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Bio-physical bases of antixenotic mechanism of resistance in ridge -gourd [*Luffa acutangula* (L.) Roxb.] Cucurbitacae) against fruit fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae)

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Abstract
Plant genotypes possess different phenotypic and/or biochemical properties, which resultantly induce in them different mechanisms of resistance. These mechanisms enable the plants to avoid, tolerate or recover from the effects of insect pest attacks. An investigation on screening of ridge gourd [*Luffa acutangula* (L.) Roxb.] genotypes against fruit fly, *Bactrocera cucurbitae* (Coquillett) was undertaken during the year 2013-2014 at the Department of Entomology K.R.C. College of. Horticulture, Arabhavi, Karnataka. The results of the present studies revealed that there was significant variation in tested Ridge-gourd genotypes for percentage fruit-infestation and larval-density per fruit. KRCCH-1 and Amoha were highly resistant and resistant genotypes respectively and identified as a resistance source for fruit fly, *Bactrocera cucurbitae*. The larval density per fruit had a significant positive correlation with percentage fruit infestation. The fruit-length, fruit diameter, number of longitudinal ribs/fruit and number of small ridges/cm2, which were significantly lower in resistant and higher in susceptible genotypes, had a significant positive correlation with the percent fruit infestation and larval-density per fruit. However, fruit toughness, height of small ridges, height of longitudinal ribs and pericarp thickness, which were significantly higher in resistant and lower in susceptible genotypes, showed significant negative correlation with the percent fruit infestation and larval-density per fruit. Step-wise multiple regression analysis indicated that the tested biophysical fruit traits explained 100 percent of the total variation in fruit fly infestation. The fruit width, fruit, length, depth of longitudinal ridge and toughness explained 89.6 percent of the total variation in fruit infestation by fruit fly. The maximum variation in fruit infestation was explained by width of the fruit (31.50%) followed by depth of longitudinal ridges (24.31%), length (17.36%) and toughness of the fruit. Other two explained only less than 11 percent total variation in fruit infestation by fruit fly.These can be used as marker traits for selection of fruit fly resistant genotypes of ridge gourd.

Keywords: Fruit fly, Resistance, fruit infestation, pericarp thickness, fruit toughtness, and thickness of longitudinal ribs

1. Introduction

Ridge gourd (*Luffa acutangula* L. Roxb.), belongs to family cucurbitaceae, popularly known as "*Kalitori*" and it is called Heere kayi in kannada and also called as angled gourd, angled loofah, Chinese okra, silky gourd and ribbed gourd. The productivity of ridge gourd is influenced by several abiotic and biotic factors like diseases and insect pests. Many insects *viz*., red pumpkin beetles, epilachna beetle, leaf miner and melon fruit fly are the major constraints in the successful production of ridge gourd, especially the melon fruit fly *Bactrocera cucurbitae* is the major limiting factors in obtaining high yield [12]. Fruit fly, *B. cucurbitae* is predominant and geographically distributed in all the ridge gourd growing locations of Karnataka. The fruit fly prefers to infest young, green, soft skinned fruits. It inserts the eggs 2 to 4 mm deep in the fruit tissues, and the maggots feed on the fleshy part of fruits causing decay of fruits and in some cases premature dropping of fruits. The affected fruits are distorted and lose their market value. The pupation occurs in the soil at 0.5 to 15 cm below the soil surface depending on the nature and type of soil [1].
There are significant differences in genotypic susceptibility to melon fruit fly among ridge -gourd genotypes [1]. which suggest the need to identify sources of resistance to the target pests, followed by an identification of physio-chemical factors involved in host plant selection by the insects either for oviposition or feeding [6]. And larval performance [2, 5].

Hence, the development of varieties resistant to melon fruit fly is an important component of an integrated pest management programme for melon fruit fly [11]. The development and then the cultivation of fruit fly-resistant ridge -gourd cultivars has been impaired, because of the lack of adequate information on the sources of plant and fruit-traits associated with resistance and their influence on the pest multiplication [1]. Therefore, it becomes imperative to identify physical and biochemical fruit-traits associated with resistance [1]. and get knowledge of their influence on oviposition preference, larval performance [2] and pest multiplication [1]. for devising sustainable pest management strategies for the control of fruit flies [2]. The ridge-gourd cultivars and/or genotypes resistant to the melon fruit flies on the basis of biophysical and biochemical fruit-traits have not yet been identified. This study was, therefore, planned to screen out resistant genotypes of the available ridge -gourd accessions in Karnataka, in order to determine their biophysical sources of resistance against the melon fruit fly.

Material and Methods

The present investigation on "Screening of ridge gourd genotypes against against fruit fly *Bactrocera cucurbitae* (Coquillett) (*Diptera: tephritidae*) was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka, India during the year 2012-2013. A brief note on experimental materials and methodologies adopted to carryout various studies are discussed here under.

The total number of eggs per fruit was recorded on the basis of number of eggs present in the fruit. To record the number of eggs per fruit, the infested fruits from each genotype were harvested and brought separately to the laboratory in polythene bags. The five randomly selected infested fruits from each genotype were cut open separately and observed under the microscope to count the total number of eggs present in individual fruit. The percent hatch of eggs was calculated following formula

$$\text{Percent egg hatch} = \frac{\text{Number of maggots}}{\text{Total number of maggots + un-hatched eggs}} \times 100$$

The maggot population was recorded on the basis of number of maggots per infested fruit. To record the maggot population, the infested fruits from each genotype were harvested and brought separately to the laboratory in polythene bags. The infested fruits were cut open to count the total number of maggots per fruit. The number of maggots per fruit was computed by observing five randomly taken fruits from each genotype

The five fruits were selected at random for measuring the fruit length with help of centimetre scale the average was worked out and expressed in centimetres. The same five fruits were also used for measuring the fruit diameter with the help of Vernier calipers and the average was worked out. The measurement was expressed in millimeters. The same five fruits were selected for measuring the fruit toughness, it was measured with the help of penetrometer and the average was worked out. The measurement was expressed in kg/cm^2. Five fruits were selected randomly and the number of ridges was counted by visual observations. Fruit rind thickness was measured with the help of Vernier callipers by using the same fruits which were used for measurement of fruit length and diameter. The average was calculated and expressed in millimetres. Fruit longitudinal ridges thickness was measured with the help of Vernier Callipers by using the same fruits which were used for measurement of fruit pericarp thickness and diameter. The average was calculated and expressed in millimeters. Depth of the longitudinal ridges was measured with the help of Varnier Callipers by using the same fruits which were used for measurement of pericarp thickness and diameter. The average was calculated and expressed in millimeters.

Statistical analysis

The data collected on percentage fruit infestation and larval density per fruit of among the tested ridge gourd genotypes, during the screening trial were analyzed through a Multivariate General Linear Model (MGLM) Technique [16], through Factorial ANOVA test. The biophysical fruit traits of tested genotypes of ridge gourd under lab and field conditions were analyzed through one way ANOVA technique, by using SPSS software [10]. to determine either the differences in above mentioned parameters are significant or non-significant. The means of significant parameters, among the tested genotypes, were compared by using DMRT post hoc test. The data were also subjected to correlation, simple regression and step-wise multiple regression analysis using SPSS 10.00 tool and Statistical XL tool.

Result and Discussion

The percent fruit infestation was assessed for all the genotypes of ridge gourd screened during the course of study at different DAS. The pooled mean (±SE) of percent fruit infestation varied significantly across the genotypes ($F_{17,54}$=2.31; p<0.01), DAS ($F_{2,54}$=5.63; p<0.006) and statistically no significant difference was observed between the interaction of genotypes and DAS ($F_{34,54}$=1.35; p<0.163). The pooled mean (±SE) of fruit infestation was significantly highest for the genotype, Vijayawad local with pooled mean (±SE) of 78.27±9.98 percent compared to the rest of the genotypes screened.

However, Vijayawad local was found to be on par with Sureka and JL-5 with pooled means (±SE) of 59.79±14.24 and 50.99±15.93 percent, respectively. In the same way, the genotype, KRCCH-1 registered significantly lowest pooled mean (9.91±5.32%) percent compared to rest of the genotypes. However, this genotype was observed to be on par with the Amoha with a pooled mean of 14.66±5.53 percent fruit infestation.

The pooled mean percent infestation was also found to vary across DAS and the significantly lowest pooled mean percent infestation of 34.46±7.45 was recorded at 45 DAS. The pooled mean percent infestation of fruit was significantly highest at 60 and 75 DAS with means of 50.75±3.87 and 36.50±2.48 percent respectively, however, statistically no significant difference was observed between 60 and 75 DAS. Table. 1 [13].

The mean percent infestation of fruit was found to be non-significant between the interactions of genotypes and DAS. However, relatively maximum percent infestation was noticed at 60 DAS for most of the genotypes screened during the course of study.

The percent infestation of fruits varied significantly between genotypes. The highest percent fruit infestation was reported in the genotype, Vijayawad local (78.27%) and this was followed by Sureka (59.79%) and JL-5 (50.99%).While the significantly lowest percent fruit infestation was recorded in the genotypes, KRCCH-1 (9.91%), Amoha (14.66%) and the genotypes with moderate percent fruit infestation. The variation in percent infestation is attributed to the biophysical and biochemical traits of the fruits of the genotypes. The findings of the present investigation are in line with the findings in bitter gourd table. 1 [3].

The percent infestation of fruits also varied across the age of the fruits, the lowest percent infestation of fruits was recorded at initial growth of the fruits (34.46% at 45 DAS). The percent infestation swelled exponentially at 60 DAS (50.75%) and again the infestation level declined at 75 DAS (36.50%). The results clearly explained that the fruits of 15 days old are more preferred by the fruit fly adults for infestation. Similar results were reported in ridge gourd [7].

The percent fruit infestation was significantly different between the genotypes at different stages of development. However, most of the genotypes recorded maximum percent fruit infestation at 60 DAS compared to 45 and 75 DAS. Indicating the favourable stages of infestation.

Table 1: The distribution of percent infestation of fruit by fruit fly, *B. cucurbitae* across genotypes of ridge gourd and across age

Genotypes	45DAS	60DAS	75DAS	Pooled mean
Amoha	0.00±0.0 (0.00±0.00)	22.92±10.41 (27.98±7.27)	21.05±5.26 (27.14±3.72)	14.66±5.53 (18.37±6.18)^{ab}
Arabhavi local	0.00±0.0 (0.00±0.0)	66.67±33.33 (62.63±27.36)	23.64±3.63 (29.02±2.45)	30.10±15.07 (30.55±13.46)^{abc}
Arka sumeet	16.67±16.66 (17.63±17.63)	41.41±14.14 (39.83±8.35)	35.29±0.00 (36.44±0.00)	31.12±7.74 (31.30±6.66)^{abc}
Chintamani local	50.00±50.00 (45.00±45.00)	31.67±1.66 (34.23±1.02)	38.95±1.25 (38.49±0.73)	40.14±13.35 (39.24±11.79)^{abc}
Gadag local	50.00±50.00 (45.00±45.00)	45.83±4.16 (42.60±2.39)	43.05±0.94 (41.01±0.54)	46.30±13.01 (41.01±0.54)^{abcd}
JL-5	66.67±33.33 (41.01±0.54)	68.75±31.25 (63.88±26.11)	17.56±6.44 (24.40±4.93)	50.99±15.93 (50.31±12.81)^{cd}
Kadahatti local	50.00±50.00 (45.00±45.00)	52.68±9.82 (46.57±5.67)	39.29±3.57 (38.80±2.09)	47.32±13.44 (43.45±11.81)^{abcd}
Kolar local	0.00±0.00 (0.00±0.00)	43.75±6.25 (41.38±3.61)	48.08±1.92 (43.89±1.10)	30.61±9.85 (28.42±9.05)^{abc}
KRCCH-1	0.00±0.00 (0.00±0.00)	12.50±12.50 (15.00±15.00)	17.22±10.55 (23.38±8.42)	9.91±5.32 (12.79±6.20)^{a}
Mudigere local	0.00±0.00 (0.00±0.00)	49.43±13.06 (44.66±7.57)	51.32±1.31 (45.75±0.75)	33.58±11.15 (30.13±9.73)^{abc}
Naga	31.25±31.25 (26.12±26.11)	63.07±0.57 (52.58±0.33)	26.48±8.30 (30.69±5.45)	40.27±11.06 (36.46±8.61)^{abc}
Parabhani padmini	50.00±50.00 (45.00±45.00)	62.50±12.50 (52.50±7.50)	20.20±2.20 (26.68±1.44)	43.23±15.50 (41.39±12.74)^{abcd}
Pusanasdar	55.71±15.71 (48.45±9.22)	80.56±2.77 (63.88±2.01)	33.44±1.85 (35.31±.12)	56.57±9.55 (49.22±5.77)^{bcd}
RGM-11	0.00±0.00 (0.00±0.00)	48.08±1.92 (43.89±1.10)	54.09±10.61 (47.40±6.14)	34.06±11.17 (30.43±9.77)^{abc}
Sureka	100.00±0.00 (90.00±0.00)	39.29±10.71 (38.65±6.34)	40.07±22.42 (38.53±13.69)	59.79±14.24 (55.73±11.51)^{cd}
TorilongKrisnha	50.00±50.00 (45.00±45.00)	48.48±15.15 (44.08±8.82)	43.912.24 (41.49±1.29)	47.4713.55 (43.52±11.86)^{abcd}
Vijay local	0.00±0.00 (0.00±0.00)	60.93±8.29 (51.41±4.90)	43.75±6.25 (41.38±3.61)	34.89±11.78 (30.93±10.07)^{abc}
Vijayawad local	100.00±0.00 (90.00±0.00)	75.00±25.00 (67.50±22.50)	59.80±6.86 (50.71±4.02)	78.27±9.98 (69.40±9.30)^{d}
Pooled mean	34.46±7.45 (31.10±6.68)^{a}	50.75±3.87 (46.29±2.99)^{b}	36.50±2.48 (36.70±1.56)^{b}	

Figures in parentheses are Arc sin√% values

Figures with same alphabet in the pooled mean column and pooled mean row are not significantly different from each other following DMRT post hoc test,

DAS: Days after sowing

Genotypes: $F_{17,54}$=2.31; *p*<0.01, DAS: $F_{2,54}$=5.63; *P*<0.006,

Genotypes X DAS:$F_{34.54}$=1.35; *P*>0.163

Distribution of immature stages of fruit fly, *B. cucurbitae* across the genotypes of ridge gourd

The number of eggs and maggots per fruit was recorded for all the genotypes screened during the course of study at 60 DAS. The mean (±SE) number of eggs per fruit was found to vary significantly across the genotypes screened during the course of study ($F_{17,18}$=270.52; *p*<0.001) (Fig. 1a). The mean (±SE) number of eggs per fruit was found to be significantly lowest in the genotype, KRCCH-1 with mean (±SE) of 5.37±1.21 eggs per fruit. However, KRCCH-1 was observed to be on par with Arabhavi local, Amoha and JL-5 with means (±SE) of 5.63±1.28, 6.00±1.43, 6.13±1.35 and 6.25±1.13 eggs per fruit, respectively and these genotypes were not significantly different from one another. The genotypes, RGM-11 recorded significantly highest mean (±SE) number of eggs per fruit (27.13±1.11) compared to rest of the genotypes screened. This was followed by Vijayawad local and Chintamani local with means (±SE) of 24.88±1.34 and 23.87±1.33 eggs per fruit, respectively and these were on par with each other. The mean (±SE) number of maggots per fruit was found to vary significantly across the genotypes screened during the course of the ivestigation ($F_{17,18}$=255.59; *p*<0.001) (Fig 1b). The genotype, registered significantly lowest mean (±SE) number of maggots per fruit with mean (±SE) of

3.00±0.85 maggots per fruit. This was on par with Arabhavi local, KRCCH-1, Amoha and JL-5 with means (±SE) of 3.25±0.83, 3.25±0.81, 3.38±0.95 and 4.13±1.04 maggots per fruit respectively. Significantly, highest mean (±SE) number maggots per fruit was observed in RGM-11 with mean (±SE) of 23.25±1.37 compared to the other genotypes. This genotype was followed by Vijayawad local and Chintamani local with means (±SE) of 20.5±1.42 and 20.25±1.41 maggots per fruit, respectively. However, they were statistically on par with each other.

The distribution of mean (±SE) number of immatures was found to vary significantly across the genotypes screened during the course of study ($F_{17,18}$=317; p<0.001) (Fig. 1c). The mean number (±SE) of immature was found to be significantly lowest for the genotypes, KRCCH-1, Arabhavi local, and Amoha with means (±SE) of 8.63±1.95, 8.88±2.05, 9.13±2.18 and 9.38±2.33 immatures per fruit, respectively compared to rest of the genotypes and statistically no significant difference was found between these genotypes. Further these were also on par with JL-5 with mean (±SE) of 10.38±1.77. Statistically highest mean (±SE) number of immatures were recorded for the genotype, RGM-11 with mean (±SE) of 50.37±2.32 immatures per fruit compared to all other genotypes followed by the genotypes, Vijayawad local and Chintamani local with means (±SE) of 45.37±2.65 and 44.13±2.65 immatures per fruit, respectively and were on par with each. Fig 1.

An attempt was made to know the distribution of immatures of fruit fly across the genotypes of ridge gourd at 60 DAS. The lowest egg load was recorded in the genotypes, KRCCH-1 (5.37), Arabhavi local, Amoha (6.00), Parabhani padmini (6.13) and JL-5 (6.25). Whereas, the fruits of RGM-11 (27.13), Vijayawad local (24.88) and Chintamani local (23.87) recorded with the highest number of fruit fly eggs. Similarly, the number of maggots per fruits also varied significantly across the genotypes of ridge gourd. The number of maggots per fruit was significantly lowest in Arabhavi local (3.25), KRCCH-1 (3.25), Amoha (3.38) and JL-5 (4.13) and highest was observed in RGM-11 (23.25), Vijayawad local (20.50), Chintamani local (20.25). In the same way, total immatures (eggs+larvae) per fruit also varied significantly across the genotypes, the lowest immature stages were observed in KRCCH-1 (8.63), Arabhavi local (8.88), Parabhani Padmini (9.13) and Amoha (9.38) compared to rest of the genotypes. Whereas, the fruits of RGM-11 (50.37), Vijayawad local (45.37) and Chintamani local (44.13) recorded highest load of immature stages per fruit.

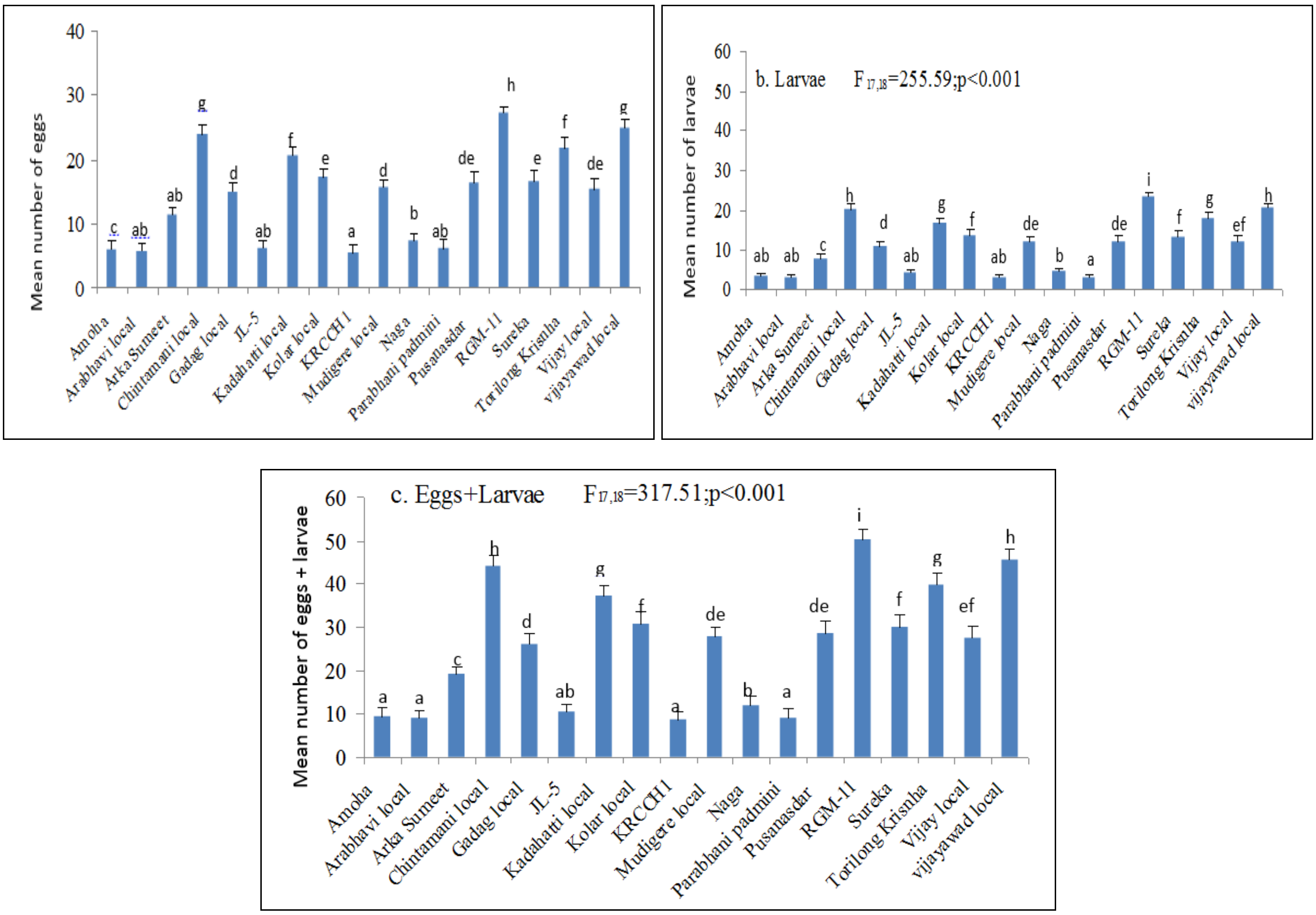

Fig 1: Distribution of mean (±SE) number of eggs, larvae and eggs + larvae across the genotypes of ridge gourd at 60 DAzzS

Study of the biophysical parameters of ridge gourd genotypes

The biophysical traits of fruits such as fruit length, fruit diameter, toughness of the fruit, depth of ridges, thickness of ridges and pericarp thickness were recorded at 60 DAS for the marketable fruits of all the genotypes to know the variation of biophysical traits across the screened genotypes (Table 2).

The mean length of the marketable fruit was found to vary significantly across the genotypes ($F_{17,\ 72}$=24.89; p<0.001) (Table 2). The genotype, Sureka registered significantly highest mean (±SE) length (31.6±0.62cm) compared to remaining genotypes, followed by Naga, RGM-11 and with mean (±SE) length of 25.10±0.50, 23.60±0.84 and 23.40±0.79 cm, respectively latter two genotypes being on par with each other. The mean (±SE) length of the fruit was found to be significantly less for the genotype Vijay local with mean (±SE) of 10.65±0.21 cm compared to other genotypes screened. This genotype was followed by JL-5, Totilong Krishna and Mudigere local with mean (±SE) length of 11.80±0.51, 12.90±1.20 and 13.60±1.17 cm respectively. However, these were on par with each other. (Table 2).

The diameter of marketable fruit in mm was documented and was found to be significantly different between the genotypes ($F_{17,72}$=21.13; p<0.001) (Table 2). The genotype, Gadag local registered significantly maximum mean (±SE) diameter with mean (±SE) of 43.76±0.95 mm compared to rest of the genotypes. However, Gadag local was found to be on par with Sureka, Arka Sumeet and KRCCH-1 having the diameter means (±SE) of 42.24±0.63, 42.01±2.77 and 40.71±0.59 mm, respectively. Similarly, significantly lower mean (±SE) diameter was documented for the fruits of Torilong Krishna with a mean of 25.00±0.65mm. Torilong Krishna was also found to be on par with Vijay local and Kolar local with means (±SE) of 27.38±0.46 and 27.20±0.73 mm, respectively. (Table 2).

The toughness of the fruit was recorded using Penetrometer and expressed in kg/cm^2. The mean (±SE) toughness of the fruit was found to vary significantly across the genotypes ($F_{17,72}$=8.36; p<0.001) (Table 2). The mean (±SE) toughness of the fruit was significantly superior for the genotype, Kadahatti local with mean (±SE) of 8.24±0.21 kg/ cm^2 compared to rest of the genotypes. This was followed by the genotypes, JL-5 and Vijay local with mean (±SE) toughness of 7.78±0.32 and 7.25±0.14 kg/cm^2 respectively, however, these genotypes were on par with each other. The genotype, Torilong Krishna (4.48±0.18 kg/cm^2), registered significantly lowest mean (±SE) toughness compared to other screened genotypes. However, this genotype was found to be on par with Chintamani local, Pharabhani padmini, RGM-11 and Pusa Nasdar with mean toughness of 4.99±0.24, 5.10±0.88, 5.52±0.23 and 5.53±0.34 kg/ cm^2, respectively. (Table 2).

The mean (±SE) depth of the ridges recorded for marketable fruits varied significantly among the genotypes ($F_{17,72}$=19.63; p<0.001) (Table 2). The mean (±SE) depth of the ridge was found to significantly more for the genotype, Arabhavi local (3.58±0.1 mm), which was on par with Vijayawad local (2.60±0.10 mm). These genotypes were followed by Mudigere local, Kolar local, Pusa Nasdar, Kadahatti local, Arka Sumeet and RGM-11, with means (±SE) of 2.58±0.05, 2.53±0.11, 2.44±0.09, 2.39±0.19, 2.37±0.23 and 2.33±0.09 mm respectively. However, all these genotypes were on par with each other. (Table 2).

The mean (±SE) thickness of the ridges varied significantly among the genotypes ($F_{17,72}$= 6.37; p<0.001) (Table 2). The genotype, Pusa Nasdar had significantly thickest ridges with mean of 3.81±0.96 mm compared to rest of the genotypes. This genotype was followed by Kadahatti local, Mudigere local and Sureka with mean (±SE) of 2.50±0.10, 2.45±0.08 and 2.43±0.12 mm, respectively and no significant difference was noticed between these genotypes. Further, these genotypes were found to be on par with KRCCH-1, Vijayawad local, Kolar local and Arabhavi local with means (±SE) of 2.42±0.17, 2.42±0.07, 2.41±0.10 and 2.41±0.06 mm, respectively. On contrary, Parabhani Padmini registered significantly lowest thickness of ridges of fruits with mean (±SE) thickness of 1.07±0.03 mm compared to other genotypes screened. This was followed by the genotypes Amoha, Torilong Krishna and Vijay local with mean (±SE) of 1.43±0.07, 1.48±0.04 and 1.51± 0.08 mm, respectively and no significant difference was noticed between them.

The pericarp thickness among the genotypes to exhibited statistically significant differences ($F_{17,72}$=15.89; p<0.001) (Table 2). The mean (±SE) pericarp thickness was found to be significantly highest for the genotype Kolar local (2.99±0.19) compared to other genotypes studied, however, this genotype was found to be on par with KRCCH-1 (2.78±0.07mm) and RGM-11 (2.65±0.11mm). The genotype, Chintamani local registered significantly lowest pericarp thickness with mean (±SE) of 1.49±0.10 mm and this were followed by Amoha, Vijay local, Arka Sumeet and Gadag local with means (±SE) of 1.53±0.06, 1.54±0.12, 1.55±0.08, 1.66±0.05 and 1.76±0.18 mm, respectively and no significant difference were noticed between these genotypes. The diameter also varied significantly between genotypes of ridge gourd. The genotype, Gadag local yielded marketable fruits (43.76 mm), which were significantly larger in diameter compared to rest of the genotypes. This was followed by Sureka (42.24 mm), Arka Sumeet (42.01 mm) and KRCCH-1 (42.01 mm) yielded medium sized marketable fruits. Similarly, marketable fruits with a lesser diameter were harvested from the genotypes Torilong Krishna (25.00 mm) Kolar local (27.20 mm) and Vijay local (27.38 mm). The results of the present study are in line with the findings of in bitter gourd [14] (Table 2).

The depth of the ridges is not constant for all the genotypes of ridge gourd and it is one of the vital traits influencing the penetration of ovipositor and thus oviposition by adult female fruit fly. Present study, the depth of the ridges varied significantly between the genotypes of ridge gourd. The depth of ridges was more in genotypes Arabhavi local (3.58 mm) and Vijayawad local (2.60 mm) compared to other genotypes. The genotypes, Parabhani Padmini (1.23 mm), Amoha (1.31 mm), Torilong Krishna (1.43 mm) and Vijay local (1.46) yielded marketable fruits with smaller depth of the ridge. Table:2.

The toughness of the fruit is directly related to the penetration of the adult fruit fly ovipositor into the fruits of ridge gourd. The toughness is not uniform for all the genotypes and also across the age of the fruit. The toughness of the fruit varied significantly across the genotypes screened. The Kadahatti local (8.24 kg/cm^2) yielded the fruits with high toughness than other genotypes. However, JL-5 (7.78 kg/cm^2) and Vijay local (7.25 kg/cm^2) had also yielded fruits with medium toughness and can be comparable with Kadahatti local genotype. The toughness of the fruits was significantly low for the genotypes, Torilong Krishna (4.48 kg/cm^2), Chinatamani local (4.99 kg/cm^2), Pharabhani Padmini (5.10 kg/cm^2), RGM-11 (5.52 cm^2) and Pusa Nasdar (5.53 kg/cm^2). Similar variation in the toughness of the fruits was recorded in bitter gourd by [15].

Thickness of the marketable ridge gourd fruits varied significantly from genotypes to genotypes. The fruits with a thickest ridges was noticed in genotype, Pusa Nasdar (3.81 mm) compared to other genotypes. Fruits with medium ridge thickness were recorded in Kadahatti local (2.50 mm), Mudigere local (2.45 mm) and Sureka (2.43 mm).The genotypes, Parabhani padmini (1.07mm), Amoha (1.43 mm), Torilong Krishna (1.48 mm) and Vijay local (1.51) had yielded fruits with a significantly lowest thickness of ridges. The results of the findings are well matched with findings made in bitter gourds [8]. Table:2.

The pericarp thickness of marketable fruits was recorded for all the genotypes and there was statistically significant difference between the genotypes. The kolar local (2.99 mm), KRCCH-1 (2.78 mm) and RGM-11 (2.65 mm) had yielded fruits with highest pericarp thickness compared to other genotypes. The genotype, Chintamani local (1.49 mm), Amoha (1.53), Vijay local (1.54 mm), Parabhani Padmini (1.55 mm), Arka Sumeet (1.66 mm) and Gadag local (1.76 mm) yielded fruits with lowest pericarp thickness. Similar variation in the thickness of pericarp between the genotypes was documented in bitter gourd [4]. Table:2.

Table 2: The distribution of biophysical traits of fruits of ridge gourd across genotypes

Genotypes	Fruit length (cm)	Fruitwidth (mm)	Fruit toughness (kg/cm^2)	Depth of ridges (mm)	Thickness of ridges (mm)	Pericarp thickness (mm)
Amoha	18.7±0.88^{e}	29.07±0.45^{i}	5.62±0.29^{fg}	1.31±0.07^{ef}	1.42±0.07^{de}	1.53±0.06^{g}
Arabhavi local	15.60±0.94^{defgi}	34.25±1.14^{efg}	5.91±0.13^{efg}	3.58±0.11^{a}	2.40±0.06^{bc}	2.27±0.16^{cde}
Arka Sumeet	20.45±0.48^{cd}	42.01±2.77^{ab}	6.75±0.50^{bcde}	2.37±0.23^{bc}	1.60±0.31^{cde}	1.66±0.05^{g}
Chintamani local	17.60±2.09^{defg}	29.91±1.02^{hi}	4.99±0.24^{gh}	2.31±0.11^{bc}	1.71±0.10^{bcde}	1.49±0.10^{g}
Gadag local	17.40±0.95^{defg}	43.76±0.95^{a}	5.50±0.26^{fgh}	2.20±0.10^{bc}	1.73±0.06^{bcde}	1.76±0.18^{fg}
JL-5	11.80±0.51^{jk}	30.96±0.50^{ghi}	7.78±0.32^{ab}	2.01±0.24^{cd}	2.09±0.12^{bcd}	2.08±0.11^{ef}
Kadahatti local	14.50±1.17^{ghij}	37.54±2.05^{cde}	8.24±0.21^{a}	2.39±0.19^{bc}	2.50±0.10^{b}	2.26±0.05^{de}
Kolar local	18.10±1.56^{def}	27.20±0.73^{ij}	7.01±0.31^{bcd}	2.53±0.11^{b}	2.41±0.10^{bc}	2.99±0.19^{a}
KRCCH-1	14.10±0.82^{hij}	40.71±0.59^{abc}	6.91±0.33^{bcde}	1.60±0.09^{ef}	2.42±0.17^{bc}	2.78±0.07^{ab}
Mudigere local	13.60±1.17^{ijk}	38.87±1.46^{bcd}	6.58±0.30^{cdef}	2.58±0.05^{b}	2.45±0.08^{b}	2.52±0.07^{bcd}
Naga (East-west)	25.10±0.50^{b}	33.35±1.58^{fgh}	5.93±0.36^{efg}	1.71±0.07^{de}	1.79±0.05^{bcde}	2.43±0.09^{cde}
ParabhaniPadmini	23.40±0.79^{bc}	33.42±0.90^{fgh}	5.10±0.88^{gh}	1.23±0.13^{f}	1.07±0.03^{e}	1.55±0.08^{g}
Pusa Nasdar	14.80±1.53^{ghij}	36.56±1.53^{def}	5.53±0.34^{fgh}	2.44±0.09^{bc}	3.81±0.96^{a}	2.45±0.15^{cde}
RGM-11	23.60±0.84^{bc}	33.24±1.05^{fgh}	5.52±0.23^{fgh}	2.33±0.09^{bc}	2.20±0.08^{bcd}	2.65±0.11^{abc}
Sureka(Mahyco)	31.60±0.62^{a}	42.24±0.63^{ab}	5.83±0.11^{efg}	2.18±0.13^{bc}	2.43±0.12^{b}	2.22±0.12^{de}
Torilong Krisnha	12.90±1.20^{ijk}	25.00±0.65^{j}	4.48±0.18^{h}	1.43±0.08^{ef}	1.48±0.04^{de}	2.42±0.09^{cde}
Vijay local	10.65±0.21^{k}	27.38±0.46^{ij}	7.25±0.14^{abc}	1.46±0.12^{ef}	1.51±0.08^{de}	1.54±0.12^{g}
Vijayawad local	18.95±1.18^{de}	35.74±0.61de^{f}	5.86±0.24^{efg}	2.60±0.10^{ab}	2.42±0.07^{bc}	2.28±0.08^{cde}
$F_{17,72}$	24.89; P<0.001	21.13; P<0.001	8.36; P<0.001	19.63; P<0.001	6.37; P<0.001	15.89; P<0.001
S.Em±	5.34	5.61	1.00	0.58	0.62	0.46
CD	15.05	15.83	2.82	1.65	1.75	1.31

The figures with same alphabet in the columns are not significantly different from each other following DMRT post ho

The correlation between biophysical traits of fruit and percent fruit infestation in ridge gourd genotypes

Correlation and regression analysis between biophysical fruit traits and percent fruit infestation, revealed that the fruit length (r=0.32; p<0.002), fruit width (r=0.30; p<0.004), number of oviposition punctures per fruit (r=0.38; p<0.000) exhibited a significant positive correlation with percent fruit infestation. Whereas, the fruit toughness (r=-0.31; p<0.003), depth of the longitudinal ridge (r=-0.28; p<0.009), thickness of the longitudinal ridges (r=-0.30; p<0.004), pericarp thickness (r=-0.23; p<0.032) showed a significant negative correlation with the percent fruit infestation. Similarly, the fruit length (p=0.065; p<0.541), thickness of longitudinal ridges (r=0.135; p<0.205) and pericarp thickness (r=0.112; p>0.292) had non-significant correlation with percent fruit infestation, but showed positive trend with immature (eggs+lavae) density per fruit. Whereas, the fruit width (r=-0.064; p>0.552), depth of the longitudinal ridges (r=-0.21; p<0.046), toughness of the fruit (r=-0.230; p<0.032) and number of oviposition punctures (r=-0.151; p<0.156) exhibited a negative relationship with the density of immature stages per fruit. However, fruit width and oviposition punctures were non-significant and depth of longitudinal ridges, toughness of fruit and oviposition punctures showed significant correlation with a density of immature stages per fruit (Table2; Fig. 2and 3).

Further, step-wise multiple regression analysis was performed to know the influence of biophysical traits on fruit infestation by fruit fly using statistiXL analysis tool. The analysis indicated that the biophysical fruit traits explained 100 percent of the total variation in fruit fly infestation. The fruit width, fruit, length, depth of longitudinal ridge and toughness explained 89.6 percent of the total variation in fruit infestation by fruit fly. The maximum variation in fruit infestation was explained by width of the fruit (31.50%) followed by depth of longitudinal ridges (24.31%), length (17.36%) and toughness of the fruit. Other two explained only less than 11 percent total variation in fruit infestation by fruit fly (Table 3). These can be used as marker traits for selection of fruit fly resistance genotypes of ridge gourd.

In conclusion, K.R.C.C.H-1 and Amoha, which were identified as source of resistance for melon fruit fly, *B. cucurbitae* can be used in IPM program for melon fruit fly and breeding program of ridge gourd. Among determined biophysical fruit traits, fruit toughness, fruit-diameter and number of longitudinal ribs can be used as marker traits to induce resistance against melon fruit fly in the genotypes of ridge gourd.

Table 3: Step-wise regression models, showing coefficient of determination (R^2) values of different biophysical fruit traits for mean percent fruit infestation by fruit fly

Regression models	F- test	R^2 in percent	Percent role of each traits
$y=-4.19+1.46X_1$	$F_{1,88}=8.67$	31.25	31.25
$y=-11.20+1.01X_1+1.26X_2$	$F_{2,87}=7.11$; $p<0.001$	48.61	17.36
$y=11.15+1.19X_1+0.96X_2-10.82X_3$	$F_{3,86}=7.37$; $p<0.001$	72.91	24.31
$y=21.28+1.29X_1+0.84X_2-6.05X_3-10.69X_4$	$F_{4,85}=6.63$; $p<0.001$	82.63	9.72
$y=54.51+1.25X_1+0.50X_2-4.29X_3-7.4X_4-5.86X_5$	$F_{5,84}=6.72$; $p<0.001$	99.31	16.67
$y=57.11+1.23X_1+0.50X_2-4.26X_3-6.76X_4-5.84X_5-1.65X_6$	$F_{6,83}=5.45$; $p<0.001$	100	0.69

X_1: Fruit width in mm, X_2: Fruit length in cm, X_3: Depth of longitudinal ridge, X_4: Thickness of longitudinal ridge, X_5: Toughness of fruit and X_6: Thickness of perica

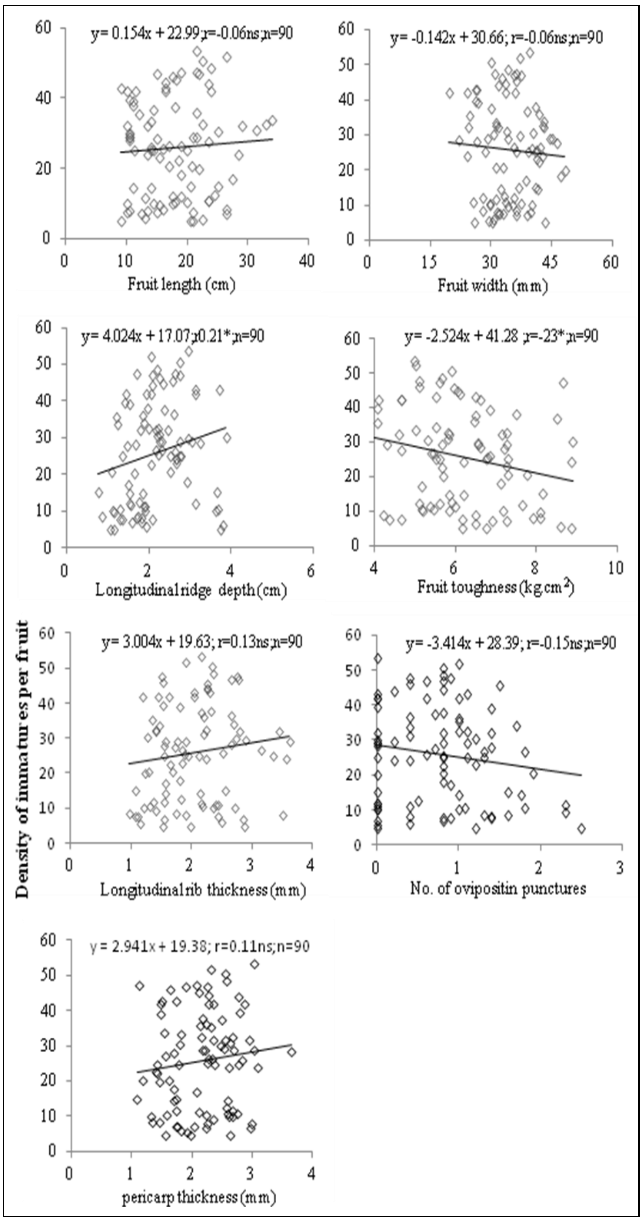

Fig 2: The correlation coefficients and individual regression models of biophysical traits of fruits of ridge gourd genotypes with density of immatures of per fruit fly per fruit

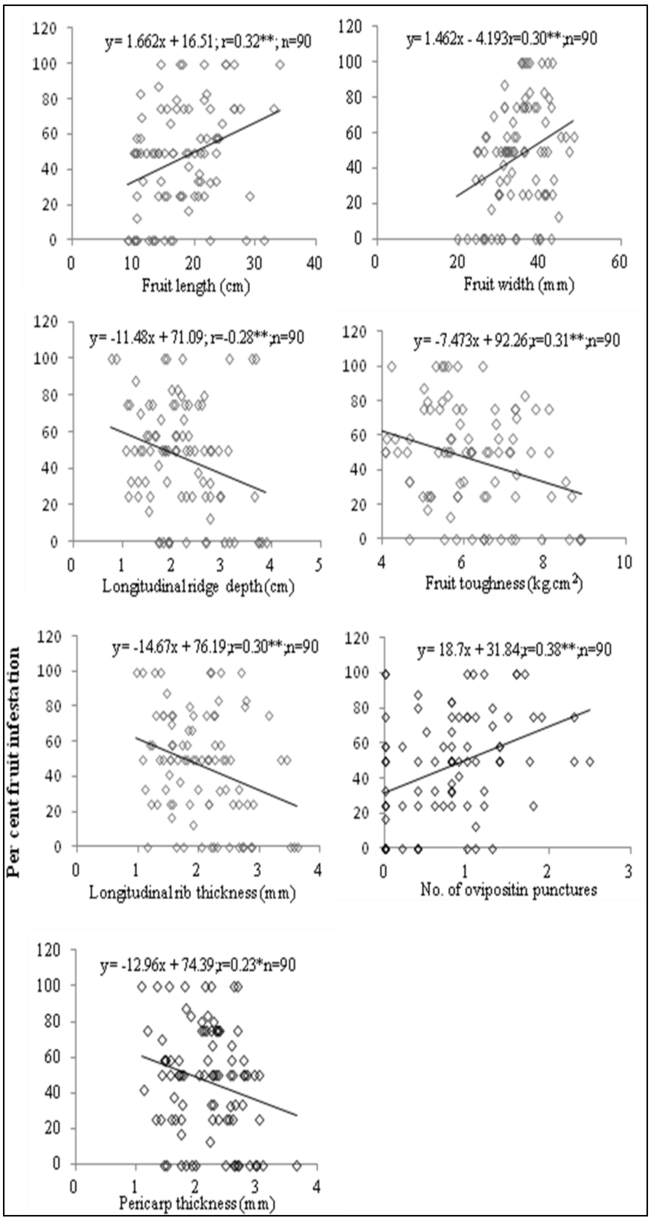

Fig 3: The correlation coefficients and individual regression models of biophysical traits of fruits of ridge gourd genotypes with percent fruit infestion by fruit fly, *B. cucurbitae*

Table 4: Step-wise regression models, showing coefficient of determination (R^2) values of different biophysical fruit traits for mean percent fruit infestation by fruit fly

Regression models	F- test	R^2 in percent	Percent role of each traits
$y=-4.19+1.46X_1$	$F_{1,88}=8.67$	31.25	31.25
$y=-11.20+1.01X_1+1.26X_2$	$F_{2,87}=7.11$; $p<0.001$	48.61	17.36
$y=11.15+1.19X_1+0.96X_2-10.82X_3$	$F_{3,86}=7.37$; $p<0.001$	72.91	24.31
$y=21.28+1.29X_1+0.84X_2-6.05X_3-10.69X_4$	$F_{4,85}=6.63$; $p<0.001$	82.63	9.72
$y=54.51+1.25X_1+0.50X_2-4.29X_3-7.4X_4-5.86X_5$	$F_{5,84}=6.72$; $p<0.001$	99.31	16.67
$y=57.11+1.23X_1+0.50X_2-4.26X_3-6.76X_4-5.84X_5-1.65X_6$	$F_{6,83}=5.45$; $p<0.001$	100	0.69

X_1: Fruit width in mm, X_2: Fruit length in cm, X_3: Depth of longitudinal ridge, X_4: Thickness of longitudinal ridge, X_5: Toughness of fruit and X_6: Thickness of pericarp

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