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Potential of okra (*Abelmoschus esculentus* (L.) Moench) lines/crosses for resistance to Okra Yellow Vein Mosaic Disease and to pests in Thailand

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Abstract Studies of disease and pest resistance can assist in selecting heterotic cross models for the commercial exploitation of okra lines/crosses. Among twenty investigated lines, four lines of okra [KN-OYV-01 (P1), KN-OYV-02 (P2), LUCKYFILE 473 (P3) and RED FINGER (P4)] were identified as the best and subjected to full diallelic crosses to produce twelve F_1 hybrids. Then, the four parent lines, twelve F_1 hybrids and a commercial benchmark (OP line), were evaluated for prevalence and severity of the epidemiological factors of Okra Yellow Vein Mosaic Disease (OYVMD) and resistance to pests at Thaksin University. The experiments followed a randomized complete block design with four replications. The results revealed that the incidence of OYVMD ranged from 0.00 to 10.42%. Several crosses and parent lines, including P2, P4, P1xP2, P1xP4, P2xP1, P2xP3, P2xP4, P3xP2, P4xP1, P4xP2, exhibited immunity to Okra Yellow Vein Mosaic Virus (OYVMV) with 0.00% infection rate. Among the pests that cause economic damage to okra, the lines tested were significantly different ($P \leq 0.05$) in responses to *Aphis gossypii* Glover, *Thrips palmi* Karny, *Amrasca biguttula biguttula* Ishida, *Bemisia tabaci* Genn and *Helicoverpa armigera* (Hübner). The lowest counts of the pests *A. gossypii* Glover, *T. palmi* Karny, *A. biguttula biguttula* Ishida and *B. tabaci* Genn were recorded on P2xP1, P1, P1xP2 and P2 (3.25±0.92, 19.55±3.21, 2.11±4.45 and 1.10±1.24 insects/plant, respectively). In contrast, the OP line had the highest levels of infestation by *A. gossypii* Glover, *T. palmi* Karny, *A. biguttula biguttula* Ishida, *B. tabaci* Genn, *H. armigera* (Hübner) and leaf miners at 9.34±1.04, 45.84±84.21, 14.99±4.42, 9.14±2.22, 0.06±0.10 and 0.75±0.33 insects/plant, respectively. Moreover, the highest trichome density was recorded on P2 line (142.45±3.24 cm^2 leaf area), while the OP line exhibited the least number of trichomes (102.21±3.80 cm^2 leaf area). Thus, the trichomes are a major factor in the resistance of okra against diseases and pests.

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Keywords: Insect, Resistance, Trichomes, Yield

Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) belongs to the Malvaceae family (Phornvillay *et al.*, 2020; Jannah *et al.*, 2025). It is believed to have originated in tropical Africa (Benchasri, 2012). Okra is an important vegetable crop grown in tropical and subtropical regions of the world (Adesina and Wiro, 2020). It has good nutritional value, particularly in the high contents of vitamin C (47 mg/100g), vitamin A (0.18 mg/100g), calcium (84 mg/100g), iron (1.20 mg/100g) and fiber (1.70 g/100g) in the edible fruit (Rynjah *et al.,* 2018). Okra is also an excellent source of iodine, zinc, manganese and nickel (Graham *et al*., 2017), which is useful for the treatment of goiter (Abd El-Fattah *et al.*, 2020; Tatmala *et al.*, 2026). Moreover, phenolic compounds are considered the main bioactive components in okra fruit and are responsible for its various bioactivities (Shen *et al.,* 2019). Many pharmacological studies have reported that okra fruit possesses various bioactivities, such as anti- diabetic, anti- hyperlipidemic, antioxidant and anti-hyperglycemic effects (Durazzo *et al.*, 2019; Mangena *et al.,* 2026).

Okra is cultivated in many areas of Thailand including, Saraburi, Angthong, Kanchanaburi, Nakorn pratom, Supanburi, Phichit and Phatthalung provinces. The area of okra cultivation in Thailand is approximately 1,996.80 ha and the crop yield is about 11,232 tons/ha. As the demand of okra is increasing, the volume of production in Thailand is insufficient and growers in all regions have come across many problems. A number of viruses, fungi, bacteria, phytoplasma, nematodes, and pests attack this crop. OYVMD is a major disease in okra, which is transmitted by the whitefly (*B. tabaci* Genn) in Thailand (Benchasri, 2013). Infection of 100% of the plants in a field is very usual, and yield loss ranges between 50 and 100% depending on the stage of crop growth at which infection occurs (Tsai *et al.,* 2013). These production challenges not only threaten farmers' livelihoods but also hinder progress toward Sustainable Development Goals: SDGs 2 (Zero Hunger), which emphasizes increasing agricultural productivity and ensuring food security. Furthermore, recurring disease and pest pressure often leads to increased chemical interventions, which can negatively affect ecosystems and biodiversity, underscoring the importance of sustainable management strategies aligned with SDGs 15 (Life on Land).

In addition, [cotton aphid, *A. gossypii* Glover (Hemiptera: Aphididae)], [cotton thrips, *T. palmi* Karny (Thysanoptera: Thripidae)], [cotton leafhopper, *A. biguttula biguttula* Ishida (Homoptera: Cicadellidae)], [Tobacco white fly, *B. tabaci* Genn. (Homoptera: Aleyrodidae)], [cotton bollworm (*H. armigera* (Hübner)] and leaf miner have been listed as major pests of okra production in

Thailand. These pests infest leaves, stems, branches, flowers and fruit pods. Information on the incidence and severity of these diseases and pest attacks will be an important pre- requisite for developing appropriate and effective management strategies to improve the germplasm yield of okra. This study investigated the incidence and severity of OYVMD and pest infestations of germplasm okra plants under natural field conditions for analyses to provide a basis for the exploitation of valuable hybrid combinations in future breeding programs and their commercial utilization in Thailand.

Materials and methods

The present experimental study consists of germplasm screening, F_1 hybrids production, and evaluation of diseases and pests

Germplasm screening

Twenty lines of okra (Table 1), including varieties such as FAKDANG, KN-OYV-01, KN-OYV-02, KN-OYV-03, KN-OYV-04, KN-OYV-11, KN-OYV-12, KN-OYV-13, KN-OYV-14, KN-OYV-16, KN-OYV-25, LUCKYFILE 473, NO-71, OP (Open Pollination, control genotype), PC52S5, PJ.03, RED FINGER, RED 322, TVRC 064 and TVRC 064, were collected from various areas of Thailand and other countries, and were planted in a randomized complete block design with four replications at a spacing of 75×75 cm. The experiment was conducted at the Thaksin University, Thailand (7° 37' 0" N, 100° 5' 0" E). The four best parent lines that gave the highest fruit yields were selected.

F_1 hybrid production

The four best parent genotypes from among the twenty genotypes were KN-OYV-01 (P1), KN-OYV-02 (P2), LUCKYFILE 473 (P3) and RED FINGER (P4). They were crossed with full siblings in diallelic crosses to produce twelve F_1 hybrids (P1xP2, P1xP3, P1xP4, P2xP1, P2xP3, P2xP4, P3xP1, P3x P2, P3xP4, P4x P1, P4xP2 and P4xP3 (Table 2).

Disease and pest resistance evaluation

The four parents and their twelve F_1 hybrids were cultivated along with a commercial line (OP) as baseline or control, in a randomized complete block design with four replications. The row spacing was 75 cm, and the planting distance was 75 cm, with twelve plants/ plot, at the experimental Vegetable Research Station farm in Faculty of Agriculture, Thaksin University Phatthalung Campus, Phatthalung Province, Thailand. Standard agronomic practices were

followed from sowing until harvest. The genotypes were grown on ridges, and furrow irrigation was applied weekly. Compost manure at a recommended dose of 650 kg/ha and chemical fertilizer at a recommended dose of 650 kg/ha were applied to the experimental field. Plant protection measures were regularly carried out to safeguard the okra plants. Major disease (OYVMD) and pests were recorded.

Table 1. The twenty okra lines in experimental screening for best yield

No.	Genotypes/lines	Sources	Types	Sources
1	FAKDANG	Phatthalung Province	indeterminate	Thailand
2	KN-OYV-01	PHRC	indeterminate	India
3	KN-OYV-02	PHRC	indeterminate	India
4	KN-OYV-03	PHRC	indeterminate	India
5	KN-OYV-04	PHRC	indeterminate	India
6	KN-OYV-11	PHRC	indeterminate	India
7	KN-OYV-12	PHRC	indeterminate	India
8	KN-OYV-13	PHRC	indeterminate	India
9	KN-OYV-14	PHRC	indeterminate	India
10	KN-OYV-16	PHRC	indeterminate	India
11	KN-OYV-25	PHRC	indeterminate	India
12	LUCKYFILE 473	Bangkok Province	indeterminate	Japan
13	NO 71	PHRC	semi-determinate	India
14	PC 52S5	PHRC	semi-determinate	Thailand
15	PJ 03	PHRC	indeterminate	Thailand
16	RED FINGER	Beijing	determinate	China
17	RED 322	Pahang	indeterminate	Malaysia
18	TVRC 06	PHRC	semi-determinate	India
19	TVRC 064	PHRC	semi-determinate	India
20	OP (BASELINE)	Phatthalung Province	indeterminate	Thailand

PHRC: (Phichit Horticulture Research Center)

Table 2. Full siblings in diallelic crosses model

Crosses	KN-OYV-01 (P1)	KN-OYV-02 (P2)	LUCKYFILE 473 (P3)	RED FINGER (P4)
KN-OYV-01 (P1)	-	P1 X P2	P1 X P3	P1 X P4
KN-OYV-02 (P2)	P2 X P1	-	P2 X P3	P2 X P4
LUCKYFILE 473 (P3)	P3 X P1	P3 X P2	-	P3 X P4
RED FINGER (P4)	P4 X P1	P4 X P2	P4 X P3	-

Major disease investigation

OYVMD is one of the major constraints to okra cultivation in Thailand. Okra infected with OYVMV was first reported in Thailand by Tsai *et al.* (2013). The OYVMD was recorded based on visual observations of its typical symptoms

in field conditions. Eight weeks after planting (WAP), (56 days) the OYVMD was found on twelve plants that were tagged for observation. Data were recorded in the mornings between 7 and 10 am. The disease entry was assessed according to Khaskheli *et al*. (2017). The disease symptoms were yellowing of veins, chlorosis, yellowing and dwarfing of leafs in okra crop (Figure 1) and these were the basic criteria (Table 3). The following formula was used to calculate the disease incidence (Kumar and Tayde, 2018).

$$\text{Percent Disease Incident (PDI)} = \frac{\text{Number of diseased plants}}{\text{Total number of plants observed}} \times 100$$

Figure 1. Symptoms of OYVMD on leaves (A) at 8th (WAP), and (B) at 12th (WAP) (bars = 5 cm)

Pest determination

Important pests of okra, namely cotton aphids (*A. gossypii* Glover), cotton thrips (*T. palmi* Karny), cotton leafhopper (*A. biguttula biguttula* ischida), tobacco whitefly (*B. tabaci* Genn), cotton bollworm (*H. armigera* Hubner), and leaf miner were estimated in the four parents, twelve F_1 hybrids and a commercial baseline genotype (OP) randomly selected at 8 WAP. Okra leaves were carefully examined by observing both the adaxial and abaxial surfaces. Insect pests were identified, counted and recorded as either major or minor based on their incidence patterns. This was usually done between 6.00 am and 10.00 am when these insects are easy to find while feeding on the surfaces of the leaves. The numbers of adult pests caught on each occasion as well as their species identities were

recorded. Insects were caught by hand picking since they were only capable of exhibiting limited flight.

Table 3. Disease rating scale of OYVMV

	Rating	Severity Range (%)
0	Immune	0 %
1	Highly resistant	1-10 %
2	Moderately resistant	11-25 %
3	Tolerant	26-50 %
4	Moderately susceptible	51-60 %
5	Susceptible	61-70 %
6	Highly susceptible	71-100 %

Source: Ali *et al.* (2005) and Rynjah *et al*. (2018)

Analysis of trichome density and morphology

Scanning Electron Microscopy (SEM) is extensively used to observe structure details on surfaces of biological samples. The conventional SEM sample preparation procedure involves fixation, dehydration, drying, and optionally conductive coating (Talbot and White, 2013). In this study, SEM imaging was conducted using S-3200N (Hitachi) and JSM-5800 (JEOL) microscopes (Takeda *et al.,* 2013). Leaf samples were fixed for 24 hr in a solution of 2.5% paraformaldehyde, 2.5% glutaraldehyde buffered with 0.5 M sodium phosphate buffer at pH 7.0. The samples were dehydrated with 50-100% ascending ethanol series on rotation (50, 60, 70, 80, 90, 95 and 100% dry), with 20 min per step at 35-37°C, and sputter coated with a 20 nm conductive layer (JEOL JFC 1500). Samples were examined with 15 kV accelerating voltage and images were captured digitally.

Statistical analysis

The investigation followed a randomized complete block design with four replications. Data collected were subjected to the analysis of variance using the statistical program SPSS (Statistical Package for Social Science, for Windows) version 16.0. Means were tested for significant differences by using the Least Significant Difference (LSD) test.

Results

Disease incidence

Disease incidence of OYVMD was in the range between 0 to 10.42%, in Phatthalung province, Thailand, at 8 WAP, in the four best lines, twelve crosses,

and a local baseline case (OP). The responses of the lines/crosses to OYVMD varied when compared based on the percentage of plants infected**.** P2, P4, P1xP2, P1xP4, P2xP1, P2xP3, P2xP4, P3xP2, P4xP1, P4xP2 showed immunity to OYVMV with 0.00% infection rate**.** The six lines/crosses P1, P3xP4, P1xP3, P4xP3, P3, and P3xP1 were highly resistant with low infection rates (2.08, 2.08, 2.22, 2.22, 6.25, and 6.25%, respectively**).** The maximum 10.42% disease severity was recorded in the commercial line (OP), which was graded as moderately resistant (Table 4). Therefore, The OP line had the poorest PDI resistance level, which causes the most OYVMD infections and makes this line easier to destroy than the other lines/crosses.

Table 4. Observed percentages of OYVMD incidences in different species of okra

Lines/crosses	Total plants	Disease count	PDI	Level of OYMD resistance
P1	48	1	2.08	Highly resistant
P2	48	0	0.00	Immune
P3	48	3	6.25	Highly resistant
P4	48	0	0.00	Immune
OP (BASELINE)	48	5	10.42	Moderately resistant
P1xP2	46	0	0.00	Immune
P1xP3	45	1	2.22	Highly resistant
P1xP4	46	0	0.00	Immune
P2xP1	46	0	0.00	Immune
P2xP3	47	0	0.00	Immune
P2xP4	46	0	0.00	Immune
P3xP1	48	3	6.25	Highly resistant
P3xP2	48	0	0.00	Immune
P3xP4	48	1	2.08	Highly resistant
P4xP1	46	0	0.00	Immune
P4xP2	46	0	0.00	Immune
P4xP3	45	1	2.22	Highly resistant

Insect abundance

A natural field study was carried out to assess the choices of different pests in the Vegetable Research Station farm, Thaksin University, Thailand at 8 WAP (Table 5). The results showed that *A. gossypii* Glover, *T. palmi* Karny, *A. biguttula biguttula* Ishida, and *B. tabaci* Genn were highly significantly different ($P \leq 0.05$) between the lines/crosses**.** The OP line had the highest level of impairment by *A. gossypii* Glover, *T. palmi* Karny, *A. biguttula biguttula* Ishida, and *B. tabaci* Genn at 9.34±1.04, 45.84±84.21, 14.99±4.42 and 9.14±2.22 insects/plant, whereas the lowest counts of the pests *A. gossypii* Glover, *T. palmi* Karny, *A. biguttula biguttula* Ishida, and *B. tabaci* Genn were recorded in P2xP1, P1, P1xP2 and P2 (3.25±0.92, 19.55±3.21, 2.11±4.45 and 1.10±1.24 insects/plant, respectively). *H. armigera* (Hübner) was most attracted to OP

(0.06±0.10 insects/plant). P1, P2, P1xP2, P2xP1, P2xP3, P2xP4, P3xP2, P4xP1, and P4xP2 were resistant to cotton bollworm with no damage**.** The leaf miners are among the numerous species of insects that in their larval stages live in, and eat, the leaf tissues of okra plants**.** Leaf miners did not show significant difference in the study and had low rates of infecting the okra genotypes.

Table 5. Numbers of pests in okra lines/crosses

Lines/ crosses	Cotton aphid	Cotton thrip	Cotton leafhopper	Tobacco whitefly	Cotton bollworm	Leaf miner
P1	4.82±1.14bc	19.55±3.21d	8.66±3.78b	2.49±1.55cd	0.00±0.00c	0.33±0.15
P2	3.68±1.02de	20.55±5.03d	4.44±4.51b	1.10±1.24d	0.00±0.00c	0.45±0.19
P3	5.20±0.92b	30.11±5.12bc	8.89±4.12b	6.24±1.23b	0.02±0.01bc	0.70±0.24
P4	4.54±1.03bcd	22.33±5.02cd	2.76±3.38c	2.11±1.01d	0.02±0.02bc	0.47±0.15
OP	9.34±1.04a	45.84±84.21a	14.99±4.42a	9.14±2.22a	0.06±0.10a	0.75±0.33
P1xP2	3.37±1.13e	20.19±4.25d	2.11±4.45c	3.15±1.35c	0.00±0.00c	0.45±0.14
P1xP3	4.00±1.07cde	22.11±4.83d	4.89±3.56bc	2.25±2.24d	0.02±0.01bc	0.50±0.15
P1xP4	4.87±1.07bc	23.99±3.78bcd	3.33±3.79c	3.44±2.04c	0.02±0.01bc	0.50±0.15
P2xP1	3.25±0.92e	20.12±3.96d	2.55±3.99c	2.21±1.06d	0.00±0.00c	0.66±0.14
P2xP3	3.50±0.83de	25.67±4.04bcd	2.22±3.12c	2.44±1.25cd	0.00±0.00c	0.67±0.16
P2xP4	3.62±0.74de	28.33±5.75b	2.56±3.91c	2.44±2.38cd	0.00±0.00c	0.48±0.13
P3xP1	5.11±0.97b	29.67±2.33bc	7.88±3.34bc	4.33±1.18bc	0.02±0.01bc	0.71±0.15
P3xP2	3.43±0.98e	25.55±4.54bcd	5.26±2.75bc	8.99±1.01a	0.00±0.00c	0.51±0.22
P3xP4	5.18±0.81b	30.78±4.89b	6.55±1.98bc	5.89±1.15b	0.02±0.01bc	0.73±0.18
P4xP1	4.12±1.24bcde	27.56±5.14bc	3.22±2.73c	3.22±1.21c	0.00±0.00c	0.63±0.21
P4xP2	4.18±0.72bcde	22.67±7.35bcd	5.02±2.73bc	3.21±2.13c	0.00±0.00c	0.65±0.15
P4xP3	4.47±0.42bcd	21.67±7.35d	4.15±3.74bc	3.04±2.23cd	0.04±0.01ab	0.62±0.11
$LSD_{0.05}$	1.09	7.17	5.41	2.02	0.02	0.49
F-test	*	*	*	*	*	ns
CV.(%)	8.14	9.21	9.28	8.79	5.05	7.38

Means±SD from 4 replicates for each treatment, values with different letters are significantly different at P≤0.05 based on the LSD test.

Trichome density and morphology

The abaxial surfaces (lower surfaces) of leaflets (excluding the midvein) were used to count trichomes (Table 6). In the present the two major types of trichomes were glandular (Figure 2A) and eglandular foliar (Figure 2B). Among the eglandular trichomes, unicellular trichomes were observed in the four parents (P1, P2, P3, P4) and in all the F_1 hybrids (P1xP2, P1xP3, P1xP4, P2xP1, P2xP3, P2xP4, P3xP1, P3xP2, P3xP4, P4xP1, P4xP2 and P4xP3). In contrast, the OP line has a papillate trichome type**.** The results on trichome density on abaxial surfaces revealed significant differences among the germplasms screened**.** The highest trichome density was recorded for the P2 line (142.45±3.24 cm^2 leaf area). The least trichomes were recorded for the OP line (102.21±3.80 cm^2 leaf area). The present evaluation of the trichome length of different okra germplasm collections revealed significant differences among the germplasms evaluated.

The longest trichomes were recorded for the parent (P2) (668.16±4.66 μm) (Figure 3A), while the susceptible line (OP) had the shortest trichomes (223.58±6.08 μm) (Figure 3B).

Table 6. Trichome density and length for the okra lines/crosses

Line/cross	Type of trichomes	Trichome density/cm^2 of leaf	Trichome length (μm)/piece
P1	unicellular	130.25±2.45bc	25.536±4.98bcd
P2	unicellular	142.45±3.24a	668.16±4.66a
P3	unicellular	118.18±4.65c	505.49±4.20e
P4	unicellular	138.95±4.01a	512.98±4.36de
OP(BASELINE)	papillate	102.21±3.80d	223.58±6.08f
P1xP2	unicellular	140.15±2.94a	559.67±3.85ab
P1xP3	unicellular	129.17±3.96bc	34.512±6.45de
P1xP4	unicellular	125.42±4.08bc	16.531±5.73bcde
P2xP1	unicellular	141.81±2.09a	17.565±4.59ab
P2xP3	unicellular	140.16±2.90a	25.512±35.09de
P2xP4	unicellular	124.82±3.98bc	541.02±4.92bc
P3xP1	unicellular	120.67±4.02c	518.61±5.01ced
P3xP2	unicellular	130.28±3.06bc	526.54±3.87bcde
P3xP4	unicellular	132.39±2.89abc	516.78±4.91cde
P4xP1	unicellular	134.32±4.06abc	529.25±4.89bcde
P4xP2	unicellular	139.16±4.09ab	545.48±4.76ab
P4xP3	unicellular	120.51±3.30c	525.18±4.98bced
$LSD_{0.05}$		10.23	26.34
F-test		*	*
CV.(%)		5.67	6.18

Means±SD from 4 replicates for each treatment, values with different letters are significantly different at P≤0.05 based on the LSD test.

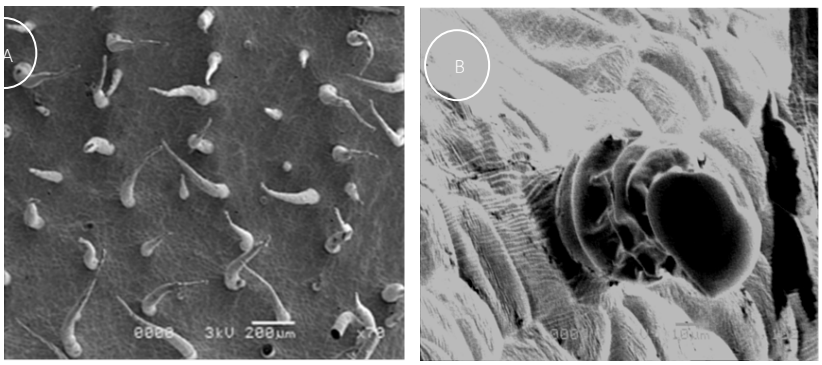

Figure 2. Initial morphological characterization of unicellular (A), and papillate trichome (B) with secretion, imaged using SEM (bars = 200 μm)

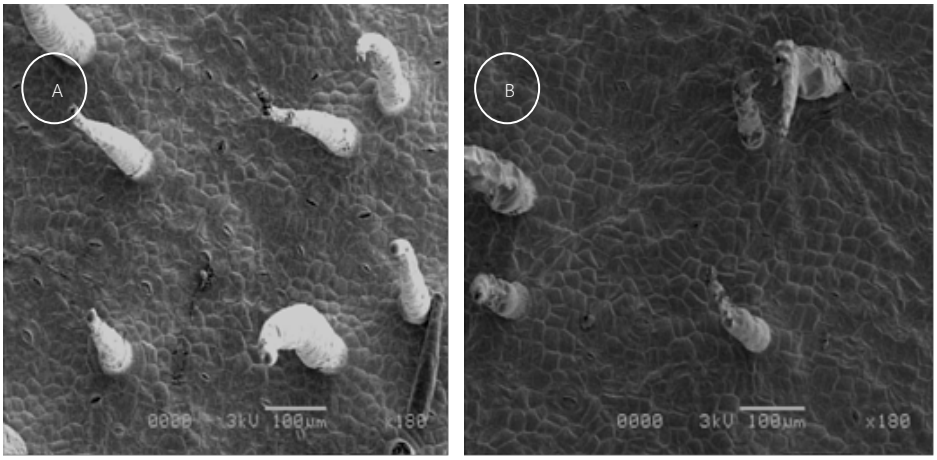

Figure 3. Trichome density on abaxial surface of P2 line (A), and for OP line under natural field conditions (bars = 100 µm)

Discussion

OYVMD incidence

To develop and evolve new hybrids, it is necessary to understand the genetic architecture of quantitative characters for formulating an efficient breeding program**.** Selection of suitable parents is an important step in the hybridization program (Naim *et al.*, 2019). It is essential that the parents should be chosen on the basis of this genetic value because phenotypically superior lines may also yield poor combinations**.** Okra is very much susceptible to whitefly transmitted OYVMV and several attempts have been made to mitigate the disease through vector control, resistance screening and other breeding strategies**.** Emphasis needs to shift towards development of OYVMV resistant lines**.** This study looked for potential sources of resistance to OYVMD under natural field conditions**.** In this study, two parents (P2, P4) and eight F_1 hybrids (P1xP2, P1xP4, P2xP1, P2xP3, P2xP4, P3xP2, P4xP1, and P4xP2) did not express any symptoms of OYVMD and appeared immune to the disease**.** Similarly, AE 64, AE 65, and AE 66 did not express any symptoms of OYVMD and were immune to the disease according to Rynjah *et al*., 2018. The remaining cross combinations AE 66 x VRO 106, Kashi Pragati x VRO 106, and VRO 106 x AE 66 showed high disease incidences. the disease incidence varies by genotype**.** The preferences of insects among cultivars are affected by biochemical substances or metabolites, including phenols, terpenoids, flavonoids, alkaloids, catalase, etc., which play a vital role in imparting resistance to diseases or pests (Mubeen *et al.,* 2017).

Pests influence

A. gossypii Glover are about 1-1.5 mm long and constitute the major pest of okra in Asia. Aphids feeding on okra cause direct damage to the plant by removing photoassimilates. The damage is caused both by nymphs and adults by sucking sap, thus weakening the line/cross of okra, and the excreted sticky honeydew grows sootlike mold on leaves that hinders photosynthesis (Abang *et al.,* 2016). Hence, they reduce the yield and market value of okra and indirectly cause damage by transmitting pathogenic viruses, such as the yellow vein mosaic virus in okra (Muimba-Kankolongo, 2018). Therefore, the most effective strategy to lessen these harmful effects is to use genetically resistant commercial okras. To date, P2xP1, P1xP2, P3xP2, P2xP4, and P2 as main sources of resistance to *A. gossypii* Glover are mostly used in okra breeding: P2xP1, P1xP2, P3xP2, P2xP4, and P2 lines/crosses carry the dominant resistance gene, while the commercial line (OP) was susceptible to aphids and to their virus transmission (Ranga *et al.*, 2024).

T. palmi Karny infestation on different okra lines/crosses varied significantly. The highest and the lowest *T. palmi* Karny populations of 45.84±84.21 and 19.55±3.21 insect/plant were recorded for OP and P1, respectively. Syed *et al.* (2003) studied the effluence on leaf development and yield of various okra genotypes and found that morphological characters such as okra leaf, red color, glandness, nectariliness, or smooth leaf were associated with resistance. In general, genotypes with very hairy leaves (pilose) are associated with a high level of resistance to *T. palmi* Karny (Arif *et al*., 2004). The *T. palmi* Karny population on different varieties of okra varies significantly, as also seen in the current study.

A. biguttula biguttula Ishida attacks okra at its early growth stage**.** Nymphs and adults of *A. biguttula biguttula* Ishida are found on the undersides (abaxial surfaces) of the leaves. *A. biguttula biguttula* Ishida sucks the cell sap from the leaves (Patel *et al*., 2018). As a result, the leaves curl upwards along the margins and have a burnt look, which extends over the entire leaf area (Kamble and Sathe, 2015). Later the plants showed stunted growth, especially the OP line, while the other lines/crosses had lesser symptoms**.** Prithiva *et al.* (2019) reported that the development and cultivation of resistant varieties to pests provide a suitable and desirable means of pest management. The success of such a program depends upon the extent of genotypic variation. The results show that no line/cross had 100% resistance against *A. biguttula biguttula* Ishida, but there were significant differences in resistance by genotype. In the present study, the OP line had the highest *A. biguttula biguttula* Ishida population (susceptible), while P1xP2 showed comparatively lesser *A. biguttula biguttula* Ishida population (resistant).

Prithiva *et al.* (2019) have reported Pusa Sawani genotype as highly susceptible to *A. biguttula biguttula* Ishida **(**no genotype had 100% resistance to leafhopper**)** which conform with our present findings.

Adults of *B. tabaci* Genn are winged, they are 1**-**1.5 mm long and their yellowish bodies are slightly dusted with white waxy powder. *B. tabaci* Genn has two pairs of pure white wings and prominent long hind wings. The milky white minute whiteflies and nymphs suck the cell sap from okra leaves**.** The affected leaves curl and dry (Akbar and Khan, 2015). The okra plants then show stunted growth. *B. tabaci* Genn is also transmitting OYVMV (Kedar *et al.,* 2014). *B. tabaci* Genn populations on the different lines/crosses of okra varied significantly. The maximum and minimum populations were 9.14±2.22 and 1.10±1.24 insects/plant, recorded for OP and P2 respectively**.** The comparatively high infestation by *B. tabaci* Genn on the OP line might be due to it being hairless (Vyskočilová *et al.,* 2019). Similarly, Leite *et al.* (2005) observed a morphological basis of resistance to whitefly**.** Hatab *et al.* (2013) found that hair density and leaf thickness negatively correlate with the population of *B. tabaci* Genn. Hence, to reduce *B. tabaci* Genn population, these characteristics are desirable. The four parents and all F_1 hybrids are great sources of lines/crosses because their *B. tabaci* Genn resistance was far superior over the OP line.

H. armigera (Hübner), a highly devastating polyphagous crop pest, has a broad host spectrum and causes significant yield losses in many agriculturally important crops, like okra, cotton, chickpea, pigeon pea, corn, maize, tomato, and groundnut (Volpicella *et al.*, 2003). Thirty percent of all pesticides used worldwide are directed against *H. armigera* (Hübner), which has resulted in high levels of insecticide resistance in this pest**.** Insecticide resistance in *H. armigera* (Hübner) is a widespread problem in Thailand, India, Pakistan, China, and Indonesia (Aggarwal *et al*., 2006). The use of *Bacillus thuringiensis* (*Bt*) either in the form of formulation or in transgenic plants may cause the insect to develop resistance in a short period since many pests have developed resistance to *Bt***-**like chemical pesticides. Therefore, it is important to search and develop alternative methods of controlling this pest. Genetically Modified Organisms (GMOs) are not allowed in many countries (Benchasri *et al.,* 2020). Thailand is one of the countries that does not allow the commercialization of GM crop production, and open**-** field trials remain highly regulated. In addition, the import regulations of GM products are rather stringent**.** Hybridization has been the most successful approach in increasing the productivity in vegetable crops Silva Dias (2014). Selection of genetically superior and suitable genotypes is the most important stage from the standpoint of hybridization of vegetable crops to develop new genotypes having desirable characteristics, such as disease and pest resistance (Anitha and Karthika, 2018). To break the disease and pest barriers in existing

open-pollinated varieties of okra, a hybridization-based breeding strategy would be desirable. F_1 hybrid breeding has been the most successful approach to increasing the disease and insect- resistant germplasms in vegetable crops (Medagam *et al*., 2012).

The population density of leaf miner on the okra lines/ crosses showed that, OP (baseline), harboured the most of them (0.75±0.33 insect/plants), while KN-OYV-01(P1) had the least of them (0.33±0.15 insect/ plants) and no case was significantly superior over all the others. The present investigation agrees with Hatab *et al*. (2013**)** in the typical size of the population of leaf miners, which on different okra genotypes ranged from 15.83 leaf miners/ 10 leaves on Str. L6 to 1.75 leaf miners/10 leaves on Str.L2, recording no significantly superior line.

Trichome influence

Trichomes have features that vary between species of plants and organs of a single plant (Nawab *et al*., 2014). Trichomes in *Abelmoschus* spp. are multicellular and have been classified into seven types according to the presence or absence of glandular cells, and the shape and number of cells, including the capitate, conical, flask shaped, forked stellate, papillate, peltate and uniseriate multicellular (Krishnakumar *et al.,* 2018). Research on trichomes has traditionally focused on understanding the specialized metabolic pathways operating in glandular trichomes (Spyropoulou *et al*., 2014; Galdon-Armero *et al*., 2018). However, trichomes also play a series of important physiological roles, including in tolerance to biotic and abiotic stresses, especially in tolerance to disease and insect attacks (Sandhi *et al*., 2017). A major function of the trichome is thought to be in plant defense against diseases and insects (Halder *et al*., 2016). The present investigation observed granular and eglandular capitate trichome in four parents, a commercial baseline case, and six direct and six reciprocal F_1 hybrids. All lines/crosses of okra except for OP showed granular unicellular trichome types. Similarly, Krishnakumar *et al*. (2018) observed a micromorphological characters, distribution of both glandular and eglandular foliar trichomes in thirty accessions of okra. Unicellular ones are slightly broader at the base and narrow upwards forming a necklike portion with apical opening. Unicellular types decrease damage from enemies (Hagenbucher *et al*., 2013). Osawaru *et al*. (2011) reported distributions of trichomes on leaf surfaces and okra fruit in fifty-three lines. The abaxial surfaces among the lines in the taxon possess unicellular filiform hairs, whereas the adaxial surfaces are conspicuously covered with conical macroform hairs uniquely on the ribs. On the fruit, the grooves are densely covered with unicellular conical hairs. This is responsible for the nature of fruits**.** The ridges are strictly and sometimes sparsely covered

with macroform conical hairs, which sometimes make the fruit spiny. Moreover, Jamir *et al*. (2020) have also reported some of the morphological traits act as mechanical barriers to diseases or pests, including the pubescence by trichomes or hairs on leaf lamina, while others influence the general growth habits and appearance of the plant, of leaves or red pigmentation, or even of the microclimatic conditions of leaves. On the other hand, the OP line had papillate trichome type and was more susceptible to OYVMD and various insect pests **(**cotton aphids, cotton thrips, cotton leafhoppers, tobacco white flies, cotton bollworms and leaf miners) than the other lines/crosses. Therefore, variations in morphology and distribution of the foliar trichomes emerged as an important indicator, for identifying diverse lines/crosses of okra that are appropriated for a disease and pest resistance breeding program in the next generation.

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Conflicts of interest

The authors declare no conflict of interest.

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