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COMPARATIVE ANALYSIS OF VOLATILE COMPOUND PROFILES IN PARENTAL GENOTYPES AND HYBRIDS OF HOT PEPPERS

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SUMMARY

The volatile compounds emitted by hot pepper (*Capsicum frutescens* L.) flowers play a crucial role in plant-insect interaction and natural insect resistance. This study aimed to analyze the volatile compound (VoC) profile of hot pepper flowers derived from four genotypes, comprising two parental lines and their two F1 hybrids. Volatiles' sampling used the HS-SPME (Headspace-Solid Phase Micro Extraction), analyzed via GC–MS (gas chromatography-mass spectrometry), and identified using the NIST (National Institute of Standards and Technology) 14 spectral reference. VoCs entailed groupings based on the presence or absence of each compound. Data then underwent the principal component analysis (PCA). The study identified 133 volatile compounds in the flowers of the parental genotype and its F1 hybrid. F1 hybrid flowers obtained through cross-hybridization between the parental lines exhibited varied ratios of volatile compounds. PCA revealed the parental lines (A and B) and their reciprocal F1 hybrids exhibited distinct profiles of volatile compounds. Notably, the F1 hybrids produced additional repellents, such as *D*-Limonene, *cis*-jasmone, and farnesol, against insect pests. The analysis displayed 11 interesting pattern variations. Understanding the volatile composition of hot pepper genotypes is beneficial in breeding programs aimed at developing pest-resistant cultivars based on the antixenosis mechanism, thereby enhancing passive plant defense against pests and virus-carrying insects.

Keywords: Hot pepper (*C. frutescens* L.), flowers, nectars, volatile compounds, insect resistance, pests, plant defense, repellent, breeding program

Key findings: The study identified 133 volatile compounds with diverse ratios in four populations of hot pepper (*C. frutescens* L.). The F1 hybrids produced volatile compounds that act as pest repellents and attractants. These repellents could aid in pest management, especially against *Bemisia tabaci* and *Myzus persicae*.

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INTRODUCTION

Hot pepper (*Capsicum frutescens* L.) is an essential vegetable commodity utilized worldwide (Guijarro-Real *et al.,* 2023) and has become the primary staple condiment for the Indonesian population (Undang *et al.,* 2023). According to FAOSTAT 2025, global production of chili and pimento reached 38 million tons of green fruits in 2023, cultivated across two million hectares. Despite various challenges in its cultivation within tropical climates, it is essential to maintain hot pepper production to meet the growing demand. Hot pepper production in Indonesia had risen to 1.5 million tons, accounting for 5% of the global production (BPS, 2024). More than 30 types of pests and diseases interact negatively with chili plants throughout their life cycle, from seedling to vegetative and reproductive phases, even during the harvest phase, making it a significant challenge to overcome (Fadhilah *et al*., 2023). In South Asia, yield losses of chili caused by the top 10 viral diseases ranged from 15% to 100% (Kushwaha *et al*., 2021). These pests can potentially reduce hot pepper yields in Indonesia by up to 33.14%. The greatest potential yield loss occurs under field conditions, particularly in soils with low water content (Ahmad *et al*., 2024).

Plants produce secondary metabolites as adaptive tools to survive and thrive in their environments. Secondary metabolites released by plants serve as host-seeking signals (Ali *et al*., 2023), chemical barriers (Luna-Ruiz *et al*., 2018), defense tools (Divekar *et al*., 2022), and sexual communication signals (Montagné, 2024), as well as floral volatiles, all of which play a crucial role in the complex interactions between plants and insects. Volatile compounds (VoCs) released by plants serve as a medium of interaction between plants and insects. The release of volatile compounds helps plants by attracting beneficial insects and pollinators and repelling vector insects (Ali *et al*., 2022). Plants seemed to be protected from insects by having more repellent volatile compounds than attractants. Some compounds have reached confirmation as attractants and repellents for various crops and their pests (Divekar *et al*., 2022). However, their specific role in attracting or repelling hot pepper plants remains to be identified (Ayala *et al*., 2019).

Given their ecological role, hybridization may alter VoC composition and enhance insect resistance in chili plants. In breeding, cross-hybridization aids in assembling beneficial traits and eliminates undesirable and harmful traits in chili genotypes. For example, hybridization in *Capsicum* spp. enhances the aroma of fully ripe fruits (Moreno-Peris *et al*., 2020). Somatic hybrids between eggplant (*Solanum melongena*) and its relatives have shown significantly enhanced resistance to *Ralstonia solanacearum*, the causal agent of bacterial wilt (Du *et al*. 2023). Several studies have reported cross-hybridization between the desirable parental genotypes has successfully achieved the best combination of yield and biochemical characteristics in their F1 hybrids (Maulani *et al*., 2023; Syukur *et al*., 2023; Kirana *et al*., 2024). Thus, it has been a suspicion that variations in the composition of volatile compounds released by chili plant flowers can be successful through cross-hybridization. However, reports about the variations in the profile of volatile compounds released by chili due to cross-hybridization are still rare.

This study examined how cross-hybridization between two parental chili lines affects the VoC compound profiles of hot peppers. The VoC profile of the parental lines and their F1 hybrids incurred isolation using headspace solid-phase microextraction (HS-SPME), detected through gas chromatography-mass spectrometry (GC-MS), and compared. Since the 1990s, HS-SPME has been advantageous to analyze floral volatiles in species such as *Rosa* and *Camellia* (Rout *et al*., 2012). More recently, its effectiveness in isolating and identifying VOCs from Tillandsia flowers has been demonstrated when coupled with GC-MS (Lo *et al*., 2021). The research hypothesis was that the cross-hybridization of two pepper lines can produce new individuals with a more desirable volatile compound profile than both parental genotypes.

Figure 1. Parental lines (A and B) and F1 Hybrids (AB and BA) performance.

MATERIALS AND METHODS

The chili flowers used for the analysis of the volatile compounds were harvests coming from four different populations: parental line A, parental line B, and two F1 hybrids (AB and BA) (Figure 1). All these hot pepper genotypes' planting on agricultural land took place in Lembang, West Java, Indonesia (1,250 masl) at coordinates of 6°47'57" S, 107°39'01" E.

Sample extraction

The flowers of all four hot pepper genotypes were samples used for the extraction of volatile compounds via the Headspace-Solid Phase Micro Extraction (HS-SPME) method. The flowers reaching ST3 (completely colored mature flower buds) to ST5 (open flowers with highly visible pollen) based on Lin *et al*. (2022) incurred placing in clear 40 mL vials (AGI 32008, USA), filling up the vial to ¾ of its volume (approximately 4 g), and sealing with a PTFE/Si cap (AGI 283488, USA). Each genotype sampling had duplicates. The samples proceeded to transfer to the laboratory within 24 h before heating to 30 °C for 45 min. Then, the extraction of volatile compounds used the solid-phase microextraction (SPME) with a DVB/CAR/PDMS fiber.

Detection methods

The extract samples entailed further usage for the detection of the volatile compounds using the gas chromatography-mass spectrometry (GC-MS). Each sample's introduction into an Agilent 7890A gas chromatograph had a temperature of 250 °C for 5 min in splitless mode. Establishing the initial temperature of the oven at 45 °C ran for 2 min. Subsequent raising of the temperature to 250 °C had a rate of 5 °C per minute. Maintaining it at 250 °C for an additional 2 min ensued before further elevating to 250 °C at the same rate for 5 min. The identification of volatile compounds was reliant on their retention times in the gas chromatograph, coupled with a mass spectrometer (MS Agilent 5875 C XL EI/CI with Triple Axis Detector). Separation was successful in using an HP-5MS column (30 m × 250 μm × 0.25 μm), with helium as the carrier gas at a flow rate of 0.8 ml/min. The relative quantity of volatile compounds based on the area under the peak attained its determination by comparing each compound's spectrum with the NIST14 library, as described by Kirana *et al*. (2019) and Hafsah *et al*. (2020). The peaks with sharp and clear mass spectra, which have a probability matching above 85%, are the selected compounds to be reported. All contaminants' removal has already occurred from the detected original peak.

Data analysis

The observed data on volatile compounds served as the basis for forming different patterns. Patterns shaped depended on the presence/detected area (+) or absence/undetected area (-) of the volatile compounds in the four examined genotypes of the hot pepper. The names of the observed volatile compounds entailed grouping based on the formed patterns, followed by the principal component analysis (PCA), as used to map the positions of the parent lines and their F1 hybrids. The algorithm employs a paired group (UPGMA) method, and the similarity index utilizes the Euclidean distance (Sestras and Sestras, 2023), which utilized the PAST Program (Hammer *et al*., 2001).

RESULTS AND DISCUSSION

The volatile compounds identified totaled 135 in the flowers of the hot pepper parental lines (A = 70, B = 65), with the majority comprising terpenes, esters, and aromatic compounds (Table 1). These compound categories also showed linkage through metabolic pathways. Lanier *et al*. (2023) mentioned these pathways displayed intricate metabolic networks featuring branching routes and various sub-pathways. Meanwhile, sesquiterpene compounds within the Solanaceae family indicated frequent association with external stressors that affect plants, such as pest infestations (Fiesel *et al*., 2023). In this research, the analysis of VoCs revealed a distinct metabolic signature between the two parental lines, demonstrated with groups 5, 6, and 7 containing compounds additionally found in parent line A (Table 1). The group 5 specifically included a terpene of (E)-4,8-Dimethylnona-1,3,7-triene derived from the terpene precursor (E)-nerolidol, which itself emerged from the isoprene units (Câmara *et al*., 2024). This compound's detection also appeared in the filial. In contrast, group 8, comprising aromatic compounds derived via the shikimic pathway (Yokoyama *et al*., 2022), was exclusively notable in the parental line B, suggesting the parental lines have distinct metabolic pathways associated with these substances.

Cross-hybridization between these two parental lines resulted in the F1 hybrids (AB and BA) exhibiting a total volatile compound content (AB = 65, BA = 67, respectively, for a total of 132), as summarized in Tables 1 and 2. The study conducted by Moreno-Peris *et al*. (2020) demonstrates that interspecific hybridization between *Capsicum annuum* (cv. BlockyR2) and *C. chinensis* (cv. AjiD) results in progeny totaling 24 volatile compounds (VoCs), surpassing the counts of their respective parental lines, which are nine and 15 VoCs. In contrast, the intraspecific crosses of *C. annuum* cv. Arbol × *C. annuum* cv. BlockyR1-15225 and *C. annuum* cv. Cayenne-Serrano × *C. annuum* cv. BlockR1-15225 exhibited similar or lesser volatile compounds than their respective parental lines.

The hybrid-specific patterns indicate heterosis may amplify the protective traits, offering a genetic toolkit for breeding resistant cultivars without compromising agronomic value. The intraspecific hybridization within species *C. frutescens* revealed a different trend (Tables 1 and 2). Specifically, F1 hybrids exhibited 11 distinct VoC pattern groups, indicating hybridization can introduce new or altered volatile profiles. This suggests the recombination between parents can generate novel or altered volatile profiles without expanding overall compound diversity. Consistent with previous research findings, the inclusion of volatile compounds in pattern 1 (Table 1) in this study, together with patterns 2 and 3, proved valid to be released by almost all types of chilies (Kirana *et al*., 2019) and considered as key compounds for chilies. Patterns 9, 10, and 11 were unique to F1 hybrids (Table 2), while patterns 4, 7, and 8 were exclusive to the parental lines, with no complete inheritance (Table 1). Patterns 5, 6, and 7 were the volatile compounds suspected to be influenced by the female parental genotype. Meanwhile, pattern 5 was the only one detected in parental line A, which was inherited by its offspring.

Table 1. Volatile compounds in the flowers of hot pepper parental genotypes (A, B) and their F1 hybrid populations (AB and BA).

Pattern	A	B	AB	BA	Volatiles	Names of Volatile Compounds
1	+	+	+	+	12	Terpene 3-Carene; 1,3,8-p-Menthatriene; Neo-allo-ocimene; *trans*-β-Ocimene; β-Myrcene; β-Ocimene. Alcohol 2-(Vinyloxy) ethanol; o-Xylene, 3-ethyl-1-Butanol; Phenylethyl alcohol; Piperazine, 2-methyl-; Acetaldehyde
2	+	+	+	-	2	Terpenoid Citronellol; Linalool
3	+	+	-	+	1	Terpene α-Pinene
4	+	+	-	-	47	Aromatic Methane, di-p-tolyl-; (4-Acetylphenyl)phenyl methane; 2,2'-Dimethylbiphenyl; 4,4'-Dimethylbiphenyl; Benzene, pentamethyl-; Biphenyl, 3-methyl-; Biphenyl, 4-methyl-; Hydroquinone; Indan, 4,7-dimethyl-; m-Ethyl toluene; Naphthalene, 2-methyl-; Naphthalene, 1,4,6-trimethyl-; Naphthalene, 1,4-dimethyl-; Naphthalene, 1,5-dimethyl-; Naphthalene, 1,6,7-trimethyl-; Naphthalene, 1,6-dimethyl-; Naphthalene, 1,7-dimethyl-; Naphthalene, 1,8-dimethyl-; Naphthalene, 1-ethyl-; Naphthalene, 1-methyl-; Naphthalene, 2,7-dimethyl-; Furan, 2-(1-pentenyl)-, (E)-; 2-Phenyl-2-pentene Terpenoids γ-Terpinene; *cis*-β-Farnesene; Citronellyl propionate; Isomyocorene; Lavandulyl butyrate; *trans*-Alloocimene; α-Cubebene; α-Fenchene; β-Phellandrene; γ-Himalachene. Esters *cis*-3-Hexenyl-α-methylbutyrate;Hexyl 2-methylbutyrate; Hexyl butyrate; Hexyl isobutyrate; Methyl palmitate; n-Hexyl methacrylate; Phenol, 3-methyl-; *trans*-3-Hexenyl butyrate Alcohol Cyclobutanol Other compounds 2-Methoxycinnamaldehyde; Decanal; 1-Hexene; 1-Isopropylcyclohex-1-ene; Caffeine
5	+	-	+	+	4	Terpenoid (E)-4,8-Dimethylnona-1,3,7-triene; Ester *cis*-3-Hexenyl isovalerate; Methyl salicylate Aromatic Oxime-, methoxy-phenyl-
6	+	-	+	-	2	Aromatic p-Cymene; Pyridine, 2,3-dimethyl-
7	+	-	-	-	2	Aromatic Benzyl alcohol, p-ethyl-; m-Cymene
8	-	+	-	-	3	Aromatic p-Xylene; Pyridine, 2,4-dimethyl- Alcohol *cis*-Pinen-3-ol

Notes: (-) not detected; (+) detected. A and B are chili lines. AB and BA are offspring lines from the A and B crossing. The detection of volatiles used the GC-MS method. The results entailed comparison with the NIST14 library.

Table 2. Volatile compounds in the flowers of hot pepper detected only in F1 hybrid populations (AB and BA).

Pattern	A	B	AB	BA	Volatiles	Names of Volatile Compounds
9	-	-	+	+	35	Terpenoid (*E,E*)-2,6-alloocimene; Caryophyllene; Copaene; *D*-Limonene; Farnesol; *α*-Thujene; *β*-Elemene Aromatic *psi,*-Cumene; Anisole; Mesitylene; *m*-Xylene, 5-ethyl- ; *m*-Xylene; o-Cymene; p-Diethyl benzene; Toluene; *cis*-jasmone; Indole, 1-methyl-2-phenyl-; Indole; Phenol; Pyrrole, 1-methyl-; Ester Dimethyl salicylate; *cis*-3-Hexenyltiglate; Ethyl 2-methoxybenzoate; Hexyl (E)-2-methylbut-2-enoate; Hexyl crotonate; Lavandulylisobutyrate; Methyl geraniate; n-Butyl tiglate; Pentyl (E)-2-methylbut-2-enoate; Tridecane; Methyl ester Terpenoid (S)-(-)-Citronellic acid Other compounds Dodecane; 2,6-Nonadienal, (E,Z)-; 3-Hydroxydecanoic acid;
10	-	-	-	+	15	Terpene *β*-Humulene Terpenoid Alloaromadendrene; Himachal-2,4-diene; *α*-Himachalene; *α*-Muurolene; *β*-Bourbonene; γ-Gurjunene; 5-Hepten-2-one, 6-methyl-; Geraniol; Citral; *β*-Citral; Geranyl acetate; Aromatic Acetylenic glycol; Pyrazine, 2-methoxy-3-(2-methyl propyl)- Other compounds Pentadecane;
11	-	-	+	-	10	Terpene Humulene; Terpenoid *trans*-β-Bergamotene; *α*-Longipinene; *γ*-Cadinene; (±)-Lavandulol; 6-Nonen-1-ol, E- Ester Heptyl 2-methylbutyrate Aromatic 3,5-Dimethoxytoluene; Indole, 5-methyl-2-phenyl-; Other compounds Nonadecane;

Notes: (-) not detected; (+) detected. A and B are chili lines. AB and BA are offspring lines from the A and B crossing. The detection of volatiles used the GC-MS method. The results incurred comparison with the NIST14 library.

Several intriguing findings emerged from the analysis of volatile patterns, particularly regarding the presence of volatiles exclusively found in the parental genotypes or F1 hybrid populations. The results also revealed cross-hybridization among the parental lines significantly altered the VoC composition of their F1 hybrids. These alterations can manifest as a reduction in the diversity of volatile compounds, the emergence of new compounds, and variations in their concentrations (Pagès-Hélary *et al*., 2023), describing hybridization-driven modifications in metabolic flux and gene regulation within secondary metabolism. The results suggested conventional hybridization could enhance the composition of volatile compounds within the genus *Capsicum*, even though it does not increase total compound count.

Notably, while interspecific crossing (*C. annuum* × *C. chinense*) leads to greater VoC diversity, Moreno-Peris *et al*.'s (2020) findings indicated an increase in the variety of volatile organic compounds (VOCs) by crossing *C. annuum* genotypes with varied VOC profiles; however, the interspecific hybridization in this study did not produce additional VoC types. This discrepancy may refer to the narrower allelic variations in our crosses and the complexity of terpene synthase gene families and regulatory networks in hot peppers. Variations occur in the complexity of the gene families involved and the intricacies of the metabolic pathways, particularly for volatile compounds such as terpenoids (Lanier *et al*., 2023).

The comprehensive analysis of volatile compounds' profile derived from direct and reciprocal crosses, meticulously labeled as AB and BA, has yielded a compelling revelation. Asymmetry governs the inheritance patterns of a discrete subset of these volatile compounds, thereby implicating a parent-of-origin effect in the transmission of specific volatile constituents (Gawande *et al*., 2020). Specifically, the presented investigation was successful in unearthing 10 volatile compounds (pattern 11; Table 2) that were exclusively detectable in the AB progeny, where parental line A assumes the role of the maternal progenitor. However, these were conspicuously absent in the reciprocal cross BA progeny, where parental line B serves as the maternal progenitor. Conversely, a distinct set of 15 volatile compounds (pattern 10; Table 2) revealed an inheritance of reciprocal pattern, being uniquely found in the cross BA progeny while remaining undetectable in the cross AB progeny. These observations considerably suggested the inheritance of these volatile compounds was a partial determination from the nuclear genes of the parental genotypes, which was also influenced by the maternal effects.

Several observed volatile compounds demonstrated their biological role as attractants for various insect pests. For instance, the *α*-Pinene (pattern 3; Table 1) attracts *Drosophila* sp. and *Rhodesiella bhutanensis* in banana flowers (Masriany *et al*., 2020), while reports of the *n*-Pentadecane (pattern 10; Table 2) have stated that it attracts the Tsetse Fly *Glossina morsitans* Westwood (Hargrove *et al*., 2021). The *β*-Ocimene (pattern 1; Table 1) is a widely recognized general attractant compound for pollinators; however, it is also typical to attract pest species, such as *Aphidius ervi* and *Aphytis melinus*. Similarly, *D*-Limonene proved to attract *Aphytis melinus* (pattern 9; Table 2) (Mohammed *et al*., 2020). However, it has also emerged as a repellent against certain insects, including the whitefly *Bemisia tabaci* (Johnston *et al*., 2022).

The detected volatile compounds also act as repellents for several insect pests. Linalool (pattern 2; Table 1) commonly serves as a repellent for various insects. Many studies indicate that linalool is effective in repelling aphids *Myzus persicae* and *Cimex lectularius* L. (Gaire *et al.,* 2019), as well as *Lasius niger, Metrioptera bicolor*, and other phytophagous insects and pathogens (Schaeffer *et al.,* 2019). Linalool's effectiveness has usually increased when combined with other volatile compounds. *Cis*-jasmone and farnesol (pattern 9; Table 2) are repellents and toxic to *Myzus persicae* (Cantó-Tejero *et al*., 2022), and *β*-trans-ocimene (pattern 1; Table 1) is famous for repelling aphids (Li *et al.,* 2019).

The 5-hepten-2-one and 6-methyl- (pattern 10; Table 2) and *β*-elemene and caryophyllene (pattern 9; Table 2) act as repellents for several mosquitoes (Tchumkam *et al.*, 2023). The *α*-Pinene (pattern 3; Table 1) is a repellent and bio-insecticide for *Musca domestica, Sitophilus zeamais, S. granarius, Tribolium confusum* and *Rhyzopertha dominica* (Langsi *et al.,* 2020; Atay *et al.,* 2023). The *β*-Myrcene (pattern 1; Table 1) is a repellent for *Tribolium castaneum* and *Lasioderma serricorne* (Jiansheng *et al.,* 2020). The *m*-Cymene (pattern 7; Table 1) also works as a resistant for *Liposcelis bostrychophila* and *Tribolium castaneum* (Feng *et al.,* 2021). The *γ*-Cadinene (pattern 11; Table 2) is revolting for *Tribolium confusum* (Tabti *et al.,* 2020), and *cis*-Pinen-3-ol (pattern 8; Table 1) effectively repels the *Anopheles gambiae* (Thomas *et al.,* 2024).

Additional volatile compounds were evident only in the F1 hybrids (AB and BA), which produced several repellents for insect pests, including *D*-Limonene, *cis*-jasmone, and farnesol. These compounds effectively prevent the presence of *B. tabaci* and *M. persicae* (Johnston *et al*., 2022; Cantó-Tejero *et al*., 2022). The presence of these new volatile compounds in the F1 hybrids offers the possibility of developing new lines that are more resistant to insect pest attacks. Therefore, further biochemical analysis is essential to develop these crossbreed results. Moreover, these F1 hybrids produced some new volatile compounds with the potential to attract insect pests to hot pepper plants, such as nonadecane, geraniol, and *α*-Pinene. Geraniol can attract whiteflies (*B. tabaci*), which are known to be vector insects damaging a significant portion of hot pepper plants (de Oliveira *et al.,* 2018). The *α*-Pinene typically attracts *Drosophila* sp., which also acts as a pest to banana plants (Masriany *et al*., 2020).

Principal component analysis (PCA) mapped VoC profiles both in the parental genotypes and their F1 hybrids based on 11 identified patterns, showing that parental lines (A and B) and the F1 hybrids (AB and BA) occupied different quadrants. This indicates a diverse volatile compound profile in each tested genotype (Figure 2). The parental lines A and B occupied quadrants 1 and 2, which were placed on the right, while the F1 hybrids (AB and BA) occupied quadrants 3 and 4, occupying the left. The clustering analysis, using the Euclidean similarity index of the volatile compounds based on the paired group (UPGMA) method, showed a considerable difference (60%) between the parental lines and their F1 hybrids. In comparison, the difference between AB and BA descendants reached 36%. However, the parental lines have an 18% difference in volatile compound profiles (Figure 3). Similar differentiation via PCA has been evident in peppers and other crops, where hybrids and parents form non-overlapping clusters, reflecting divergent chemical profiles (Moreno-Peris *et al*., 2020).

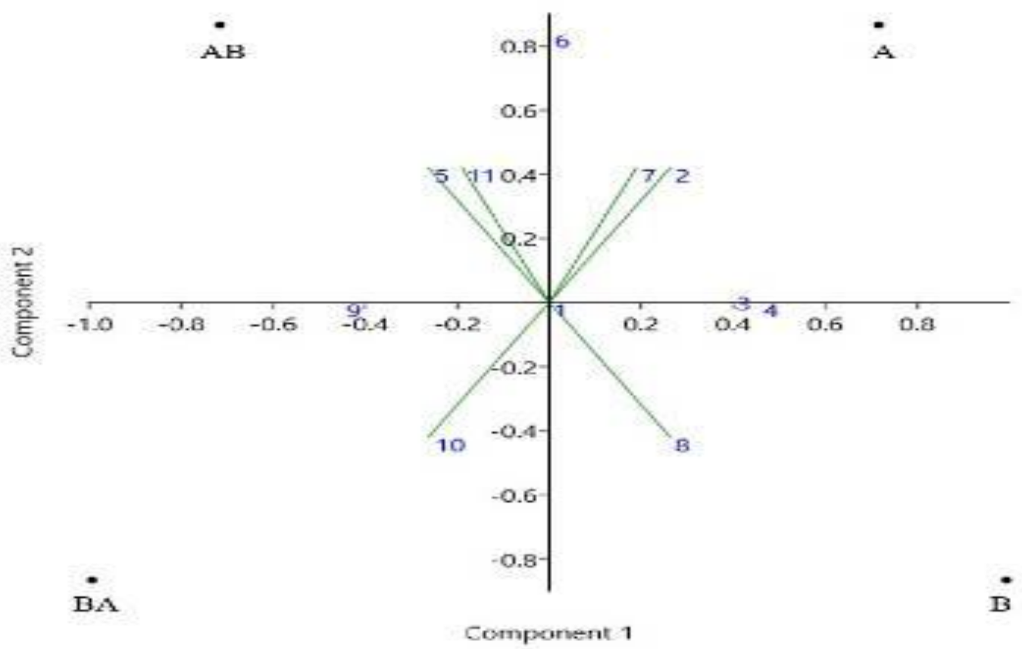

Figure 2. Mapping of volatile compound patterns (1–11) and the positions of the hot pepper parental genotypes (A, B) and their F1 hybrid populations (AB and BA) on the formed map.

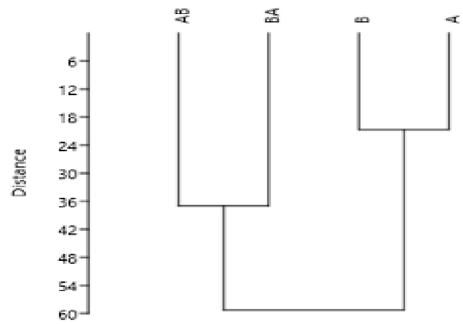

Figure 3. Euclidean similarity index of volatile compounds based on paired group (UPGMA) of the hot pepper parental genotypes (A, B) and their F1 hybrid populations (AB and BA).

The directional difference, which tends to move apart between the hot pepper parental genotypes and the F1 hybrids, strengthens the indication of variations in the volatile compound profiles due to cross-hybridization. The variation in the volatile compound profiles entails expectations to enhance the resistance level of the F1 hybrids to environmental stress factors, especially for insect vectors carrying viruses. The promising research represents an initial study profiling volatile compounds resulting from the cross-hybridization of two chili parental lines, which will be helpful for the development of chili varieties resistant to insect vectors based on an antixenosis mechanism. However, further research is necessary to fully understand the stability of the volatile compounds' profiles. This includes the inheritance patterns of these compounds, the effectiveness of the F1 hybrids as insect repellents, and the quantification of the critical volatile compounds detected in this study.

CONCLUSIONS

The analysis of flower volatile compounds of the parental lines (A and B) and their F1 hybrids (AB and BA) resulted in a total of 133 compounds, and each genotype showed different volatile compounds. The F1 hybrids produced volatile compounds that serve as repellents and attractants for chili pests. The additional observed volatile compounds, like *D*-Limonene, *cis*-jasmone, and farnesol in the F1 hybrids, will provide a valuable integrated pest management strategy to protect the hot peppers from aphids. However, further research is essential to determine the stability of the formed volatile compounds, the efficacy of F1 hybrids, and the quantification of the volatile compounds playing a crucial role as repellents and attractants for insect pests in hot peppers.

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