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Antixenotic and allelochemical resistance traits of ber (*Ziziphus mauritiana*) against stone weevil (*Aubeus himalayanus)* in hot arid region of India

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Abstract

Plants possess different antixenotic and allelochemical properties, which resultantly induce in them different mechanisms of resistance. The ber varieties/ genotypes Kali, Katha, Illaichi and Tikadi were found to be resistant; Akharota, Dandan, Gola, Goma Kirti, Sanaur-1, Seb, Umran and ZG-3 moderately resistant; Badami, Banarasi Karaka, Gularvasi, Jogia, Kaithli, Mundia, Reshmi, Sanaur-3, Thar Bhubhraj, Thar Sevika and Thornless susceptible and Banarsi Pebandi, Chhuhara, Sanaur-2, Sanaur-4 and Sanaur-5 highly susceptible varieties/ genotypes against stone weevil. The fruit infestation ranged from 8.80 to 49.44 % on retained fruits and 13.31 to 73.77% on dropped fruits. Tannins, phenols, alkaloids and flavonoids contents had significant negative correlations (P = 0.01) with the percentage fruit infestation on retained fruits and the fallen fruits. The pulp: stone ratio was having significant positive correlations (P = 0.01) with percent fruit infestation on retained and the dropped fruits. Two principal components (PCs) were extracted with eigen value =1.0, after varimax rotation with Kaiser normalization procedure which converged in three iterations. The extraction communalities for all the variables tested were = 0.5 indicating that the variables were well represented by the extracted PCs which together explained a cumulative variation of 90.75 %. PC1 explained 70.74 % of the variation while PC2 explained 20.01 % of variation. PC1 had the loadings for flavonoid content (0.91), tannins content (0.71), total alkaloid (0.93) and phenols content (0.95). Pulp: stone ratio of different varieties/ genotypes of ber (0.96) were loaded in PC2.

Key words: Ber, antixenotics, allelochemicals, stone weevil, resistance.

Introduction

The ber, *Ziziphus mauritiana* is native to Province of Yunnan in southern China to Afghanistan, Malaysia and Queensland, Australia (Morton, 1987). It is native of South and Central Asia, found throughout the arid and semi-arid tracts. It is cultivated to some extent throughout its natural range on commercial scale and has received much horticultural attention in India (Morton, 1987). *Z. mauritiana* is a gregarious spiny shrub or a small tree, ends of branches curved or drooping. Branches and branchlets armed with short stipular spines. The plant is a vigorous grower and has a rapidly-developing tap root. The richness of the pulp in nutritive compounds has been widely recognised. Nonetheless, there are no definitive values for pulp composition. However ber is richer source of protein, phosphorus, calcium, carotene and vitamin C (Bakhshi and Singh, 1974). The crop is gaining popularity among the growers because of its adaptability to adverse climatic conditions and good returns of yield. The crop is suffered great losses due to insect-pests and diseases (Singh, 2008) and more than 130 species of insect-pests were found to attach the crops in India. Balikai (2009) reported a total of 22 insect and non-insect species and likewise, Kavitha and Savithri (2002) documented about 23 insect species on *ber*. In addition to these, the ber stone weevil, *Aubeus himalayanus* Voss (Coleoptera: Curculionidae) appeared to be an emerging pest reported from various region of India (Karuppaiah *et al.*, 2010; Balikai *et al.*, 2013, Haldhar *et al.*, 2012; Haldhar *et al.*, 2013d; Haldhar *et al.*, 2016). The stone weevil is an emerging threat for ber production in India especially in Northern India.

Plants having antibiosis characters such as flavonoids, phenols, tannins, alkaloids *etc.* may cause reduced insect survival, prolonged development time, decreased size and reduced fitness of new generation (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 fields of horticultural crops (War *et al.*, 2012; Haldhar *et al.*, 2015a; Haldhar *et al.*, 2015b, Haldhar *et al.*, 2017, Haldhar *et al.*, 2018). 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 either kill or retard the development of the herbivores (Hanley *et al.*, 2007). Identification of ber genotypes/ varieties resistant to stone weevil had not yet been initiated owing to inadequate information on the sources of plant traits and understanding of the effects of crop variability. The present investigation was undertaken to identify various antixenotics (biophysical structures) and allelochemicals (biochemical compounds) traits of *Z. mauritiana* cultivars associated with resistance to stone weevil infestation under field conditions.

Materials and methods

Survey was conducted at different places of Rajasthan, Maharastra, Haryan, Delhi, Punjab and different varieties/ genotypes of *Z. mauritiana* were collected. During the survey, trees were selected randomly on the basis of tree spread and height, leaf and fruit characters. In each location three cutting with bud from a single tree were collected, labeled and brought to CIAH farm. The seed of wild ber, *Z. rotundifolia* were used for raising the seedling in the nursery. The collected scion buds were used for shield budding on wild ber seedling rootstocks. Three budded seedlings of each place were planted with a spacing of 6 x 6 m in the field gene bank of ICAR-CIAH farm for establishment. Twenty nine varieties/ genotypes of ber, *Z. mauritiana* were finally selected for conservation, evaluation and resistance study at the field gene bank at experimental farm of ICAR-Central Institute for Arid Horticulture, Bikaner (at 28°06'45.0"N 73°20'52.4"E and altitude of 234.84 m above sea level). All the recommended agronomic practices (*e.g.* weeding, fertilization, hoeing, *etc.*) were performed equally in each experimental plant. Twenty fruit were randomly selected in each of 3 replicates and average incidence was calculated as the per cent of fruit infested with *A. himalayanus* during 2015-16 and 2016-17. Based on Kaiser Normalization method, the resistance category was mentioned as immune (no damage), highly resistant (1-10%), resistant (11-20%), moderately resistant (21-50%), susceptible (51-75%) and highly susceptible (76-100%) of all varieties/ genotypes of Indian ber against *A. himalayanus* infestation. Two fresh fruits of each variety/ genotype from each replication were selected, cut into small pieces and dried. For the estimation of biochemicals, the procedures used for each biochemical were flavonoids, phenols, tannins and alkaloid content and the analysis were also determined on the basis of these procedures (Haldhar *et al.*, 2018). Ten marketable fresh fruits of each of the twenty-nine ber cultivars were used to record data on the morphological traits (pulp: stone ratio, fruit surface and stone hardness). The data on percentage fruit infestation, biochemical fruit traits and principal component analysis were analyzed by one-way ANOVA using SPSS 16 software (O'Connor, 2000). The means of significant parameters among tested genotypes were compared using Tukey's honestly significant difference (HSD) tests for paired comparisons at a probability level of 5%.

Result and Discussion

The twenty nine ber varieties/ genotypes were taken for resistance study against stone weevil. The significant differences were found in percentage fruit infestation in retained and dropped fruits among the tested varieties/ genotypes during study. The varieties/ genotypes Kali, Katha, Illaichi and Tikadi were found to be resistant; Akharota, Dandan, Gola, Goma Kirti, Sanaur-1, Seb, Umran and ZG-3 moderately resistant; Badami, Banarsi Karaka, Gularvasi, Jogia, Kaithli, Mundia, Reshmi, Sanaur-3, Thar Bhubhraj, Thar Sevika and Thornless susceptible and Banarsi Pebandi, Chhuhara, Sanaur-2, Sanaur-4 and Sanaur-5 highly susceptible varieties/ genotypes against stone weevil at ICAR-CIAH, Bikaner. The fruit infestation ranged from 8.80 to 49.44 % on retained fruits and 13.31 to 73.77% on dropped fruits during 2015-16. The per cent fruit infestation was found highest in Sanaur-2 (49.44 % in retained fruit and 73.77 % in dropped fruits) and the lowest in Tikadi (8.80 % in retained fruits and 13.31 % in dropped fruits) followed by Katha (9.07 % in retained fruits and 13.71 % in dropped fruits) during 2015-16 (Table 1). The per cent infestation was recorded highest in Sanaur-2 (49.88 % in retained fruits and 74.16 % in dropped fruits) followed by Sanaur-5 (49.07 % in retained fruits and 72.14 % in dropped fruits) during 2016-17 while minimum per cent infestation was found in Tikadi (9.02 % in retained fruits and 13.57 % in dropped fruits) followed by Katha (9.26 % in retained fruits and 14.04 % in dropped fruits). The fruit infestation was ranged from 9.02 to 49.88 % in retained fruit and 13.57 to 74.16 5 in dropped fruits and significantly lowers in resistant varieties/ genotypes and higher in susceptible varieties/ genotypes (Table 2). 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; Haldhar *et al.*, 2018). Plant defense 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 of insects on their hosts that is resistance traits (Johnson and Agrawal, 2005; Haldhar *et al.*, 2013c; Haldhar *et al.*, 2017). Numerous studies have shown that varieties/ genotypes of the same crop species could significantly differ in their resistance to insect-pests (Dhillon *et al.* 2005; Sarfraz *et al.* 2006; Gogi *et al.* 2010, Haldhar *et al.*, 2013a, Haldhar *et al.*, 2013b, Cartea *et al.*, 2014; Haldhar *et al.*, 2015a) and it is effected by biochemical traits of plants. Similar our findings also incorporated with Gogi *et al.* (2010) and Haldhar *et al.* (2015b) that studied and observed the lower fruit infestation and larval densities on resistant varieties/ genotypes of bitter gourd and ridge gourd than on their susceptible varieties/ genotypes.

Tannins, phenols, total alkaloid and flavonoid contents ranged from 123.61 to 222.06 mg/100g, 42.95 to 90.33 mg/100g, 0.52 to 1.48 % and 9.32 to 24.42 mg/100g, respectively with values significantly higher in resistant varieties/ genotypes and lower in susceptible varieties/ genotypes (Table 3). Tannins, phenols, alkaloids and flavonoid contents had significant negative correlations ($P = 0.01$) with the percentage fruit infestation on plant fruits and the fallen fruits (Table 5). The antixenotic fruit traits like fruit surface, stone hardness and pulp: stone ratio was observed for different varieties/ genotypes of ber. The pulp: stone ratio ranged from 2.12 to 27.13 and was significantly high in susceptible and low in resistance varieties/ genotypes. The highest pulp: stone ratio was found in variety Mundia and least in variety Tikadi. Most of the resistant varieties were having extremely hardy stones and in susceptible varieties the stones were slightly hard (Table 4). The pulp: stone ratio was having significant positive correlations (P = 0.01) with percent fruit infestation on retained and the dropped fruits (Table 5). Isoflavonoids isolated from the wild relatives of chickpea acted as antifeedant against *H. armigera* at 100 ppm. Judaicin and maackiain were also found to be deterrent to *S. littoralis* and *S. frugiperda*, respectively (Simmonds and Stevenson, 2001). Flavonoids played a central role in various facets of plant life especially in plant-environment interactions. These defended plants against various biotic and abiotic stresses including UV radiations, pathogens and insect-pests (Treutter, 2006). Tannins had a strong deleterious effect on phytophagous insects and affected the insect growth and development by binding to the proteins, reduced nutrient absorption efficiency and caused midgut lesions (Barbehenn and Peter Constabel, 2011). Phenols acted as a defensive mechanism not only against herbivores but also against microorganisms and competing plants. Qualitative and quantitative alterations in phenols and elevation in activities of oxidative enzyme in response to insect attack was a general phenomenon (Barakat *et al.*, 2010; War *et al.*, 2011; 2015c). Phenols also played an important role in cyclic reduction of reactive oxygen species (ROS) such as superoxide anion and hydroxide radicals, H_2O_2 and singlet oxygen, which in turn activated a cascade of reactions leading to the activation of defensive enzymes (Maffei *et al.*, 2007). Plant structural traits such as leaf surface wax, thorns or trichomes, cell wall thickness and lignifications formed the first physical barrier to feeding by the insect (Agrawal *et al.*, 2009). In these findings, biophysical traits were also found significantly different among tested genotypes (Gogi *et al.*, 2010). The first line of plant defense against insect-pests is the erection of a physical barrier either through the formation of a waxy cuticle (Hanley *et al.*, 2007) and/ or the development of spines, setae and trichomes (Sharma *et al.*, 2009). Chamarthi *et al.* (2011) reported that leaf glossiness, plumule and leaf sheath pigmentation were responsible for shoot fly *A. soccata* resistance in sorghum, *S. bicolor*.

Based upon the above morphological and biochemical characters individually, it was impossible to group the entities as variables were not in agreement to each other. Hence, principal component analysis was performed to achieve parsimony and reduce the dimensionality by extracting the smallest number of components that accounted for most of the variation in the original multivariate data. Taking into consideration five parameters *viz*, flavonoid content, total alkaloid, tannin content, phenol content and pulp: stone ratio principal component analysis (PCA) was performed. Two principal components (PCs) were extracted with Eigen value =1.0, after varimax rotation with Kaiser Normalization procedure which converged in three iterations. The extraction communalities for all the variables tested were = 0.5 indicating that the variables were well represented by the extracted PCs which together explained a cumulative variation of 90.75 %. PC1 explained 70.74 % of the variation while PC2 explained 20.01 % of variation. PC1 had the loadings for flavonoid content (0.91), tannins content (0.71), total alkaloid (0.93) and phenols content (0.95). Pulp: stone ratio of different varieties of ber (0.96) were loaded in PC2 (Table 6 & Figure 1). According to Gogi *et al.* (2010) maximum variation in fruit infestation was explained by tannin and flavanol contents whereas, rest of the biochemical fruit traits explained <0.2% variation in the fruit infestation. Haldhar *et al.* (2015a) found that two principal components (PCs) were extracted explaining cumulative variation of 90% in melon fruit fly infestation and length of ovary pubescence, rind thickness, flavonoid content, ascorbic acid, free amino acid, tannins content, and phenols content were the reliable variables for characterization of resistance. Prasad *et al.* (2015) observed two principal components (PCs) were extracted explaining cumulative variation of 76.2%. Seed weight, grain hardness, oviposition, adult emergence, median development period and grain weight loss were the reliable variables for characterization of resistance to *S. oryzae*. The sorghum lines EC 24, EC 22, PEC 8, PEC 7, EP 78, EP 57, AKR 354 were classified as resistant to *S. Oryzae*.

Thus, from the foregoing account, it could be argued that reduction in stone weevil infestations on resistant varieties/ genotypes could be due to antibiosis (allelochemicals) and phenotypics (biophysical). Ber varieties/ genotypes Kali, Katha, Illaichi and Tikadi were classified as resistant to stone weevil and these could be used in future breeding programme as resistant sources. Certain biochemical traits (*e.g.* flavonoid, tannins, phenols content and total alkaloid) and biophysical traits (*e.g.* stone hardness, fruit surface and pulp: stone ration) were linked to resistance of ber against *A. himalayanus* and therefore, could be used as marker traits in plant breeding programmes to select resistant varieties/ genotypes.

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Table 1. Per cent fruit infestation of stone weevil, *Aubeus himalayanus* on different varieties/ genotypes of ber during 2015-16

S. No.	Genotypes	Per cent fruit infestation		Resistance category
		Retained fruits	Dropped fruits	
1.	Akharota	22.63 (28.39)	34.01 (35.66)	MR
2.	Badami	36.27 (36.99)	53.78 (47.15)	S
3.	Banarsi Karaka	25.95 (30.53)	35.09 (36.31)	S
4.	Banarsi Pebandi	45.71 (42.52)	62.60 (52.28)	HS
5.	Chhuhara	43.50 (41.25)	60.43 (51.00)	HS
6.	Dandan	27.39 (31.53)	38.03 (38.06)	MR
7.	Gola	14.41 (22.29)	27.82 (31.82)	MR
8.	Goma Kirti	16.27 (23.73)	30.21 (33.32)	MR
9.	Gularvasi	36.76 (37.31)	57.42 (49.25)	S
10.	Illaichi	9.76 (18.19)	15.49 (23.16)	R
11.	Jogia	36.50 (37.15)	58.57 (49.92)	S
12.	Kaithli	34.31 (35.84)	56.12 (48.50)	S
13.	Kali	10.46 (18.86)	14.79 (22.61)	R
14.	Katha	9.07 (17.52)	13.71 (21.67)	R
15.	Mundia	32.21 (34.56)	49.41 (44.64)	S
16.	Reshmi	31.71 (34.25)	47.64 (43.62)	S
17.	Sandura No. 1	22.63 (28.39)	32.94 (34.98)	HR
18.	Sanaur-1	24.70 (29.79)	29.16 (32.58)	MR
19.	Sanaur-2	49.44 (44.66)	73.77 (59.26)	HS
20.	Sanaur-3	42.84 (40.87)	55.08 (47.90)	S
21.	Sanaur-4	46.01 (42.69)	66.48 (54.72)	HS
22.	Sanur-5	48.89 (44.34)	71.58 (57.78)	HS
23.	Seb	18.72 (25.62)	30.07 (33.24)	MR
24.	Thar Bhubhraj	41.58 (40.14)	60.02 (50.84)	S
25.	Thar Sevika	36.68 (37.26)	54.80 (47.75)	S
26.	Thornless	46.85 (43.18)	63.92 (53.12)	S
27.	Tikadi	8.80 (17.25)	13.31 (21.38)	R
28.	Umran	17.80 (24.94)	25.63 (30.40)	MR
29.	ZG-3	19.01 (25.76)	28.53 (32.27)	MR
SEm±		0.93	1.21	
LSD (P = 0.05)		2.63	3.43	

*Values in parenthesis are angular-transformed
Value foll owing different letter down the column are R - resistant, MR- moderately resistant, S- susceptible and HS-Highly susceptible

Table 2. Per cent fruit infestation of stone weevil, *Aubeus himalayanus* on different varieties/ genotypes of ber during 2016-17

S. No.	**Genotypes**	**Per cent fruit infestation**		**Resistance category**
		Retained fruits	**Dropped fruits**	
1.	Akharota	22.38 (28.22)	34.49 (35.94)	MR
2.	Badami	36.66 (37.22)	54.47 (47.55)	S
3.	Banarsi Karaka	26.28 (30.73)	35.54 (36.57)	S
4.	Banarsi Pebandi	46.23 (42.82)	63.08 (52.57)	HS
5.	Chhuhara	44.05 (41.57)	60.92 (51.29)	HS
6.	Dandan	27.78 (31.79)	38.40 (38.27)	MR
7.	Gola	14.72 (22.54)	28.10 (31.99)	MR
8.	Goma Kirti	16.58 (23.98)	30.48 (33.49)	MR
9.	Gularvasi	37.17 (37.55)	57.66 (49.39)	S
10.	Illaichi	10.09 (18.5)	15.66 (23.29)	R
11.	Jogia	36.90 (37.39)	58.99 (50.16)	S

12.	Kaithli	34.88 (36.18)	56.44 (48.68)	S
13.	Kali	10.84 (19.19)	15.10 (22.86)	R
14.	Katha	9.26 (17.7)	14.04 (21.95)	R
15.	Mundia	32.91 (34.98)	49.58 (44.74)	S
16.	Reshmi	32.29 (34.61)	47.74 (43.68)	S
17.	Sandura No. 1	23.33 (28.86)	33.20 (35.14)	HR
18.	Sanaur-1	25.14 (30.07)	29.81 (33.01)	MR
19.	Sanaur-2	49.88 (44.91)	74.16 (59.51)	HS
20.	Sanaur-3	43.14 (41.04)	55.25 (48.00)	S
21.	Sanaur-4	46.57 (43.01)	66.82 (54.93)	HS
22.	Sanaur-5	49.07 (44.44)	72.14 (58.14)	HS
23.	Seb	18.80 (25.68)	30.42 (33.46)	MR
24.	Thar Bhubhraj	41.99 (40.37)	60.63 (51.20)	S
25.	Thar Sevika	36.90 (37.39)	55.20 (47.99)	S
26.	Thornless	47.08 (43.31)	64.25 (53.32)	S
27.	Tikadi	9.02 (17.45)	13.57 (21.60)	R
28.	Umran	17.84 (24.97)	25.84 (30.54)	MR
29.	ZG-3	19.20 (25.89)	28.87 (32.49)	MR
SEm±		**1.08**	**1.22**	
LSD (P = 0.05)		**3.07**	**3.47**	

*Values in parenthesis are angular-transformed
Value following different letter down the column are R - resistant, MR- moderately resistant, S - susceptible and HS -Highly susceptible

Table 3. Biochemical (allelochemical) fruit traits of different varieties/ genotypes of ber

S. No.	Varieties/ genotypes	Flavonoid content (mg/100g)*	Tannins content (mg/100g)	Phenols content (mg/100g)	Total alkaloid content (%)
1.	Akharota	16.32	179.60 (13.43)	77.73 (8.84)	1.14
2.	Badami	13.29	140.07 (11.88)	55.42 (7.49)	0.62
3.	Banarsi Karaka	15.72	171.60 (13.12)	77.13 (8.82)	1.23
4.	Banarsi Pebandi	10.99	128.99 (11.39)	48.24 (7.01)	0.61
5.	Chhuhara	12.28	122.92 (11.12)	44.22 (6.72)	0.52
6.	Dandan	19.47	159.41 (12.66)	70.71 (8.46)	1.04
7.	Gola	18.36	170.90 (13.11)	79.47 (8.96)	1.15
8.	Goma Kirti	20.35	175.67 (13.28)	77.64 (8.86)	0.93
9.	Gularvasi	15.48	136.42 (11.71)	57.66 (7.66)	0.65
10.	Illaichi	23.65	215.97 (14.72)	87.83 (9.42)	1.36
11.	Jogia	12.86	123.61 (11.15)	58.32 (7.70)	0.64
12.	Kaithli	15.02	137.23 (11.75)	61.40 (7.90)	0.57
13.	Kali	21.74	197.38 (14.07)	80.26 (9.01)	1.44
14.	Katha	24.42	198.14 (14.09)	85.71 (9.29)	1.48
15.	Mundia	12.36	145.96 (12.11)	53.70 (7.40)	0.80
16.	Reshmi	14.40	152.94 (12.40)	56.59 (7.59)	0.67
17.	Sandura No. 1	16.29	154.10 (12.44)	65.54 (8.16)	1.13
18.	Sanaur-1	16.35	160.80 (12.71)	63.95 (8.06)	1.11
19.	Sanaur-2	11.61	115.03 (10.76)	42.95 (6.63)	0.52
20.	Sanaur-3	14.02	144.88 (12.06)	52.28 (7.30)	0.68
21.	Sanaur-4	9.32	123.85 (11.15)	48.81 (7.06)	0.54
22.	Sanaur-5	11.32	116.03 (10.80)	43.58 (6.68)	0.40
23.	Seb	20.28	176.77 (13.32)	76.44 (8.79)	0.99
24.	Thar Bhubhraj	13.03	158.40 (12.62)	53.16 (7.36)	0.67

25.	Thar Sevika	14.10	162.24 (12.76)	56.94 (7.61)	0.71
26.	Thornless	11.35	222.06 (14.93)	45.75 (6.83)	0.54
27.	Tikadi	23.75	200.67 (14.20)	90.33 (9.55)	1.53
28.	Umran	16.35	169.50 (13.05)	63.97 (8.06)	1.17
29.	ZG-3	18.00	171.74 (13.13)	67.51 (8.27)	1.22
SEm$\pm$		0.66	0.36	0.22	0.05
LSD (P = 0.05)		1.88	1.03	0.61	0.14

* Analysis taken on dry weight basis of ber stone

Table 4. Morphological (antixenotic) fruit traits of different varieties/ genotypes of ber

S. No.	**Varieties/ genotypes**	**Pulp: stone ration**	**Stone hardness**	**Fruit surface**
1.	Akharota	9.46	Medium	Plain
2.	Badami	5.43	Slightly	Ridge
3.	Banarsi Karaka	26.88	Highly	Ridge
4.	Banarsi Pebandi	18.30	Medium	Ridge
5.	Chhuhara	19.42	Slightly	Plain
6.	Dandan	9.51	Highly	Plain
7.	Gola	10.13	Extremely	Plain
8.	Goma Kirti	14.24	Highly	Ridge
9.	Gularvasi	19.83	Medium	Ridge
10.	Illaichi	7.56	Extremely	Ridge
11.	Jogia	12.06	Medium	Ridge
12.	Kaithli	16.64	Medium	Ridge
13.	Kali	6.70	Extremely	Ridge
14.	Katha	6.99	Extremely	Ridge & Wart
15.	Mundia	27.13	Medium	Ridge
16.	Reshmi	11.73	Medium	Ridge
17.	Sandura No. 1	7.31	Highly	Ridge & Wart
18.	Sanaur-1	9.07	Medium	Wart
19.	Sanaur-2	12.91	Slightly	Ridge & Wart
20.	Sanaur-3	15.01	Medium	Ridge
21.	Sanaur-4	15.34	Slightly	Ridge
22.	Sanaur-5	18.31	Slightly	Ridge
23.	Seb	14.25	Extremely	Plain
24.	Thar Bhubhraj	10.78	Slightly	Ridge
25.	Thar Sevika	12.26	Slightly	Ridge
26.	Thornless	10.50	Medium	Ridge
27.	Tikadi	2.12	Highly	Plain
28.	Umran	6.85	Highly	Ridge
29.	ZG-3	9.77	Medium	Ridge & Wart
SEm$\pm$		**0.73**		
LSD (P = 0.05)		**2.06**		

Table 5. Correlation coefficient (r) between per cent infestation on retained fruits and dropped fruits along with different allelochemical and antixenotic fruit traits of ber varieties/ genotypes

	Per cent infestation on plant fruit	Per cent infestation on fallen fruit	Phenols content (mg/100g)	Tannins content (mg/100g)	Flavonoid content (mg/100g)*	Total alkaloid content (%)
Per cent infestation on fallen fruit	0.983**					
Phenols content (mg/100g)	-0.947**	-0.928**				
Tannins content (mg/100g)	-0.705**	-0.741**	0.716**			

Flavonoid content (mg/100g)*	-0.924**	-0.916**	0.931**	0.716**		
Total alkaloid content (%)	-0.935**	-0.966**	0.910**	0.726**	0.875**	
Pulp: stone ratio	0.479**	0.496**	-0.421*	-0.481**	-0.504**	-0.474**

**Significant at P = 0.01 (two-tailed)
* Significant at P = 0.05 (two-tailed)

Table 6. Component loadings of parameters for resistance against stone weevil, *Aubeus himalayanus* in ber fruits

S. No.	Parameters	Principal components	
		1	2
1	Per cent infestation on plant fruit	-0.95	0.24
2	Percent infestation on fallen fruit	-0.95	0.27
3	Phenols content (mg/100g)	0.95	-0.19
4	Tannins content (mg/100g)	0.71	-0.40
5	Flavonoid content (mg/100g)*	0.91	-0.29
6	Total alkaloid content (%)	0.93	-0.25
7	Pulp: stone ration	-0.24	0.96

Rotation Method: Principal Component Analysis with Varimax with Kaiser Normalization.
Rotation converged in 3 iterations

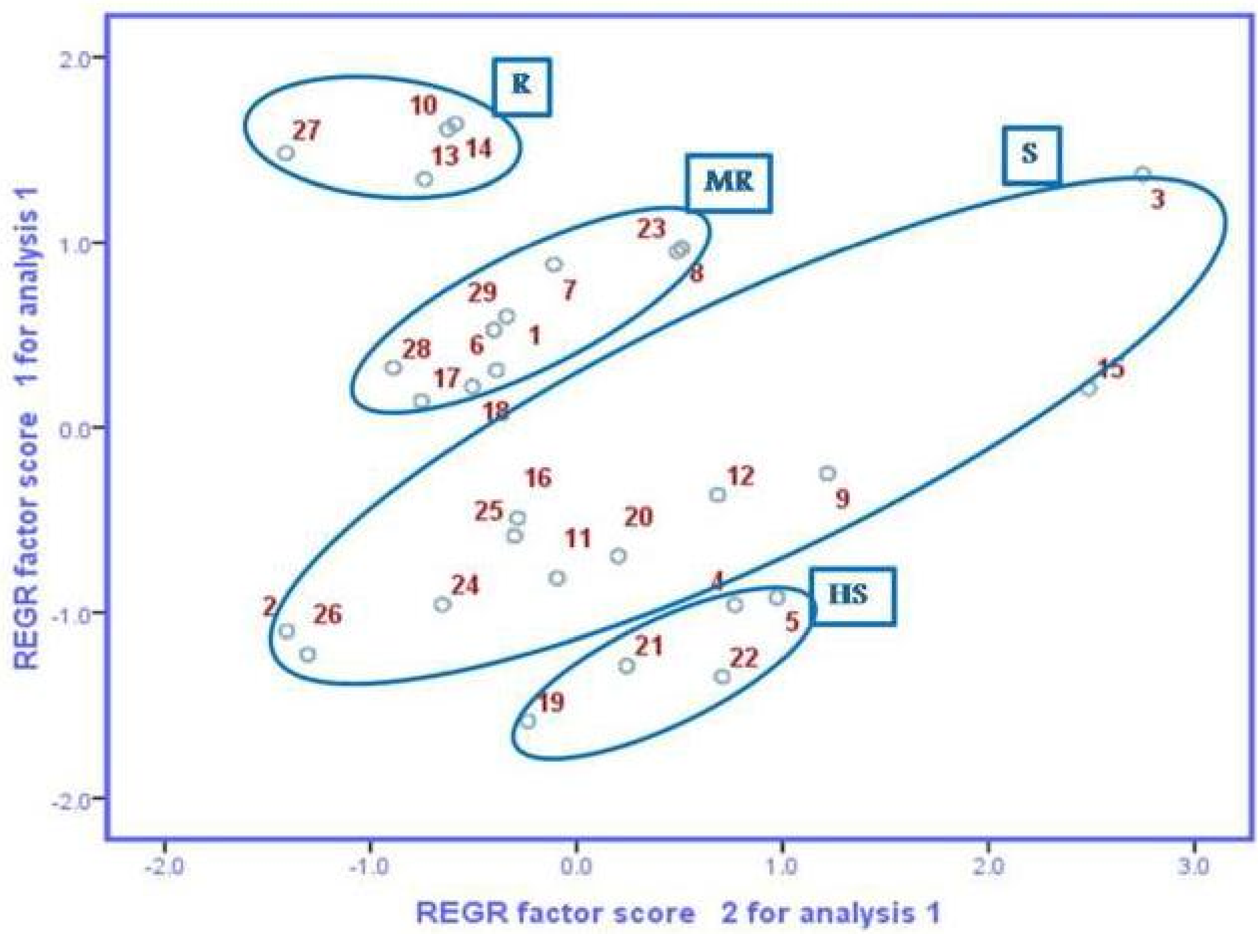

Fig. 1: Plot of PC1 and PC2 showing clusters of ber genotypes showing resistance to stone weevil, *Aubeus himalayanus*

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