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Effects of Environmental Variables and Role of Food Attractants for Management of *Bactrocera zonata* (Saunders, 1842) and *Bactrocera dorsalis* (Hendel, 1912) (Diptera: Tephritidae) in Mango Orchard

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ABSTRACT

The exploitation of food attractants for tephritid fruit flies (Diptera: Tephritidae), is the key element widely used for pest management. Population dynamics and the relative attractiveness of five commercially available chemicals in different concentrations were studied for the suppression of both sexes of *Bactrocera* species in mango orchards. The fruit flies, *Bactrocera zonata* (Saunders) and *Bactrocera dorsalis* (Hendel) exhibited maximum reduced population intensity from August to February and an increased population from March to July. The peak population of adult flies emerged in June depending on the host fruit maturity and meteorological influences. Observable differences in attractiveness between the tested products were confirmed at the experimental site of host institute. Resultantly, the attractions of female and male fruit flies of both species in Ammonium acetate, Trimethyl amine and Putrecine mixture were significantly more efficient than the male populations. Both male and female sexes exhibited an enhanced response to Torula yeast and Boric acid with the rise in their concentrations. Expressively, higher flies were collected in a combination of Torula yeast and Boric acid with 7:3 ratio. Concludingly, both *Bactrocera* species constantly revealed a substantial positive response to the odor of proteinaceous food attractants for their management.

Keywords: Fruit flies, food sprays, baits, mango pests, insects control.

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INTRODUCTION

Fruit flies (Diptera) belong to the maximum numbers of primarily vital pest species due to their direct economic impacts. The Dacini tribe, genus *Bactrocera* in the family Tephritidae, is of great significance (San Jose et al, 2018). Among the *Bactrocera* genus, *B. dorsalis* (Hendel), *B. correcta* (Bezzi), *B. zonata* (Saunders) and *B. cucurbitae* (Coquillett) are economically significant pests. The first three *Bactrocera* species mostly damage to the fruit crops, whereas *B. cucurbitae* damages diverse species of cucurbits (Verghese, Madhura, Jayanthi, & Stonehouse, 2004). The fruit flies, *B. zonata* and *B. dorsalis* have a wide range of geographical distribution and are deliberated important quarantine insect pests in various countries (Zeng et al, 2019; Zingore et al, 2020).

Mango (*Mangifera indica*), peach (*Prunus persica*), guava (*Psidium guajava*) and other fruit crops serve as hosts for various pests (Sarwar, 2006, 2023). Both studied flies seriously harm a variety of economically important fruit crops. Infected regions suffer high protection costs due to additional efforts and resources employed for eliminating the pest (Alzubaidy, 2000). The damage caused by *B. dorsalis* in mango is assessed from 40 to 90% depending on the varieties, geographical locations and the seasons (Vayssières et al, 2009; Nankinga et al, 2014; Badii et al, 2015). The average fruit loss due to tephritid populations in mango orchards varied from 12% at the beginning of April to 50% in June (Vayssieres, Goergen, Lokossou, & Akponon, 2005).

Pakistani mango and other horticultural crops are facing severe damage from both *B. zonata* and *B. dorsalis* as major fruit pests. Both pests have influential effects on local and export markets (Sarwar et al, 2013). *Bactrocera dorsalis* is one of the most damaging horticultural insects in the Asia-Pacific (Huang & Chi, 2014) and may harm up to 250 fruits and vegetables host species (Schutze et al, 2017). *Bactrocera zonata* is famous for damaging over 50 known fruit plants and vegetables (El-Akhdar & Afia, 2009). Fruit flies are a major threat to the fruits especially mango, peach, apricot, fig, apple, guava and vegetables including cucurbits, squash, tomato, capsicum, cucumber and eggplant are their favorite hosts. However, plants belonging to the family Cucurbitaceae are most preferred (El-Akhdar & Afia, 2009; Sarwar, 2014a; 2014b; 2016; 2020a). Therefore, a complementary study is necessary to confirm the prevalence of the genus *Bactrocera* and to conduct a better inventory of the various food attractants, and meteorological information.

Producers organize expensive commodity for pest protection arrangements to meet trade necessities at the global level; however, inevitable increases in chemical uses can adversely impact the environment (Shah, Ahmad, Sarwar, & Tofique, 2014; Sarwar, Ahmad, Rashid, & Shah, 2015). The prevailing fruit flies control strategies are exclusively depending on chemical control, which has serious persuasions and negative impacts on the ecosystem and populations of beneficial organisms. Therefore, eco-friendly pest control approaches remain needful over time (Roessler, 1989). Various chemicals have been empirically identified as attractive to females of certain *Bactrocera* species. Field studies conducted by Oliver et al, 2004, Ros et al, 2005 and Shivayya, Kumar, & Jayappa, 2008 on the management of *Bactrocera* flies using different food attractants were found to be promising in reducing the incidence of pest flies and showed very good results. Methyl eugenol, protein hydrolysate bait and malathion are often used to trap the male populations of both *B. dorsalis* and *B. zonata* in the field (Agarwal, Pramod, & Vinod, 1999). Management of *B. zonata* and *B. dorsalis* relies on the choice of appropriate attractants, which can be used in traps and spot treatments. The utilization of 'methyl eugenol' in traps for trapping tephritid fruit flies is quite popular in many localities and has been established to be effective both for surveillance and control (Sarwar, 2015a; 2015b). Even though methyl eugenol has considerably established better effectiveness in discovering and or management of the *Bactrocera* flies (Jang & Light, 1996), but its attraction is restricted merely to males control.

The significance of methyl eugenol as a male lure has accelerated positive determinations to advance female lures of comparable attraction. Female attractants for tephritid fruit flies are needed to complement currently used male attractants. These would help to eradicate the future progeny and improve surveillance programs (Jang, 1997). So, significant work on other food-type attractants, such as protein products and synthetic chemicals is needed to focus on the female flies in the field environment. An improved female trapping system would be important for finding early populations and then eradication plan (Miranda, Alonso, & Alemany, 2001). Recently various efforts were appreciated in improving trapping methods aimed to capture female populations. The combinations of food-based attractants have been emerged as synergistic (Heath et al, 1997). Recently, these female attractants have already been tried effectively in several countries (Epsky et al, 1999). Different researchers have been endeavoring to identify further attractive chemicals within certain compounds to enhance the development of such products (Sarwar, 2020b).

Therefore, the present research was commenced to evaluate different chemicals. The diverse concentrations and combinations were exploited to improve fruit flies attraction technique for the management of *Bactrocera* species in mango orchards.

MATERIALS AND METHODS

Study site

Research and experiments to study the fruit fly populations build-up to construct a link between trap catches and environmental variables (temperature, humidity rain and cloudiness) and comparative efficacy of food attractants on *Bactrocera* fruit flies infesting mango orchard were conducted at the Nuclear Institute of Agriculture, Tando Jam, Pakistan. For this study, the mango orchard of late variety, "Began Pali" was selected, wherein the study site is an important area of exportable horticultural products.

Population dynamics of *B. zonata* and *B. dorsalis*

Fluctuations in tephritid populations in mango orchards and the levels of mango fruit fly infestations due to tephritid species were studied. Fruit flies were captured in orchards using para pheromone traps baited with methyl eugenol (85%), sugar solution (10%) and Endosulfan (5%) retained on cotton wool sticks placed in Steiner plastic trap with small openings at either end to facilitate the access of flies laid out @ 5 traps per acre. The fruit specimens were collected from the ground or randomly detached from the trees. These treatments were replicated five times. Traps were commonly retained in fruit trees at about 2 m above ground level in mango orchards during flowering up to fruit harvesting season and emptied regularly at weekly intervals. Traps were placed in mango branches at the lower third of the foliage to avoid long exposure to the sun rays. Traps were checked once a week and trapped flies were counted. Insecticide, lure and cotton wool were changed and filled at monthly intervals. Once a week, the infested fruits were collected and retained within plastic containers in the laboratory under standardized laboratory conditions of 25 ^{O}C and 65% RH until the full decay of the host fruits. Different life stages including larvae and pupae of fruit flies were observed once a week and collected in separate vials/ petri dishes until the complete emergence of adult flies.

To characterize fruit fly species involved in mango infestations, pest species that emerged as adults from fruits were identified by following Vreysen et al, (2007). Meteorological observations during the study periods were obtained from Regional Agro Met Center, Tandojam.

Evaluation of different chemicals to attract the female or male of *B. zonata* and *B. dorsalis*

The aim of this field experiment was to develop improved attractants for attracting females of *B. zonata* and *B. dorsalis* in commercial mango orchards. A bait attractant trial was conducted at the research station in the months of March to July. This study compared different products from different groups such as Torula Yeast plus Boric Acid in different formulations (1:1, 2:3, 3:2, 3:7 & 7:3), as well as Ammonium Acetate, Trimethyl amine plus Putrescine and Ammonium Acetate, Trimethyl amine plus Boric acid in similar formulations (1:1:1). The formulation of every treatment was organized by liquefying the respective product of each mixture in 200 ml of water.

The chemicals were tested separately to catch adult female or male populations placed inside Plastic Cylindrical Traps having a 2.5-liter capacity. The mixture of 200 ml of 10 percent attractant was utilized for baiting purposes in each trap. The traps were placed in mango plants at a height of 2.0 m from the ground level. The trapping system comprised the installation of approximately 5 traps per acre in each replicate. The traps were re-baited with the lure at one weak interval. The installation scheme of traps carried out was identical for all treatments. Traps were checked twice a week, trapped flies collected in tubes using flexible grips and the flies caught, counted, sexed and recorded. All traps were cleaned at one-week intervals and changed after two-month intervals. These treatments were replicated five times. Comparative data on the effectiveness of synthetic lures among different treatments were evaluated by comparing the detection, monitoring and counting of the captured flies.

STATISTICAL ANALYSIS

Data generated from these studies were analyzed using the computer package Statistix 8.1 software, and Analysis of Variance (ANOVA) was performed at $p < 0.05$. Further, for the fruit flies, correlation between environmental factors and population abundance were calculated through multiple linear regression and Pearson correlation coefficient (Sarwar & Rasool 2022a; 2022 b; Schober, Boer, & Schwarte, 2018).

RESULTS

From the initiation of experiments to onward, *B. zonata* and *B. dorsalis* were found the only the most abundant and frequent fruit fly species in mango orchards. During the rainy season (abiotic factor) and in accordance with the phenological maturing stage of the mango fruit (biotic factor), these were the most prevalent pests.

Population dynamics and environmental variables of *B. zonata* and *B. dorsalis*

The population dynamics of fruit flies followed the tendency of mango fruit's development from formation towards the maturity stages and occurrence of prevailing climatic factors. Samples of infested fruits and fly trap catches in mango habitats taken from treated and untreated areas during each week, investigated that both *B. zonata* and *B. dorsalis* were the most prevalent species during field testing. Following the figure 1 trend, it was noted that during the trapping periods in the mango habitat, flytrap catches were not regular (Fig. 1). However, data coincided with the time of fruiting of its major mango host and meteorological factors (Fig. 2).

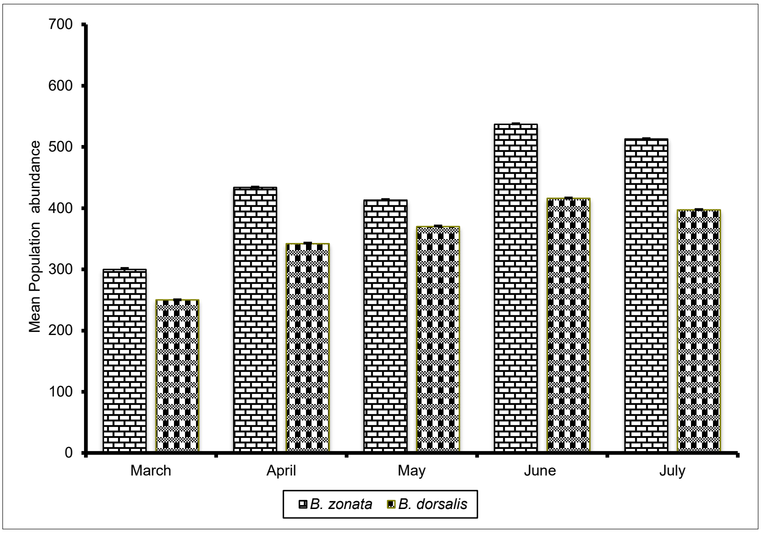

Figure 1. Mean populations of *B. zonata* and *B. dorsalis* during the study months.

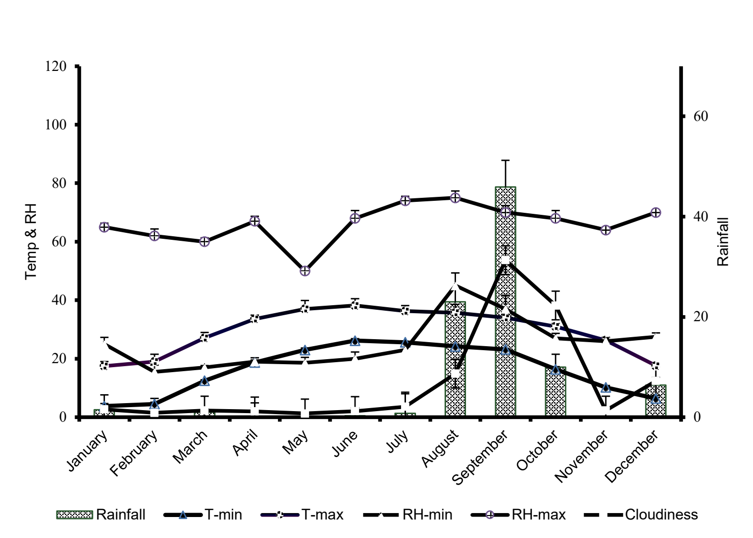

Figure 2. Mean meteorological observations noted at the Regional Agro Met Center, Tandojam, during the year (2018-2020), Temperature (°C), Relative Humidity (%), Rainfall (millimeter) and cloudiness (octas).

The population build up in traps was started from March. It was fair during April and May and attained the peak during June and July. The population build-up in traps was observed during March, while April and May had a fair number of catches, but June and July revealed the peak populations density. The environmental factors (rainfall, temperature, relative humidity and cloudiness) seemed to have effects on the populations buildup of both *B. zonata* and *B. dorsalis*. At the start of the rainy season, it was observed that the populations of *B. zonata* and *B. dorsalis* were enhanced by the rain (0.03-0.8 mm), temperature (minimum 26.2-25.6 °C, maximum 38.2-36.3 °C), relative humidity (68-74%) and cloudiness (2.1-3.6 octas) in June and July, respectively. There was a positive link of populations of fruit flies with maximum rain, temperature, relative humidity and cloudiness. This jump over was attenuated by the important rainfall recorded in June and July making it possible to reach the peak population intensity. Environmental variables (temperature, humidity, rainfall and cloudiness) during the research period and arena are expressed in Figure 2. Monthly average minimum and maximum temperatures were expressed in the range of (3.8 and 26.2 °C) and (17.5 and 38.2 °C), respectively. Minimum relative humidity ranged from 15.5 to 45.0% and the maximum from 50.0 to 75.0%. The mean higher rainfall was observed in September (45.9 mm) followed by August (23.0 mm) and December (6.4 mm). High populations of fruit flies were observed during the warmer months and lower density in cooler months. The Pearson correlation coefficient and multiple linear regression analysis exhibited a significant correlation between density abundance and mean monthly temperature, humidity and rainfall (Table 1). A weak negative correlation was observed in *B. zonata* (- 0.118), and a moderate negative correlation with *B.*

dorsalis (- 0.450) for the overall mean monthly maximum temperature. Further, the overall mean monthly minimum temperature presented a weak negative correlation in *B. zonata* (- 0.032) and *B. dorsalis* (- 0.270). The moderate positive correlation in *B. zonata* (0.425), and *B. dorsalis* (0.544) was calculated for monthly average maximum relative humidity. The monthly average minimum relative humidity exhibited a weak correlation in *B. zonata* (0.102) and *B. dorsalis* (0.217). A significant strong positive correlation was recorded between rainfall values in *B. zonata* (0.720) and moderate in *B. dorsalis* (0.677). The weak positive correlation was recorded between cloudiness values in *B. zonata* (0.167) and in *B. dorsalis* (0.225). The populations of *B. zonata* and *B. dorsalis* showed a negative link with sunshine hours, wind speed and wind direction (wind-blown from south to west direction). In orchard habitations, populations reduced towards the completion of fruiting seasons, but the opposite trend of low population captures was observed during cooler months, flowering, fruit setting and after fruit harvesting phases. Thus, the reductions in populations were resulted between August to February. Fruit sampling results throughout the experiment indicated that in the control orchard, both males and females were found from the first week of samplings.

Table 1. Fruit flies abundance and monthly average environmental variables (temperature, relative humidity, rainfall and cloudiness) exhibited through Pearson coefficient correlation (r-values) and multiple linear regressions (p-values) from January 2018 to December 2020.

Environmental variables	Fruit flies			
	B. zonata		*B. dorsalis*	
	r-value	p-value	r-value	p-value
Maximum Temperature (◦C)	− 0.118	<0.000	− 0.450	<0.030
Minimum Temperature (◦C)	− 0.032	<0.000	− 0.270	<0.025
Maximum Relative Humidity (%)	0.425	<0.023	0.544	<0.010
Minimum Relative Humidity (%)	0.102	<0.020	0.217	<0.012
Rainfall (mm)	0.720	<0.020	0.677	<0.032
Cloudiness (octas)	0.167	<0.019	0.225	<0.017

r = 1.0-0.9 (very strong correlation), r = 0.89-0.7 (strong correlation), r = 0.69-0.4 (moderate correlation), r = 0.39-0.1 (weak correlation), p < 0.05 (significant).

Evaluation of different chemicals to attract the female or male of *B. zonata* and *B. dorsalis*

The attraction of female fruit flies to all the tested chemicals was considerably more than the males. Three mixtures (ammonium acetate, trimethyl amine and putrescine) exhibited significantly the highest attraction as compared to the other compounds in both *B. zonata* and *B. dorsalis* for either male or female sexes. Torula yeast and Boric acid improved the attraction gradually with the increase in concentrations in response to both sexes. A comparatively higher number of flies were significantly collected from torula yeast and Boric acid combination with the ratio of 7:3. The results further revealed that both *B. zonata* and *B. dorsalis* constantly showed a substantial positive response to the odor of proteinaceous food attractants (Tables 2- 3). Therefore, efforts will be continued to further standardize the female attracting system for *B. zonata* and *B. dorsalis*. Clearly, Ammonium acetate, trimethyl amine and putrescine showed a better potential for attracting the females of *B. zonata* and *B. dorsalis*. Hence, these three chemicals are needed to be evaluated in still different concentrations to standardize the attracting system for both sexes of fruit flies. Experimental results indicated that all female food attractant lures were highly choosy for females, which represented an average of higher number than male captures, thus more females attracted than the number of males caught by the chemical attractants.

Table 2. Evaluation of different chemicals as female attracting system for *B. zonata.*

Treatment	Catches of fruit flies per trap per week during different months					
	May		June		July	
	Female	Male	Female	Male	Female	Male
Torula yeast + Boric acid (7:3)	15.5 b	13.0 b	21.0 b	16.5 b	25.2 b	22.7 b
Torula yeast + Boric acid (3:2)	10.7 cd	9.5 c	12.5 c	13.7 bc	15.5 c	14.5 c
Torula yeast + Boric acid (1:1)	10.2 cd	7.5 cd	13.0 c	13.7 bc	14.7 c	15.2 c
Torula yeast + Boric acid (2:3)	11.7 c	7.2 d	12.7 c	13.5 bc	15.7 c	16.0 c
Torula yeast + Boric acid (3:7)	9.2 d e	7.7 cd	12.7 c	14.2 bc	14.2 c	14.2 c
Ammonium acetate + Trimethyl amine + Putrecine (1:1:1)	25.0 a	15.7 a	45.2 a	22.0 a	65.2 a	38.7 a
Torula yeast + Ammonium acetate + Boric acid (1:1:1)	8.7 cd	6.7 d	10.7 c	13.2 c	13.7 c	14.2 c

Means followed by different letters within treatments are significantly different at $p < 0.05$.

Table 3. Evaluation of different chemicals as female attracting system for *B. dorsalis.*

Treatment	Catches of fruit flies per trap per week during different months					
	May		June		July	
	Female	Male	Female	Male	Female	Male
Torula yeast + Boric acid (7:3)	13.5 c	11.0 c	19.0 b	14.5 c	23.0 b	20.2 b
Torula yeast + Boric acid (3:2)	7.7 cd	8.5 cd	11.5 c	10.3 c	13.2 c	12.1 c
Torula yeast + Boric acid (1:1)	8.2 cd	7.0 cd	12.5 c	11.5 c	12.4 c	13.0 c
Torula yeast + Boric acid (2:3)	10.2 c	5.2 d	9.7 c	10.2 c	12.2 c	12.0 c
Torula yeast + Boric acid (3:7)	7.2 cd	6.7 cd	10.2 c	11.2 c	11.0 c	12.0 c
Ammonium acetate + Trimethyl amine + Putrecine (1:1:1)	21.0 b	14.7 a	40.2 a	20.0 b	57.2 a	32.5 a
Torula yeast + Ammonium acetate + Boric acid (1:1:1)	8.2 cd	6.0 d	8.5 cd	11.2 c	13.0 c	11.7 c

Means followed by different letters within treatments are significantly different at $p < 0.05$.

DISCUSSION

The results presented on the population dynamics and fruit fly control experiments were convincingly successful and significant. The results indicated that a low pest population level was detected in early fruiting (March, April and May), whereas there was a higher density near to fruit ripening stage (June and July). A similar trend was obtained for female and male captures in all treatments. Such dissimilar patterns of pests population were certainly due to the phenological stage of the mango fruit and environmental deviations from month to month. This discrepancy of trap catches trends exhibited that during the experiment, odor emission from the traps and lures were not uniform as induced by the variable climatic variations of temperature and precipitation, which encouraged or discouraged flies activity.

Previous research has also reported a significant role of environmental features in the catches of *Bactrocera* fly species. Miranda et al, (2001) explained that rain and temperature are important environmental variables that could have shown important raise or fall in trap captures. The temperature and humidity levels had direct and indirect effects on species demography, availability of host plants and the existence of natural enemies (Vayssieres, 2004). Ndiaye, Elhadji, & Gilles (2008) mentioned that the development of fly populations had been related to rainfall. The current findings may be due to the effects of the cooler months because at that period flies were at very low-intensity levels, therefore incapable to be identified at the ratio of attractants utilized in experiments. So, the opinion may be extracted that the development of eggs present in fruits was delayed during the lower winter temperatures. Nevertheless, the sensitivity of attractants to discover the pest in low population levels and unfavorable environmental variables need time. This is for the reason that it is a vital aspect of early population management approaches. Hence, trapping methodologies as necessary elements of monitoring, surveillance and control may deliver information on existing species and seasonal distribution, and helpful to build an arena with freedom from fruit fly species. The population build-up until May was inadequate, which might be due to the limitation of environmental variables and or very low survived overwintering adult populations during cooler months. Fruit infestation rate was identified in tree fruits and fallen ground fruits. The early fruit infestation resulted from the least adult appearance, whereas late infestation had high captures in traps because the fruit was then available or mainly due to optimum temperatures. A small peak between March and April was observed, which was most probably due to the early mango fruiting period. This peak was commonly exaggerated between May and June when the investigational arena practiced one of the best mangoes spells.

The present research displays a tendency for greater fruit fly density at the end of the mango season. This kind of build-up of fruit fly populations may be due to the continuous accessibility of enormous attractive fruit. Thus, host fruit availability is another important contributor to the seasonal abundance of fruit flies, which is in agreement with other workers such as Drew, Zalucki, & Hooper (1984). According to Mahmood & Mishkatullah (2007), the availability of host fruits was an essential factor affecting population fluctuations. In agreement with this, other workers Gupta & Bhatia (2000), discovered the maximum fly catch corresponded with the maturity period of fruits in a mango plantation. The mango plants are damaged in Central Punjab in July-August and 35% of the fruiting bodies were spoiled by *B. dorsalis* and *B. zonata* (Mohyuddin & Mahmood, 1993). Fifteen species of *Bactrocera* fruit flies were captured in total during the survey and the populations were not of high density every year, and few fruit flies were captured from September to March (Kawashita, Rajapakse, & Tsuruta, 2004). The population dynamics of three important *Bactrocera* species (*zonata, cucurbitae* and *dorsalis*) exhibited a low density from November to February and higher from March to August. The highest population was observed in July and August, and the maximum reduction perceived in October depending on the host fruit maturity and environmental variables (Mahmood & Mishkatullah, 2007). Consequently, the availability of host fruits and meteorological parameters are essential factors affecting fruit flies population fluctuations.

Of all attractants tried for the attraction of both sexes of fruit flies, Ammonium acetate, Trimethyl amine and Putrecine composite appeared to be the most effective, while Torula yeast and Boric acid at an increased concentration showed promising results. Torula yeast, Ammonium acetate and Boric acid compound were reasonably effective, but their efficacy still needs to be improved further. In concurrence with this, a number of scientific publications dealing with technology for controlling of tephritid pests had stated the successful implication of attractants for the attraction of female and male fruit flies. Earlier research revealed that the mixture of molasses with ethyl acetate and ethyl butyrate at the ratio of 5:5 had 54.7% higher attraction effects on flies. Furthermore, various mix ratios with molasses displayed a high attraction of 60.5% of female populations (Liu & Hwang, 2000). During the research when *Bactrocera* fruit flies were fed with an attractant-bait mixture comprising boric acid-borax (3:1) and protein hydrolysate (4%), resulted in 40-98.3% population reduction with diverse (1-12%) formulations (Sunandita & Gupta, 2001). Duyck, Quilici, Fabre, & Ryckewaert (2004) studied the relative attractiveness of six commercially available protein hydrolysates and the influences of their concentrations on adult *Bactrocera* flies. Clear differences in attractiveness between the tested products were demonstrated, within the range of 0.5-10%, and a general tendency for an increase in effectiveness with increasing concentration was shown. Alkalinization of the bait solution appeared to increase the attractiveness to the flies. Rousse, Duyck, Quilici, & Ryckewaert (2004) evaluated the relative attractiveness of yeasts to the *Bactrocera* flies. The addition of higher rates of acid or alkali decreased attractiveness. Olivero, Garcia, Wong, & Ros (2004) proved that plastic McPhail and the Tephri-Trap with the Nu Lure hydrolyzed protein were the best treatments for capturing of female *Bactrocera* individuals. Saafan (2005) conducted experiments to evaluate the efficiency of some different attractants for adults of the peach fruit fly *B. zonata*, in mango orchards. All attractants attracted peach fruit flies, but Diammonium phosphate 2% was the most effective in attracting of adults, followed by Diammonium phosphate 3%. Lu et al, (2006) reported that whenever the sex attractant was offered in the trapping pots with 1/3 or 1/4 each time in a surveillance arena, it could calculate precise male population density records.

Because of the noticeable variance in the male population densities between diverse positions inside and outside plants, the surveillance arena should include both the plants and the adjacent places. The findings also discovered that annual population dynamics records of the male could be found by surveillance of huge and varied orchard arenas. Countering to this, disproportionate observations were drawn by Khattak, Shahzad, & Ghulam (2006), who evaluated the repellent and growth-inhibiting effects of certain extracts on the settling and growth of fruit flies. The adults emergence was considerably less in all the extracts as compared to the control. In the current field studies, findings were able to demonstrate that relative trapping efficiency was variable among the different attractants of the *B. zonata* and *B. dorsalis* females. The average number of female fruit flies trapped during the investigation time in all the tested chemicals was considerably more than the males. In this sense, these results are similar to previous reports of female fruit fly attraction to certain chemicals.

According to Jang & Light (1996), and Cornelius, Duan, Messing, & Cornelius (2000), the food-type attractants, such as hydrolyzed protein products and synthetic chemical blends were reasonably attractive to both males and females of many tephritid species. Siderhurst & Jang (2006) reported a similar attraction of both male and female fruit flies due to certain extracts. An uncommon non-target host plant and ovipositional attractants for females have also been described in previous studies as well (Jang & Light, 1996). The current findings have practical implications in fly trapping techniques suggesting that female attraction sensitivity could be improved with a further detailed study. Moreover, the present results would be suitable for observing females at high or lower pest density levels. Investigational results further pointed out that responses of females and males to Torula yeast and Boric acid were improved and considerably higher flies have been trapped in Torula Yeast and Boric acid treatment, though all the treatments captured more females compared to males. Additionally, all attractants tried showed negligible or less non-targeted insect detection, which is an important aspect that should be kept in mind, while evaluating the lure's consequence. This may propose that these chemicals determine a different odor emission rate, and thus may play an important role in insect attractiveness and detection.

In the present work, Torula yeast and Boric acid treatments increased the number of female captures, so, all female attractant treatments were more selective for females, which represented an average of about 25% higher number of female captures, thus many times more female trapped than the number of males captured by the female attractants. Furthermore, the present results may suggest that there were also discerning effects of attractants to attract females, which could be an important way of improving sterility assessment. Furthermore, the present results among synthetic lures proved more effective to attract females than males *B. zonata* and *B. dorsalis,* consistently exhibiting a significant positive response of females to the odor of proteinaceous food attractants. In concord with this, other research had led to the confidence that males and females have some basically diverse behaviors, which are a result of physiological alterations in insects. Females have a more multifarious attributable repertoire, which comprises the need for food required in nutrition and ovarian growth, mating, oviposition, host finding and egg-laying (Sarwar, 2015c; 2020b). Whereas, male flies do not have to betroth, oviposition and egg-laying attributes (Jang, 1997). Both sexes require protein for their normal growth and development. However, females are fascinated more by protein bait sprays in greater numbers than males due to their need for protein to develop their eggs and oviposition (Vickers, 1997). In addition, the collection for large numbers of specimens of major flies pest species using traps baited with male cue lure and methyl eugenol, provided valuable data and evidenced that these lure traps will become important tools for both fruit fly pests monitoring and field pests management. These traps also attracted large numbers of mature female fruit flies, thus adding value to this new technology (Maula et al, 2023). Additionally, the life cycle study of fruit fly revealed that when their maggots emerge inside the fruit and change to an adult form, they must feed regularly on carbohydrates and water. In contrast, female flies require proteinaceous base food for the development of their sexual organs and survival (Khan, Hussain, & Jehangir, 2023). These facts insight into how female behavior might be measured in these species and other economically important tephritid fruit flies, which may be key directions toward the development of female lures. And such approaches should be one of the primary deliberations in search of better and qualitative female attractants. Further attempts to improve and identify the chemicals and novel compounds responsible for the attractiveness of both fruit flies sexes should be continued.

CONCLUSIONS

Qualitative and efficient female attractants will advance the surveillance, monitoring and management of fruit flies, and supplement existing male lures. On the basis of the present findings all food attractants applied in diverse formulated combinations were efficient in fruit flies management. Pests destruction intensities were carried to large using the formulation of Ammonium acetate, Trimethyl amine and Putrecine compounds where the attraction of female fruit flies was significantly more than the males for the period of the trials. This may develop qualitative consideration of attractants to identify the pest in low density, which is the mainly significant trait of initial population control approaches. The anticipatory positive results accomplished with these attractants can be replicated using the new formulations and their regular applications are essential. It is expected that long shelf life preparations of these products may establish both spray and bait appropriate for use in traps. The findings of the present investigation revealed that different environmental factors have striking effects on the development of *B. zonata* and *B. dorsalis*. Environmental variables are substantial factors affecting the overall fruit flies abundance in the research arena. The present achievement of this endeavor and the solicitation of similar tools in other arenas will consequently be dependent on economics, awareness of the farmers and appreciation of product value for efficient fruit fly management.

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