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Bottom-up effects of different host plant resistance cultivars on ber (*Ziziphus mauritiana*)-fruit fly (*Carpomyia vesuviana*) interactions

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ABSTRACT

The fruit fly, *Carpomyia vesuviana* Costa (Tephritidae: Diptera) is an important pest of ber (*Ziziphus mauritiana* L), leading to significant losses in yield in the hot arid agro-climate of India. Variation in resource input (anti-xenotics and allelochemicals) to plants trigger bottom-up effects on ber-fruit fly interactions. However, variation in plant extrinsic and intrinsic traits in response to resource availability may modify the bottom-up effects. The objectives of this study were to identify and categorize sources of resistance in ber cultivars to *C. vesuviana* from the arid region of India. We found that: (i) three cultivars were resistant; 13 cultivars were moderately resistant; 6 cultivars were susceptible and three cultivars were highly susceptible to fruit fly infestation; (ii) the phenol, tannin and flavonoid contents had significant negative correlations with percent fruit infestation. The percent fruit infestation had significant positive correlations with fruit length, pulp: stone ratio and had significant negative correlation with pericarp thickness. Pulp texture and fruit surface were found to be hardy and rough, respectively, in resistant cultivars of ber; and (iii) flavonoid and phenols content explained (89%) of the total variation in fruit fly infestation. Two principal components (PCs) were extracted which explained the cumulative variation of 84.7% in fruit fly infestation. PC1 explained 59.9% of the variation while PC2 explained 24.9% of the variation. Growers can adopt the potential resistant cultivars of ber (Tikadi, Katha and Illaichi cultivars) with minimal financial investment to obtain higher yields. Hence, a benefit of resistance cultivars for yield potential is apparent and resistance cultivars can be used as an important component of sustainable management.

1. Introduction

Plant-arthropod interactions are thought to be of utmost importance for understanding the dynamics of ecological communities (Sarmento et al., 2011; Han et al., 2016). Plant defence strategies against insect herbivores may involve the synthesis of a plethora of biologically active compounds (allelochemicals), which are phylogenetically conserved in specific plant families or genera (Mithofer and Boland, 2012). Plants frequently display genetic variation within and between population for traits that influence the preference and non-preference of insects on their hosts that are resistance traits (Johnson and Agrawal, 2005; Haldhar et al., 2017; Samadia and Haldhar, 2017; Muthusamy et al., 2017). It has been widely recognised that biological diversity plays a vital role in structuring community ecosystem processes (Snyder et al., 2006; Haddad et al., 2011; Sarmento et al., 2011; Tooker and Frank, 2012). The genotypic variation may influence the distribution and damage levels of herbivores on focal plants through processes referred to as associational resistance or susceptibility (Barbosa et al., 2009). Exploitation of bottom-up effects in the crop plant is an economical and environment-friendly method of insect management. The attractive and beneficial feature of bottom-up effects is that they are farmer friendly and do not need much financial investment for pest control. The identification and development of crop specific genotypes with resistance to pests is determined by the nutrients and concentrations of secondary metabolites. Host plants play an important role in determining insect populations in respect to concentrations and proportions of nutrients, which differ among species (Schoonhoven et al., 2005). Plants having antibiosis characters such as flavonoids, phenols, tannins etc. may cause reduced insect survival, prolonged development time, decreased size and reduced fitness of new generation adults (Gogi et al., 2010; Haldhar et al., 2013a). Hence, such mechanisms of plant resistance have been effectively and widely used for managing insect pests in horticultural crops (Moslem et al., 2011; War et al., 2012; Haldhar et al., 2015a, 2015b, 2017). Direct defenses are mediated by plant characteristics that affect the herbivore's biology such as mechanical protection on the surface of the plants (e.g., hairs, trichomes, thorns, spines, and thicker leaves) that retard the development of herbivores (Hanley et al., 2007).

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The ber (*Ziziphus mauritiana* Lamark) also called 'desert apple', 'jujube', 'Chinese apple', 'Ber (Hindi)', 'Indian plum' and 'Permseret (Anguilla)' is a tropical fruit tree species, belonging to the family Rhamnaceae (Balikai et al., 2013). Ber has been reported as an immune stimulant, anti-biotic, anti-nephritic, antiulcer, anti-diabetic, anti-inflammatory and anti-oxidant. Fruit fly, *Carpomyia vesuviana* Costa (Diptera: Tephritidae) is the most destructive pest of ber in India. It is a monophagous pest, infests *Zizyphus* species only and contributes towards low yield and poor quality of fruits (Haldhar et al., 2012, 2013b, 2016; Dhileepan, 2017). The total duration of the fruit fly life cycle varies with respect to environmental condition. The pre-oviposition, oviposistion and post oviposition periods last 2–12, 3–44 and 0–14 days respectively. About 80% of females deposit eggs after 3–7 days and lay an average of 23 eggs. The egg stage 1–4 days, the larval period 7–24 days, prepupal stage 3–8 h pupal stage (short 5–42 days) long (43–122 days) cycle pupation occurred in 80 and 20% of pupa, respectively. The pupation duration is more in November, December and April. Adult longevity ranges from 4 to 55 days (Lakra and Singh, 1983). The fruit fly causes yield losses of up to 80% under severe infestation when no control measures as taken (Batra, 1953). Cultivation of resistant cultivars to fruit fly is a major component of integrated pest management programmes and therefore this work was taken for the studies. Development of ber cultivars resistant to fruit fly had not yet been initiated owing to inadequate information on the sources of plant traits and understanding of the bottom up effects of crop variability. The present investigation was undertaken to identify various antixenotics (biophysical structures) and allelochemicals (biochemical compounds) of *Z. mauritiana* cultivars associated with resistance to fruit fly infestation under field conditions.

2. Materials and methods

2.1. Survey and collection of cultivar accessions

A survey was conducted at different places of Rajasthan, Maharashtra, Haryana, Delhi, Punjab and different cultivar accessions of *Z. mauritiana* were collected. During the survey, trees were selected randomly on the basis of tree spread, height, leaf, fruit, incidence of fruit fly. In each location three cuttings with bud from a single tree were collected, labeled and brought to ICAR-Central Institute for Arid Horticulture (ICAR-CIAH) farm. The seeds of wild ber, *Ziziphus rotundifolia* Lam. were used for raising the seedlings in the nursery. The collected scion buds were used for shield budding on wild ber seedling rootstock. Three budded seedlings of each place were planted with a spacing of 6 by 6 m under drip irrigation system in triplicate at the field gene bank of ICAR-CIAH farm (Table 1) for establishment and all the recommended agronomic practices (e.g. weeding, fertilization, hoeing, *etc*.) were followed. At the time of this study, the plantlets were approximately 12 years old.

Table 1
Different cultivar accessions of Indian ber, *Ziziphus mauritiana* and their collection sites.

Cultivars	Collection site
Akharota	MPKV, Rahuri
Aliganj	CAZRI, Jodhpur
B. S. 75-1	MPKV, Rahuri
Badami	MPKV, Rahuri
Bagwadi	MPKV, Rahuri
Banarasi Karaka	CCSHAU, Hisar
Banarasi Pawandi	CCSHAU, Hisar
Betawadi	MPKV, Rahuri
Chhuhara	CCSHAU, Hisar
Chirana-1	Shekhawati, Sikar
Dandan	CCSHAU, Hisar
Dharki No. 1	MPKV, Rahuri
Glori	MPKV, Rahuri
Gola	CCSHAU, Hisar
Golar	FRS, Bahadurgarh
Goma Kirti	CHES, Godhara
Gorafa	MPKV, Rahuri
Gularvasi	CSSRI, Karnal
Illaichi	CCSHAU, Hisar
Jogia	MPKV, Rahuri
Kaithli	CCSHAU, Hisar
Kali	CAZRI, Jodhpur
Katha	MPKV, Rahuri
Kheera	CSSRI, Karnal
Laddu	IARI, New Delhi
Lakhan	IARI, New Delhi
Maharwali	CAZRI, Jodhpur
Mehrun	CAZRI, Jodhpur
Mundia	MPKV, Rahuri
Nalgarhi	MPKV, Rahuri
Narikali	FRS, Bahadurgarh
Narma	CCSHAU, Hisar
Neharu (Mandal)	MPKV, Rahuri
Nonki	IARI, New Delhi
Panthani	FRS, Bahadurgarh
Reshmi	CCSHAU, Hisar
Safeda	FRS, Bahadurgarh
Sanaur-3	IARI, New Delhi
Sanaur-4	FRS, Bahadurgarh
Sanaur-5	CCSHAU, Hisar
Sauveda	MPKV, Rahuri
Seb	CCSHAU, Hisar
Shamber	MPKV, Rahuri
Sua	MPKV, Rahuri
Surati	FRS, Bahadurgarh
Tesbetes	MPKV, Rahuri
Thar Bhubhraj	CIAH, Bikaner
Thar Sevika	CIAH, Bikaner
Thornless	IARI, New Delhi
Tikadi	CAZRI, Jodhpur
Umran	CCSHAU, Hisar
Villiati	FRS, Bahadurgarh
ZG-2	FRS, Bahadurgarh
ZG-3	CCSHAU, Hisar

2.2. Screening of ber cultivars

The established fifty-four cultivar accessions of *Z. mauritiana* at the field gene bank at experimental farm of ICAR-CIAH, Bikaner (at 28°06′45.0″N 73°20′52.4″E and altitude of 234.84 m above sea level) were used for preliminary resistance study (Table 1). Twenty fruits were randomly selected from each replication and average incidence was recorded as percent fruit infested with *C. vesuviana* during 2014–15. Twenty-five selected cultivars from preliminary screening of ber were used in two years (2015–16 & 2016–17) for final incidence of fruit fly, plant morphology and biochemical studies. The cultivars were categorised by following the rating system given by Haldhar et al. (2017) for fruit infestation as: immune (no damage), highly resistant (1–10%), resistant (11–20%), moderately resistant (21–50%), susceptible (51–75%) and highly susceptible (76–100%).

2.3. Morphological fruit mechanism of ber cultivars

Ten marketable fresh fruits of each of the twenty-five ber cultivars were used to record data on the morphological traits (Pericarp thickness, fruit length fruit diameter, pulp: stone ratio, fruit surface and pulp texture). The length of pericarp thickness, fruit diameter and fruit length were measured at five different positions of each fruit using Digital Vernier Caliper (MITU-TOYO, 300 mm, 0.01 mm reading capacity).

2.4. Biochemical fruit traits of ber cultivars

Two fresh fruits of twenty-five cultivars from each replication were selected, cut into small pieces and dried. For the estimation of biochemicals, the procedures used for each biochemical were flavonoid,

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