Distribution of volatile compounds of traditional aromatic Joha rice (*Oryza sativa* L.) of upper Assam, India

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ABSTRACT

Background and Objectives: Joha is aromatic endemic rice cultivated in the upper Brahmaputra valley of Assam. As reported 2-acetyl-1-pyrroline (2AP) and other volatile compounds are responsible for its flagrancy. The present study was designed as a way to identify the 2AP and other volatile compounds in the collected landraces of Joha rice.

Methodology: Toluene extract of the fifteen (15) genotypes of Joha rice was analyzed through gas chromatography/mass spectrometry (GC-MS), which was sowing and harvested in the trial paddy field of Dibrugarh University during the study period. Reported compounds were identified by Library Search (NIST MS Search Program v.2.0g) for each peak using retention time (RT), and mass (m/z). Principal component analysis (PCA) was done, and a dendrogram was prepared using the unweighted pair group method (UPGMA).

Main Results: Forty (40) volatile compounds were detected under 12 chemical categories, including 17 alkanes, 1 alkene, 1 aromatic aldehyde, 1 aromatic amino acid, 6 aromatic hydrocarbons, 5 esters, 1 organo-halogen, 1 phenol-containing compound, 1 poly(organosiloxanes), 3 polycyclic aromatic compounds, 1 carboxylic acid, and 1 pyrroline. The 2AP along with other fragrant volatile compounds were detected in these landraces. Six other volatile compounds namely; 1-Iodododecane, 4-tert-butylcalix[4] arene, pentacyclo(9.5.1.13.-9.15.15.17.13)octasiloxane, 1,3,5,7,9,13-hexamethyl-11,15-diphenyl-3,5-diphenyl-1,2,4-trioxolane, 1,5,7,9,11,13-hexamethyl-3,15-diphenyloctaprismo-octasilasesqui-oxane and 1-(3α, 7α, 12α-tris(trimethylsiloxy)-5β-cholan-24-oyl) were newly detected in these landraces of Joha rice, for the first time. The PCA indicates that components are spatially distributed, and 3 clusters are being formed depending on the distribution among the landraces.

Conclusions: The present investigation reported, for the first time, the presence of 6 volatile compounds in Joha rice along with 2AP in Joha rice found in the upper Brahmaputra valley of Assam, India. The study has not only evaluated the reasons behind flagrancy in Joha rice but also encourages plant breeders and harvesters to cultivate Joha rice.

Keywords: GC-MS, Joha rice, 2-acetyl-1-pyrroline (2AP)

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INTRODUCTION

Joha is a well-known transition of *Oryza sativa indica* and *Oryza sativa japonica* varieties (Jain *et al*., 2004) because of its innate scent, essence, and exemplary taste. They have a sweet aroma as other scented rice of India, like basmati or jasmine (Raina *et al*., 1987). Joha rice is cultivated in Assam for its well-known flavor, aroma, and taste, even not cultivated commercially for its low yielding. Works have been carried out on volatile compounds in aromatic rice, and more than 100 volatile components have been identified in cooked rice (Yasumatsu *et al*., 1966a; 1966b; Yajima *et al*., 1979; Tsugita *et al*., 1980; 1983). Lahkar and Tanti (2018) found volatile carbonyl compounds such as acetaldehyde, propanol, 2-butanone, pentanal, and hexanol in fragrant rice varieties, and Buttery *et al*. (1983) identified 2-acetyl-1-pyrroline (2AP) as the principal fragrant compound associated with aromatic rice.

The volatile profile of rice variety is important not only in rice breeding programs but also to assure the quality of whole-grain or grain products in the market. Most of the volatile compounds that are produced through metabolic pathways are dependent on various factors such as variety, agronomic practices, storage conditions, post-harvest handling, etc. (Champagne, 2008). So, the question arose among the present researchers that what kind of volatile compounds accumulated in Joha rice during traditional sowing and harvesting practices in Assam. Because, it was well-known, that volatile profiles have the potential to not only mark the variety and interpret the quality of rice but also improve breeding programs for grain quality improvement and quality assurance studies. Therefore, the present research work has been carried out to identify the various volatile compounds accumulated during the traditional practices of Joha rice of upper Assam, which might be responsible for its flagrancy.

MATERIALS AND METHODS

Collection and Identification of Landraces

Fifteen Joha rice landraces (Table 1, Figure 1) were collected from different pockets of the upper Brahmaputra valley of Assam, India, and encoded with JR1 to JR15. Collected landraces were identified at the Department of Life Sciences; a herbarium was prepared and submitted to the same (Figure 2). The landraces were stored at room temperature before sowing in the field.

Sowing and Harvested the Landraces

Landraces were sowing the Dibrugarh University trail field in similar natural conditions from November 2020 to January 2021. Ripening rice grains were harvested, separated from straw, and kept for 2 months at room temperature before extraction, as traditionally ripening rice grains were usually kept 2–3 months before decorticating.

Extract Preparation

Five grams of decorticated ripening rice grain was dried in a dehumidifier at 30 °C for 48 h, ground to a fine powder, and extracted with 50 mL of 100% toluene (analytical grade) for 24 h with 3 mL of 1.0 M NaOH. The extract was then filtered through Whatman No. 1 paper, concentrated, and stored at 0–4 °C for further use (Saikia *et al*., 2023).

GC-MS Protocol for Volatile Profiling

Gas chromatography coupled with mass spectrophotometry (GC-MS) was utilized to identify the volatile compounds present in the toluene extract of the Joha rice. Direct insertion probe (GC-DIP) was used to insert the sample into the GC-MS system (JMS-T100GCV High-performance Gas Chromatography–Time-of-Flight Mass Spectrometer, Make-Jeol) with a capillary column (DB-5ms, Make-Agilent Technologies) non-polar, 30 m × 0.25 mm and film thickness (0.2 µm). Helium was an internal carrier. The operation of the mass spectrometer was carried out in electron impact (EI) mode, with an electron energy of 70 eV. The volatile compounds were then screened by an ionizing volt of 70[V] and detector volt of 2,250[V] and TOF for 45 min with a mass range (m/z) of 10–350 (Luo *et al*., 2008).

Table 1 Collected landraces of Joha rice and their location

Sl No.	Accession number	Landraces	Location	District	Latitude (N°)	Longitude (E°)
1	JR1	Boga Bhaboli Joha	Khanamukh	Sivasagar	26°56'16.02"	94°28'24.89"
2	JR2	Boga Kunkuni Joha	Sootea	Sonitpur	26°43'29.54"	93°2'47.39"
3	JR3	Bogakon Joha	Sootea	Sonitpur	26°44'0.84"	93°2'47.26"
4	JR4	Bos Joha	Bahana	Jorhat	26°35'17.15"	94°11'13.98"
5	JR5	Dangor Joha	Moidhal	Dhemaji	27°31'55.00"	94°35'42.49"
6	JR6	Joha Bora	Tezpur	Sonitpur	26°39'10.25"	92°47'33.25"
7	JR7	Kola Joha 1	Sootea	Sonitpur	26°44'0.25"	93°2'47.23"
8	JR8	Kola Joha 2	Jaysagar	Sivasagar	26°57'19.26"	94°37'18.44"
9	JR9	Kola Kunkuni Joha	Sootea	Sonitpur	26°44'0.57"	93°2'44.48"
10	JR10	Manikimadhuri Joha	Gahpur	Sonitpur	26°52'45.24"	93°36'23.35"
11	JR11	Podumoni Joha	Sootea	Sonitpur	26°44'8.74"	93°2'36.43"
12	JR12	Ranikajol Joha	Sootea	Sonitpur	26°43'59.23"	93°2'37.49"
13	JR13	Ronga Bhaboli Joha	Titabor	Jorhat	26°35'23.57"	94°11'12.09"
14	JR14	Ronga Joha	Dikhowmukh	Sivasagar	26°58'46.30"	94°27'52.30"
15	JR15	Tulsi Joha	Bekajaan	Jorhat	26°43'13.15"	94°11'17.36"

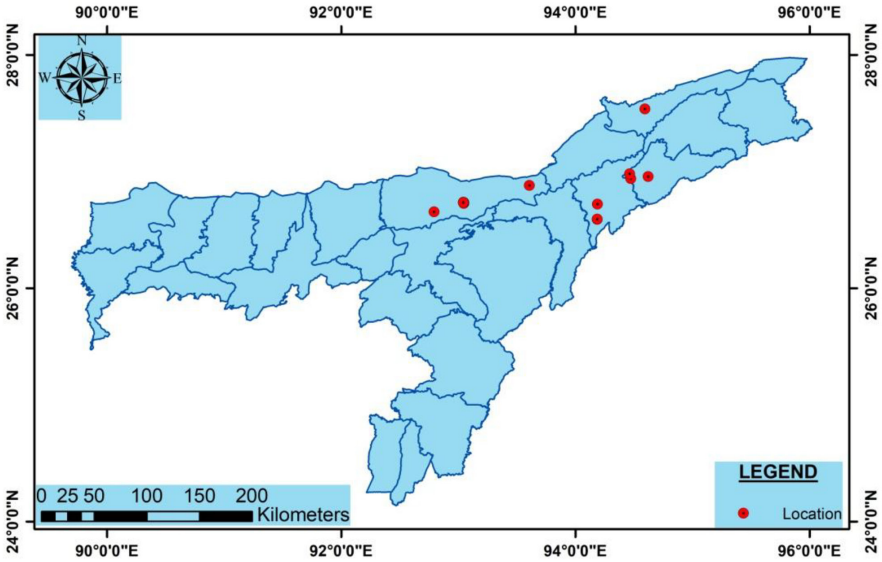

Figure 1 Map showing the collected area of the accession of Joha rice in the upper Brahmaputra valley of Assam (Administrative district viz; Dhemaji, Sivsagar, Jorhat, and Sonitpur)

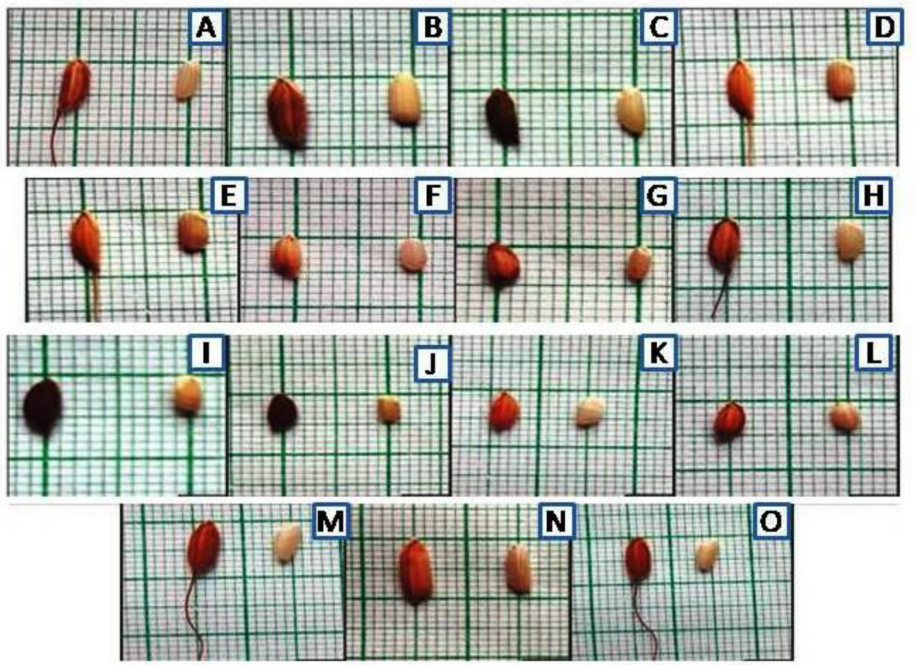

Figure 2 Corticated and decorticated grain of Ronga Joha (A), Joha Bora (B), Kola Joha 1 (C), Kola Joha 2 (D), Boga Bhaboli Joha (E), Ronga Bhaboli Joha (F), Manikimadhuri Joha (G), Boga Kunkuni Joha (H), Bogakon Joha (I), Kola Kunkuni Joha (J), Ranikajol Joha (K), Dangor Joha (L), Tulsi Joha (M), Joha Bora (N), and Podumoni Joha (O)

Identification of Compounds

The volatile compounds were then identified by Library Search (NIST MS Search Program v.2.0g) for each peak, retention time (RT), and mass (m/z). The volatile compounds identified were matched with the mass spectra (having a match quality of over 85%; Nickerson and Likens, 1966; Büchi and Wüest, 1971).

Data Analysis

A binary matrix was prepared by scoring present (1) or absent (0) of identified compounds among the landraces for analysis of the principal component analysis (PCA) and preparing a dendrogram using the unweighted pair group method (UPGMA) in PAleontological Statistics (PAST) version 4.03 program.

RESULTS AND DISCUSSION

Volatile Profile of Traditional Joha Rice Varieties

Sixty-two volatile compounds were detected in MS fingerprinting, out of which forty (Figure 3), were confirmed based on probability percentage (>85%). These forty volatile compounds include 17 alkanes, 1 alkene, 8 aromatic hydrocarbons including aldehydes and amino acids, 6 esters, 1 alkyl-halide, 1 phenol derivative, and 5 polycyclic aromatic hydrocarbons and 1 pyrroline (Table 2).

Seventeen alkenes were identified by GC-MS analysis of the rice grain of Joha landraces. The alkenes identified are docosane, dodecane, 2,6,11-trimethyldodecane,2,7,10-Trimethyldodecane, 2-methyleicosane, heneicosane, heptacosane, hexacosane,

2-methyloctadecane, octadecane, 3-ethyl-5-(2-ethylbutyl), 9-ethyl-9-n-heptylpctadecane, pentacosane, tetracosane, 11-decylettracosane, tricosane, undecane and 4-7-dimethylundecane. The sole alkene identified by GCMS analysis of an extract of Joha rice grain is 1-docosene. L-arginine,N2-(phenylmethoxy)carbonyl) is the only aromatic amino acid along with benzaldehyde as the sole aromatic aldehyde identified in the rice grain.

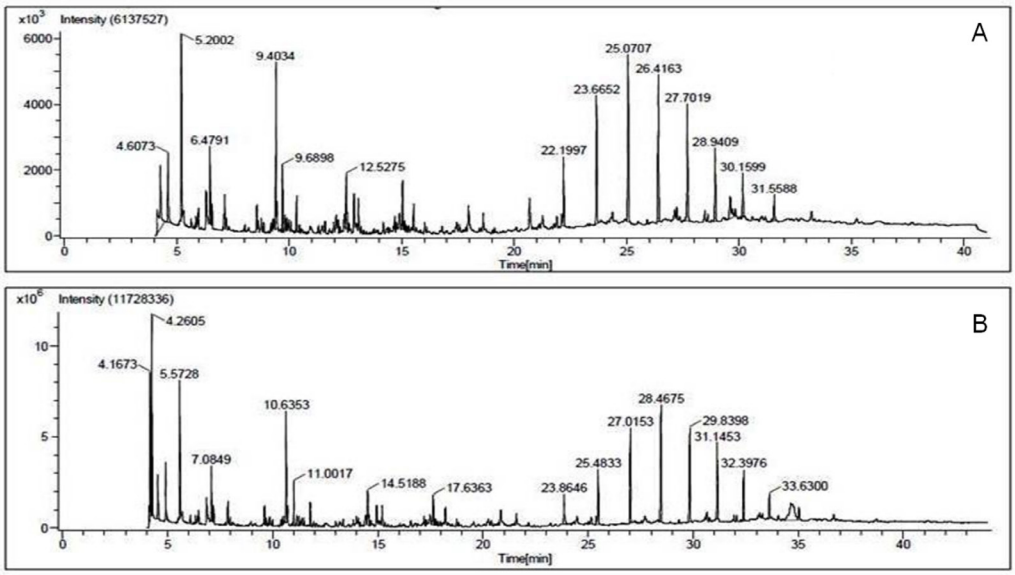

Figure 3 GC chromatogram of Boga Bhaboli Joha (A) and Kola Kunkuni Joha (B)

Other aromatic hydrocarbons identified by screening of volatile compounds in the grain of Joha rice landraces include benzyl oxy tridecanoic acid, benzene,1,3-bis(1,1-dimethylethyl), ethylbenzene, 2-phenylethyl formate, p-xylene, and styrene. Volatile compounds belonging to ester groups identified by GCMS consist of oxalic acid, isobutyl hexadecyl ester, (E)-9-octadecenoic acid ethyl ester, linoleic acid ethyl ester, bis(2-ethylhexyl) terephthalate, and trichloroacetic acid, pentadactyl ester.1-lodododecane is the only alkyl halide and phenol, 2,4-bis(1,1-dimetylethyl) is a phenol derivative screened in the grain of Joha rice. 4-tert-butylcalix[4] arene, pentacyclo(9.5.1.13.9.15.15.17.13) octasiloxane, 1,3,5,7,9,13-hexamethyl-11,15-diphenyl-,3,5-diphenyl-1,2,4-trioxolane,1,5,7,9,11,13-hexamethyl-3,15 diphenyloctaprismo-octasilasesquioxane, pyrrolidine, 1-(3α, 7α, 12α-tris(trimethylsiloxy)-5β-cholan-24-oyl)- belongs to polycyclic aromatic hydrocarbon screen in the grain of Joha rice. Of these polycyclic aromatic hydrocarbons pentacyclo(9.5.1.13.9.15.15.17.13) octasiloxane, 1,5,7,9,11,13-hexamethyl-3,15-diphenyloctaprismo-octasilasesquioxane, pyrrolidine, 1-(3α, 7α, 12α-tris(trimethylsiloxy)-5β-cholan-24-oyl) are siloxane or oxide of silica. Carbonic acid, decyl ethyl ester is the only carbonic acid derivative and 2-ccetyl-1-pyrroline belongs to the pyrroline class of molecules identified and screened in GCMS analysis of the extract from rice grain of Joha landraces.

Table 2 Distribution of volatile compounds among the Joha landraces

Sl No.	Compound name	Boga Bhaboli Joha	Boga Kunkuni Joha	Bogakon Joha	Bos Joha	Dangor Joha	Joha Bora	Kola Joha 1	Kola Joha 2	Kola Kunkuni Joha	Manikimadhuri Joha	Podumoni Joha	Ranikajol Joha	Ronga Bhaboli Joha	Ronga Joha	Tulsi Joha
01	Styrene	+	-	-	+	+	-	+	-	+	+	+	+	+	+	+
02	2-Phenylethyl formate	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-
03	Benzyl oxy tridecanoic acid	-	+	+	-	-	+	-	-	+	-	-	-	+	-	-
04	2-Acetyl-1-pyrroline	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
05	Carbonic acid, decyl ethyl ester	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
06	Ethylbenzene	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
07	p-xylene	-	+	+	+	+	-	-	-	+	-	-	+	+	-	+
08	3,5-Diphenyl-1,2,4-trioxolane	+	-	-	-	-	-	+	+	-	-	-	-	-	-	-
09	Dodecane	-	-	-	-	+	+	-	-	+	-	-	-	-	-	-
10	Benzaldehyde	-	+	+	-	+	-	-	-	+	+	+	+	+	-	+
11	L-Arginine,N2-((phenylmethoxy)carbonyl)-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
12	4,7-Dimethylundecane	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
13	Undecane	+	-	-	-	-	-	+	-	+	-	-	-	-	-	-
14	2,6,11-Trimethyldodecane	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
15	2,7,10-trimethyldodecane	+	-	-	-	+	-	+	+	-	-	-	-	-	-	-
16	Benzene,1,3-bis(1,1-dimethylethyl)	-	+	+	+	-	+	-	-	-	+	+	+	+	-	+
17	2-Methyleicosane	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-
18	1-Iodododecane	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
19	Phenol, 2,4-bis(1,1-dimetylethyl)	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-
20	2-Methyloctadecane	+	-	-	-	-	-	+	+	-	-	-	-	-	-	-
21	Docosane	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
22	Tetracosane	+	-	-	-	-	-	+	-	+	-	+	-	-	-	-
23	1-Docosene	+	-	+	-	-	+	+	+	+	-	-	+	-	-	-

Table 2 Cont.

Sl No.	Compound name	Boga Bhaboli Joha	Boga Kunkuni Joha	Bogakon Joha	Bos Joha	Dangor Joha	Joha Bora	Kola Joha 1	Kola Joha 2	Kola Kunkuni Joha	Manikimadhuri Joha	Podumoni Joha	Ranikajol Joha	Ronga Bhaboli Joha	Ronga Joha	Tulsi Joha
24	Hexacosane	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
25	Linoleic acid ethyl ester	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-
26	(E)-9-Octadecenoic acid ethyl ester	+	-	-	-	-	-	-	-	-	-	-	-	+	-	+
27	Oxalic acid, isobutyl hexadecyl ester	-	+	+	+	+	+	+	+	-	-	-	+	-	-	-
28	Pentacosane	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
29	Tricosane	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+
30	Bis(2-ethylhexyl) terephthalate	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-
31	Heptacosane	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+
32	Trichloroacetic acid, pentadecyl ester	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
33	11-Decyltetracosane	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-
34	Octadecane, 3-ethyl-5-(2-ethylbutyl)	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
35	Heneicosane	-	-	+	-	+	-	+	+	-	-	+	-	-	+	+
36	9-Ethyl-9-n-heptyloctadecane	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	4-Tert-Butylcalix[4]arene	-	-	+	+	-	+	+	-	-	+	+	+	+	-	+
38	Pyrrolidine, 1-(3α, 7α, 12α-tris(trimethylsiloxy)-5β-cholan-24-oyl)-	+	+	+	-	-	+	-	-	-	+	-	+	+	+	+
39	Pentacyclo(9.5.1.13.9.15.15.17.13) octasiloxane,1,3,5,7,9,13-hexamethyl-11,15-diphenyl-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-
40	1,5,7,9,11,13-Hexamethyl-3,15-diphenyloctaprismooctasilasesquioxane	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-

Note: (+) the symbol indicates the presence and the (–) symbol indicates the absence of these compounds in the 15 Joha landraces

Aromatic rice varieties, such as basmati and jasmine, have unique flavors and have been widely cultivated in the Indian subcontinent as well as Thailand. This aroma or flavor in scented rice is due to the presence of over 300 volatile compounds along with 2AP, which is considered the key compound that gives the characteristic flavor in scented rice (Buttery *et al*., 1982; 1983; 1988; Lin *et al*., 1990; Tanchotikul and Hsieh, 1991). Over the past three decades, intensive research has been carried out on 2AP after its identification in aromatic rice. The odor thresholds of 2AP (Harrison and Dake, 2005), the biosynthetic pathway for the synthesis of 2AP along with its intermediates (Yoshihashi, 2002; Yoshihashi *et al*., 2002; Dudareva *et al*., 2006), genes related to 2AP accumulation in grain (Bradbury *et al*., 2008; Chen *et al*., 2008; Niu *et al*., 2008; He and Park, 2015; Kaikavoosi *et al*., 2015), and factor determining its concentration (Yoshihashi *et al*., 2005; Hien *et al*., 2006; Huang *et al*., 2008) in rice were examined extensively. The present investigation also suggested that the presence of 2AP in each genotype of rice grain could be considered an emerging finding in most indigenous Joha rice cultivated in the North Easter regions of India which can impact most of the rice breeders of national and internationally for promoting this very nutritious rice in near future.

Distribution of Volatile Compounds

Of all the forty volatile compounds, only a few were abundantly found in almost all the landraces (Table 2). 2-Acetyl-1-pyrroline was found in all of the landraces, followed by trichloroacetic acid, pentadactyl ester in 14 landraces, tricosane in 13 landraces, heptacosane in 13 landraces, styrene in 11 landraces, benzaldehyde in 9 landraces, benzene,1,3-bis-1,1-dimethylethyl in 9 landraces and 4-tert-butylcalix[4]arene in 9 landraces, pyrrolidine, 1-(3α, 7α, 12α-tris(trimethylsiloxy)-5β-cholan-24-oyl) in 9 landraces ,p-xylene in 8 landraces and oxalic acid, isobutyl hexadecyl ester in 8 landraces. The remaining 29 volatile compounds were found in seven or less than seven Joha landraces. Carbonic acid, decyl ethyl ester was found in Bogakon Joha while ethyl benzene and L-Arginine,N2-((phenylmethoxy)carbonyl) were observed in Joha Bora and Bos Joha, respectively. Pentacosane and 4,7-dimethylundecane were found in only Kola Joha, whereas bis(2-ethylhexyl) terephthalate and 9-ethyl-9-n-heptyloctadecane were observed in Kola Kunkuni Joha and Boga Bhaboli Joha respectively (Table 2).

During the present investigation, 40 volatile compounds were identified across 15 Joha rice landraces, most of them impart aromatic character to these rice. The compounds identified could be classified into 11 chemical classes, viz. alkane (17), alkene (1), aromatic aldehyde (1), aromatic amino acid (1), aromatic hydrocarbon (6), ester (5), organohalogen (1), phenol containing compound (1), poly(organosiloxanes) (1), polycyclic aromatic compound (3), carboxylic acid (1), and pyrroline (1). Of all these compounds identified by the mass spectrophotometer of the GC chromatograph, few of them have pre-identified aroma character. For example, benzaldehyde which was found across all of the landraces of Joha rice gives a nutty, sweet smell (Shanthinie *et al*., 2019); ethyl benzene was also found in all landraces, and it gives a gasoline-like odor (Chen and Zhang, 2010), *p*-xylene gives strong, sweetish odor; 2-Acetyl-1-pyrroline which is the key component of aromatic rice was also observed in all of these landraces, gives popcorn-like aroma (Buttery *et al*., 1983; 1988). Most of the alkenes give either a gasoline-like odor or are odorless. Linoleic acid ethyl ester imparts a characteristic flavor to Joha rice. Of the 40 volatile compounds identified during the investigation, 6 of them were not reported earlier as volatile compounds in aromatic rice *viz.* 1-lodododecane, 4-tert-butylcalix[4] arene, pentacyclo(9.5.1.13.-9.15.15.17.13) octasiloxane, 1,3,5,7,9,13-hexamethyl-11,15-diphenyl-, 3,5-diphenyl-1,2,4-trioxolane, 1,5,7,9,11,13-hexamethyl-3,15-diphenyloctaprismooctasilasesqui-oxane and pyrrolidine, 1-(3α, 7α, 12α-tris(trimethylsiloxy)-5β-cholan-24-oyl)-. Aroma property of some of the identified volatile are still unknown, such as L-arginine,N2-((phenylmethoxy)carbonyl)-, pyrrolidine, 1-(3α, 7α, 12α-tris(trimethylsiloxy)-5β-cholan-24-oyl)- and 1,5,7,9,11,13-hexamethyl-3,15-diphenyl-octaprismooctasilases-quioxane.

This aroma or flavor in scented rice is due to the presence of over 300 volatile compounds along with 2AP, which is considered the key compound that gives the characteristic flavor in scented rice (Buttery *et al*., 1982; 1983; 1988; Lin *et al*., 1990; Tanchotikul and Hsieh, 1991). Bryant and McClung (2011) analyzed the presence of volatile compounds in aromatic and non-aromatic rice using solid-phase micro-extraction (SPME)-GCMS. A total of 93 volatile compounds were identified during the investigation, of which 64 were not reported previously in rice. Among the 64 newly reported volatile compounds, 8 siloxane derivatives were also reported. Aromatic and non-aromatic rice had differences in the volatile compound's composition as well as the absence or very little presence of 2AP in the latter. During our investigation of the volatile compound in Joha rice, 3 siloxanes were also screened by MS, thus proving that these siloxanes are also present as a volatile compound in aromatic Joha rice.

Principal Component Analysis (PCA)

Two principal components could distinguish the samples from the fifteen landraces of Joha rice. The distribution of volatile compound clusters was distinctly separated into three clusters. Boga Bholari Joha in Cluster I, Kola Joha, Dangar Joha, Ronga Joha, Podumi Joha, and Bos Joha in Cluster II, and the rest of the landraces in Cluster III (Figure 4).

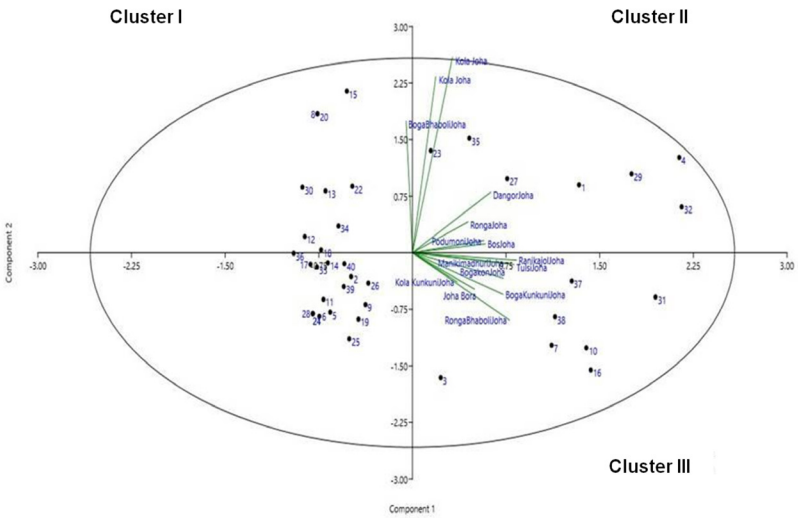

Figure 4 Principal component analysis (PCA) of volatile compounds of fifteen landraces

The PCA is a common method that could extract the characteristic information of samples from complicated information by reducing dimensions and data transformation without loss of original information (Fu *et al*., 2022). In Figure 4, the cumulative variance contribution rate of PC-1 and PC-2 which indicated the two principal components could retain most of the information of these samples and was sufficient to analyze the similar relationship between samples. It could be seen that the spatial distribution of principal components of the fifteen landraces was relatively scattered, and those from each origin region were relatively concentrated and separated. Therefore, the two principal components could distinguish the samples from the fifteenth landraces of Joha rice. The distribution of volatile compound clusters was distinctly separated into three clusters. Boga Bholari Joha in Cluster I, Kola Joha, Dangar Joha, Ronga Joha, Podumi Joha, and Bos Joha in Cluster II, rest of the landraces in Cluster III.

CONCLUSION

A total of 40 volatile compounds were identified across the 15 Joha rice landraces, of which most of them impart the aromatic character to

this rice, including 17 alkanes, 1 alkene, 1 aromatic aldehyde, 1 aromatic amino acid, 6 nonaromatic hydrocarbons, 5 esters, 1 organohalogen, 1 phenol containing compound, 1 poly(organosiloxanes), 3 polycyclic aromatic compounds, 1 carboxylic acid, and 1 pyrroline. The PCA analysis indicates that components are spatially distributed, and three clusters are being formed depending on the distribution among the landraces. The present investigation also reported for the first time, the presence of 6 volatile compounds in Joha rice. The study has not only evaluated the reasons for fragrances in Joha rice scientifically but also encourages plant breeders to grow this important rice nationally and internationally. Further, an investigation is going on into the assessment of genetic marker-assisted with these most abundant volatile compounds in these landraces.

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