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Performance of flax genotypes with respect to infestation of capsule borer, *Helicoverpa armigera* (Hubner) and other yield parameters in the hills of Darjeeling, India

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Abstract
A field experiment was conducted to study the performance of seven flax genotypes for their reaction to the infestation of capsule borer, Helicoverpa armigera (Hubner) as well as various yield attributes at Uttar Banga Krishi Viswavidyalaya, Kalimpong, Darjeeling, West Bengal during the winter seasons of 2004-05 and 2005-06. The capsule borer, *Helicoverpa armigera* (Hubner) was observed to be the major pest during the period of present investigation. It appeared during the budding and reproductive stage of the crop inflicting considerable damage to the young buds and green capsules. The pooled analysis of variance of flax germplasm over the two years revealed that the genotypes varied significantly for primary and secondary branches/plant, capsules/plant, seeds/capsule, seed yield and biomass yield, irrespective of the year. But the capsule borer infestation did not show any significant variation amongst the genotypes. The incidence of flax capsule borer, *H. armigera*, failed to show any significant correlation with any yield components in flax. The incidence of *H. armigera* had a very low direct effect on the biomass yield, thereby indicating absence of any linear relationship between the capsule borer infestation level and the biomass yield. The genotype FT-895 had the highest total rescaled index value of 6.447 and ranked 1 followed by the genotype FT-897 and JRF-1.

Keywords: Flax germplasm, performance, yield attributes, *Helicoverpa* infestation, Darjeeling

1. Introduction
Flax (*Linum usitatissimum*) belonging to the family Linaceae is one of the oldest and important fibre crops of the world. Flax fibre is of very high quality and having a number of industrial uses. 'Linen' obtained from flax is one of the world's best raw materials for textile purposes. It is non-lignified, soft, flexible, lustrous, shining, pale yellow fibre and possesses a high water absorbency quality [1]. There is an urgent need to increase the production and productivity of flax (as fibre and seed) in India to meet the needs of industry and to save valuable foreign exchange. However, at present there is hardly any acreage under flax as a fibre crop in India [2]. Therefore, high yielding flax genotypes are being developed by the Sunnhemp Research Station under ICAR-CRIJAF, Pratapgarh, Uttar Pradesh. India's first genetically improved flax fibre variety JRF-2 (Tiara) was released in 2015. JRF-1, JRF-3, JRF-4, FT-895, FT-896 and FT-897 are some other improved strains for the selection of right genotype and getting quality seed for obtaining higher yield [2].
The gram pod borer, *Helicoverpa armigera* (Hubner) is a major pest of flax in respect of bud and capsule damage in the mid-hills of Darjeeling [10] and in the terai region of West Bengal [9]. It has also been reported as a major pest on linseed, *Linum usitatissimum* L. from different agro climatic regions of India [4] [12]. The larvae of the pest appear to coincide with the flowering and budding stage of flax. They feed on the flower/buds and after capsule formation bore into it and devour the inner content of the capsule. One larva can damage a number of capsules migrating from one branch to another and inflicts serious economic loss to the crop. Searching for genotypes having significant tolerance to pest infestation is the most economically and environmentally sound method of pest management and crop improvement. This approach is less labour intensive and more secured compared to other methods, thus very appropriate for the resource-limited farming community. Due to these merits, developing varieties with high yield potentiality and sustainable resistance to important insect pests is a

major goal of present day breeding programs. Hence, the present study has been undertaken with different available germplasm accessions of flax to study their performance in relation to capsule borer and other yield parameters.

2. Materials and Methods

2.1 Study area

The experiment was conducted at Kalimpong (27˚ 04′ N latitude and 88˚ 35′ E longitude at an elevation of 1250 meter above the MSL) lying in the northern part of West Bengal (India) in the mid-hills of the eastern Himalayas. The average maximum and minimum temperature recorded round the year was 20˚ C and 2˚ C respectively. The relative humidity varied from 70 to 80% depending upon the season with an average annual rainfall of 2500-3000 mm.

2.2 Experimental details

The experiment was carried out during the winter seasons of 2004-05 and 2005-06. The seven germplasm accessions (viz. JRF-1, JRF-2, JRF-3, JRF-4, FT-895, FT-896 and FT-897) were sown in plots of 3m x 1.5m in the first week of November and fourth week of October during 2004-05 and 2005-06, respectively. The crop was raised with the application of FYM @ 5 tonnes/ha and N:P:K dose of 60:40:40 kg per ha. The experiment was laid out in Randomized Block Design (RBD) with four replications.

2.3 Sampling and data collection

The data was recorded by selecting five plants from each replication. The data on plant height, number of primary and secondary branches was recorded during the maximum vegetative stage of the crop at 75 days after sowing. The number of capsules per plant was recorded at the time of harvest, from five plants per replication. For counting the number of seeds per capsule, 25 capsules per replication was taken and mean number of seeds per capsule was derived. The data on seed yield and biomass yield was recorded from each plot at the time of harvest. Observations on per cent capsule damage due to the borer *H. armigera* were recorded at the time of harvest by counting the number of total and damaged capsules from 5 plants from each plot. The percent infestation was calculated as,

$$\text{Per cent infestation} = \frac{\text{Number of damaged capsules}}{\text{Number of total capsules}} \times 100$$

2.4 Statistical analysis

The analysis of variance (ANOVA) for RBD was estimated as suggested by Panse and Sukhatme [11]. The genotypic and phenotypic variances were calculated according to the method suggested by Johnson *et al*. [8] and Comstock and Robinson [3]. The genotypic coefficient of variance (GCV) and the phenotypic coefficient of variance (PCV) were calculated by the method suggested by Singh and Chaudhary [13]. The heritability in broad sense for yield was calculated using the formula suggested by Hanson *et al*. [6]. The genetic advance (GA) was calculated by the method suggested by Johnson *et al*. [8]. The genotypic correlation was estimated and path analysis was carried out by the technique outlined by Dewey and Lu [5]. An overall ranking of the seven flax genotypes was done for the eight characters, out of which seven were yield attributing characters and one was the incidence of *H. armigera* as per the rescaling index method suggested by Iyengar and Sudarshan [7]. When the observed values are related positively to the main factor biomass yield, the standardization is achieved by employing the formula

$y_{id} = (X_{id} - Min\ X_{id})/(Max\ X_{id} - Min\ X_{id})$

and when the values of X_{id} is negatively related to the main factor biomass yield, the standardized value is computed by

$y_{id} = (Max\ X_{id} - X_{id})/(Max\ X_{id} - Min\ X_{id})$

where Min X_{id} and Max X_{id} are the minimum and maximum of (X_{i1}, X_{i2},……X_{in}) respectively.

3. Results and Discussion

3.1 Pooled ANOVA of flax germplasm

The pooled ANOVA of the flax germplasm accessions over two years (2004-05 and 2005-06) is presented in Table 1. The perusal of the table reveals that the seven flax genotypes differed significantly for the characters primary branches/plant, secondary branches/plant, capsules/plant, seeds/capsule, seed yield and biomass yield. The flax genotypes did not show any significant variation for plant height and incidence of *H. armigera*. But the capsule borer infestation exhibited significant variation in infestation over the two years, irrespective of the flax genotypes indicating the probable influence of other abiotic and ecological factors on the infestation of capsule borer. When both genotype and year were considered as sources of variation, only capsules/plant registered significant variation.

3.2 Genetic parameters for the different characters of flax genotypes

The GCV and PCV values of the different characters differed a lot for most of the characters like plant height, primary branches/plant, secondary branches/plant, seed yield, incidence of *H. armigera* and biomass yield, which indicated that environment during the two years, i.e., 2004-05 and 2005-06, influenced the expression of these characters (Table 2). However, for the characters capsules/plant and seed/capsule, it was observed that the GCV and the PCV did not differ much indicating lower influence of the environment in the expression of these two characters. Both the GCV and PCV were high for capsules/plant and biomass yield indicating higher variability in these two characters. The biotic stress component namely the incidence of *H. armigera* showed high PCV and low GCV indicating substantial variability in the flax genotypes in relation to the capsule borer infestation. Only three characters namely, capsules/plant, seeds/capsule and biomass yield showed high heritability along with high genetic advance, indicating that these characters are controlled by additive gene action and can be improved through appropriate selection for the present set of flax genotypes. In case of the biotic stress components, the incidence of *H. armigera* exhibited low heritability and genetic advance, indicating that the reaction of the genotypes to the capsule borer infestation is not controlled by additive gene action and hence cannot be improved in the present seven flax genotypes by simple selection, as it seems that the infestation of the capsule borer is more influenced by other environmental factors.

3.3 Association between yield components and capsule borer incidence

The perusal of the Table 3 makes it explicit that the incidence of flax capsule borer, *H. armigera* failed to show any significant correlation with any yield components in flax. Therefore, it can be concluded that the yield components under consideration had limited influence on the infestation of capsule borer in different flax genotypes.

3.4 Direct and indirect effect of different yield components and incidence of *H. armigera* on biomass yield

None of the yield components and incidence of *H. armigera* had any positive association with biomass yield, which is a direct indicator of fibre yield in flax (Table 4). However, two yield components namely, secondary branches/plant and seed yield had a high direct effect on biomass yield. The incidence of *H. armigera* had a very low direct effect on the biomass yield, thereby indicating absence of any linear relationship between the capsule borer infestation level and the biomass yield. This information makes it clear that breeding for tolerance to the capsule borer is quite complex and requires inclusion of more yield components to accommodate the total variability for biomass yield.

3.5 Ranking of flax genotypes with respect to yield parameters and pest infestation

Table 5 shows that based on the rescaled index value the genotype FT-897 performed best with respect to pest infestation as it exhibited the highest rescaled index value (1.000) followed by JRF- 4 (0.692) and FT-896 (0.501). The genotype JRF-3 performed the worst with rescaled index value of 0.000. On the basis of all the eight characters, including the biotic stress component, it was found that the genotype FT-895 had the highest total rescaled index value of 6.447 and ranked 1 followed by the genotype FT-897 (rank 2) and JRF-1 (rank 3). Other genotypes were also ranked according to their total rescaled index values.

Table 1: Pooled analysis of variance of the flax genotypes over two years (2004-05 and 2005-06) at Kalimpong

Sources of variation	df	Mean Sum of Squares							
		Plant height (cm)	Primary branches/ plant (cm)	Secondary branches/ plant	Capsules/plant	Seeds/ capsule	Seed yield (g/m^2)	Incidence of *H. armigera*	Biomass yield (q/ha)
Genotype (G)	6	80.393	0.732*	9.045*	1052.839**	1.968**	303.155**	0.843	2012.473**
Year (Y)	1	4428.643**	0.026	58.222**	2851.431**	2.200	149.864	9.753*	22.113
G × Y Interaction	6	42.669	0.339	6.302	514.081**	0.109	177.217	0.389	23.969
Error	36	55.536	0.253	3.180	57.847	0.264	81.669	0.420	343.045

* Significant at 5% probability level, ** Significant at 1% probability level

Table 2: Genetic parameters for the different characters of flax genotypes

Characters	Mean	Range	GCV	PCV	Heritability (Broad Sense)	GA as percentage of Mean
Plant height (cm)	105.750	86.40 – 134.00	1.623	5.295	0.094	1.025
Primary branches/ plant (cm)	2.179	1.40 – 4.20	8.832	23.185	0.145	6.931
Secondary branches/ plant	7.241	3.40 – 15.00	10.835	22.590	0.230	10.706
Capsules/plant	68.293	42.40 – 122.40	16.421	17.881	0.843	31.066
Seeds/ capsule	7.873	6.00 – 9.00	5.976	7.186	0.692	10.236
Seed yield (g/m^2)	56.695	34.72 – 84.26	8.704	15.623	0.310	9.989
Incidence of *H. armigera*	2.192	0.70 – 4.32	10.003	24.009	0.174	8.585
Biomass yield (q/ha)	90.311	41.20 – 137.50	16.440	20.567	0.639	27.071

Table 3: Genotypic correlation between yield components and insect pest incidence in flax

Characters	Primary branches/ plant	Secondary branches/ plant	Capsules/ plant	Seeds/c apsule	Seed yield (g/m^2)	Incidence of *H. armigera*	Biomass yield (q/ha)
Plant height (cm)	0.997**	0.788*	0.819*	0.050	-0.515	-0.246	-0.255
Primary branches/plant		0.439	0.689*	0.243	-0.049	-0.389	0.066
Secondary branches/plant			0.562	0.201	-0.204	-0.250	-0.039
Capsules/plant				0.083	-0.089	-0.181	-0.068
Seeds/ capsule					0.211	0.080	0.130
Seed yield (g/m^2)						-0.510	0.518
Incidence of *H. armigera*							-0.479

* Significant at 5% probability level

Table 4: Direct (diagonal) and indirect (off-diagonal) effects of different yield components and insect pest incidence on biomass yield in flax

Characters	Plant height (cm)	Primary branches/ plant (cm)	Secondary branches/ plant	Capsules/ plant	Seeds/ capsule	Seed yield (g/m^2)	Incidence of *H. armigera*	Correlation with biomass yield
Plant height (cm)	-0.085	-0.680	0.778	-0.091	0.003	-0.319	0.138	-0.255
Primary branches/plant	-0.189	-0.306	0.433	-0.077	0.016	-0.030	0.219	0.066
Secondary branches/plant	-0.149	-0.299	0.444	-0.063	0.013	-0.126	0.141	-0.039
Capsules/plant	-0.155	-0.469	0.555	-0.050	0.005	-0.055	0.102	-0.067
Seeds/capsule	-0.009	-0.165	0.199	-0.009	0.029	0.131	-0.045	0.130
Seed yield (g/m^2)	0.097	0.033	-0.201	0.010	0.014	0.279	0.287	0.518
Incidence of *H. armigera*	0.046	0.265	-0.247	0.020	0.005	-0.316	-0.253	-0.479

Residual Effect = 0.78

Table 5: Mean performance of the flax genotypes averaged over two years and their ranking on the basis of rescaled index value as suggested by Iyengar and Sudarshan (1982)

Germplasm Accession	Plant height (cm)		Primary branches/plant		Secondary branches/plant		Capsules/plant		Seeds/capsule	
	X	Rescaled Index value (A) = (X-Min)/(Max-Min)	X	Rescaled Index value (B) = (X-Min)/(Max-Min)	X	Rescaled Index value (C) = (X-Min)/(Max-Min)	X	Rescaled Index value (D) = (X-Min)/(Max-Min)	X	Rescaled Index value (E) = (X-Min)/(Max-Min)
JRF-1	106.275	0.490	2.150	0.265	6.350	0.000	64.150	0.194	8.200	0.707
JRF-2	106.150	0.477	2.050	0.147	6.825	0.149	69.325	0.350	7.325	0.000
JRF-3	105.263	0.382	2.000	0.088	6.962	0.192	61.725	0.121	7.413	0.071
JRF-4	102.325	0.069	1.975	0.059	6.875	0.165	59.975	0.069	7.613	0.233
FT-895	111.063	1.000	2.775	1.000	9.538	1.000	90.900	1.000	8.375	0.848
FT-896	101.675	0.000	1.925	0.000	6.700	0.110	57.700	0.000	8.563	1.000
FT-897	107.500	0.620	2.375	0.529	7.437	0.341	74.275	0.499	7.625	0.242

X=Mean performance of the character; *Ranking has been done in descending order taking the highest rescaled value as 1 (first rank) followed by other lower rescaled values from rank 2 onwards. The formulas for the index value (rescaled value) are the same for all the characters except in case of "Incidence of *H. armigera*" where the lower value is desired.

Table 5: (Continued)

Germplasm Accession	Seed yield (g/m^2)		Incidence of *H. armigera*		Biomass yield (q/ha)		Total of the rescaled index values (I) I=(A+B+C+D+E+F+G+H)	Ranking on the basis of the total rescaled index value*
	X	Rescaled Index value (F) = (X-Min)/(Max-Min)	X	Rescaled Index value (G) = (X-Min)/(Max-Min)	X	Rescaled Index value (H) = (X-Min)/(Max-Min)		
JRF-1	59.800	0.690	2.510	0.146	93.518	0.495	3.286	3
JRF-2	50.938	0.152	2.210	0.452	71.470	0.000	2.019	6
JRF-3	48.427	0.000	2.653	0.000	73.610	0.048	1.137	7
JRF-4	57.638	0.559	1.975	0.692	96.527	0.562	2.449	5
FT-895	52.770	0.263	2.165	0.498	81.524	0.226	6.447	1
FT-896	62.377	0.846	2.162	0.501	99.595	0.631	3.088	4
FT-897	64.912	1.000	1.673	1.000	116.030	1.000	5.612	2

X=Mean performance of the character; *Ranking has been done in descending order taking the highest rescaled value as 1 (first rank) followed by other lower rescaled values from rank 2 onwards. The formulas for the index value (rescaled value) are the same for all the characters except in case of "Incidence of *H. armigera*" where the lower value is desired.

4. Conclusion
Thus it can be concluded that out of eight characters, six yield attributing characters varied significantly, irrespective of the year and on the other hand the flax capsule borer infestation did not show any significant variation amongst the genotypes. Absence of any linear relationship was observed between the incidence of the capsule borer and biomass yield. Moreover in the path analysis, the residual effect was quite high, suggesting that more characters needed to be included in the study to get a clearer picture of the cause and effect relationship. The genotype FT-895 was the highest ranker (rank 1) on the basis of all the eight characters under present study.

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