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Location, Fertility and Mean Room Temperature Effect on Resistance Potential of Field Pea Genotypes for Adzuki Bean Beetle (*Collosobruchus chinensis* L.) in Ethiopia

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Abstract **– Adzuki bean beetle (*Collosobruchus chinensis* L.) is one of the devastating storage pests of field pea (*Pisum sativum* L.) crop that serves as a stable food in Ethiopia. In direct increments of insect pest due to an application of organic and in organic fertilizers for yield increment also another challenge. This study was focuses on resistance potential of field pea genotypes across location and different fertility levels. The reaction of 35 field pea genotypes were evaluated with no choice condition to *C. chinensis* infestation in the laboratory with RCBD with three replications 2017/18 growing season. The combined ANOVA over the two locations showed significant difference at (P<0.01 and P<0.05) for most characters regardless of the soil fertility levels, genotypes except for thousand seed weight and proportion of seed coat weight (Tables 3). Traits like; number egg, date of adult emergency, number of adult emerged, adult recovery, mean number of hole per seed, susceptibility index and thousand seed weight, proportion of seed coat, percentage of seed weight loss showed highly significant (p < 0.01) differences due to the application of fertility levels (table 5). The regressions among seed weight loss (%) and considered field pea genotypes based on fertility levels were showed similar distribution even if it was vary in magnitude. Interrelations between the traits revealed strong associations in a number of cases both in positive and negative directions across location and fertility levels. Nearly all traits were responsive to the location difference (table 5) because of daily temperature variation. Genotypes with better seed size revealed shortest media development; while the longest media developments were recorded for small seeded one. This insect had the capacity to infest and develop on all field pea genotypes tested, however with significant differences among locations and fertility levels that stemmed the existence of moderately resistance field pea genotypes those can be used with other integrated pest management practices in breeding system.**

Keywords **– Adzuki Bean Beetles, Fertility, Genotypes.**

I. INTRODUCTION

Field pea (*Pisum sativum* L.) with other food legumes covers about 11-15% of the total 6 -7 million hectares of crop areas in Ethiopia and is the 3rd most important stable food legume among the highland pulses in rural Ethiopia (CSA, 2018). It is one of the major pulses grown in the highlands (1800-3000 m.a.s.l.) of Ethiopia, were the need for chilling temperature is satisfied. Especially this crop is very much important in some parts of east showa, low lands of Arsi basin, highlands of Arsi and South Eastern Ethiopia since it fetches cash for the farming community and also serves as rotational crop which play great role in controlling disease epidemics in areas were cereal mono-cropping is abundant (CSA, 2018). It also plays a significant role in soil fertility restoration as a suitable rotation crop that fixes atmospheric Nitrogen (Jarso *et al*., 2006).

Even though the importance's of this crop were clearly known in the country's agriculture, its average seed yield has remained very low and highly exposed to high storage losses by adzuki bean beetle (*colloso bruchus chinensis* L.) that might be resulted from the familiarity of Ethiopian farmers to different Cultural methods like crop fertilization can affect susceptibility of plants to insect pests by altering plant tissue nutrient levels that directly related to the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of soils. This insect damage is irreversible and direct on the grain (Kananji, 2007). Due to the adzuki bean beetle' high fertility, ability to re-infest and short generation times, even low initial infestation rates can lead to tremendous damage (Yamane, 2013). Adzuki bean beetle causes overall seed weight loss, loss of seed viability and altered nutritional quality due to the presence of insect frass, excrement and dead insects in and on the seed. A single beetle is able to cause 3.5% weight loss in some legumes crop like cowpea seeds (Tembo *et al.*, 2016).

In Ethiopia bruchid (adzuki bean beetle) losses become a big issue for most stable legumes crops because most subsistence farmers rely on traditional storage structures under the same roof, which are highly vulnerable to this insect attack and lead to cross infestations among stored products which are sharing a common pest (Naito, 1999). This makes the farmers in significant grain price discounts (Mishili *et al.*, 2011) and thus forcing farmers to sell legumes within 2-3 months after harvest, so as not to incur total grain losses (Ebinu *et al.*, 2016).

In terms of control, use of storage pesticides is recommended; however, the method is expensive for resource-poor farmers, toxic to environment and often leads development of pesticide resistance (Mulungu *et al.*, 2007). For this reason, use of resistant varieties is most preferable as part of an integrated pest management strategy to reduce losses and maintain grain quality. From the farmer's perspective, the use of resistant cultivars may represent one of the simplest and most convenient methods of bruchid control (Kananji, 2007). So this study was mainly focus on the effects of location and different fertility levels to resistance potential of field pea genotypes in Ethiopia.

II. Material and Methods

Table 1. Location and descriptions of both locations.

Location	Geographic position		Altitude	Temperature(° c)		Rain Fall (mm)	Relative Humidity
	Latitude	Longitude		Min	Max		
Kulumsa	08°00'02"N	39°09'11"E	2210	10	22.4	811	60.6
Melkasa	08°24'N	39°21'"E	1550	14	28.4	763	43

Sources: *http://www.eiar.gov.et*

Table 2. List of field pea accession used in the study.

SN	Accessions	Source/Locality	Altitude	Zone	Year of Released/G.C	Region
1	fpcoll-1/07	Metatera	1600	North Wollo	-	Amhara
2	fpcoll-8/07	Dikowuha	1878	North Wollo	-	Amhara
3	fpcoll-9/07	Dikowuha	1870	North Wollo	-	Amhara
4	fpcoll-10/07	Dikowuha	1878	North Wollo	-	Amhara
5	fpcoll-11/07	Walidia	1937	North Wollo	-	Amhara
6	fpcoll-12/07	Jemedo Mariam	1470	South Tigray	-	Tigray
7	fpcoll-13/07	Keyi amba	1470	South Tigray	-	Tigray

SN	Accessions	Source/Locality	Altitude	Zone	Year of Released/G.C	Region
8	fpcoll-14/07	Luchuberet	1472	South Tigray	-	Tigray
9	fpcoll-15/07	Jemedo Mariam	1470	South Tigray	-	Tigray
10	fpcoll-32/07	Daguyat	2500	South Tigray	-	Tigray
11	fpcoll-33/07	Daguyat	2500	South Tigray	-	Tigray
12	fpcoll-34/07	Kidana	1450	South Tigray	-	Tigray
13	fpcoll-35/07	Hiziba	2400	South Tigray	-	Tigray
14	fpcoll-36/07	Endamohoni	2200	South Tigray	-	Tigray
15	Mahandarfer	HARC/KARC	-	-	1979	-
16	Burkitu	HARC/KARC	-	-	2009	-
17	Adi	HARC/KARC	-	-	1995	-
18	Tegegnech	HARC/KARC	-	-	1994	-
19	Markos	HARC/KARC	-	-	1995	-
20	Gume	HARC/KARC	-	-	2006	-
21	Bursa	HARC/KARC	-	-	2015	-
22	Bilalo	HARC/KARC	-	-	2010	-
23	Letu	HARC/KARC	-	-	2010	-
24	PDFPT p-313-010	ICARDA	-	-	-	-
25	FP PDFPT P-313-045	ICARDA	-	-	-	-
26	PDFPT P-313-086 ‘	ICARDA	-	-	-	-
27	PDFPT p-313 MILKY	ICARDA	-	-	-	-
28	PDFPT P-313-098	ICARDA	-	-	-	-
29	PDFPTp-313–HASABE	ICARDA	-	-	-	-
30	PDFPT p-313 HOLETA	ICARDA	-	-	-	-
31	PDFPT p-313-089	ICARDA	-	-	-	-
32	PDFPT p-313-067	ICARDA	-	-	-	-
33	PDFPT p-313-003	ICARDA	-	-	-	-
34	EH-08086-1	Holeta	2200	-	-	-
35	EK-08021-5	Kulumsa	2100	-	-	-

Experimental Field Layout and Management

Treatments Seeds of field pea genotypes were grown in 2017/18 main cropping season under three different soils fertility levels i.e. with phosphorus plus rhizobium, only with rhizobium and with neither rhizobium nor phosphorus. The genotypes were laid independently on their plot areas of (4m x 0.8m) with 80 seeds per each four rows. The spacing between rows and plants were 20cm and 5cm. Phosphorus was applied at the rate of 32g per plot (3.2 m^2) in the form 24 of triple supper phosphate (TSP) which was recommended by Negash and Mulualem (2014). An effective isolate of Rhizobium was inoculated based on 500gm/ha recommendation, which means at the rate of approximately (0.16g for 3.2m^2) of inoculums which consists a total of 320 seeds per plot (Menagesha bio-fertilizer manufacturer PLC) recommendation. All agronomic practices were applied as per its recommendation. Harvested seeds of each genotype were cleaned manually from foreign materials and adjusted to 9-10 % moisture contents and disinfected in a deep freeze at about -20 o C for a month prior to the study to eliminate any pre-storage infestation (eggs, larvae and adult bruchids) (Gemechuet *et al*., 2012; Sisay, 2018).

Mass-rearing of the Insect

Mass-rearing was conducted at Kulumsa and Melkassa Agricultural Research Center, Entomology Laboratory. The procedures based on Gemechu *et al*. (2012) recommendation on susceptible chickpea variety 'Shasho'. The beetle were introduced to each 4 kg of seeds from the susceptible variety and kept at ambient temperature and relative humidity for seven days to allow for oviposition. The parent insects were sieved out after seven days. Then the new emerged progeny was used for re-culturing and kept again at optimum condition within the susceptible variety and removed after seven days. This re-culturing was continued and after the enough number of a new emerged insect was obtained, i.e. 1-2 day old adult, unsexed insects were used for the different experiments.

Experimental Design and Infestation

The experiment was conducted under room temperature and relative humidity in a randomized complete block design with 3 replications. Since the harvested seed was cleaned and kept in cold room for one moth and disaffected from any of the insect egg. Two hundred seeds of each genotype were allocated per experimental unit (a plastic jar of 250 ml; 6 cm x 7 cm). Each jar considered as an experimental unit. The field pea genotypes were assigned to jars at random within each block. Fourteen 1-2 days old unsexed adults of Adzuki bean beetles were collected from the maintained culture and randomly selected and released in each jar. The male to female ratio in this insect was 1:1 (Lemma, 1990); it is assumed that each jar was received 7 males and 7 female with a total of fourteen (14) insect in a single jar (Gemechu *et al.*, 2012 and Sisay, 2018). Serration antennae described by Hill (1990) used as a parameter to identify the sex. For oviposit ion, adults were kept in the jars for 7 days after introduction and removed from the jars. The plastic jars containing seeds were inspected for the emergence of first progeny every day. After emergence of the first progeny is completed, the first progeny were removed from the jars for evaluation of the level of attack and loss incurred by the first progeny. Temperature and relative humidity of the room were recorded daily with the help of thermo-hygrometer until the end of the experiment to perceive the daily fluctuation.

Data Collected

Based on the total number of seeds and insect based characters the following data were recorded from each pot with their respective orders. Total number of eggs (TNE): Total number of eggs laid on the surface of seeds of each genotype was counted on a daily basis started from the 4th day to the 14th day of infestation and records were taken from each treatment Days to adult emergence (DAE): The number of days required to adult emerges was recorded on a daily basis start from the 20th day to the 32th day of infestation until adult emerged Number of adults emerged (NAE): Total number of emerged adults from each genotype was counted on a daily basis started from the 22^{th} to the day to32th day of infestation.

Susceptibility Index (SI):

Susceptibility index calculated Dobie (1977) using the formula:

$$SI = \frac{\text{Log Y}}{T} \text{ X } 100 \quad (1)$$

Where SI = Susceptibility index, Y = Number of F1 emerged adults, T = Mean developmental periods (days), estimated as the time from the middle of ovipositor period to the 50% emergence of the F1 progeny. The values of the susceptibility indices were used to rank genotype susceptibility to the bruchids into five categories according to Mensah (1986) as follows:

i. Genotypes with values from 0.0-2.5 were considered resistant genotypes (R).

ii. Genotypes with values from 2.6-5.0 were considered moderately resistant (MR).

iii. Genotypes with values from 5.1-7.5 were considered moderately susceptible (MS).

iv. Genotypes with values from 7.6-10.0 were considered susceptible (S).

v. Genotypes with values greater than 10.0 were considered highly susceptible (HS).

The Percentage of Seed Damage (PSD):

The percent damage of each genotype was calculated by separating healthy grains (without holes) from the sieved samples and used for percent damage calculations using the formula described by Khattak *et al.* (1987).

$$\text{Percentage of seed damage } = \frac{\text{Nds}}{\text{Tns}} \text{x} 100 \quad (2)$$

Where Nds = number of damaged seed, Tns = total number of seeds.

Percentage of Adult Recovery (PAR):

The actual number of adults that emerged compared with the actual number of eggs laid on the surface of seeds.

Thousand Seed Weight in Gram (TSW):

Cleaned grains sample was taken after adjusted standard moisture content (10%) from each genotype and 1000-grain seeds were counted from each sample grown under the same conditions.

Proportion of Seed Coat by Weight in Percent (PSC):

Seed coat weight as percent of total seed weight of the same genotypes grown under the same conditions were taken.

Seed Weight Loss in Gram (SWL):

The seeds were separated into damaged and undamaged categories and Weight loss was adjusted to 10% moisture content. The damaged and undamaged seeds were counted and weighed. Seed weight loss was estimated by using following equation (FAO, 1985):

Weight loss (%) $= \frac{(UNd) - (DNu)}{U(Nd+Nu)} x\ 100$ (3)

Where U = Weight of undamaged grains Nu = number of undamaged grains D = Weight of Damaged grains Nd = Number of damaged grains.

Statistical Analysis

Analysis of Variance (ANOVA)

Based on quantitatively collected data from both locations for all parameters, calculation of components of variation for quantifying differences among genotypes and genetic variation response to infestation by adzuki bean beetle in field pea was subjected to analysis of variance (ANOVA) using SAS version 9.3 statistical software package (SAS Institute, 2010). By using Hartley (1950) methods of combined analysis of variance, the homogeneity of error variance was tested using the F-max method, which is based on the ratio of the larger mean square of error (MSE) from the separate analysis of variance to the smaller mean square of error as: F-ratio= $\frac{\text{Larger MSE}}{\text{Smaller MSE}}$

As Gomez and Gomez, (1984) indicated, if the larger error mean square is not three-fold larger than the smaller error mean square, the error variance was considered homogeneous. Mean separation was made using Tukey's test at both 5% and 1% probability levels.

Separate analyses of variance were conducted to quantify the total variation among the genotypes using the following model:

$P_{ijkf} = \mu + (b/l)_{ik} + g_j + l_k + f + (gl)_{jk} + (gf)_{fj} + (glf)_{fjk} + e_{fijk}$ (4)

Where, P_{ijkf} = phenotypic observation on genotype j in block i (at location k and fertility level f) (i = 1…B, j = 1…G, k = 1…L and f = 1…f) and G, L,B and f = number of genotypes, location, block and fertility, respectively, μ = grand mean, $(b/l)_{ik}$ = the effect of block i (within location k), g_j = the effect of genotype j, l_k = the effect of location k, f = the effect of fertility f, $(gl)_{jk}$ = the interaction effect between genotype j and location k, $(gf)_{fj}$ = the interaction effect between genotype j and fertility f, $(gl)_{fjk}$ = the interaction effect between genotype j, fertility f and location k, and e_{fijk} = the residual or effects of random error. Existence of significant difference among the genotypes, locations, fertility levels and their interaction were determined using the F-test.

III. Results and Discussion

Analysis of Variance

Table 3. Mean square of combined analysis for selected traits used to assess field pea genotypes exposed to infestation by adzuki bean beetles in Ethiopia.

Characters[1]										
Mean Square	**NE**	**DAE**	**NA**	**AR (%)**	**MNHPS**	**TSW**	**PSC (%)**	**PSD (%)**	**PSWL (%)**	**SI**
Location (L)	**	**	**	**	**	NS	NS	**	**	**
Fertility (F)	**	**	**	**	**	NS	NS	**	**	**

Characters[1]										
Mean Square	**NE**	**DAE**	**NA**	**AR (%)**	**MNHPS**	**TSW**	**PSC (%)**	**PSD (%)**	**PSWL (%)**	**SI**
Genotype (G)	**	**	**	**	**	**	**	**	**	**
G × L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G × F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G × L × F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
%CV	8	5.7	11	13	12.8	0.9	2.6	23	14.7	7.3

** = highly significant (P <0.01), * = significant (P<0.05) and NS = non-significant (P>0.05). 1NE = total number of egg, DAE = days to adult emergence, NA = number of adults emerged, AR = adult recovery, MNHPS = mean number of holes per seed, TSW = Thousand seed weight, PSC = proportion of seed coat weight, PSD = percentage of seeds damage, PSWL = percentage of seed weight loss, SI = susceptibility index, CV = coefficient of variation.

The combined ANOVA over the two locations showed significant difference at (*P*<0.01 and *P*<0.05) for most characters regardless of the soil fertility levels, genotypes except for thousand seed weight and proportion of seed coat weight (Tables 3). This might be resulted due to the wider genetic variability of considered field pea accessions and/or due to the usage of different fertility amendment and/or different testing environment. This designated the genotypes selected for better resistance at one location may not display a similar relative performance at other locations for most of the trait considered that might be resulted due to the variation in temperature and relative humidity among the areas that can able to affect plant susceptibility to pests and diseases (Nandjui *et al.,* 2018). In overall, traits with significant difference may be evident that, the genotypes were responded for the difference across locations and fertility levels were discriminated the genotypes or the level of frequent rank order changes were happened.

Effect of Fertility on the Level Resistance in Field Pea

This study result indicated all insect related and seed related traits (Number egg, Date of adult emergency, Number of adult emerged, Adult recovery, Mean number of hole per seed, susceptibility index and thousand seed weight, proportion of seed coat, percentage of seed weight loss) showed highly significant (p < 0.01) differences due to the application of fertility levels (Table 5). Predominantly, soil fertility practice significantly influenced almost all considered traits like the mean number of eggs laid by the beetles and mean number of emerged adult on the tested field pea genotypes. Mean number of eggs laid by adzuki bean beetles were (108.4), (119.9) and (117.6) under neither rhizobium nor phosphorus, with rhizobium and with rhizobium and phosphorus and mean number of emerged adult (75.6), (91.9) and (83.3) under neither rhizobium nor phosphorus, with rhizobium and with rhizobium and phosphorus respectively. In conclusion, field pea fertilization can affect susceptibility of considered field pea genotypes to adzuki bean beetles. In increasingly different authors reported crop fertilization can affect susceptibility of plants to insect pests by altering plant tissue nutrient levels (Conway and Pretty, 1991; Magdoff and van Es, 2000; Morales *et al*., (2001); Altieri and Nicholls, 2003 and Argaye, 2018).

Table 1. Combined mean performance of ten traits of 80 field pea genotypes grown under different fertility levels to infestation by '*C. Chinensis'* which is tested in 2018 at Kulumsa and Melkasa agricultural research center.

Character	Neither Rhizobium nor Phosphorus		With Rhizobium		With Rhizobium and Phosphorus	
	Range		Range		Range	
NE	108.4^{c}	52-198	119.9^{a}	54-201	117.6^{b}	44-214
DAE	27.7^{b}	23-33	27.3^{c}	23-38	28.3^{a}	25-33
NA	75.6^{c}	40-182	91.9^{a}	42-189	83.3^{b}	25-178
PSWL (%)	19.1^{c}	11-51	25.6^{a}	11-51	23.2^{b}	7-50
PSD (%)	28.4^{c}	17-80	41.6^{a}	17-80	40.3^{b}	12-84
PSC (%)	14.4^{b}	7-25	14.5^{a}	7-25	14.5^{a}	7-22
TSW	121.6^{a}	56-124	120.2^{b}	56-123	121.6^{a}	56-223
SI	6.6^{b}	5-10	7.1^{a}	5-10	6.6^{b}	4-8
AR	66.2^{c}	54-92	74.7^{a}	54-92	67.3^{b}	42-89
MNHPS	0.35^{c}	0.2-0.9	0.46^{a}	0.2-0.9	0.43^{b}	0.1-0.9

The regressions among seed weight loss (%) and considered field pea genotypes based on fertility levels were showed similar distribution even if it was vary in magnitude below the graph, that might be resulted due to Soil fertility management can have several effects on plant quality, which in turn, can affect insect abundance and subsequent levels of herbivore damage (Altieri and Nicholls, 2003).

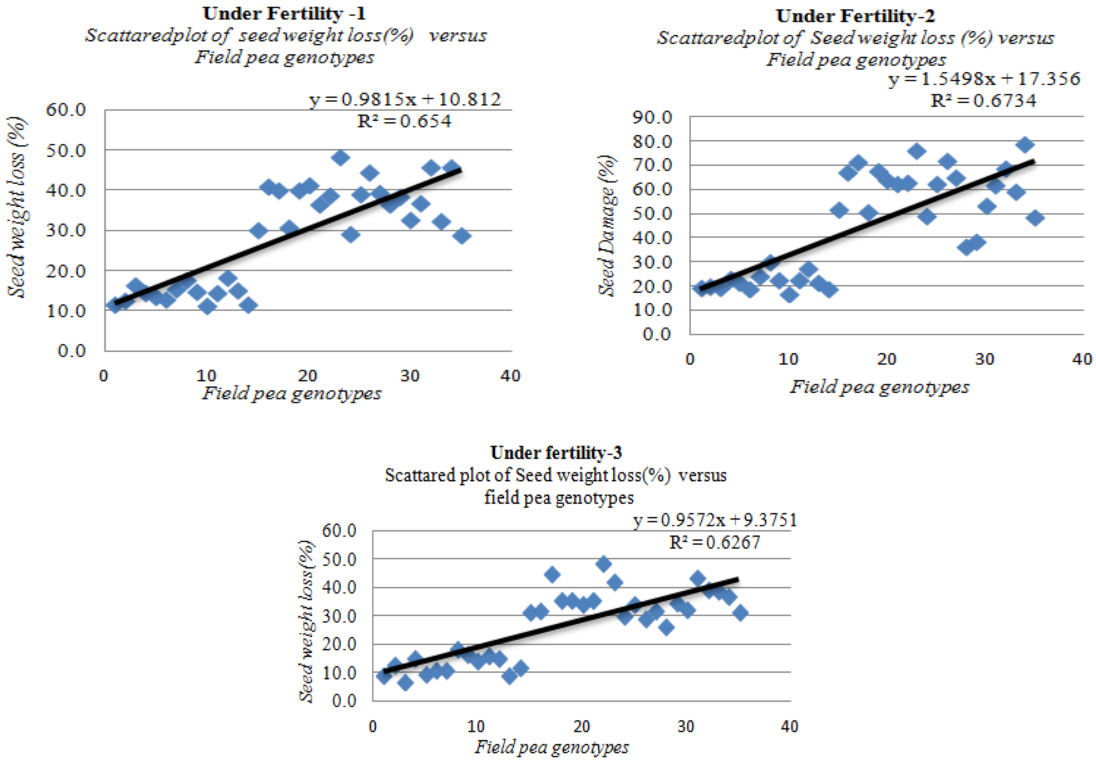


Fig. 1. Regression of percent seed weight loss of against field pea genotypes by *C. chinensis* emergence for the 35 genotypes at the three fertility levels and fertility-1,2,3 indicates when the field pea genotypes were grown with Neither rhizobium nor phosphorus, With rhizobium and With rhizobium and phosphorus.

From the combined data across the location and fertility levels, the interrelations between the traits revealed strong associations in a number of cases both in positive and negative directions. So, breeders should take care during selection for genetic exploitation of these traits at the same time in order to reduce high infestation. Accordingly, seed size and seed weight loss (%), seed size and developmental periods, seed size and total number of egg laid has a strong positive association that indicate indirect improvements of the traits. Whereas, seed coat (%) and seed size, seed damage (%) and seed size and adult developmental periods has a strong negative association as indicated below the figures.

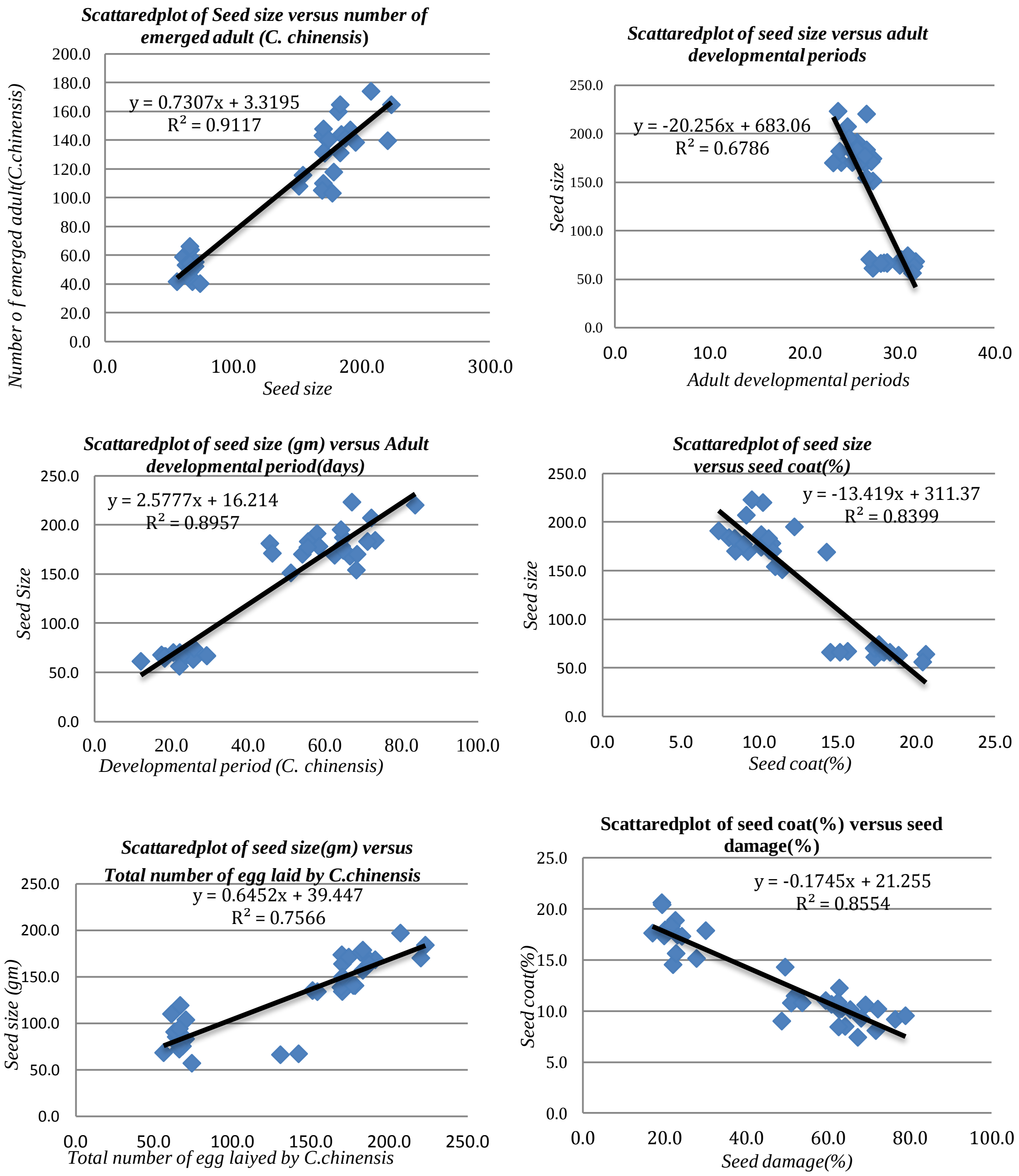


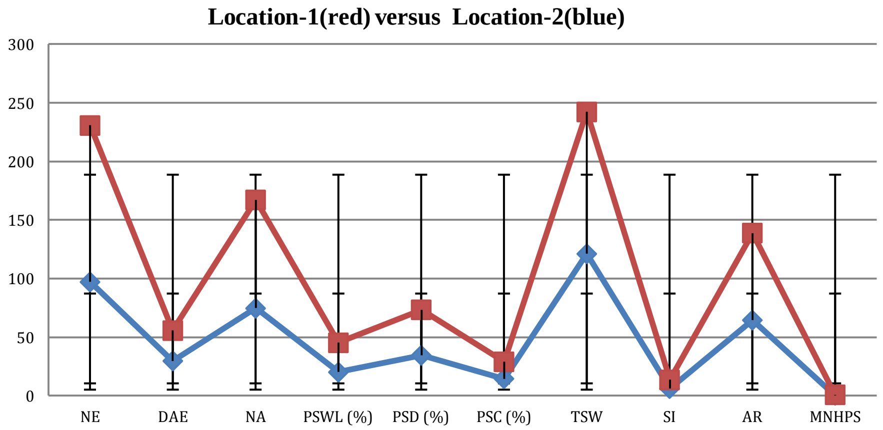
Fig. 2. Associations of some measured traits contributed to different field pea genotypes infestation by *C. chinensis.*

Effect of Location on the Level Resistance in Field Pea

Based on combined mean performance of considered traits; number egg, date of adult emergency, number of adult emerged, adult recovery, mean number of hole per seed, susceptibility index, percent of seed damage, seed weight loss in percent showed significant difference except thousand seed weight, proportion of seed coat. Hence nearly all traits were responsive to the location difference (table 5). The traits like number egg (97.1) and (133.6), date of adult emergency (29.7) and (25.9), number of adult (74.6) and (92.6), percentage of seed weight loss (20.1) and (25.1) , adult recovery (64.5) and (74.4) and mean number of hole per seed (0.37) and (0.46) under location-1 and location-2 with their respective orders. From this study result mainly location-2 was more conducive environment for these beetles than location-1 due to the better relative humidity and temperature condition (Figure 3). Therefore multi locations experiment helps to exploit the genetic potential of a field pea genotype to the targeted problem of adzuki bean beetles infestation. In addition environmental conditions, which include the overall conditions of climate change, are the reality that needs to be considered as one of the crucial phenomena of changing location when planning future security and/or pest management strategies (Emani and Hunter, 2013, Argaye, 2018).

Table 3. The effect of location based on 10 measured trait of field pea genotypes

Traits	Location-1		Location-2	
		Range		Range
NE	97.1[b]	54-132	133.6[a]	85-266
DAE	29.7[a]	26-34	25.9[b]	22-28
NA	74.6[b]	40-111	92.6[a]	80-238
PSWL (%)	20.1[b]	6-27	25.1[a]	10-42
PSD (%)	34.5[b]	22-84	38.9[a]	34-98
PSC (%)	14.5[a]	7-25	14.5[a]	7-25
TSW	121.1[a]	55-123	121.2[a]	55-223
SI	6.1[b]	4.8-8	7.4[a]	5-10.8
AR	64.5[a]	47-119	74.4[b]	75-200
MNHPS	0.37[b]	0.1-0.8	0.46[a]	0.3-0.9



Location-1 (Kulumsa) and Location-2 (Melkasa) and for the abbreviation of characters and figures sharing no similar letters within rows are statistically significant.

Effect of Temperature on the Level Resistance in Field Pea

Temperature variation has an effect on measured traits at both locations. The difference in mean room temperatures of both location resulted different mean values of traits viz. the lowest mean number of egg laid (39.3), number of adult emerged (33.8), percentage of seed damage (33), susceptibility index (5.6) and percentage of seed weight loss (22.3) whereas, the highest mean number of date of adult emergency (28.7) in Kulumsa location as compared to Melkasa location with the highest mean values of traits like number of egg laid (89), number of adult emerged (74.2), percentage of seed damage (47.7), percentage of seed weight loss (26.7) and susceptibility index (6.8) and lowest mean value with date of adult emergency (21.2). In conclusion Melkasa location were more conducive temperature than Kulumsa location for adzuki bean beetles insect with high fecundity and hatchability and longevity performance in (table). These are happened because of the temperature of the location were more closer to preferred temperature range for this insect (Bursell, 1974a). In overall, there is no pure resistances were obtained from all considered field pea genotypes.

Table. The effect of the mean daily room Temperature (^{0}C) from April 19 to May 25, 2018 on mean values of traits across location.

Location	**Traits**	**Mean daily room Temperature (^{0}C)**							
		19^{0}C	**22^{0}C**	**25^{0}C**	**28^{0}C**	**31^{0}C**	**34^{0}C**	**Total**	**Mean**
Kulumsa	NE	27	39	52	-	-	-	118	39.3
	DAE	31.2	28.8	26.1	-	-	-	86.1	28.7
	NA	22.3	28.4	50.6	-	-	-	101.3	33.8
	PSD	25.2	31	44.8	-	-	-	101	33
	PSWL	14.7	18.1	34.2	-	-	-	67.3	22.3
	SI	4.8	5.2	6.7	-	-	-	16.7	5.6
Melkasa	NE	8	20	68	81	98	-	267	89
	DAE	-	24	21	20	20	-	85	21.2
	NA	-	25	59	72	67	-	223	74.2
	PSD	-	31	49.5	57.2	53.2	-	190.9	47.7
	PSWL	-	12	29.2	34	31.6	-	106.8	26.7
	SI	-	6.3	6.1	7.6	7	-	27	6.8

Insect Median Development Period

Results on median development periods (MDP) of the 35 studied field pea genotypes at two locations are presented in Figure 2. Forty four percent of the genotypes had media development periods range 24-31 days in Kulumsa location, whereas, fifty six percent of the genotypes had media development periods range 24-31 days in Melkasa location. Six percent of the genotypes had media development periods range 16-23 days in Kulumsa location, while fifteen percent of the genotypes had media development periods range 16-23 days in Melkasa location. Further twenty percent of the genotypes had media development periods range 32-39 days in Kulumsa location, but nine percent of the genotypes had media development periods range 32-39 days in Melkasa location. Lastly ten percent of the genotypes had media development periods range 40-48 days in Kulumsa location and irrespectively none of the genotypes had media development periods range 40-48 days in Melkasa location. No genotype had media development periods range below 15 days at both location. However, 30% of the genotypes had media development periods range above the mean experimental mean (32.2 days) in Kulumsa location but 9% of the genotypes had media development periods range above the mean experimental mean (26.4 days) in Melkasa location. The predominant media development period was 32.2 and 26.4 days in Kulumsa and Melkasa location. Genotype fpcoll-1/07 to fpcoll-43/07 (34-42, days) and fpcoll-2/07, fpcoll-3/07, fpcoll-4/07, fpcoll-8/07 fpcoll-7/07, fpcoll-11/07 fpcoll-16/07, fpcoll-20/07 fpcoll-18/07, fpcoll-31/07 fpcoll-27/07, fpcoll-39/07 fpcoll-23/07, fpcoll-33/07 fpcoll-26/07, fpcoll-31/07 fpcoll-40/07, fpcoll-41/07 fpcoll-42/07, fpcoll-35/07 fpcoll-34/07 and fpcoll-38/07 (34-38, days) mostly '*pisum var. abysinicum'* groups had the longest media developmental period and genotypes PDFPT p-313-010, Bilalo, Adi, Burkitu, Markos, Bursa, Gume, PDFPT p-313-046, PDFPT p-313 MILKY, PDFPTp-313–HASABE, PDFPT p-313-067, PDFPT p-313-003, EH-08086-1(<32, days) and all most all of the genotypes(<26, days) had the shortest media developmental period of in Kulumsa and Melkasa location (Table 2). Generally in this finding, environments had a crucial role on resistivity of the considered field pea genotype to adzuki bean beetles infestation, i.e. those genotypes showed the lowest susceptibility index values at one location was not reflecting the same performance at another location. So breeders should take a serious care during selection for insect resistance cultivars.

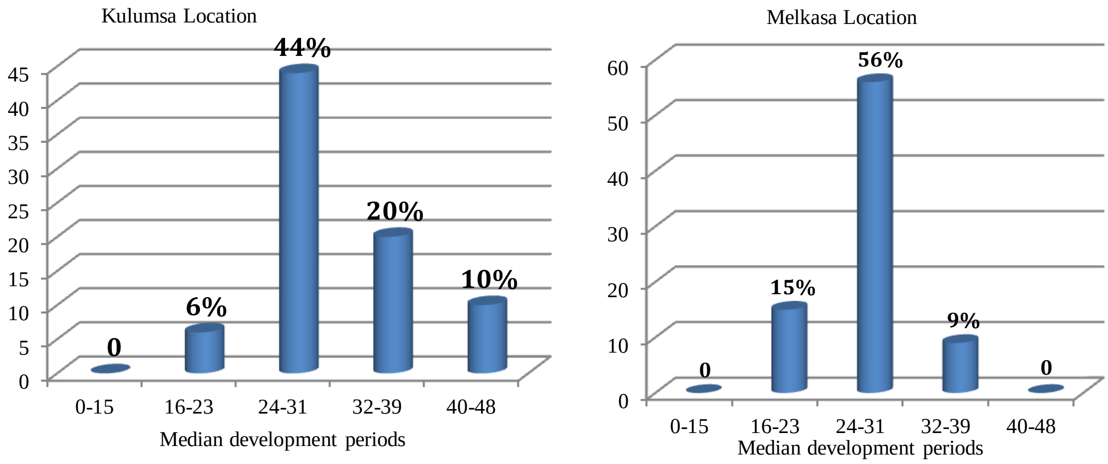


Fig. 3. The status of media development (MDP)/date of adult emergency of considered genotypes at across locations.

Effect of Physical Characteristics of the Seeds on Bruchid Infestation

Based on the combined data of both location and all fertility levels, the effects of physical characteristics of the seeds (thousand seed weight and percentage of seed coat) were studied on oviposition, developmental period and number of adult emergency of bruchids (*C. chinensis*). In considered field pea genotypes, less numbers of eggs and lower percentage of emergence was recorded in small (39.2 per 200 seeds and 74.1% emergence) and mostly grey seeds (56.9 per 200 seeds and 63.3% emergence) as compared to the large (89.0 eggs and 97.8% emergence) and dull (78.3 eggs and 90.7% emergence) seeds. Preference of female for egg lying in large and dull seeds could be possibly due to the ease for settling of adults for ovipoistion. Similarly in field pea, small sized (24.6 eggs per 200 seeds) and more related to black (39.4 eggs per 200 seeds) seeds recorded lower number of eggs as compared to 81.8 eggs in large seeds and 94.8 eggs in white coloured seeds that might be resulted due to a females '*C. chinensis'* are better at judging seed mass and distribute their eggs in a manner that maximize the amount of resources per offspring. More relative results were also reported by (Jason and Charles, 2003; Rathore and Chaturvedi ,1997; Chavan *et al*,. 1997; Keneni *et al*,.2012 and Argaye, 2018). Increasingly different authors identified as Traits contributing to resistance/susceptibility of mungbean to bruchids include seed color, texture, hardness, size and chemical constituents (Asian Vegetable Research and Development Center [AVRDC], 1979, 1981; Sarikarin *et al*., 1999; Appleby and Credland, 2003; Lattanzio *et al*., 2005; Somta et al., 2007). It is evident from above information that significant variability exists in considered genotypes against C. *chinensis* resistance and the less susceptible genotypes may be utilized in crop improvement programme.

Susceptibility Index (SI)

The results on susceptibility index (SI), which is an indicator of genotype suitability to *Callosobruchus chinensis* development, showed that the insect had the capacity to infest and develop on all field pea genotypes tested but with significant differences among locations and fertility levels. Progressively, locations responded differently to the considered field pea genotypes viz. 40% and 27% of the genotypes were under the moderately resistance (MR) category and 11.4% and 9% as well under moderately susceptible(MS) at Kulumsa and Melkasa location orderly. In addition to this 45.7% and 58% were also laid under susceptible (S) category and 2.9% and 5% of the considered field pea genotypes were under highly susceptible (HS) category at kulumsa and Melkasa location. This indicates there is a probability of a single field pea genotypes have laid in different levels of susceptibility index (SI) due to the location conduciveness to *C. chinensis* development. In other side larval development within the seed depends on chemical composition of the grain (Sharma and Thakur, 2014c). The inability of *C. chinensis* to develop at the same rate in the genotypes would be an indication that genotypes had varying some nutritional contents (Swella and Mushobozy, 2009; Tripathi *et al*., 2013; Srinivasan and Durairaj, 2007). Maximum growth of *C. chinensis* was on all improved, introduced and some breeding lines of field pea genotype, implying that those genotypes had the large seed size, brown, white, dull seed color and may be they had least anti-nutritional factors and, therefore, was the most suitable genotype for development of the *C. chinensis*; while all collections particularly, '*pisium var. abysinnicum*' genotypes those have small seed size had moderately resistance (MR) and may be the most anti-nutritional factors which made it the least suitable.

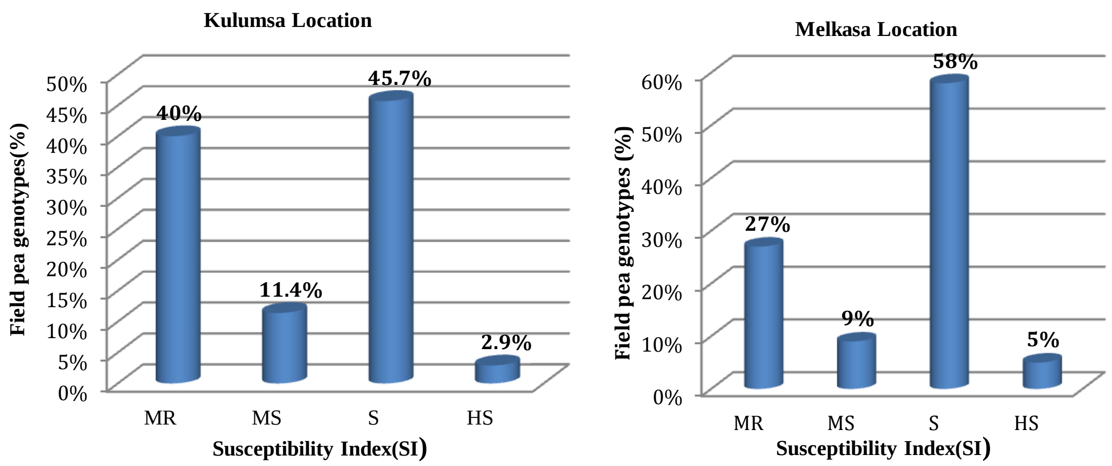


Fig. 4. Indicates the response of field pea genotypes to the susceptibility levels for *C. chinensis* infestation at Kulumsa and Melkasa Location.

Fertility levels also vary the number of field pea genotypes laid under different susceptibility index (SI) levels. Accordingly, 48%, 33%, 31% of the genotypes were laid under moderately resistance (MR) and 17%, 11%, 9% of the genotypes were also laid under moderately susceptible (MS) with neither rhizobium nor phosphorus, with rhizobium and with rhizobium and phosphorus application. Similarly, the highest percentage of genotypes viz. 34%, 51% and 54% were laid under susceptible level, while least percentage viz. 1%, 5% and 6% of the genotypes were laid under highly susceptible (HS) group with neither rhizobium nor phosphorus, with rhizobium and with rhizobium and phosphorus application orderly (figure 5). This finding inclined to show the effect of fertility inoculation on measured traits i.e, majority of the field pea genotypes were more infested by *C. chinensis* than the non-inoculated one. Progressively, as Altieri and Nicholls, (2003) report, there is a potential of crop fertilization impact on susceptibility of plants to insect pests by altering plant tissue nutrient levels.

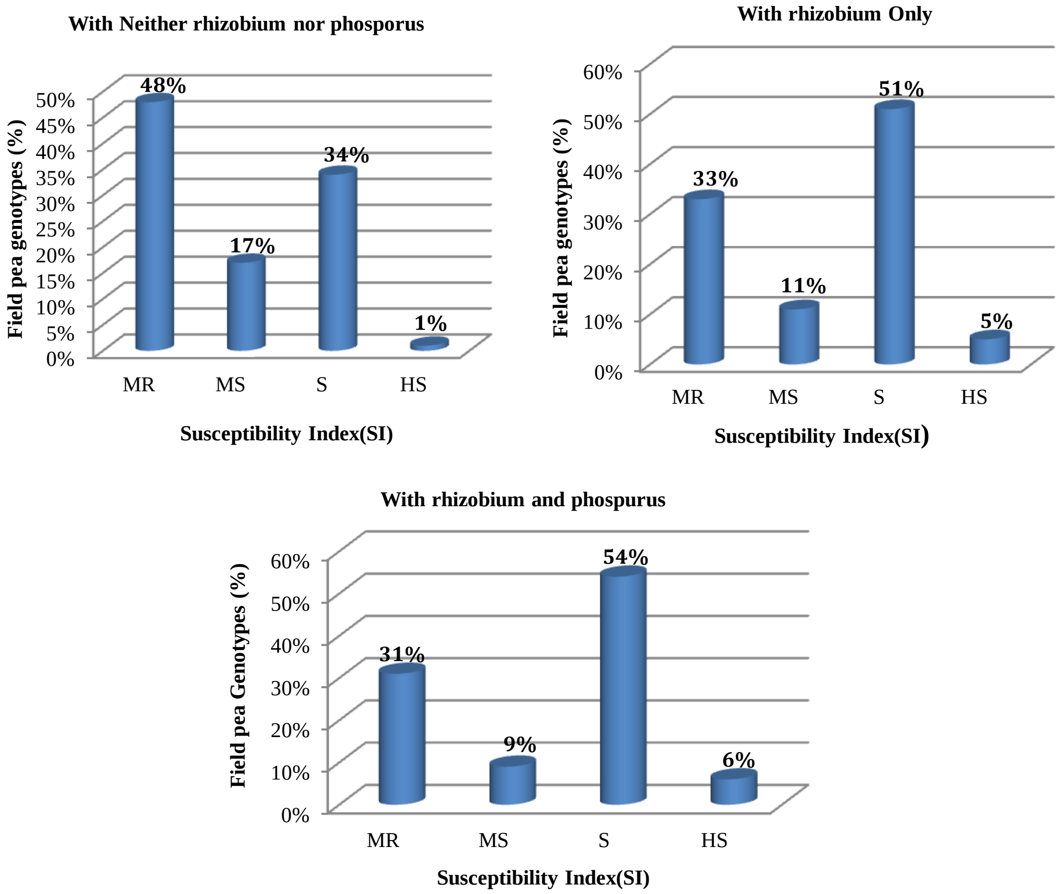


Fig. 5. The response of fertility levels on field pea genotypes infestated by *C. chinensis*.

IV. Conclusion

Two main conclusions can be drawn from this study. Firstly, Location had a crucial role on insect pest particularly; *C. chinensis* infestation level of considered field pea genotypes, those grouped under the ranges of moderately resistance (MR), moderately susceptible (MS), susceptible(S) and highly susceptible (HS). They also vary in number of field pea genotypes in one susceptibility levels that might be resulted due to temperatures variation among locations. Secondly, inoculations of different fertilization had effect on susceptibility of considered field pea genotypes to *C. chinensis* pest; viz. inclined to the probability of resistance is linked directly to the physiology of the plant and thus any factor that affects the physiology of the plant may lead to changes in resistance to insect pests. This study also tending to the existence moderately resistance field pea genotypes those can be used with other integrated pest management practices in breeding system.

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