

Research Article



Influence of Flowering Plants and Artificial Diets on Performance of *Cotesia Flavipes* (Cameron)

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Abstract | The experiment was conducted on effect of artificial diets and ornamental plants on parasitoid performance. Among artificial diets tested were honey, sugar, protein hydrolysate solution to enhance fecundity and fertility of the parasitoid under laboratory conditions and compared with the provision of flower nectars such as ornamental sunflower, merry gold and hollyhock in the laboratory. The ornamental plants sunflower, merry gold and hollyhock were also tested in the field for conservation of the *C. flavipes*. The results showed that during 2013 and 2014, the *C. flavipes* fed on Hollyhock produced more cocoons. During 2013 and 2014 *C. flavipes* fed on marigold occupied 2nd position in production of cocoons. Among flower based diets, cocoon development, exist holes, *C. Infuscatellus* pupae, *C. flavipes* larvae, *C. Infuscatellus* larvae, *C. flavipes* moths, *C. flavipes* adults was higher when parasitoid was fed on marigold, Holly hock and sunflower; while in 2014, the cocoon development and exist holes were higher when parasitoid was fed on marigold flower than sunflower and Holly hock; while *C. Infuscatellus* pupae and moths were higher in sunflower and Holly hock diets. However, control diet resulted in higher values during both the years compared to treatments.

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Introduction

Sugarcane shoot borer, *Chilo infuscatellus* (Snellen) is widely distributed in all sugarcane growing areas of Pakistan; the adults start oviposition in the third week of February and continue till fourth week of October. The active larvae of different instars are available in the field from February to November (Hamid and Mohyuddin, 1989). The borer infestation during the germination phase kills the parent shoot, generally the clumps get destroyed and gaps occur in the field. Due to severe attack the shoots are dried and the reddish streaks appear on the mid rib of leaves (Kumar et al., 2007).

a gregarious, larval endoparasitoid of lepidopteran stemborers that infest cereal crops. This braconid has been successfully introduced into more than 40 countries as part of the tropics and subtropics in classical and new association biological control programs of crambid stemborers, primarily those in the genera *Chilo* and *Diatraea* (Polaszek and Walker, 1991). *C. flavipes* is used as a classical biological control agent of *C. partellus* (Overholt et al., 1997). *C. flavipes* populations are gradually increasing and the parasitoid is currently being released in many more countries. As *C. flavipes* is a koinobiont, host larvae continue to feed and damage infested plants after being parasitized.

The larval parasitoid (Camericon), *Cotesia flavipes* is

The parasitoid *C. flavipes* is an important source of

mortality against indigenous stalk borers of rice and sugarcane (Mohyuddin et al., 1981), *Chilo infuscatellus* is also effectively controlled by *C. flavipes* (Shenhmar, 1996; Ngumbi et al., 2005). The introduction of *C. flavipes* has been introduced in many countries of the world for biological control of sugarcane borers. Rossi and Forler (2003) reported decrease in infestation of *D. saccharalis* in sugarcane fields since its introduction in 1970s from Pakistan. *C. flavipes* has been used for the biological control of *C. partellus* in eastern and southern Africa (Emana, 2009).

Keeping in view the out break position of sugarcane stem borers in sugarcane crop the present study was planned on the potential of *Cotesia flavipes* for population management of *Chilo Infuscatellus* on sugarcane and experiments for this purpose were conducted at Nuclear Institute of Agriculture (NIA) Tando Jam. The results of the studies will obviously be helpful for research personnel, extension workers farming community and all the stakeholders related to the sugarcane crop.

Materials and Methods

For testing artificial diets various chemicals such as honey, sugar, protein hydrolysate solution were tested to enhance fecundity and fertility of the parasitoid under laboratory conditions and compared with the provision of flower nectors such as ornamental sunflower, merry gold and hollyhock in the laboratory. The ornamental plants sunflower, merry gold and hollyhock were also tested in the field for conservation of the *C. flavipes*. For this purpose the mentioned ornamental plants were grown around the sugarcane field and effect of these plants on the establishment of the parasitoid were worked out. This laboratory experiment was conducted at Nuclear Institute of Agriculture, Tandojam.

1. Various chemicals such as honey, sugar (10 ml in 90 ml water), protein (10%) were used and hydrolysate solution was prepared in the laboratory of NIA Tandojam. 10 pairs of *C. flavipes* were exposed each in jars through test tubes under lamp, then chemicals were applied through brush on cars in each of the jars in each replication. These jars were checked after 24-36 hours and then shifted the setts of sugarcane and later checked after 9-11 days and cocoon were counted.
2. Different flowers performance was checked in

the laboratory at NIA Tandojam. The flowers i.e. hollyhock, sunflower amd marigold pots were put in the cages of same size. Pots were covered with the plastic bags; and 10 pairs of parasitoid were exposed through test tube in cages under lamp condition. Ten larvae of *C. infuscatellus* were exposed in each cages and after parasitized for 24-26 hours, the setts of sugarcane were transferred to the jars. The data was collected after 9-11 days to count the each cocoon in each replication.

3. The field experiment was conducted at NIA experimental farm Tandojam. Different flowers sown under field conditions with sugarcane variety Thatta-10. The plot area was about 10 ghunta (half acre) and experiment was laid out in RCB design. Three flowers of hollyhock, sunflower and marigold were sown in rows in sugarcane variety Thatta-10. The release of parasitoids was done on daily basis in the field from March to October; while the data were collected at harvesting time.

Results and Discussion

This experiment determines the influence of flowering plants on performance of *C. flavipes*. In this experiment, fecundity and fertility of the parasitoid was determined under laboratory conditions using artificial diets such as honey, sugar, protein hydrolysate solution and compared with ornamental sunflower, merry gold and hollyhock. The influence of flowering plants was also determined under field conditions for *C. flavipes* conservation.

Development of cotesia flavipes on artificial diets and flowers (2013)

During 2013 and 2014, the parasitoid *Cotesia flavipes* was developed on artificial diets, flowers and different chemicals for to evaluate the quality of produced parasitoids. The parasitoids were fed on honey solution, protein hydrolysate, sugar solution, sunflower, holly hock and merry gold.

Cocoons produced

The data (Table 1) indicated significant effect of diets on cocoon development and the parasitoid fed on holly hock flower produced maximum number of cocoons (29.6 ± 1.72), closely followed by diets based on Marigold (27.378 ± 1.994), honey solution (23.725 ± 2.413), sunflower (17.175 ± 2.199), sugar solution (15.975 ± 2.162), protein hydrolysate (10.425 ± 1.964) while the number of cocoons were

lowest (9.625 ± 1.846) when the parasitoid was fed on control. There was tremendous increase in number of cocoons when the parasitoid was fed on artificial diets, particularly when fed on holly hock, marigold flowers and honey solution. Sunflower and sugar solution used as diets also resulted positive impact on produced number of cocoons. This indicates that parasitoid responded appreciably for cocoon production when fed on holly hock and marigold flowers.

Adult emergence

The data (Table 1) further showed that maximum emergence (27.875 ± 1.695) was recorded when parasitoid was fed on holly hock flower, followed by diets based on Marigold (25.875 ± 1.92), sunflower (25.7 ± 2.107), honey solution (22.325 ± 2.313), sugar solution (14.5 ± 2.043), protein hydrolysate (9.925 ± 1.923); while emergence was lowest (8.95 ± 1.741) when the parasitoid was fed on control. The emergence was markedly higher when the parasitoid was fed on holly hock, marigold flowers and sunflower, followed by honey solution.

Pupal development

The effect of artificial and natural diets showed that the pupal development of *Cotesia flavipes* (Table 1) varied significantly ($P < 0.05$) under different types of diet and pupal population was highest (0.4 ± 0.301) when protein hydrolysate based diet was provided; while pupal population decreased to 0.15 ± 0.023 and 0.15 ± 0.057 when parasitoid fed on sugar solution and control diet, respectively. *C. flavipes* pupal development showed a declining trend to 0.102 ± 0.048 , 0.05 ± 0.034 and 0.05 ± 0.034 when given diets based on honey solution, sunflower and marigold, respectively; while lowest pupal development of 0.025 ± 0.024 was recorded when fed on holly hock flowers. This indicates that protein hydrolysate was effective for pupal development of parasitoid; while diets were ineffective to produce pupal development higher than the control diet.

Sex ratio

The sex ratio in *Cotesia flavipes* was examined and the data (Table 1) indicate that parasitoid fed on holly hock flower produced maximum males (13.4 ± 0.866), followed by diets based on Marigold (12.7 ± 0.954), sunflower (12.3 ± 1.046), honey solution (10.9 ± 1.132) and sugar solution (6.8 ± 1.003), while males were least in number when parasitoid was fed on protein hydrolysate (4.775 ± 0.940) and control (4.17 ± 0.818).

It was noted that parasitoid diet based on holly hock, marigold flowers and sunflower produced more male as compared to rest of the diets and control.

While examining the female *Cotesia flavipes* in result of different diets and the data (Table 1) indicate that parasitoid fed on Marigold flower produced maximum *C. flavipes* females (14.275 ± 0.872), followed by diets based on holly hock flower (13.275 ± 1.068), honey solution (11.3 ± 1.227), sunflower (7.55 ± 1.067) and sugar solution (7.5 ± 1.017), while females were least in number when parasitoid was fed on protein hydrolysate (5.34 ± 1.017) and control (4.725 ± 0.965). It was noted that parasitoid diet based on flowers and honey solution was more effective to produce females compared to rest of the diets and control.

Adult longevity (male)

The effect of diet on longevity of male *Cotesia flavipes* (Table 1) showed that holly hock and marigold flowers used as diet resulted in maximum male longevity of 5.5 ± 0.258 and 4.41 ± 0.115 days, respectively; while the parasitoid male longevity was 2.6 ± 0.233 and 2.25 ± 0.214 days when parasitoid fed on sunflower and honey solution, respectively. The parasitoid male longevity decreased to 1.07 ± 0.144 and 0.725 ± 0.113 days when managed on sugar solution and control, respectively; while the minimum male longevity (0.525 ± 0.079 days when protein hydrolysate was used as diet. The data showed that parasitoid male longevity improved appreciably when marigold and holly hock flowers were used as diet; while remaining diets did not show an appreciable increase in insect male longevity except sunflower and honey solution which also showed considerable increase in male insect longevity as compared to control.

Adult longevity (female)

The effect of diet on longevity of female *Cotesia flavipes* (Table 1) indicated that sugar solution used as diet resulted in maximum female longevity of 10.75 ± 1.699 days; while female longevity decreased to 5.575 ± 0.252 and 4.75 ± 0.299 days when parasitoid fed on holly hock and marigold flowers, respectively. The parasitoid female longevity showed a decline to 2.6 ± 0.717 and 2.35 ± 0.230 days when managed on sunflower and honey solution, respectively; while the minimum female longevity of 0.78 ± 0.124 and 0.55 ± 0.087 days on control and protein hydrolysate diets, respectively. This suggested that sugar solution as parasitoid diet was exceptionally effective to

Table 1: *Evaluating the artificial diet, flowers and different chemicals for production of good quality parasitoids during 2013.*

Diets	No of cocoon Mean±S.E	Emergence Mean±S.E	Sex ra- tio Male Mean±S.E	Sex ratio Female Mean±S.E	Longevity Male Mean ±S.E	Longevity Female Mean±S.E	Pupae Mean±S.E	Mortality Mean±S.E
Honey Solution	23.725±2.413	22.325±2.313	10.9±1.132	11.3±1.227	2.25±0.214	2.35±0.230	0.102±0.048	0.15±0.057
Protein hydro- lysate	10.425±1.964	9.925±1.923	4.775±0.940	5.34±1.017	0.525±0.79	0.55±0.087	0.4±0.301	0.496±0.078
Sugar Solution	15.975±2.162	14.5±2.043	6.8 ±1.003	7.5±1.017	1.07±0.144	10.75±1.699	0.15±0.023	0.15±0.023
Sunflower	17.175±2.199	25.7±2.107	12.3±1.046	7.55±1.067	2.6±0.233	2.6±0.717	0.05± 0.034	0.1±0.047
Holly Hock	29.6±1.720	27.875±1.695	13.4±0.866	13.275±1.068	5.5 ±0.258	5.575±0.252	0.025±0.024	0.025±0.024
Merry gold	27.3785±1.994	25.875±1.920	12.7±0.954	14.275±0.872	4.4 1±0.115	4.75±0.299	0.05±0.034	0.05±0.034
Control	9.625± 1.846	8.95±1.741	4.175±0.818	4.725±0.965	0.725±0.113	0.78±0.124	0.15±0.057	0.275±0.071
S.E.	14.89	13.56	6.92	8.45	0.22	0.22	0.245	0.323
CV%	6.16	7.93	7.02	13.02	18.46	22.61	6.16	5.213
P-Value	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**

increase female longevity, followed by holly hock and marigold flowers, while sunflower and honey solution were also effective to improve female longevity over control diet.

Mortality (%)

The influence of artificial and natural diets on the mortality rate of *C. flavipes* (Table 1) was significant ($P<0.05$) and lowest mortality (0.025 ± 0.301) was recorded when fed on holly hock flower; while mortality increased to 0.05 ± 0.034 , 0.1 ± 0.047 , 0.15 ± 0.057 and 0.15 ± 0.023 when the parasitoid was fed on diet based on marigold flower, sunflower, honey solution and sugar solution, respectively. The *C. flavipes* pupal mortality showed rise to 0.275 ± 0.071 and 0.496 ± 0.078 when the insect was given control diet and protein hydrolysate based diet. It was observed that pupal mortality was markedly lower when holly hock, marigold and sunflower based diet was given; while honey solution and sugar solution also kept the mortality below the control.

Development of cotesia flavipes on artificial diets and flowers (2014)

Number of cocoons: The data in Table 2 showed a significant difference in the number of cocoons and the parasitoid fed on holly hock flower developed more cocoons (29.6 ± 1.72), followed by diets based on Marigold (27.325 ± 1.991), sunflower (26.175 ± 2.196); while reduced number of coccons were determined on diets based on honey solution (22.975 ± 2.344), sugar solution (18.2 ± 2.184), protein hydrolysate (12.125 ± 1.863) and lowest number of cocoons

(7.36 ± 1.465) were determined on control diets. There was significant effect of diet on the number of cocoons when the parasitoid was fed on artificial diets, particularly when fed on holly hock, marigold flowers and honey solution. Sunflower and sugar solution used as diets also resulted in positive impact on produced number of cocoons. This indicates that parasitoid responded appreciably for cocoon production when fed on holly hock and marigold flowers during 2014.

Emergence

The data (Table 2) further showed that maximum emergence (27.875 ± 1.695) was recorded when parasitoid was fed on holly hock flower, followed by diets based on Marigold (26.025 ± 1.923), sunflower (25.7 ± 2.108), honey solution (21.725 ± 2.256), sugar solution (16.575 ± 2.043), protein hydrolysate (11.367 ± 0.823); while emergence was lowest (6.7 ± 1.329) when the parasitoid was fed on control. The emergence was also higher when the parasitoid was fed on holly hock followed by marigold flowers, sunflower and honey solution.

Pupal development

The effect different diets on pupal development of *Cotesia flavipes* (Table 2) was significant ($P<0.05$) and pupal population was highest (0.175 ± 0.60) when control diet was provided; while pupal population decreased to 0.15 ± 0.057 , 0.15 ± 0.036 and 0.15 ± 0.057 when parasitoid fed on honey solution, protein hydrolysate and marigold flower, respectively. *C. flavipes* pupal development showed further decline to 0.1 ± 0.047 , 0.1 ± 0.047 and 0.1 ± 0.047 when given diets

Table 2: Evaluating the artificial diet, flowers and different chemicals for production of good quality parasitoids during 2014.

Diets	No of cocoon Mean±S.E	Emergence Mean±S.E	Sex ratio Male Mean ±S.E	Sex ratio Female Mean±S.E	Longevity Male Mean ±S.E	Longevity Female Mean±S.E	C1 Pupae Mean ±S.E	C1 Mortality Mean ±S.E
Honey Solution	22.975 ±2.344	21.725±2.256	10.7 ±1.122	11.275 ±1.162	4.225±0.408	4.425±0.398	0.15±0.057	0.1±0.047
Protein hydrolysate	12.125±1.863	113675±823	5.514±0.869	6.15±0.961	2.825±0.524	2.825±0.333	0.15±0.036	12.125±1.863
Sugar Solution	18.2±2.184	16.575±2.043	7.975±1.018	8.35±1.049	3.675±0.396	3.65±0.383	0.1±0.047	0.175±0.060
Sunflower	26.175±2.199	25.7±2.108	12.3 ±0.895	13.275±1.068	2.717±0.240	2.625±0.236	0.1±0.047	0.1±0.047
Holly Hock	29.6±1.721	27.875±1.695	13.4± 0.886	14.525±0.702	5.5±0.258	5.575±0.252	0.1±0.047	0.1±0.047
Merry gold	27.325±1.991	26.025±1.923	12.825±0.919	13.275±0.971	2.76±0.240	2.77±0.245	0.15±0.57	0.1±0.047
Control	7.35 ±1.465	6.7±1.329	3.125±0.625	3.4± 0.674	0.475±0.107	0.6±0.099	0.175±0.60	0.325±0.047

LSD: 9.319; P: 0.0000**

based on sugar solution, sunflower and holly hock, respectively. This indicates that pupal development do not have any association with other parameters previously studied.

Sex ratio (male)

The sex ratio in cocoons of *Cotesia flavipes* was analysed and the data (Table 2) indicate that parasitoid fed on holly hock flower produced maximum males (13.4±0.886), followed by diets based on Marigold (12.825±0.919), sunflower (12.3±1.895), honey solution (10.7±1.122) and sugar solution (7.975±1.018), while males were least in number when parasitoid was fed on protein hydrolysate (5.514±0.869) and control (3.125±0.625). It was noted that parasitoid diet based on holly hock, marigold flowers and sunflower produced more male as compared to rest of the diets and control.

Sex ratio (female)

While examining the female *Cotesia flavipes* ratio in result of different diets and the data (Table 2) indicate that parasitoid fed on Holly hock flower produced maximum *C. flavipes* females (14.525±0.702), followed by diets based on sunflower (13.275±1.068), marigold (13.275±0.971), honey solution (11.275±1.62) and sugar solution (8.35±1.049), while females were least in number when parasitoid was fed on protein hydrolysate (6.15±0.961) as well as in control (3.4±0.674). The parasitoid fed on flower based diets and honey solution produced more females compared to rest of the diets and control.

Longevity (male)

The effect of diet on longevity of male *Cotesia flavipes* (Table 2) showed that holly hock flower used as diet resulted in maximum male longevity of 5.5±0.258

days; while the longevity of male parasitoid decreased when fed on honey solution (2.225±0.408 days), sugar solution (3.675±0.396 days), protein hydrolysate (2.825±0.524 days), marigold (2.76±0.240 days) and sunflower (2.717±0.240 days); while lowest male parasitoid longevity was recorded in control diet (0.475±0.107 days). This indicates that the parasitoid fed on natural diets had maximum longevity, particularly when fed on Holly hock flower based diet, but marigold and sunflower could not surpass honey solution and sugar solution in male parasitoid longevity.

Longevity (female)

The effect of diet on female *Cotesia flavipes* longevity (Table 2) indicated that holly hock flower used as diet resulted in maximum female longevity of 5.575±0.252 days; while female longevity decreased to 4.425±0.398 and 3.65±0.383 days when parasitoid fed on honey and sugar solutions, respectively. The parasitoid female longevity showed a decline to 2.825±0.333, 2.77±0.245 and 2.625±0.236 days when managed on protein hydrolysate, marigold flower and sunflower diets, respectively; while the minimum female longevity of 0.6±0.099 days was determined in control diet. This suggested that female showed preference to holly hock flower as diet and sugar solution as well; while marigold and sunflower based diets resulted in decreased female longevity. However, yet all the natural and artificial diets were effective to produce females with higher longevity compared to control.

Mortality (%)

The influence of artificial and natural diets on the mortality rate of *C. flavipes* during 2014 (Table 2) was significant (P<0.05) and equally lowest mortality of 0.1±0.047% was recorded when fed on holly hock flower; marigold, sunflower and honey solution,

respectively. The *C. flavipes* pupal mortality showed rise to 0.175 ± 0.060 and 0.325 ± 0.047 when the insect was given sugar solution and control diet. However, the highest pupal mortality ($12.125 \pm 1.163\%$) was recorded when protein hydrolysate was given as diet. It was noted that pupal mortality was markedly lower when holly hock, marigold and sunflower based diet was given; while sugar solution and protein hydrolysate based diets and control caused higher mortality.

Comparison of flowering plants as diet on quality parameters of Cotesia flavipes under field conditions (2013)

The effect of flowers (as diet) on quality parameters of *Cotesia flavipes* was investigated and the data (Table 3) showed that the cocoon development was higher (1.468 ± 9.875) when parasitoid was fed on marigold flower as compared to diets based on Holly hock (1.395 ± 0.023) and sunflower (1.175 ± 0.130) against 0.805 ± 0.017 in control. Similarly, the exist holes were equal in number (1.283 ± 0.011) when parasitoid was fed on sunflower and marigold, slightly higher from Holly hock (1.254 ± 0.010) against highest exist holes (3.445 ± 6.921) in control. The C.I. pupae were equal in number (0.707 ± 0.000) in case of all three flower diets against highest C.I. pupae (1.07 ± 0.013) in control; while C.F. larvae were higher (1.283 ± 0.011) in marigold based diet than diets based on Holly hock (1.224 ± 0.000) and sunflower (1.07 ± 0.013) against lowest C.F. larvae (0.565 ± 0.016) in control. The C.I. larvae were higher in number (0.907 ± 0.013) under sunflower based diet as compared to Holly hock (0.865 ± 0.016) and marigold (0.805 ± 0.017) against highest C.I. larvae (1.368 ± 0.017) in control. The C.F. moths were equal (0.707 ± 0.000) when parasitoid was fed on sunflower, holly hock and marigold; and relatively higher (0.974 ± 0.015) in control. The C.F. adults were higher (1.801 ± 0.017) in Holly hock based diet than diets based on marigold (1.381 ± 0.017) and sunflower (1.0715 ± 0.013) against lowest C.F. adults (0.805 ± 0.017) in control.

Influence of flowering plants on performance of Cotesia flavipes under filed conditions (2014)

The performance of *Cotesia flavipes* under the influence of flowering plants was studied and the data (Table 4) indicated that during the year 2014 the cocoon development was higher (1.532 ± 9.526) when parasitoid was fed on marigold flower as compared to diets based on Holly hock (1.487 ± 0.014) and sunflower (1.311 ± 7.621) against 1.224 ± 0.00 in

control. Similarly, the exist holes were more in number (1.396 ± 0.010) when parasitoid was fed on sunflower, slightly higher from Holly hock (1.322 ± 0.011) and marigold (1.244 ± 0.011) against highest exist holes (3.458 ± 9.233) in control. The C.I. pupae were higher in number (1.094 ± 0.13) in sunflower based diet than diets based on Holly hock (0.707 ± 0.000) and marigold (0.707 ± 0.000) against highest C.I. pupae (1.22 ± 0.000) in control. The C.F. larvae were higher (1.336 ± 0.060) in marigold based diet than diets based on sunflower (1.307 ± 0.013) and Holly hock (1.254 ± 0.010) against lowest C.F. larvae (1.224 ± 0.000) in control. The C.I. larvae were equally higher in number (1.224 ± 0.0) under sunflower and marigold based diets as compared to Holly hock (1.074 ± 0.13) against highest C.I. larvae (1.396 ± 0.010) in control. The C.I. moths were higher in number (1.224 ± 0.000) when parasitoid was fed on sunflower as compared to holly hock (0.965 ± 0.149) and marigold (0.707 ± 0.000); and relatively higher (1.224 ± 0.000) in control. The C.F. adults were higher (2.473 ± 0.020) in marigold based diet than diets based on Holly hock (2.371 ± 0.015) and sunflower (1.716 ± 0.025) against lowest C.F. adults (1.224 ± 0.020) in control.

The study was performed on the potential of *Cotesia flavipes* for population management of *Chilo Infuscatellus* on sugarcane and this entire study was enveloped in four experiments. The first experiment examines the morphology of sugarcane varieties, demography of sugarcane stem borer and its parasitoid on sugarcane varieties having different morphological characters. In second experiment effect of artificial diets and flowering plants on parasitoid biology and parasitization performance was examined. In third experiment effect of temperature and radiation on parasitization rate and biology of parasitoid and prey was studied compared to control (Temp. $25 \pm 1^\circ\text{C}$ and 60% R.H). In fourth experiment effect of releasing *C. flavipes* cocoons in sugarcane field on infestation and population management of *C. infuscatellus* was investigated and compared with control. The major findings of the study are discussed in this chapter.

The effect of artificial diets and ornamental plants on parasitoid performance showed that during 2013 and 2014, the *C. flavipes* fed on Hollyhock produced more cacoons (29.6 ± 1.720 , 29.6 ± 1.721), higher emergence (27.875 ± 1.695 , 27.875 ± 1.695), male ratio (13.4 ± 0.866 , 13.4 ± 0.886), female ratio (13.275 ± 1.068 , 14.525 ± 0.702), male longevity (5.5 ± 0.258 , 5.5 ± 0.258),

Table 3: Influence of different flowers on the quality control parameters of *Cotesia flavipes* in field condition during 2013.

Diets	No of cocoon Mean±S.E	Exist holes Mean±S.E	C.I. Pupae Mean ±S.E	C.F. Larvae Mean±S.E	C.I. Larvae Mean ±S.E	C.I. Moth Mean±S.E	C.F adults Mean ±S.E
Sunflower	1.175±0.130	1.283±0.011	0.707±0.0001	1.071± .013	0.907± 0.013	0.707±0.000	1.0715±0.013
Marigold	1.468±9.815	1.254± 0.010	0.707± 0.000	1.283±0.011	0.805±0.017	0.707± 0.00	1.381±0.017
Holly hock	1.395±0.023	1.283± 0.011	0.707± 0.00	1.224± 0.00	0.865±0.016	0.707± 0.00	1.801± 0.017
Control	.805± 0.017	3.445± 6.921	1.071±0.013	0.865± 0.016	1.368± 0.017	0.974± 0.015	0.805± 0.017

E: 0.0047; CV: 2.16%; P-Value: 0.0000**

Table 4: Effect of different flowering plants on the performance of *Cotesia flavipes* in field condition during 2014.

Diets	No of cocoon Mean±S.E	Exist holes Mean±S.E	C.I. Pupae Mean ±S.E	C.F. Larvae Mean±S.E	C.I. Larvae Mean ±S.E	C.I. Moth Mean±S.E	C.F adults Mean ±S.E
Sunflower	1.3115±7.621	1.396±0.010	1.094±0.13	1.307±0.013	1.224±0.00	1.224±0.00	1.716±0.025
Marigold	1.532 ±9.526	1.244±0.011	0.707±0.000	1.336±0.060	1.224±0.00	0.707±0.000	2.473±0.020
Holly hock	1.487±0.014	1.322±0.011	0.707±0.000	1.254±0.010	1.074±0.13	0.965±0.149	2.371±0.015
Control	1.224±0.00	3.458±9.232	1.224±0.00	1.224±0.00	1.396±0.010	1.224±0.000	1.224±0.020

SE: 0.089; CV: 6.57%; P-Value: 0.0000**

female longevity (5.575±0.252, 5.575±0.252) with pupal development of 0.025±0.024, 0.1±0.047 and lowest mortality of 0.025±0.024, 0.1±0.047%, respectively. Costa et al. (2005) concluded that development of sugarcane borer is influenced both by the diet and the rearing container. The rearing diets of the host did not influence the biology of *C. flavipes*. Wiedenmann and Smith (2006) assessed parasitism by *C. flavipes* against borers; the borer larvae were retrieved successfully from the artificially infested. Suksen et al. (2007) reported that in mass rearing of *C. flavipes* the role of diet is most important and indicated the efficiency of *C. flavipes* for augmentative biological control of sugarcane moth borer can be associated with the diet given during the mass rearing. In artificial diets for mass rearing of parasitoid, proteins are responsible for important metabolic processes in a diet. The ingestion of protein increases the longevity of individuals and influences egg production. The performance of insects depends on the amount of protein present in the diet; utilization of protein is found when there is an optimal mix of amino acids; amino acid excess may cause osmotic problems. Egg production and longevity increase as the concentration of brewer's yeast in the diet increases. Besides, the amount of protein in the diet influences the development of immature individuals (Cangussu and Zucoloto, 1997). In order to reach the nutritional target, insects combine two or more foods to get a balanced diet or ingest foods in different ratios. Feeding adult females on artificial diets with sucrose and brewer's

yeast in mixed or separated diets found that the performance of the females of fed on separated diets was superior to the performance of females fed on a mixed diet. During 2013, parasitoid responded appreciably for cocoon production, emergence, when fed on holly hock and marigold flowers. The parasitoid diet based on flowers and honey solution was more effective to produce females compared to rest of the diets and control; while parasitoid male longevity improved appreciably when marigold and holly hock flowers were used as diet. Sugar solution as parasitoid diet was exceptionally effective to increase female longevity, followed by holly hock and marigold flowers; while protein hydrolysate was effective for pupal development. The pupal mortality was markedly lower when holly hock, marigold and sunflower based diet was given; while honey solution and sugar solution also kept the mortality below the control. In 2014, the parasitoid responded appreciably for cocoon production, emergence, male and female sex ratio, male longevity, female longevity when fed on holly hock and marigold flowers. The parasitoid fed on flower based diets and honey solution produced more females compared to rest of the diets and control. The pupal development do not have any association with other parameters previously studied; while pupal mortality was markedly lower when holly hock, marigold and sunflower based diet was given; while sugar solution and protein hydrolysate based diets and control caused higher mortality. In the present research, among flower based diets, cocoon

development, exist holes, *C. Infuscatellus* pupae, *C. flavipes* larvae, *C. Infuscatellus* larvae, *C. flavipes* moths, *C. flavipes* adults was higher when parasitoid was fed on marigold, Holly hock and sunflower; while in 2014, the cocoon development and exist holes were higher when parasitoid was fed on marigold flower than sunflower and Holly hock; while *C. Infuscatellus* pupae and moths were higher in sunflower and Holly hock diets. However, control diet resulted in higher values during both the years compared to treatments.

Conclusions and Recommendations

Effect of diet

During 2013, parasitoid responded appreciably for cocoon production, emergence, when fed on holly hock and marigold flowers.

- The parasitoid diet based on flowers and honey solution was more effective to produce females compared to rest of the diets and control; while parasitoid male longevity improved appreciably when marigold and holly hock flowers were used as diet.
- Sugar solution as parasitoid diet was exceptionally effective to increase female longevity, followed by holly hock and marigold flowers; while protein hydrolysate was effective for pupal development.
- The pupal mortality was markedly lower when holly hock, marigold and sunflower based diet was given; while honey solution and sugar solution also kept the mortality below the control.
- In 2014, the parasitoid responded appreciably for cocoon production, emergence, male and female sex ratio, male longevity, female longevity when fed on holly hock and marigold flowers.
- The parasitoid fed on flower based diets and honey solution produced more females compared to rest of the diets and control.
- The pupal development do not have any association with other parameters previously studied; while pupal mortality was markedly lower when holly hock, marigold and sunflower based diet was given; while sugar solution and protein hydrolysate based diets and control caused higher mortality.

Effect of flowering plants

- In 2013, among flower based diets, cocoon development, exist holes, *C. Infuscatellus* pupae, *C. flavipes* larvae, *C. Infuscatellus* larvae, *C. flavipes* moths, *C. flavipes* adults was higher when parasitoid was fed on marigold, Holly hock and

sunflower. However, ranking of these flowers for effectiveness was variable with the biological parameters of stem borer and its parasitoid.

- In 2014, the cocoon development and exist holes were higher when parasitoid was fed on marigold flower than sunflower and Holly hock; while *C. Infuscatellus* pupae and moths were higher in sunflower and Holly hock diets. Similarly, *C. flavipes* larvae and *C. Infuscatellus* larvae were higher in marigold and sunflower diet; while *C. flavipes* adults were higher in marigold and Holly hock flower based diets.

Author's Contribution

Bina Khanzada: Designed and conducted all research work.

Ghulam Hussain Abro: Designed experiment and analyzed data.

Tajwar Sultana Syed: Designed experiment.

Nazir Ahmed: Assisted in research work.

References

- Cangussu, J.A. and F.S. Zucoloto.1997. Effect of protein sources on fecundity, food acceptance, and sexual choice by *Ceratitis capitata* (Diptera, Tephritidae). Rev. Brasil. Biol. 57: 611-618.
- Costa, N.P., A.L. Boica, N.A. Mayer and N.A. Sotana. 2005. Influence of artificial diets and containers in the development of *Diatraea saccharalis* and its parasitoid *Cotesia flavipes* (Cam.). Rev. de Ciências Agrárias. 44: 107-117.
- Emana, G. 2009. Comparative studies of the influence of relative humidity and temperature on the longevity and fecundity of the parasitoid, *Cotesia flavipes*. J. Insect Sci. (Tucson). 7: 7-19.
- Hamid, A. and A.I. Mohyuddin. 1989. Effect inundative releases of an egg parasitoid *Trichogramma chilonis* ishii on the incidence of early shoot borer of *Chilo infuscatellus* Snellen in Sindh. Pakistan. Soc. Sug. Technolo. Rawalpindi. pp. 58-68.
- Kumar, K.S., T.U. Maheswari and K.P. Rao. 2007. Factors influencing infestation of sugarcane early shoot borer *Chilo infuscatellus* Snellen. Int. J. Agric. Sci. 3 (2): 198-201.
- Mohyuddin A.I., C. Inayatullah and E.G. King. 1981. Host selection and strain occurrence in *Apeanteles flavipes* (Hymenoptera: Braconidae) and its bearing on biological control of

- graminaceous stem borer (Lepidoptera: Pyralidae). Bull. Entomol. Res. (71): 775-781.
- Ngumbi, E.N., A.J. Ngi-Song, E.N.M. Njagi, R. Torto, L.J. Wadhams, M.A. Birkett, J.A. Pickett, W.A. Overholt and B. Torto. 2005. Responses of the stem borer larval endoparasitoid *Cotesia flavipes* (Hymenoptera: Braconidae) to plant derived synomones: laboratory and field cage experiments. Biocontrol Sci. Technol. 15: 271-279. <https://doi.org/10.1080/09583150400016985>
- Overholt, W.A., A.J. Ngi-Song, C.O. Omwega, S.W. Kimani-Njogu, J.C. Mbapila, M.N.S. Sallam and V.C. Ofomata. 1997. A review of the introduction and establishment of *Cotesia Xavipes* Cameron (Hymenoptera: Braconidae) in East Africa for biological control of cereal stemborers. Insect Sci. Appl. 17: 79-95.
- Polaszek, A. and A.K. 1991. The *Cotesia flavipes* species-complex: parasitoids of cereal stem borers in the tropics. Redia. 74 (3, Appendix): 335-341.
- Rossi, M.N. and H.G. Fowler. 2003. Temporal patterns of parasitism in *diatraea saccharalis* fabr. (Lep., crambidae) populations at different spatial scales in sugarcane fields in Brazil. J. Appl. Entomol. 127 (9/10) : 501-508. <https://doi.org/10.1046/j.0931-2048.2003.00785.x>
- Shenhmar, M. and K.S. Brar. 1996. Efficacy of two strains of *Cotesia flavipes* (Cameron) for the control of sugarcane borers. India. Sugar. 45(11): 877-879.
- Suksen, K., T. Maneerat and W. Suasa. 2007. Utilization of sugarcane moth borer parasite *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) to control sugarcane moth borers. Proc. 45th Kasetsart Univ. Ann. Conf. pp. 142-146.
- Wiedenmann, R.N. and J.W. Smith. 2006. Use of ablated stalks to assess field rates of parasitism of *Diatraea saccharalis* (Lepidoptera: Crambidae) by *Cotesia flavipes* (Hymenoptera: Braconidae). Biocontrol Sci. Technol. 16 (1/2): 37-48. <https://doi.org/10.1080/09583150500188056>