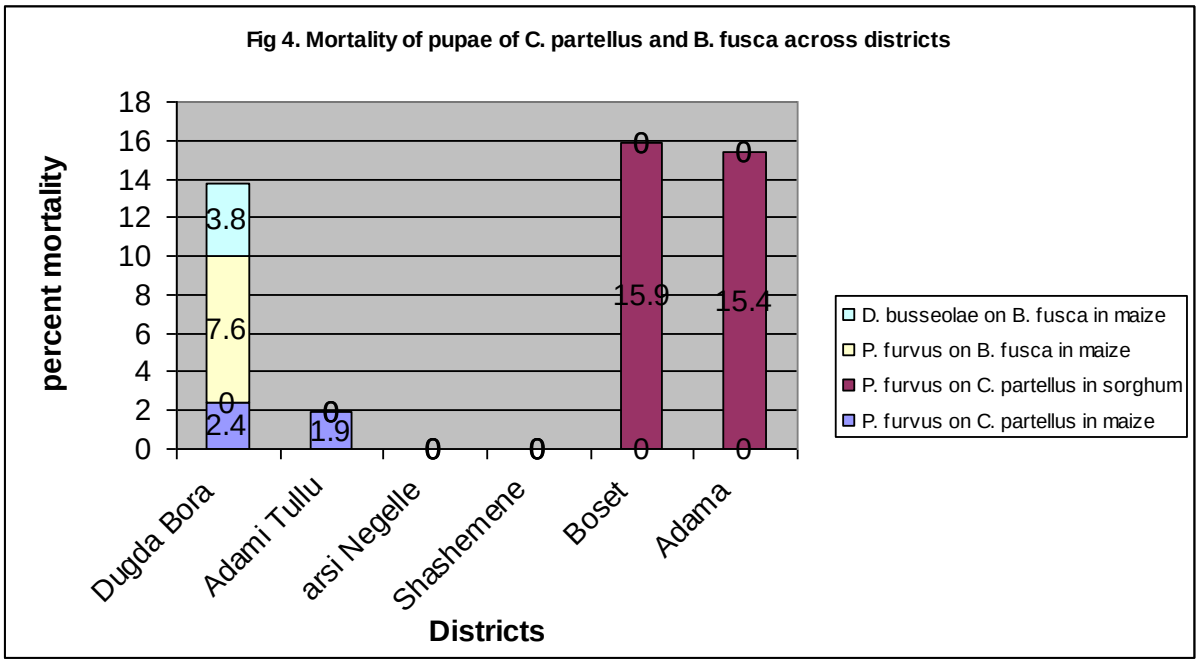

Table 10. Level of egg parasitism on exposed *B. fusca* eggs oviposited on maize seedlings

Locations	No. of egg batches	Total No. of eggs	No. of eggs predated	No. of eggs disappeared	No. of eggs parasitized	% Parasitism	Species of parasitoid
Melkassa	9	700	65	72	348	62	*Telenomus busseolae*
	2	90	10	8	55	76	*Telenomus thestor*
Arsi Negelle	3	168	25	38	36	34	*Telenomus busseolae*

not be able to establish in areas dominated by *B. fusca* because *C. partellus* is the principal host for the parasitoid. Surveys conducted by Emana *et al*. (2002) in Ethiopia indicated that *C. flavipes* developed in *C. partellus, S. calamistis* and some populations of *B. fusca*. Now it is verified that *C. flavipes* has expanded its host range by creating a new association with *B. fusca*. The current results indicated that *C. flavipes* developed in many populations of *B. fusca* in the Central Rift Valley of Ethiopia. Hence, the host range expansion of *C. flavipes* to include *B. fusca* in the area may significantly contribute to the overall reduction of stem borers. The number of parasitoid species recovered from *B*. *fusca* was high as compared to *C*. *partellus*. *C*. *flavipes*, *D. polaszeki* and *D. fusivora* successfully parasitized *B*. *fusca*. The overall percentage of larval mortality from parasitism by larval parasitoids was greater in sorghum than in maize. *D. polaszeki* was more important on *B*. *fusca* attacking sorghum than on maize. The parasitoid is very weak in maize system while it performed better in sorghum. *D. polaszeki* was found to be the second most important parasitoid of *B. fusca* larvae on sorghum. *D. fusivora* was more important on sorghum than on maize. *D*. *fuscivora* was first recorded in eastern Ethiopia by Kassahun and Assefa (1994) and was the second most important mortality factor. Emana *et al.* (2002) recorded this parasitoid in northern Ethiopia in addition to eastern Ethiopia. The current record of *D. fuscivora* in the Central

Rift Valley of Ethiopia indicates that the parasitoid is expanding its ecological niche, and may become important mortality factor of *B. fusca*. Emana *et al*. (2002) noted that pupal parasitoids are next to larval parasitoids in their contribution to suppress the stem borer populations in Ethiopia, which is in agreement with the current findings.

In previous studies, two egg parasitoids, *T. busseolae* with 0.03% parasitism and *Trichogramma lutea* Girault with 0.01% parasitism were recorded (Emana *et al*., 2002). In the current study, however, the rate of parasitism was high and this might be due to the exposure of stem borer eggs in the field. *T. thestor* is a new record as egg parasitoids in Ethiopia. *Aphnanogmus fijiensis* (Ferrire) was recorded on *C. flavipes* reared from larvae of *C*. *partellus* and *B*. *fusca.* This hyper parasitoid may reduce the efficiency of the primary parasitoid.

B*acillus spp*., *Staphylococcus*, *Escherichia coli*, *Baculovirus, Beauveria bassiana*, and *Asspergillus* were the entomopathogens isolated from stem borers collected from the Central Rift Valley of Ethiopia. The current finding agrees with Tadele and Pringe (2003a) who also isolated some of these pathogens from stem borers in eastern Ethiopia.

CONCLUSION

The results reported in this study confirmed the presence of three stem borer species namely *B*. *fusca*, *C. partellus* and, *S. calamistis* on maize and sorghum in the Central Rift Valley of Ethiopia. *C. partellus* and *B. fusca* were the dominant stem borer species. Sorghum is the most preferred host by *C. partellus* while maize is the preferred host by *B. fusca.* In the central rift valley of Ethiopia the most abundant and widely distributed larval parasitoid was *C*. *flavipes* that parasitized and cause significant larval mortality of both *B*. *fusca and C. partellus* on maize and sorghum. Other Larval parasitoids *(Dolichogenidea fuscivora* and *Dolichogenidea polaszeki);* the pupal parasitoids *(Dentichasmias busseolae* and *Pediobius furvus)* were recovered from *B. fusca* and /or *C. partellus* with different level of parasitism. *T. busseolae* and *T. thestor,* were found to be a potential egg parasitoids of *B. fusca* in maize.

Information on the geographical distribution and growth stage preferences of insect pests and parasitoids is useful to understand insect and parasitoids spread in to new areas and set priorities for insect pest management. The understanding can be increased by distinguishing density of stem borers and level of parasitism of parasitoids within the area of its occurrence and explaining the associations between density of stem borers and rate of parasitism at different growth stages of the crops. The colonization rate of parasitoids in the two major stem borers in the Central Rift Valley of Ethiopia suggests the high potential of these parasitoids in regulating populations of stem borers that attack maize and sorghum in this area. Therefore, conservation of these parasitoids in general and *C. flavipes* in particular should be one of the major stem borer control strategies in the Central Rift Valley of Ethiopia where *C. partellus* and *B. fusca* are the dominant stem borers. The pathogencity of potential entomopathogens isolated from stem borers should be studied and the effective ones should be mass-produced and applied for the control of stem borers in the Central Rift Valley of Ethiopia. Augmentation release of potential parasitoids should be done in areas where particularly *C. partellus* and *B. fusca* are a dominant stem borer species.

Conflict of Interest

Conflict of interest none declared.

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