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Screening of rice cultivars for aroma at various growth stages under different dates of sowing in Konkan conditions

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Abstract
Aroma is a critical quality attribute in rice, significantly influencing consumer preference and market value. This study investigated the aroma profiles of fifteen rice cultivars, including local and released varieties grown in the Konkan region of Maharashtra, India. The research explored the impact of growth stage (seedling, flowering, maturity) and sowing date on aroma expression. A sensory-based aroma test was conducted across different growth stages—seedling, flowering, and maturity—to assess aroma intensity using 1.7% KOH solution. Results revealed substantial variation in aroma profiles among the tested cultivars. PR-115 consistently exhibited a strong aroma across all growth stages and sowing dates, suggesting its potential stability and suitability for the region. BM-4 demonstrated a mild scent at seedling, maturity, and after cooking, but a strong scent at the flowering stage, indicating a dynamic aroma profile influenced by developmental stage. While most genotypes displayed mild to strong aroma at flowering, a smaller subset retained aroma at maturity and after cooking, highlighting the potential loss of aroma during grain development and processing. These findings contribute to identifying superior aromatic rice cultivars adapted to Konkan's specific environmental conditions and inform strategies for optimizing planting schedules to enhance aroma and yield.

Keywords: Rice aroma, *Oryza sativa*, Konkan, sowing date, growth stage, sensory evaluation

Introduction
Rice (*Oryza sativa* L.) is the staple food crop for over half of the world's population, with Asia contributing to about 90% of global production and consumption (Dubey *et al.*, 2017) [2]. Among various types, aromatic rice holds a premium place due to its unique fragrance, taste, and market value. The aroma in rice is governed by genetic and environmental interactions, primarily influenced by climatic conditions during the growth period. Aromatic rice has huge demand both for national and international trade (Dutta *et al.* 2002) [3].

The Konkan region of Maharashtra, India, it holds significant cultural and economic importance. In Konkan, as in many rice-consuming regions, aroma plays a vital role in consumer acceptance, driving preference and often commanding premium prices. Aromatic rice varieties, with their desirable aromas described as floral, nutty, or popcorn-like, enhance the eating experience and are highly sought after in both domestic and international markets. Consequently, aroma is a key trait targeted in rice breeding programs.

The expression of aroma in rice is a complex phenomenon influenced by both genetic and environmental factors. While a cultivar's genetic makeup determines its inherent potential for aroma production, environmental conditions during growth, as well as post-harvest handling practices, can significantly modulate aroma intensity and quality. Understanding this crucial interplay between genotype and environment is essential for developing stable and high-yielding aromatic rice varieties suited to specific agro-climatic zones, such as the unique conditions of the Konkan region. Identifying high-yielding aromatic varieties adapted to these local conditions is crucial for improving livelihoods and meeting market demands.

This study addresses the need for systematic screening of rice cultivars for aroma, considering the influence of growth stage and sowing date, which are known to affect aroma compound development. Specifically, this research aims to identify the most suitable aromatic rice varieties under Konkan conditions and to determine the optimal sowing dates for retaining aroma in selected varieties.

Materials and Methods

Fifteen aromatic rice genotypes (Table 1) were evaluated at the Research Farm, Department of Agricultural Botany, College of Agriculture, Dapoli, during the 2019-2020 cropping season. Dapoli is located in the sub-tropical, high-rainfall zone of the Konkan region. The experiment followed a Randomized Block Design (RBD) with three replications and six sowing dates (Table 2) (D1: 30th May, D2: 20th June, D3: 10th July, D4: 1st October, D5: 20th October, D6: 10th November). 21 day old seedlings were transplanted at a spacing of 20 x 15 cm. Standard agronomic practices were followed throughout the growing period. Aroma was determined qualitatively by using the method as described by Sood and Siddiq (1986) [7].

Aroma was assessed at three growth stages (seedling, flowering, and maturity) and in cooked rice using sensory evaluation. A panel of five trained individuals evaluated the aroma, assigning scores as follows: NS (Non-scented), MS (Mildly scented), and SS (Strongly scented). Data were analyzed using ANOVA to determine significant differences between genotypes and treatments.

Table 1: Rice Genotypes Used in the Study

Sr. No	Genotypes	Pedigree	Source
1	Botvel	Local	RARS Karjat
2	BM-4	Mutant of Botvel	RARS Karjat
3	Ambemohar	Local	RARS Karjat
4	Indrayani	Ambemohar 157 x IR8	Vadgaon Maval
5	Pawana	IR8 x Pusa 33	RARS Karjat
6	Bhogavati	Selection from Basmati composite	RARS Karjat
7	Kothmirsal	Local	RARS Karjat
8	Chimansal	-	RARS Karjat
9	Ghansal	Local selection from Kolhapur (MS)	RARS Karjat
10	PR-115	RP 2151-173-1-8/PR103*3	RARS Karjat
11	Basmati-376		RARS Karjat
12	Basmati-386	Selection from Pak Basmati	RARS Karjat
13	Basmati-370	Selection	RARS Karjat
14	Basmati-1017	-	RARS Karjat
15	Super Basmati	IR661 x Basmati 320	RARS Karjat

Table 2: Sowing and transplanting dates

Kharif-2019			*Rabi/summer* 2019-20		
	Sowing dates	Transplanting dates		Sowing dates	Transplanting dates
D_1	30th May	21st June	D_4	1st October	21st October
D_2	20th June	11th July	D_5	20th October	11thNovember
D_3	10th July	31stJuly	D_6	10th November	1st December

Results

Aroma scores recorded at different growth stages and sowing dates are presented in Tables 3, 4, 5 and 6.

Seedling Stage Aroma

The data of aroma score recorded by the sensory method of all the fifteen genotypes over six environments are given in table 3. This table showed that the genotype PR-115 had strong scent during D1 to D4 environments where as mild scent during D5 and D6 environments. Genotype BM-4 and Pawana showed the mild scent during all the six environments. Remaining all twelve did not show the scent in any date of sowing when tested as seedling stage.

Table 3: Score of leaf aroma of different genotypes at seedling stage under different dates of sowing

Sr. No	Genotypes	Dates of sowing						
		D_1	D_2	D_3	D_4	D_5	D_6	Overall
1	Botvel	NS	NS	NS	NS	NS	NS	NS
2	BM-4	MS	MS	MS	MS	MS	MS	MS
3	Ambemohar	NS	NS	NS	NS	NS	NS	NS
4	Indrayani	NS	NS	NS	NS	NS	NS	NS
5	Pawana	MS	MS	MS	MS	MS	MS	MS
6	Bhogavati	NS	NS	NS	NS	NS	NS	NS
7	Kothmirsal	NS	NS	NS	NS	NS	NS	NS
8	Chimansal	NS	NS	NS	NS	NS	NS	NS
9	Ghansal	NS	NS	NS	NS	NS	NS	NS
10	PR-115	SS	SS	SS	SS	MS	MS	MS
11	Basmati-376	NS	NS	NS	NS	NS	NS	NS
12	Basmati-386	NS	NS	NS	NS	NS	NS	NS
13	Basmati-370	NS	NS	NS	NS	NS	NS	NS
14	Basmati-1017	NS	NS	NS	NS	NS	NS	NS
15	Super Basmati	NS	NS	NS	NS	NS	NS	NS
Number of NS genotype		12	12	12	12	12	12	12
Number of MS genotype		2	2	2	2	3	3	3
Number of SS genotype		1	1	1	1	-	-	-

NS = Non scented; MS = Mild scented; SS = Strongly scented

Flowering Stage Aroma

The data of leaf aroma score recorded by the sensory method of all the fifteen genotypes over six environments are given in table 4. The genotype PR-115 and BM-4 had strong scent during all environments. Remaining all thirteen genotype showed the mild aroma during all environments at the time of flowering stage.

Table 4: Score of leaf aroma of different genotypes at flowering stage under different dates of sowing

Sr. No	Genotypes	Dates of sowing						
		D1	D2	D3	D4	D5	D6	Overall
1	Botvel	MS	MS	MS	MS	MS	MS	MS
2	BM-4	SS	SS	SS	SS	SS	SS	SS
3	Ambemohar	MS	MS	MS	MS	MS	MS	MS
4	Indrayani	MS	MS	MS	MS	MS	MS	MS
5	Pawana	MS	MS	MS	MS	MS	MS	MS
6	Bhogavati	MS	MS	MS	MS	MS	MS	MS
7	Kothmirsal	MS	MS	MS	MS	MS	MS	MS
8	Chimansal	MS	MS	MS	MS	MS	MS	MS
9	Ghansal	MS	MS	MS	MS	MS	MS	MS
10	PR-115	SS	SS	SS	SS	SS	SS	SS
11	Basmati-376	MS	MS	MS	MS	MS	MS	MS
12	Basmati-386	MS	MS	MS	MS	MS	MS	MS
13	Basmati-370	MS	MS	MS	MS	MS	MS	MS
14	Basmati-1017	MS	MS	MS	MS	MS	MS	MS
15	Super Basmati	MS	MS	MS	MS	MS	MS	MS
Number of NS genotype								
Number of MS genotype		13	13	13	13	13	13	13
Number of SS genotype		2	2	2	2	2	2	2

NS = Non scented; MS = Mild scented; SS = Strongly scented

Maturity Stage Aroma

The data pertaining to leaf aroma score recorded by the sensory method of all the fifteen genotypes over six environments are presented in table 5. This table indicated that the genotype PR-115 found the strong scent during all the environments. The genotype Ghansal showed the mild aroma only during D1 environments where as Basmati-376 did not show the aroma at D1 and D2 environments but showed the mild aroma for remaining D3 to D6 environments. The genotype Botvel, Ambemohar,

Chimansal, Basmati-1017 and Super Basmati did not show the scent for all environments. The genotype BM-4, Indrayani, Pawana, Bhogavati, Kothmirsal, Basmati-386 and Basmati-370 showed the mild aroma for all environments at the maturity stage.

At maturity, aroma profiles diversified. *PR-115* remained strongly scented (SS). Eight genotypes were mildly scented (MS), and six were non-scented (NS). *Ghansal* showed mild scent only at D1, while *Basmati-376* was non-scented in D1 and D2 but mildly scented from D3 to D6, highlighting the impact of sowing date.

Table 5: Score of leaf aroma of different genotypes at maturity stage under different dates of sowing

Sr. No	Genotypes	Dates of sowing						
		D1	D2	D3	D4	D5	D6	Overall
1	Botvel	NS	NS	NS	NS	NS	NS	NS
2	BM-4	MS	MS	MS	MS	MS	MS	MS
3	Ambemohar	NS	NS	NS	NS	NS	NS	NS
4	Indrayani	MS	MS	MS	MS	MS	MS	MS
5	Pawana	MS	MS	MS	MS	MS	MS	MS
6	Bhogavati	MS	MS	MS	MS	MS	MS	MS
7	Kothmirsal	MS	MS	MS	MS	MS	MS	MS
8	Chimansal	NS	NS	NS	NS	NS	NS	NS
9	Ghansal	MS	NS	NS	NS	NS	NS	NS
10	PR-115	SS	SS	SS	SS	SS	SS	SS
11	Basmati-376	NS	NS	MS	MS	MS	MS	MS
12	Basmati-386	MS	MS	MS	MS	MS	MS	MS
13	Basmati-370	MS	MS	MS	MS	MS	MS	MS
14	Basmati-1017	NS	NS	NS	NS	NS	NS	NS
15	Super Basmati	NS	NS	NS	NS	NS	NS	NS
Number of NS genotype		6	7	6	6	6	6	6
Number of MS genotype		8	7	8	8	8	8	8
Number of SS genotype		1	1	1	1	1	1	1

NS = Non scented; MS = Mild scented; SS = Strongly scented

Cooked Grain Aroma

The data for grain aroma recorded by the sensory method after cooking for all the fifteen genotypes over six environments are given in table 6. This table indicated that PR-115 had strong aroma during all the environments. The genotype Indrayani, Bhogavati and Basmati-386 did not show the aroma at D1 environments however showed the mild aroma in all the environments. Genotype Ghansal showed the mild aroma only during D1 environments but did not shows the aroma for remaining environments. The genotype BM-4, Pawana, Kothmirsal and Basmati-370 showed the mild aroma for all environments. The genotype Botvel, Ambemohar, Chimansal, Basmati-376, Basmati-1017 and Super Basmati did not find the aroma after cooking of rice grain.

Cooked grain aroma showed similar trends to the maturity stage. *PR-115* maintained its strong scent (SS). Seven genotypes were non-scented (NS), and seven were mildly scented (MS). *Indrayani*, *Bhogavati*, and *Basmati-386* were non-scented at D1 but mildly scented from D2 onwards. *Ghansal* was mildly scented at D1 but non-scented in later sowings, further emphasizing the combined influence of genotype and environment.

Table 6: Score of grain aroma of different genotypes after cooking under different dates of sowing

Sr. No	Genotypes	Dates of sowing						
		D1	D2	D3	D4	D5	D6	Overall
1	Botvel	NS	NS	NS	NS	NS	NS	NS
2	BM-4	MS	MS	MS	MS	MS	MS	MS
3	Ambemohar	NS	NS	NS	NS	NS	NS	NS
4	Indrayani	NS	MS	MS	MS	MS	MS	MS
5	Pawana	MS	MS	MS	MS	MS	MS	MS
6	Bhogavati	NS	MS	MS	MS	MS	MS	MS
7	Kothmirsal	MS	MS	MS	MS	MS	MS	MS
8	Chimansal	NS	NS	NS	NS	NS	NS	NS
9	Ghansal	MS	NS	NS	NS	NS	NS	NS
10	PR-115	SS	SS	SS	SS	SS	SS	SS
11	Basmati-376	NS	NS	NS	NS	NS	NS	NS
12	Basmati-386	NS	MS	MS	MS	MS	MS	MS
13	Basmati-370	MS	MS	MS	MS	MS	MS	MS
14	Basmati-1017	NS	NS	NS	NS	NS	NS	NS
15	Super Basmati	NS	NS	NS	NS	NS	NS	NS
Number of NS genotype		9	7	7	7	7	7	7
Number of MS genotype		5	7	7	7	7	7	7
Number of SS genotype		1	1	1	1	1	1	1

NS = Non scented; MS = Mild scented; SS = Strongly scented

Discussion

This table showed that PR-115 genotypes had strong scent during all the four stages i.e. seedling, flowering, maturity and after cooking as well as during all the six sowings followed BM-4 showed the mild scent during seedling, maturity and after cooking, whereas it had strong scent during flowering stage. All the fifteen genotypes showed the mild to strong scent during flowering stage in all the six sowing environments, however only eight genotypes *viz*., BM-4, Indrayani, Pawana, Bhogavati, Kothmirsal, Basmati-376, Basmati-386 and Basmati-370 showed mild to strong aroma during maturity stage in all the six sowing environments.

Some of the aromatic rice varieties are loosing their aroma during growth stages from flowering to maturity stages. This might be due to increasing the temperature at the time of flowering.

Sensory methods of aroma detection are not suitable for large number of samples because senses vary from person to person and physical damage in nasal passages may occur due to direct exposure with chemicals during smelling. These results are in resemblance with the results obtained by Hien *et al.* (2006) [5].

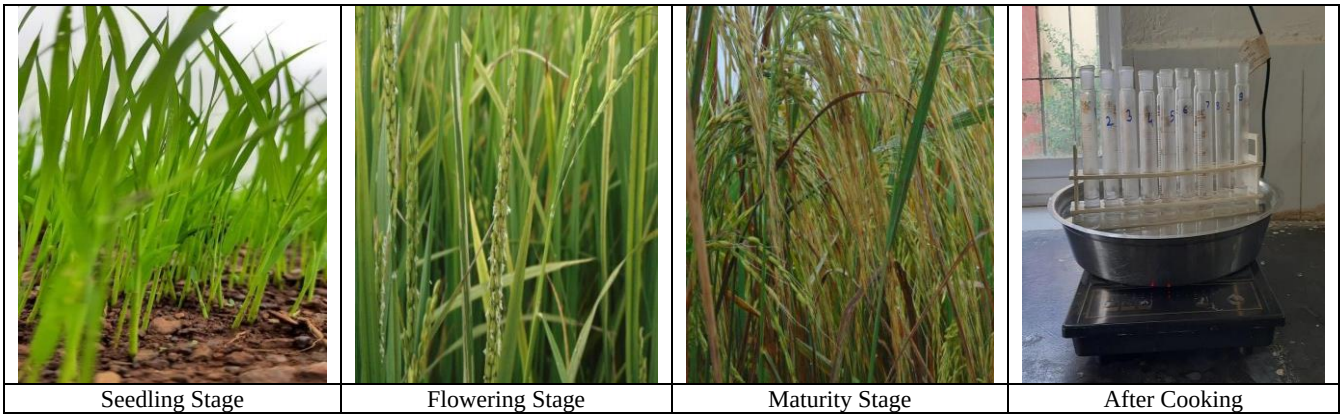
Different research worker used the sensory method for evaluation of aroma at various growth stages. Genetics, growing conditions, and post-harvest handling are factors which have been shown to affect the aroma and flavour of rice (Champagne, 2008) [1]. Rice aroma quality also highly depends on the cultivation process along with environmental conditions like temperature, soil type, abiotic stress, water, CO_2 light, salinity, shading the duration and conditions of storage, the time of harvest (Itani *et al.* 2004; Mo *et al.* 2018) [4, 6].

The observed variation in aroma among rice cultivars highlights the importance of genotype selection for improving rice quality in the Konkan region. The significant increase in aroma intensity at the flowering stage aligns with the known accumulation of volatile compounds during reproductive development. The influence of sowing date on aroma suggests a strong genotype-environment interaction. Variations in temperature, humidity, and rainfall associated

with different sowing dates likely affect the biosynthesis of aroma compounds. PR-115's consistent strong aroma across environments suggests its potential stability and suitability for Konkan. The fluctuating aroma profiles of other varieties indicate their sensitivity to environmental changes. The absence of aroma in some genotypes at specific growth stages or sowing dates might be related to their genetic makeup or their ability to adapt to the fluctuating environmental conditions during the cropping season.

Table 7: List of aromatic genotypes in different stages of crop growth

S/N	Different stages	Overall score	Genotypes
1	Seedling stage	Mild scented	BM-4, Pawana and PR-115
2	Flowering stage	Mild scented	Botvel, Ambemohar, Indrayani, Pawana, Bhogavati, Kothmirsal, Chimansal, Ghansal Basmati-376, Basmati-386, Basmati-370, Basmati-1017 and Super Basmati
		Strong scented	BM-4 and PR-115
3	Maturity stage	Mild scented	BM-4, Indrayani, Pawana, Bhogavati, Kothmirsal, Basmati-376, Basmati-386 and Basmati-370
		Strong scented	PR-115
4	After cooking	Mild scented	BM-4, Indrayani, Pawana, Bhogavati, Kothmirsal, Basmati-386, Basmati-370
		Strong scented	PR-115



Screening of aroma at different growth stages of rice

Conclusion

This study identified PR-115 as a consistently strong-scented cultivar suitable for the Konkan region. The research also demonstrated the significant influence of growth stage and sowing date on aroma expression in rice. These findings can assist farmers in selecting appropriate cultivars and optimizing planting schedules to enhance rice aroma and potentially improve yields by aligning planting with favourable conditions, contributing to higher market value and consumer satisfaction. Further research is needed to explore the specific environmental factors influencing aroma and to identify the genes responsible for desirable aroma traits to accelerate the development of superior aromatic rice varieties for the Konkan region.

Further molecular analysis may help in understanding the genetic control of aroma under varying climatic conditions.

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