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Screening of Castor Genotypes against Shoot and Capsule Borer (*Conogethes punctiferalis*)

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Abstract

Castor is an important oilseed crop grown in India. However, its cultivation is seriously affected by *Conogethus punctiferalis* commonly known as shoot and capsule borer (SCB), which has significant economic relevance. Host plant resistance is considered the best option for managing this pest. A total of 50 castor genotypes were screened against SCB under natural epiphytic conditions in ICAR-IIOR during August, 2023. The results of this study revealed that RG-2466 showed resistance to SCB, followed by DPC-9, 48-1, RG-1930 and RG-2774, all of which exhibited resistance with a score of 1. These genotypes can be utilized in breeding programmes to develop cultivars resistant to SCB. Additionally, genotypes such as RG-1711-1, RG-1813-1, RG-1757-1, RG-1829, RG-2821, JP-96 and RG-4015 exhibited a moderate level of resistance. These lines hold potential as sources for resistance breeding programmes. Correlation studies indicated that the presence or absence of bloom showed a positive correlation with resistance to SCB, while pericarp thickness exhibited a negative correlation. Therefore, these traits should be prioritized when selecting characteristics for breeding programmes aimed at SCB resistance.

Keywords : Castor, Shoot and capsule borer, Resistance, Bloom, Pericarp thickness

Castor (*Ricinus communis* L.) is the sole member of the genus *Ricinus* under Euphorbiaceae family (Anjani *et al.,* 2012). East Africa is believed to be the likely center of origin for castor, based on its high diversity (Vavilov, 1951). However, the crop is now widely distributed globally and is a vital industrial oilseed, particularly cultivated in arid and semi-arid regions. India, China, Mozambique and Brazil are the foremost global producers of castor (Anjani *et al.,* 2010). Notably, India holds a dominant position in castor production with an annual output of approximately 1.86 million tonnes (FAOSTAT, 2021), fulfilling over 80 per cent of the global demand for castor oil. Castor oil stands out among vegetable oils due to its unique composition containing around 90 per cent ricinoleic acid (da Silva Ramos *et al.,* 1984), a hydroxylated fatty acid. This exceptionally high concentration of a single fatty acid is unmatched by any other vegetable oil (Yamanura and Mohan, 2020). Castor oil and its derivatives are essential raw materials used in the production of a diverse range of industrial products, including paints, lubricants, cosmetics, nylon, pharmaceuticals, plastics and textiles (Ogunniyi, 2006 and Mutlu & Meier, 2010).

Castor oil is an excellent candidate for conversion into biodiesel. Additionally, castor cake serves as a nutrient-rich organic manure, containing approximately 4.5 per cent nitrogen, 2.6 per cent phosphorus and 1.2 per cent potassium. It also provides 22.37 per cent protein and 45-46 per cent carbohydrates (Gangadhar *et al.,*2023).

Conogethes punctiferalis, a crambid moth commonly known as the yellow peach moth, poses a significant threat to fruit production in various regions. Native to Asia, this pest inflicts substantial damage on fruit crops across a wide geographical range, encompassing temperate and tropical zones of South and East Asia, Australia and Papua New Guinea (Kumar and Khader, 2017). Its destructive nature highlights the urgent need for effective control measures to mitigate its impact on agricultural economies. *C. punctiferalis* larvae are voracious feeders with a broad host range consuming a variety of crops such as peach, chestnut, durian, citrus, papaya, cardamom, ginger, eggplant and maize (Sekiguchi, 1974 and Waterhouse. 1993). *C. punctiferalis* with its broad host range and long-distance dispersal potential, is a significant threat to many plants. In castor, *C. punctiferalis* is a major castor pest, causing yield losses of up to 63 per cent (Kapadia, 1996).

Newly hatched larvae feed on the capsule's green coat before entering through the pedicellar or stigmatic end. They bore into the castor fruit through the caruncle and create a silken gallery within the capsule to hold their excrement and frass (Suganthy, 2010). Advanced damage is characterized by capsule webbing, excrement and frass. Attacks on emerging inflorescences cause withering and death of both the inflorescence and the terminal shoot. While capable of infesting shoots, the borer primarily targets capsules. With a short life cycle of 30-35 days this pest can complete multiple generations within a single cropping season leading to rapid population growth and severe crop devastation.

Controlling this pest is challenging due to the larvae's concealed feeding habits, which limit the effectiveness of insecticides. Therefore, developing host plant resistance offers a promising approach to manage this pest. To develop resistant cultivars, a dependable source of resistance is essential. The Indian Institute of Oilseeds Research (formerly Directorate of Oilseeds Research) in Hyderabad, India, maintains a valuable collection of 3,331 castor germplasm accessions (Anjani *et al.,* 2014), both Indian and exotic, providing a rich source of desirable genes and gene combinations. Thorough screening of the extensive germplasm collections against the shoot and capsule borer (SCB) is crucial for identifying resistant sources that can be effectively utilized in castor breeding programmes. Observations have revealed variations in the susceptibility of different castor genotypes to the SCB with spike morphology influencing the extent of capsule damage. This study involved the screening of 50 castor genotypes, encompassing germplasm, inbred lines and breeding lines with the objectives of identifying resistant lines and investigating the relationship between morphological traits and the level of SCB damage.

Material and Methods

Field experiment was conducted during the second fortnight of August, 2023 at ICAR-IIOR, Hyderabad using a Randomized Block Design with two replications. Fifty different castor genotypes (Table 1) were planted with a spacing of 90 cm between rows and 60 cm between plants. All agronomic practices were conducted as per standard procedures. The experiment was conducted without the use of any insecticides allowing for the natural infestation of all genotypes. The screening of genotypes utilized an infester row design, where rows of the susceptible check DCS-9 were interspersed among the test entries at a ratio of one check row for every three test entry rows. To assess SCB damage, five plants were randomly selected from each genotype. The number of total capsules and infected capsules was recorded for each plant during the reproductive stage. The percentage of capsule borer damage was calculated and subsequently categorized on a 1-4 scale (Table 2).

TABLE 1

Castor genotypes assessed for capsule borer resistance

Genotypes	Botonical status	Source/ Origin*
RG-2774	Germplasm	ICAR-IIOR, Hyderabad
DPC-9	Parental line (pistillate)	ICAR-IIOR, Hyderabad
RG-1930	Germplasm	ICAR-IIOR, Hyderabad
RG-1813-1	Germplasm	ICAR-IIOR, Hyderabad
RG-1757-1	Germplasm	ICAR-IIOR, Hyderabad
RG-2466	Germplasm	ICAR-IIOR, Hyderabad
DCS-9	Parental line	ICAR-IIOR, Hyderabad
P3-120NSp	Inbred line	ICAR-IIOR, Hyderabad
YRCH-1	Commercial hybrid	TCRS, Yethapur
P3-80NSp	Inbred line	ICAR-IIOR, Hyderabad
K18-51-1	Inbred line	ICAR-IIOR, Hyderabad
P3-58Sp	Inbred line	ICAR-IIOR, Hyderabad
48-1	Commercial variety	ICAR-IIOR, Hyderabad
K18-40-1	Inbred line	ICAR-IIOR, Hyderabad
RG-1829	Germplasm	ICAR-IIOR, Hyderabad
DPC-25	Parental line (pistillate)	ICAR-IIOR, Hyderabad
DCS-107	Commercial variety	ICAR-IIOR, Hyderabad
ICH-5	Commercial hybrid	ICAR-IIOR, Hyderabad
K18-92A	Inbred line	ICAR-IIOR, Hyderabad
TMV-5	Inbred line	TCRS, Yethapur
VP-1	Parental line (pistillate)	COR, SK Nagar
GC-2	Commercial variety	COR, SK Nagar
K18-120	Inbred line	ICAR-IIOR, Hyderabad
RG-1711-1	Germplasm	ICAR-IIOR, Hyderabad
RG-2180	Germplasm	ICAR-IIOR, Hyderabad
RG-2805	Germplasm	ICAR-IIOR, Hyderabad
TMV-6	Parental line	TCRS, Yethapur
YRCH-2	Commercial hybrid	TCRS, Yethapur
PRAGATHI	Commercial variety	RARS, Palem
K18-29	Inbred line	ICAR-IIOR, Hyderabad
JI-35	Parental line	MORS, Junagadh
ICS-110	Inbred line	ICAR-IIOR, Hyderabad
HARITHA	Commercial variety	RARS, Palem
RG-1614	Germplasm	ICAR-IIOR, Hyderabad
RG-211	Germplasm	ICAR-IIOR, Hyderabad
RG-2821	Germplasm	ICAR-IIOR, Hyderabad
JC-22-1	Inbred line	JNKV, Jabalpur
SKI-343	Inbred line	COR, SK Nagar
GP-783	Germplasm	COR, SK Nagar
JP-96	Parental line (pistillate)	MORS, Junagadh
SKP-84	Parental line (pistillate)	COR, SK Nagar
IPC-39	Parental line (pistillate)	ICAR-IIOR, Hyderabad
IPC-42	Inbred line	ICAR-IIOR, Hyderabad
ICS-238	Inbred line	ICAR-IIOR, Hyderabad
ICS-125	Inbred line	ICAR-IIOR, Hyderabad
ICS-121	Inbred line	ICAR-IIOR, Hyderabad
RG-4023	Germplasm	ICAR-IIOR, Hyderabad
RG-4015	Germplasm	ICAR-IIOR, Hyderabad
RG-4019	Germplasm	ICAR-IIOR, Hyderabad
RG-3994	Germplasm	ICAR-IIOR, Hyderabad

* ICAR-IIOR: ICAR-Indian Insttitute of Oilseeds Research; TCRS: Tapioca and Castor Research Station; COR: Centre for Oilseeds Research, RARS: Regional Research Station; MORS: Main Oilseeds Research Station; JNKV: Jawaharlal Nehru Krishi Vishwavidyalaya.

$$\text{Percent capsule borer damage} = \frac{\text{Number of damaged capsule}}{\text{Total Number of capsule}}$$

TABLE 2

Resistance / susceptibility rating scale on the basis of per cent damage of *Conogethus punctiferalis*

% capsule damage	Scales	Resistance level
<20	1	Resistant
21-40	2	Moderately resistant
41-60	3	Moderately susceptible
>60	4	Susceptible

Spike characteristics, including the presence/absence of spines on capsules, the presence or absence of bloom, spike compactness and pericarp thickness were recorded for all selected plants. Qualitative traits were assigned numerical scores for analysis: Presence of bloom - 1, absence of bloom -2; Presence of spines - 1, Absence of spines - 2; Loose spike - 1, Semi-compact/Compact spike - 2. Since the independent variables are nominal and the dependent variable (capsule borer damage) is continuous, point-biserial correlation was employed to assess the relationship between these traits.

Point bi serial correlation:

Correlation coefficient rpb = $\sqrt{pq}\ x(\mu_1-\mu_0)/\sigma$

μ_1 - Average number of the first nominal variables

μ_0 - Average number of the second nominal variables

σ - Population standard deviation

p - proportion of first nominal variables

q - Proportion of second nominal variables

Association between pericarp thickness and per cent capsule infestation and inter-correlation was calculated using pearson correlation,

$$\text{Correlation coefficient } r_{xy} = \frac{\text{Cov}(X.Y)}{\sqrt{V_{(x)} \times V_{(y)}}}$$

rxy - Correlation coefficient between the character X and Y

CoV.(X.Y) - Covariance between characters X&Y

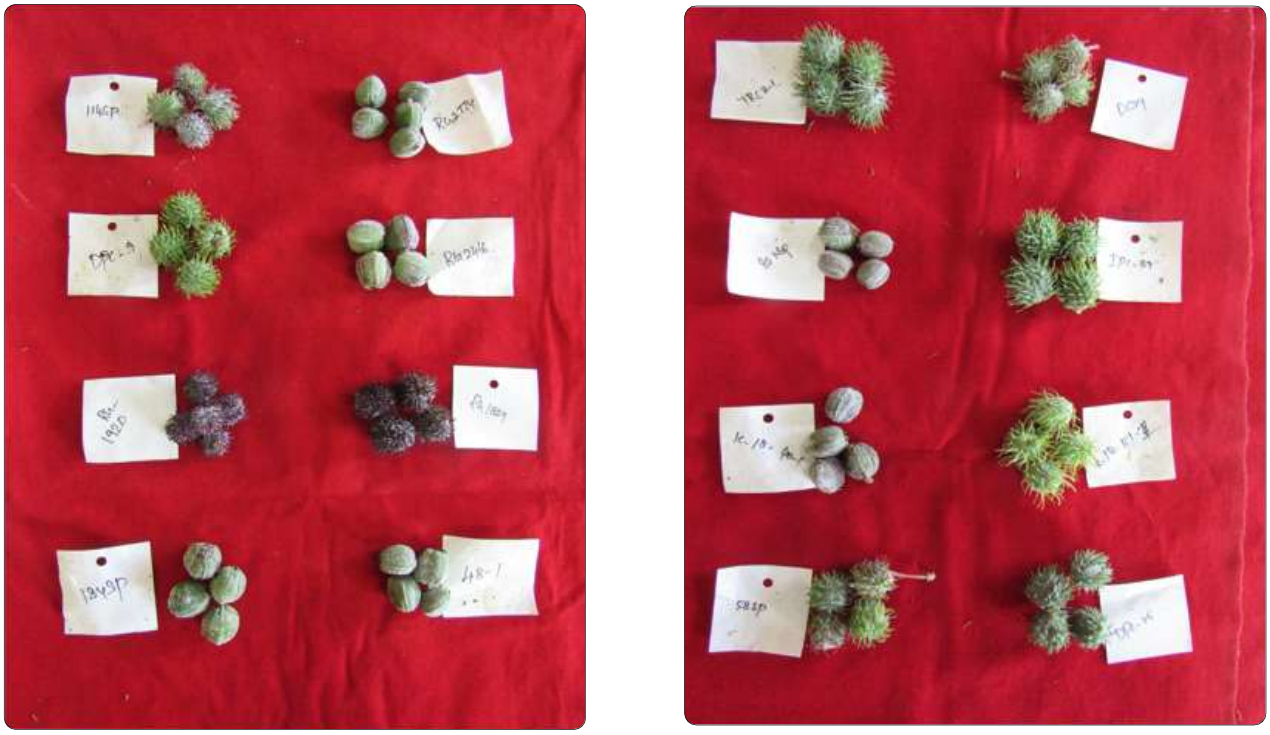
V(x) - Variance of character X

V(y) - Variance of character Y

The genotypes were categorized into two groups and compared with per cent capsule borer damage by using two sample t-test.

Results and Discussion

Selection of resistant sources by screening of diverse germplsam is common practice for infusing genetic diversity in plant breeding programmes. Breeding for resistance to SCB offers a cost-effective and environmentally friendly approach to manage these pests. This study evaluated 50 castor genotypes *viz*., parental lines, germplasm linesand advanced breeding material for resistance to SCB under natural field conditions. Among these genotypes, diversity was observed in key morphological traits (Fig. 1). Morphological characters of the selected castor genotypes were given in Table 3. Bloom type was present in 42 genotypes, while 8 exhibited no bloomand this grouping was represented as pie chart diagram (Fig. 2). Spines were observed on 41 genotypes, whereas 9 were spineless. Spike type varied across genotypes with 18 exhibiting a loose spike, 27 showing a semi-compact spike and 5 displaying a compact spike. This diverse set included 15 germplasm lines and 35 advanced breeding lines



Resistance Susceptible

Fig. 1 : Morphological variations in capsules of selected castor lines

TABLE 3

Morphological characters of selected castor genotypes

Genotypes	Bloom type	Capsule Spininess	Spike compactness	Pericarp thickness (mm)
RG-2774	Bloom	Non-spiny	Loose	1.35
DPC-9	No bloom	Spiny	Loose	1.52
RG-1930	No bloom	Spiny	Compact	1.61
RG-1813-1	No bloom	Spiny	Semi-compact	1.53
RG-1757-1	No bloom	Spiny	Loose	1.31
RG-2466	No bloom	Non-spiny	Loose	1.47
DCS-9	Bloom	Spiny	Semi-compact	0.70
RIL-120NSP	Bloom	Non-spiny	Semi-compact	0.90
YRCH-1	Bloom	Spiny	Loose	1.17
RIL-80NSP	Bloom	Non-spiny	Semi-compact	1.16
K18-51-1	Bloom	Spiny	Loose	1.30
RIL-58SP	Bloom	Spiny	Loose	0.77
48-1	Bloom	Spiny	Semi-compact	1.23
K18-40-1	Bloom	Non-spiny	Loose	0.95
RG-1829	No bloom	Spiny	Semi-compact	1.08
DPC-25	Bloom	Spiny	Semi-compact	1.12
DCS-107	Bloom	Spiny	Semi-compact	1.24
ICH-5	Bloom	Spiny	Loose	1.01
K18-92A	Bloom	Spiny	Loose	1.27
TMV-5	Bloom	Spiny	Semi-compact	1.20
VP-1	Bloom	Spiny	Semi-compact	1.03
GC-2	Bloom	Spiny	Semi-compact	1.06
K18-120	Bloom	Spiny	Loose	1.08
RG-1711-1	No bloom	Spiny	Compact	1.46
RG-2180	Bloom	Spiny	Loose	1.45
RG-2805	Bloom	Spiny	Semi-compact	1.12
TMV-6	Bloom	Spiny	Loose	1.33
YRCH-2	Bloom	Spiny	Loose	0.83
PRAGATHI	Bloom	Spiny	Compact	1.13
K18-29	Bloom	Spiny	Semi-compact	1.23
JI-35	Bloom	Spiny	Semi-compact	1.01
ICS-110	Bloom	Spiny	Semi-compact	1.27
HARITHA	Bloom	Spiny	Semi-compact	1.05
RG-1614	Bloom	Spiny	Compact	1.01

Continued....

TABLE 3 Continued....

Genotypes	Bloom type	Capsule Spininess	Spike compactness	Pericarp thickness (mm)
RG-211	Bloom	Spiny	Semi-compact	0.81
RG-2821	No bloom	Spiny	Semi-compact	1.46
JC-22-1	Bloom	Spiny	Semi-compact	1.36
SKI-343	Bloom	Spiny	Semi-compact	1.01
GP-783	Bloom	Spiny	Semi-compact	1.14
JP-96	Bloom	Spiny	Loose	1.16
SKP-84	Bloom	Spiny	Semi-compact	0.72
IPC-39	Bloom	Spiny	Compact	0.93
IPC-42	Bloom	Spiny	Semi-compact	1.10
ICS-238	Bloom	Non-spiny	Loose	1.07
ICS-125	Bloom	Spiny	Compact	0.97
ICS-121	Bloom	Spiny	Semi-compact	0.93
RG-4023	Bloom	Non-spiny	Loose	1.16
RG-4015	Bloom	Non-spiny	Semi-compact	1.32
RG-4019	Bloom	Non-spiny	Semi-compact	1.24
RG-3994	Bloom	Spiny	Loose	1.12

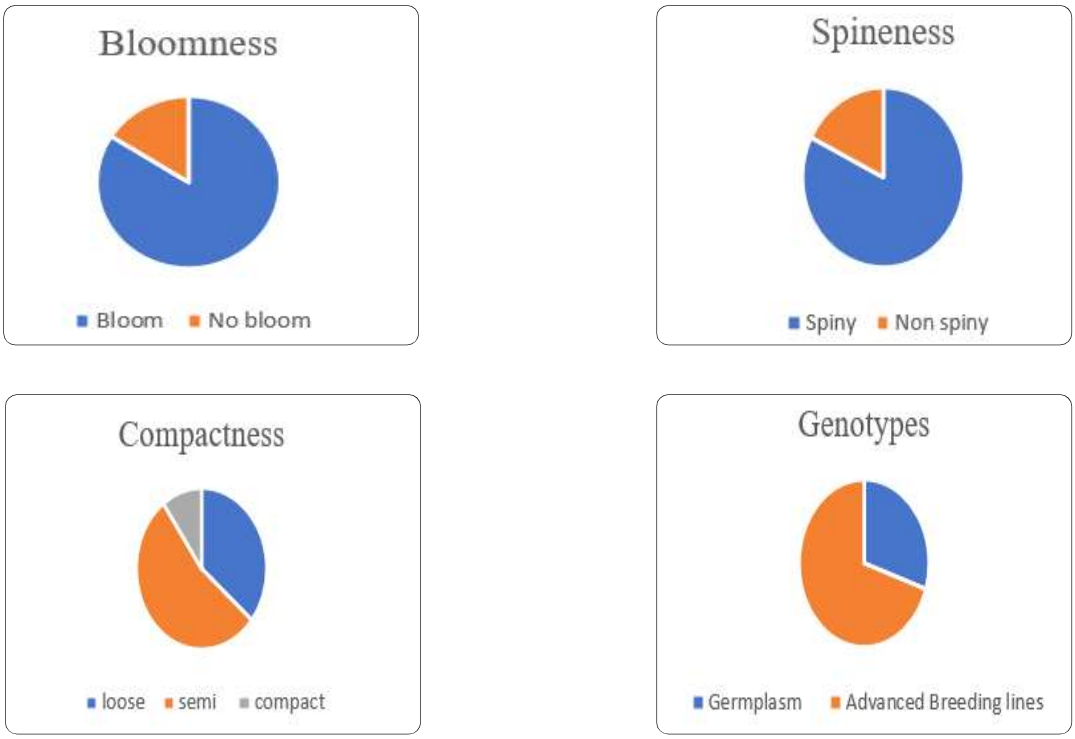


Fig. 2: Piechrat diagram for different characters of castor genotypes

ensuring a wide range of genetic variation for the study.

The reaction of lines to the SCB infestation was assessed based on mean percent capsule damage which ranged from 2 per cent in RG-2466 to 100 per cent in DCS-9 (Table 4). Among the 50 lines evaluated, six were rated as resistant (scale 1), eight as moderately resistant (scale 2), six as moderately susceptible (scale 3) and 30 as susceptible (scale 4) based on the scale rating. Among the genotypes evaluated RG-2466 displayed highly resistance reaction to SCB with only 2 per cent capsule damage, outperforming other genotypes. It was followed, in performance, by DPC-9, 48-1, RG-1930 and RG-2774. The present results are in confirmation with the results obtained by Hegde *et al.*(2009) for the entry 48-1. Hegde *et al.*(2009) screened 222 indigenous lines and found that 48-1 exhibited resistance across multiple locations, offering broader resistance compared to other lines. Similarly, Manjunatha *et al.*(2018) screened 16 lines against the SCB and identified HCGP-1, RG-3294, M-574, 48-1 and GCH-4 as tolerant. Suganthy *et al.* (2011) screened eight germplasm lines for resistance to the SCB. Their findings revealed that four lines, namely RG-2770, RG-2776, RG-2778 and RG-2849 exhibited resistance to this pest.

Germplasm lines such as RG-1711-1, RG-1813-1, RG-1757-1, RG-1829, RG-2821, JP-96 and RG-4015 exhibited moderate resistance to SCB. These resistant sources can be utilized in hybridization programs to enhance SCB resistance in castor. The limited genetic diversity of castor hampers the availability of resistance sources against SCB. Identifying these sources is crucial for understanding the mechanisms of resistance such as antixenosis (pest avoidance) and antibiosis (pest inhibition) for developing effective breeding strategies. Therefore, these lines will serve for this purpose. Field evaluation of resistance among genotypes is essential for their effective utilization in breeding programmes. The low frequency of identified resistance sources highlights their scarcity. Notably, the highly resistant lines exhibit substantial genetic diversity, making them valuable resources for incorporating SCB resistance into castor breeding programmes. Plant yield determines the production and productivity of the crop. Therefore, plant yield per plant of all the fifty castor genotypes (Table 5) were taken. The plant yield per plant varies from 189.23g (RG-2466) to 11.43 g (DCS-9). Most of the susceptible lines yielded less due to severe capsule borer infestation. Therefore, resistance lines can perform better under field infestation condition.

TABLE 4

Reaction of castor genotypes to shoot and capsule borer infestation

Genotypes	Per cent capsule damage	Reaction Score	Resistance level*	Plant yield (g)
RG-2774	18	1	R	138.21
DPC-9	10	1	R	143.42
RG-1930	16	1	R	110.23
RG-1813-1	22	1	MR	113.42
RG-1757-1	26	1	MR	124.21
RG-2466	2	1	R	189.23
DCS-9	100	4	S	11.43
P3-120NSp	98	4	S	14.12
YRCH-1	100	4	S	18.12
P3—80NSp	100	4	S	10.42
K-18-51-1	93	4	S	22.46

Continued....

TABLE 4 Continued....

Genotypes	Per cent capsule damage	Reaction Score	Resistance level*	Plant yield (g)
P3-58Sp	95	4	S	14.23
48-1	14	1	R	150.43
K-18-40-1	92	4	S	22.46
RG-1829	26	1	MR	108.42
DPC-25	86	4	S	16.23
DCS-107	92	4	S	20.14
ICH-5	80	4	S	43.21
K-18-92A	85	4	S	18.16
TMV-5	89	4	S	26.41
VP-1	100	4	S	19.43
GC-2	82	4	S	52.12
K-18-120	88	4	S	46.13
RG-1711-1	22	2	MR	76.58
RG-2180	28	2	MR	90.12
RG-2805	54	3	MS	68.13
TMV-6	96	4	S	16.22
YRCH-2	93	4	S	17.44
PRAGATHI	100	4	S	16.23
K-18-29	100	4	S	21.42
JI-35	78	4	S	46.23
ICS-110	100	4	S	18.44
HARITHA	92	4	S	16.21
RG-1614	91	4	S	24.89
RG-211	68	4	S	73.46
RG-2821	24	2	MR	94.76
JC-22-1	54	3	MS	83.12
SKI-343	88	4	S	19.46
GP-783	90	4	S	17.43
JP-96	25	2	MR	110.26
SKP-84	41	3	MS	97.42
IPC-39	64	4	S	80.17
IPC-42	52	3	MS	82.36
ICS-238	57	3	MS	74.14
ICS-125	53	3	MS	82.11
ICS-121	39	2	MR	76.48
RG-4023	52	4	MS	83.11
RG-4015	26	2	MR	137.47
RG-4019	42	3	MS	126.84
RG-3994	54	3	MS	122.1

TABLE 5

Correlation between morphological traits and reaction to capsule borer

	Bloom	Spineness	Compactness	Pericarp thickness	Reaction to pest
Bloom	1				
Spineness	-0.062	1			
Compactness	0.077	-0.908	1		
Pericarp thickness	0.578 **	0.068	-0.125	1	
Reaction to pest	0.623 **	-0.131	0.077	-0.527 **	1

In resistance breeding, understanding the correlation between plant characteristics and pest incidence is important. Correlation studies provide valuable insights into the nature and strength of the relationship between different traits. This information can guide breeding efforts by enabling the indirect selection of a desired trait through the selection of an associated trait. Point-biserial correlation, a suitable method for analysing the relationship between a dichotomous variable (presence / absence of bloom) and a continuous variable (% pest incidence), was employed in this study (Cheng and Liu, 2016). A highly significant and positive correlation (Table 5)was observed between the presence/absence of bloom and per cent pest incidence (0.623), suggesting that the presence of bloom may favours pest incidence. Hence, this trait should be prioritized in selection efforts aimed at improving resistance to SCB. This observation aligns with the findings of Sathishkumar *et al.* (2022), who studied 100 F_3 families and reported a significant correlation between presence/absence of bloom and SCB incidence. However, it contrasts with the results of Suganthi *et al.* (2011), who identified zero bloom as susceptible. This discrepancy may be attributed to the limited sample size in their study, which included only a single genotype, underscoring the potential impact of sample size on the reliability of results.

A significant and negative correlation was observed between pericarp thickness and SCB incidence (-0.527). This suggests that thicker fruit coats may deter larval feeding within the capsule. Consequently, lines with thicker fruit coats generally exhibited lower pest (Fig. 3) incidence compared to those with thinner coats. These findings indicate that fruit coat thickness

Fig. 3 : Cross section of capsules of resistant and susceptible lines varying for pericarp thickness

is a crucial trait for improving resistance to SCB in castor. Significant and positive inter correlation was found for fruit coat thickness and presence/ absence of bloom. Earlier, Lakshminarayana (2005) studied SCB preference on 12 castor lines differing in spike characteristics and reported moderate preference of SCB to the lines with small and non-spiny capsules and least preference to loose spikes. However, in this study, no correlation was found between spike compactness and capsule borer damage.

Presence/absence of bloom and pericarp thickness exhibited a significant and positive intercorrelation (0.578). No significant intercorrelations were observed among the other traits. Among the five identified resistance sources, three (RG-2466, DPC-9 and RG-1930) exhibited the no bloomphenotype (Table 3). Three resistance sources (RG-2466, 48-1 and RG-2466) were characterized by non-spiny capsules and two resistance sources (DPC-9 and RG-1930) displayed higher pericarp thickness. Genotypes were categorized into germplasm lines and Advanced breeding lines (inbreds, hybrids, parental line and variety) then compared with per cent capsule borer incidence using two sample t - test. Germplasm lines showing more resistance to capsule borer incidence compare to advanced breeding lines (Fig. 4). No bloom types showing more resistance compare to bloom types (Fig. 5). The observed correspondence between the results of correlation study, two sample t - test and the characteristics of the identified resistant genotypes strongly suggests the importance of these traits in host plant resistance to SCB. Therefore, these traits can be effectively utilized in breeding programmes aimed at developing castor varieties with enhanced resistance to this pest.

Based on the extent of capsule damage, RG-2466, DPC-9, 48-1, RG-1930 and RG-2774 demonstrated better resistance against SCB. Therefore, these germplasm lines can be effectively incorporated into breeding programmes aimed at enhancing SCB resistance. These lines can also be used to study the mechanism of resistance since these lines shows sufficient variations in all the traits. In association studies, presence/absence of bloom and spike spineness showed positive and significant association

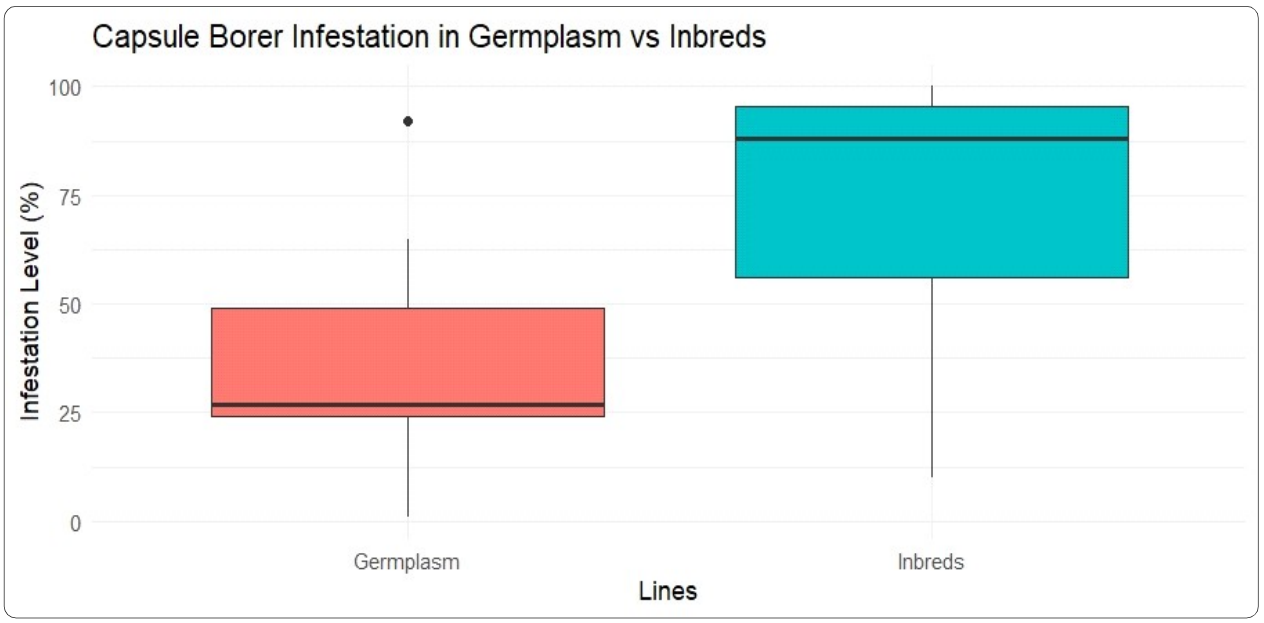


Fig. 4 : Comparison of castor genotypes with per cent capsule borer infestation

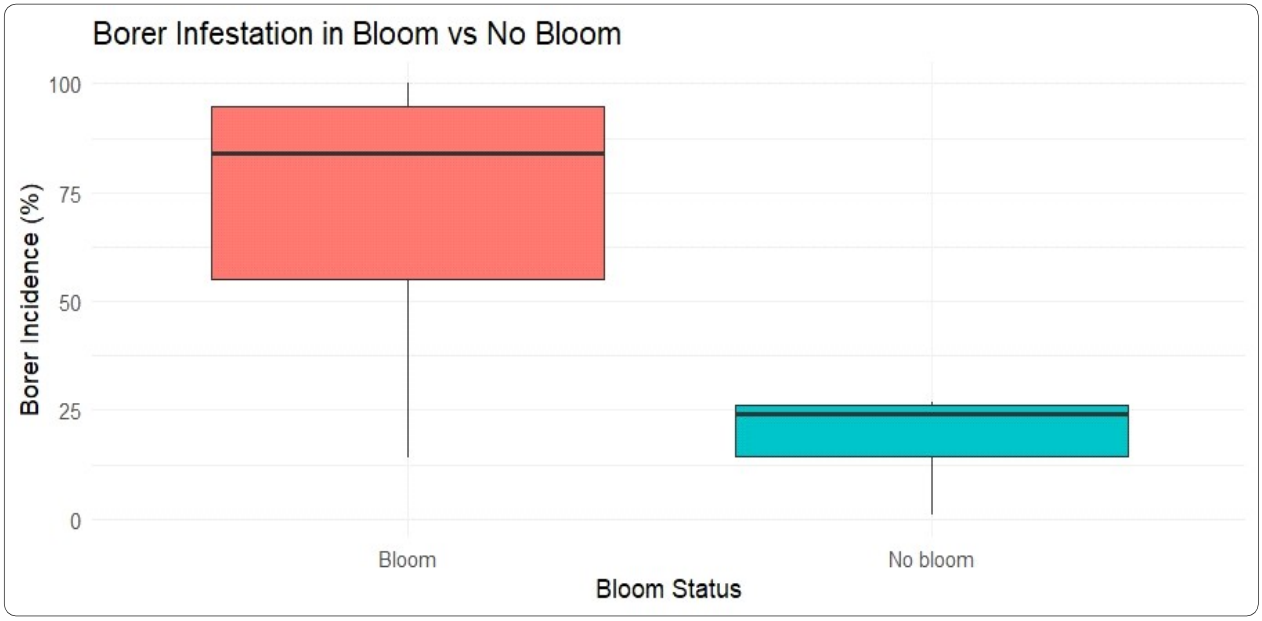


Fig. 5 : Comparison of bloom characters of castor genotypes with capsule borer infestation

with SCB resistance. The pericarp thickness showed negative and significant association with SCB incidence. These traits can be considered while selecting traits for capsule borer resistance.

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