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Rice Establishment Techniques and Their Implications on Rice Quality: BiochemicalComposition, Eating Quality, and Cooking Quality for Food and Nutritional Security

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ABSTRACT

In recent years, conventional rice production technologies have been leading to the deterioration of soil health and declining farm profitability due to high inputs of water and labor. Conservation agriculture (CA) based resource-conserving technologies i.e. zero-tillage (ZT), raised-bed planting, and unpuddled transplanted rice have shown promise as alternatives to conventional production technologies to overcome these problems. The present study was undertaken during 2015–2019 to establish an understanding of how rice establishment techniques could be practiced to save water at the field application level to improve water productivity and also have the capability to enhance productivity, profitability, and rice quality. The results showed that among different crop establishment techniques, conventional-tilled puddle transplanted rice (CT-TPR) required 14% to 25% more water than other techniques. Compared with the CT-TPR system, zero till direct-seeded rice (ZT-DSR) consumed 6%–10% less water with almost equal system productivity and demonstrated higher water productivity. Wide raised beds saved about 15%–24% water and grain yield decreased by about 8%. Direct-seeded rice after ZT or reduced tillage or on unpuddled soil provided more net income than CT-TPR. India possesses an immense wealth of Basmati and -non-Basmati aromatic rice varieties and landraces exhibiting a wide variability in their grain quality and cooking characteristics. In the present study forty varieties of Basmati and -non-Basmati aromatic rice were evaluated for their physical and quality characteristics. Among all quality characteristics aroma was considered as the most important quality parameter of high-quality rice. In our study aroma ranged from very low to strong. The gelatinizing temperature ranged from low to high intermediate category. This was indirectly decided by alkali digestion score which ranged from 7.0 to 2.0. Cooked kernel length, cooked kernel breadth, elongation ratio, gel consistency, and amylose content were also recorded. Various grain quality parameters of these varieties/lines were compared to premium Dehradun basmati 3020. The study reveals that to sustain rice productivity, CA-based planting techniques can be more viable options. However, the long-term effects of these alternative technologies need to be studied under varying agro-ecologies at texturally divergent soils western Uttar Pradesh, India. The biochemical makeup, eating quality, and cooking quality of rice are all impacted by the methods used in rice establishment, which in turn affects the rice's overall food and nutritional security. To ensure sustainable food supplies and enhance rice quality, these methods must be optimized.

Keywords: *Grain quality, Crop establishment techniques, Rice varieties, Elongation ratio, Amylose content and Food security*

INTRODUCTION

Rice (*Oryza sativa* L.) is a major dietary component of people in most of the countries. It is appreciated as one of the most nutritious staple foods among cereals (Verma et al., 2015) and is highly consumed in Asia and Africa and less in the European Union (Vlachos and Arvanitoyannis, 2008).

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This staple food is the main source of energy and protein which provides 700 calories/day per person for about 3000 million people of the world's population (Vlachos and Arvanitoyannis, 2008). Rice is a rich source of carbohydrate (CHO); it contains a moderate amount of protein and fat and is also a source of vitamin Rice Establishment Techniques and Their Implications on Rice Quality: Biochemical Composition, Eating Quality, and Cooking Quality for Food and Nutritional Securitycomplexes such as thiamine (vitamin B_1), riboflavin (vitamin B_2), and niacin (vitamin B_3) (Fresco, 2005). Rice CHO is mainly a starch which is composed of amylose and amylopectin. The grain of rice constitutes water 12%, starch 75–80%, and protein only 7 with a full complement of amino acids (Aas).

Its protein is highly digestible (93%) with excellent biological value (74%) and protein efficiency ratio (2.02–2.04%) owing to the presence of higher concentration (~4%) of lysine (Juliano, 1993). Minerals like calcium (Ca), magnesium (Mg), and phosphorus (P) are present along with some traces of iron (Fe), copper (Cu), zinc (Zn), and manganese (Mn) (Oko et al., 2012). Although the nutritional values of rice vary with different cultivars, soil fertility, fertilizer application, and other environmental conditions, the following trend still exists by comparison with other cereals: low-fat content after the removal of the bran, low protein content (about 7–10%), and higher digestibility of protein. Due to its nutritional quality and higher digestibility, rice is considered the queen among cereals (Anjum et al., 2007).

Rice quality includes various characteristics when it is being produced, processed, sold, cooked, and re eaten. In general, it involves processing quality (also called milling quality), appearance quality, cooking and eating quality, and nutritional quality. High-quality rice included 14 indicators, among which the milled rice rate, chalky degree, eating quality, and amylose content were grading indexes while roughness, chalky rate, grain shape, and gel consistency were indexed for reference. The amylose content (AC), gelatinization temperature (GT), and gel consistency (GC) are three major indicators for physical and chemical characteristics of the starch in rice endosperm which, directly affected cooking and eating quality (Sun et al., 2005).

Rice consumes around 27% of the world's total freshwater withdrawal (Barker et al., 1999). For wetland rice production, puddling alone requires 30% of the crop water consumption. Predictions indicate that 17–22 M ha of the irrigated rice area in Asia will face water scarcity (Tuong et al., 2002) by 2025, necessitating water-saving options to be practiced widely. Manual rice transplanting requires 25–50 person-days while the size of the workforce in agriculture declined by nearly 30 million between 2004–05 and 2011–12 due to rapid economic growth in Asia in non-agricultural sectors and increased labor wages (Zhang et al., 2011). Wetland rice production contributes almost 12% of anthropogenic methane and 55% of agriculturally sourced greenhouse gas (GHG) emissions in the world (IPCC, 2013). Solutions to all problems can be found in modifications of crop establishment practices (Chakraborty et al., 2017; Alam et al., 2014). Among the crop production factors, tillage alone contributes up to 20% of crop production costs and strongly influences soil properties. Novel resource-saving technologies are, therefore, being developed to cope with these factors influencing the cultivation of all crops including rice in intensive crop-growing areas (Chakraborty et al., 2017; Haque et al., 2016). The objective of the study was to compare the physicochemical, cooking, and textural properties of milled rice from different cultivars under various rice establishment techniques.

MATERIALS AND METHODS

An experiment was conducted at Ghaziabad, Hapur, Meerut, Muzaffarnagar, and Saharanpur District in a farmer's participatory mode of SardarVallabhbhai Patel University of Agriculture & Technology, Meerut (Uttar Pradesh), India, during 2015–2019. The experiment was laid out in a randomized block design with three replications. A description of different technologies is presented in (Table 1). The size of each plot was 15 m × 9 m. The climate of the area is semiarid, with an average annual rainfall of 765 mm (75%–80% of which is received from July to September), a minimum temperature of 4°C in January, a maximum temperature of 41– 45°C in June and relative humidity of 67%–83% throughout the year. In general, the soils of the experimental sites were sandy loam in texture with medium fertility status. The particle size distribution of the 0–20 cm soil layer is 64.2% sand, 18.5% silt, and 17.3% clay.

Water application and measurements

Irrigation water was applied using polyvinyl chloride pipes of 15 cm diameter and the amount of water applied to each plot was measured using a water meter (Dasmesh Co., India). The quantity of water applied and the depth of irrigation were computed using the following equations:

Quantity of water applied (L) = $F \times t$ (1)

Depth of water applied (mm) = $L / A / 1000$ (2)

Where

F is flow rate (L/s), t is time (s) taken during each irrigation and A is the area of the plot (m^2).

Rainfall data were recorded using a rain gauge installed within the meteorological station. The total amount of water (input water) applied was computed as the sum of water received through irrigation (I) and rainfall ®. Water productivity (WPI+R) (kg/m^3) was computed as follows (Humphreys et al, 2008):

WPI+R = Grain yield / (Irrigation water applied (I) + Rainfall received by the crop R. (3)

Table 1: Description of different technologies in the crop season

Name	Abbreviation	Brief description	Benefit	Limitation
Zero till transplanted rice	**ZT-TPR**	Fields are flush-irrigated to moisten the soil and allow weeds to germinate. After 5–7 d, glyphosate/ paraquat is applied to kill all weeds. Then, a zero-till drill seeder is used to open shallow slits then 21-day-old rice seedlings are transplanted in rows	Good soil structure due to non-puddling; better crop growth due to more aeration, less disease, and insect problems; healthy plants due to more photosynthetic activity	Difficult to plant manually; more weeds; labor intensive
Reduced till (non-puddled) transplanted rice	**RT-TPR**	2–3 dry tillage followed by planking/leveling and ponding water but without puddling; 21-day-old rice seedlings are transplanted at random or in rows	Faster crop; establishments labor; good soil structure due to non-puddling	Faster crop; establishments labor; good soil structure due to non-puddling

Transplanted rice on wide raised beds	**WBed-TPR**	A bed former-cum-zero-till drill is used to form 107 cm wide raised bed and 30 cm wide furrows in well-prepared pulverized soil. Transplanting of 21-day-old seedlings in six rows at 20-cm spacing on the wide raised beds. Plant-to-plant spacing was 10 cm to maintain the population equal to that of the conventional transplanted method. The plots were kept flooding after transplanting and sequent irrigations were applied to completely fill the the furrows at the appearance of hair-line cracks at the soil surface at the bottom of the furrow	Good crop stand; good drainage; savings in water; facilitates mechanical dding ding wedding	Heavy weed infestation required chemical weed control
Conventional-till Puddle transplanted rice	**CT-TPR**	The land is ploughed, puddled and leveled; 21-dayoldseedlings are transplanted at random or in Rows	Good water retention due toplow pan; fewer weedssustainable	Time consuming; labor intensive; delays wheat seeding in rice-wheat system; destroys soil structure

Physical quality of grains

Milling yield determination

Duplicate 125-g rough rice samples were used for milling determinations. Rough rice samples were dehulled with a laboratory sheller. The resulting brown rice was weighed to obtain the percentages of hulls. The brown rice was then milled in a BPL 146 McGill mill number 2 (BP lab solutions, Haryana, India) (Adair, 1952) for 30 seconds with the prescribed added weight (680 g) on the pressure cover, followed by a second milling for another 30 second without the weight. The fraction removed was considered bran in the first milling and after the second milling polish. The milled rice sample was collected in a jar or thick paper bag and sealed immediately. The weight of the total milled rice was recorded. Whole grains (head rice) were separated from the total milled rice with a rice-sizing device and weighed. The percentages of hulls of rough rice were calculated as follows:

Brown rice rate (%) = (Weight of brown rice / Weight of rough rice) × 100

Hulling rate (%) = (Weight of hulls / Weight of rough rice) × 100

Total milled rice rate (%) = (Weight of total milled rice / Weight of rough rice) × 100

Head rice recovery (%) = (Weight of head rice / Weight of rough rice) × 100

Degree of milling (%) = (Weight of total milled rice / Weight of brown rice) × 100.

Evaluation of grain quality

Seeds harvested from individual plants were analyzed for quality characters of length and width of milled rice, elongation of cooked rice, aroma, and alkali spreading value (ASV). For the determination of the length-to-to-breadth ratio, 20 fully developed wholesome milled rice grains were measured for their length and width. The elongation ratio of cooked rice was estimated as a ratio of the length of the cooked grains to that of uncooked grains. The strength of the sample-wise aroma was scored (Sood and Siddiq, 1978). ASV was estimated based on visual rating of starchy endosperm (Little et al, 1978).

Elongation ratio

The cumulative length of 10 cooked rice kernels was divided by the length of 10 uncooked raw kernels and the result was reported as an elongation ratio.

Gruel solid loss

Head rice samples (2 g) in 20 ml distilled water, for each cultivar, were cooked for minimum cooking time in a boiling water bath. The gruel was transferred to 50 ml beakers with several washings and made to volume with distilled water. The aliquot having leached solids was evaporated at 110 °C in an oven until completely dry. The solids were weighed and the percent gruel solids were reported.

Cooked length–breadth ratio

This was determined by dividing the cumulative length of 10 cooked kernels by the breadth of 10 cooked kernels. A mean of 10 replications was reported.

Textural properties

Back extrusion test

The textural properties of the cooked rice have been determined using the procedure described earlier (Singh, Sodhi, Kaur, & Saxena, 2003). A stainless steel (SS) cylinder having a diameter of 40 mm was used to conduct the back extrusion test. Cooked rice samples (50 g) were cooled to 25 °C and were placed inside the test cylinder and pressed with 150 g weight for 30 s before conducting the test. An SS cylinder plunger with a flat base, having a diameter of 38 mm, was used in conjunction with an Instron Universal Testing Machine (Model 4464, Instron, Buckinghamshire, England) for backward extrusion of the cooked rice. The test was carried out with a 500 N load cell at a crosshead speed of 100 mm/min. A force-distance curve was obtained from the test and the following textural parameters were determined:

Hardness – the average slope of the initial linear portion of the curve (N/mm),

Cohesiveness – the force required to initiate the shear and extrusion (N),

packability – distance traveled by the plunger before an average linear slope is reached (mm), ***maximum force*** – the maximum force registered during extrusion (N),

Chewiness – area under the curve (N mm)

Statistical Analysis

All data were analyzed by the Analysis of Variance (ANOVA) procedure using SAS software version 9.1 (SAS Institute, 1998). Differences were declared statistically significant when $P < 0.05$. Where significant differences were detected, the means were separated by the least significant difference (LSD) at a 5% probability level.

RESULTS AND DISCUSSION

Yields of rice with various technologies

Yields of transplanted rice on beds on the sandy loam soils declined substantially relative to conventional-till puddle transplanted rice (CT-TPR), with the same irrigation management, up to the fourth and fifth rice crop year i.e. 20015 to 2019. The relative yields of transplanted rice on permanent beds decreased progressively over the years, from 6.6% of CT-TPR in the first rice crop year (2015) to 9.8% of CT-TPR in the fifth crop cycle (2019). In addition establishment practices, and distribution of rainfall had an effect on the rice yield in the fourth and fifth years. Rice yields were higher in 2016 as compared to 20015, 2017, and 2018 in Table 2, due to favorable distribution of rainfall, that is, more rains at particular intervals during the crop establishment. Rice yields in zero till transplanted rice (ZT-TPR), reduced till direct-seeded rice (RT-TPR), and transplanted rice on wide raised beds (WBed-TPR) were on par with CT-TPR. This indicated that water and labor-intensive operation of puddling can be avoided without yield penalty in rice. WBed-TPR yielded 6.6%, 7.4%, 8.0%, and 9.8% lower in 2015 to 2019, respectively, than in CT-TPR. Moreover, WBed-TPR suffered from water stress compared to when planted on flat land resulting in lower yields.

Water application use and water productivity

The irrigation water application depends on the total rainfall and its pattern of distribution. In 1999 and 2011, a higher amount of irrigation was applied due to less rainfall. On average, the highest water application (2 960 mm/hm^2) was in RT-TPR due to the high infiltration rate, followed by CT-TPR (2 895 mm/hm^2), conventional-till puddle broadcast seeded rice (CTBCR) (2 816 mm/hm^2) and ZT-TPR (2 720 mm/hm^2). ZT-TPR applied 240 mm/hm^2 less irrigation water than RT-TPR applied 289 mm/hm^2 less water than RT-TPR, but RT-TPR applied 65 mm/hm^2 more irrigation water than CT-TPR. The minimum water was applied in transplanted rice on wide raised beds (WBed-DSR), 618 mm/hm^2 less water, and WBed-TPR applied 555 mm/hm^2 less than RT-TPR. The water productivity of rice under transplanting on WBed-TPR was 6.0% to 17.6% higher during the fifth year compared to CT-TPR. Water productivity of irrigation water (WP_{IW}) of transplanted rice on wide beds decreased with time mainly due to declining grain yield as the beds aged.

Changing from flat to bed layouts alters the hydrology of the system and allows greater control of irrigation, better surface drainage, and possibly better capture and use of rainfall. The irrigation water moves laterally from the furrow into the bed, and is driven upwards towards the bed surface by evaporation and capillarity, and downwards largely by gravity. The altered hydrology affects nutrient transformations and transport compared with irrigation on the flat (Farooq et al, 2009). In this technique, the field is divided into narrow strips of raised beds separated by furrows. The crops are planted on the bed surface and irrigation is applied through the furrows. The bed surface remains almost dry and the lateral water movement fulfills the crop water requirement. The infiltration rate of the furrow bottom remains almost zero due to compaction developed by tractor and machinery movement and irrigation which facilitates the lateral water movement of irrigated water into the bed area. Moisture stress at critical stages (panicle initiation and flowering) causes yield reduction in rice by lowering the number of grains per panicle and increasing spikelet sterility, consequently, the yield of aerobic rice is generally lower than submerged rice (Gathala et al., 2011). Reduced-till transplanting not only yields better, but it also saves labor, time, water, and energy, and thus costs (Saharawat et al., 2010). Earlier studies have shown that alternate-wetting and drying leads to improvement in rice yields by improving the oxygen status of the root zone, however, the effect is site-specific and depends on soil type and ground-water depth (Bouman et al., 2008). (Jat et al., 2008; Naresh et al., 2011; Yadav et al., 2011) also reported a saving of 7% to 10% in irrigation water under DSR.

Table 2: Yield, water application, and water productivity under various crop establishment techniques

Crop establishment technique	Yield (t/hm^2)					Water application (mm/hm^2)					Water productivity (kg/m^3)				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
ZT-TPR	2 835	2 663	2 795	2590	2575	5.50	5.90	5.45	5.25	5.35	0.194	0.222	0.195	0.203	0.208
RT-TPR	3 075	2 950	3025	2 790	2680	5.25	5.45	5.18	4.65	5.15	0.170	0.185	0.171	0.167	0.192
WBed-TPR	2 615	2 210	2465	2 330	2445	5.35	5.65	5.25	5.05	5.20	0.205	0.256	0.213	0.217	0.213
CT-TPR	2 995	2 890	2950	2 745	2865	5.73	6.10	5.65	5.60	5.75	0.191	0.211	0.192	0.204	0.201
CD at 5%	-	-	-	-	-	0.56	0.68	0.49	1.08	0.63	-	-	-	-	-

ZT-TPR, Zero till transplanted rice; RT-TPR, Reduced till transplanted rice; WBed-TPR, Transplanted rice on wide raised beds; CT-TPR, Conventional-till puddled transplanted rice

Physical characteristics

The de-hulling of rice is one of the important post-harvest processes. If the hulling percentage is high, then the recovery of rice is also increased. The hulling percentages for cultivated scented and basmati rice varieties scented cultivated rice varieties were compared (Table 3). Among scented cultivated rice varieties, hulling percentages ranged from 63 to 81%.

The highest hulling percentage (80.8%) was observed in variety Pusa Basmati-1 and lowest in Pant Dhan -12 (63.1%), whereas Haryana Basmati recorded 80.5%, Basmati -370 (80.3%) and Super Basmati (78.7%). ighty percent or more are the desirable hulling characteristics for rice (Rita and Sarawgi, 2008). The head rice recovery (HR) indicates the weight of whole grains obtained after industrial processing. For quality evaluation, HR recovery is one of the most important characteristics and more than 65% of HR recovery is desirable.

HR is the proportion of the intact grain in the milled rice. The hulling percentage for cultivated scented and basmati rice varieties ranged from 72-82 (Table 3). Rita and Sarawgi (2008) reported that the more than 80 value of hulling percentage is preferred and if the hulling percentage increases the head rice recovery also increased. Irregular cracks are caused in rice by hot-air drying but wetting of paddy tended to heal upon long soaking (Swamy and Bhattacharya, 2009). It was reported that the quality rice variety should have an HR value of at least 70%. HR value depends on the grain type, cultivation practices, and drying conditions (Dipti et al., 2003). In high-yielding rice varieties, the percentage of broken rice (BR) grains ranged from 5.3 to 36.3.

The L/B ratio ranged from 2.1-4.8. The variety 'Pusa Basmati-1' recorded the highest L/B ratio and the least was found in 'Pant Dhan -10'.

The L/B ratio among basmati varieties ranged from 3.6 to 4.8, lowest in 'Pusa Sugandh-3 and Type 9'. Based on the L/B ratio, the collected rice varieties were classified into five different categories: 'Basmati 370' (long slender), 'Tarore Basmati and Super Basmati' (long bold), 'Haryana Basmati, Vallabh Basmati- 21 andType -3' (short bold), 'Pusa Sugandh-5, HKR – 1 and CSR - 30Girga' (medium slender) and all the basmati rice varieties to the category of extra long slender grains (Table 3). Bhattacharjee and Kulkarni, 2000 analyzed some preferred brands of basmati rice and reported that the L/B ratio ranged from 4.5 to 4.8.

Table 3: Effects of crop establishment techniques on grain physical quality

Varieties	Moisture content (%)				Hulling rate (%)				Milling rate (%)				Head rice recovery (%)			
	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR
Pusa-2511	13.4	13.3	13.7	13.6	74.3	77.4	79.2	78.1	64.7	64.3	67.1	65.5	57.2	58.5	56.1	59.2
Type-3	11.4	11.2	11.9	11.7	76.5	77.2	79.3	78.2	65.1	64.9	68.5	64.7	54.5	55.1	54.7	56.1
Type- 9	11.7	11.4	12.5	12.1	75.2	77.1	80.9	79.8	64.5	64.1	65.3	65.1	54.1	55.4	54.4	55.9
Tarori Basmati	12.3	12.1	12.9	12.6	72.4	78.3	78.4	74.9	63.7	63.9	64.4	64.2	53.7	54.2	53.9	55.1
Haryana Basmati	12.6	12.4	13.1	12.8	73.4	80.5	80.7	77.2	64.4	64.1	65.6	64.9	53.9	54.9	54.1	55.8
Pusa Basmati-1	12.9	12.6	13.4	13.3	72.7	80.8	82.5	79.6	67.4	66.9	69.1	68.4	58.1	59.2	60.4	59.8
Basmati-370	13.4	13.2	14.0	13.7	80.7	80.3	81.3	75.6	72.3	71.3	74.2	73.1	56.8	57.6	55.7	58.1
Super Basmati	13.7	13.4	13.8	13.8	77.6	78.7	80.1	74.2	71.0	70.8	73.4	69.4	68.2	63.9	68.9	59.4
Basmati- 386	12.4	12.1	13.3	12.9	74.2	75.6	76.2	72.1	68.2	67.6	71.1	70.8	67.5	65.8	68.9	68.0
Ranbir Basmati	11.6	11.1	12.6	12.2	74.6	75.1	76.8	75.5	70.8	69.0	71.5	70.6	67.0	65.1	68.2	67.4
Vallabh Basmati-21	9.5	9.2	11.2	10.8	77.2	78.1	79.9	78.5	71.5	70.8	72.6	72.1	67.9	66.7	68.5	68.1
Pusa Sugandh-2	8.9	8.5	10.1	9.7	76.9	77.2	78.6	77.9	71.3	71.1	73.4	72.8	59.3	58.0	62.3	60.4
Pusa Sugandh-3	11.7	11.3	12.4	11.9	76.8	77.8	78.4	76.8	70.6	69.7	71.1	70.7	58.1	57.3	59.9	58.3
Pusa Sugandh-5	11.6	11.2	12.1	11.7	76.4	77.3	77.9	76.5	69.2	68.1	70.2	69.5	55.9	54.2	57.7	56.1
Mugadh Sugandh	12.2	11.9	13.4	12.9	75.6	76.1	77.2	75.8	66.9	64.2	68.3	67.1	57.2	55.3	59.1	58.2
Pant Dhan-10	12.8	12.1	13.7	13.1	82.6	65.5	83.4	82.8	70.2	69.2	71.9	71.1	54.6	53.1	56.7	55.0
Pant Dhan-12	12.6	11.9	13.2	12.8	80.9	63.1	82.4	81.1	68.1	64.0	69.2	68.6	56.1	55.4	57.5	57.1
CSR-30	12.5	11.7	13.3	12.6	77.8	72.4	81.4	80.7	67.2	66.7	70.1	67.9	55.8	53.1	57.2	56.4
HKR-1	11.4	11.2	13.1	12.9	79.7	72.3	82.1	81.4	65.2	64.0	69.1	68.6	56.1	54.2	59.2	57.8
NDR-118	10.6	10.8	11.6	11.3	79.9	73.3	81.9	80.8	64.2	62.4	68.4	67.6	54.1	52.7	55.3	54.8

ZT-TPR- Zero till transplanted rice; RT-TPR- Reduced till transplanted rice; WBed-TPR- Transplanted rice on wide raised beds; CT-TPR- Conventional-till puddled transplanted rice

Table 4: Effects of crop establishment techniques on grain physical parameters

Varieties	Kernel length (mm)				KernelBreadth (mm)				L/B ratio				Water uptake (mL)			
	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR
Pusa-2511	6.0	5.8	6.2	6.2	2.3	2.1	2.6	2.4	3.7	2.0	2.7	3.3	310.2	290.1	325.5	275.1
Type-3	5.9	5.6	6.3	6.1	2.6	2.3	2.8	2.6	3.8	2.1	2.8	3.5	263.2	240.6	290.4	233.2
Type- 9	6.4	6.0	6.9	6.6	2.4	2.1	2.6	2.5	3.6	1.8	2.4	3.1	281.2	267.2	297.1	260.2
Tarori Basmati	6.4	6.0	7.1	6.8	2.5	2.3	2.7	2.6	4.7	2.4	2.9	3.7	285.7	265.3	310.0	251.2
Haryana Basmati	6.5	6.2	6.8	6.5	2.6	2.4	2.8	2.7	4.4	2.2	2.4	3.1	289.2	274.5	315.3	274.1
Pusa Basmati-1	6.1	5.9	6.6	6.4	2.4	2.2	2.6	2.4	4.5	2.3	2.5	3.3	281.6	279.2	304.9	271.8
Basmati-370	5.3	5.6	5.9	5.4	2.0	2.0	2.1	1.9	4.8	2.4	2.7	2.3	377.4	354.6	390.0	314.0
Super Basmati	6.1	6.3	6.9	6.7	2.2	2.0	2.4	2.3	4.4	3.0	3.3	3.5	307.6	303.4	365.0	350.0
Basmati- 386	6.4	6.2	6.8	6.6	2.1	1.9	2.2	2.0	4.1	2.1	2.7	3.4	315.2	300.8	375.9	359.2
Ranbir Basmati	6.3	6.7	7.0	6.5	2.3	2.1	2.4	2.4	4.3	2.5	2.9	3.7	309.5	291.4	320.2	274.1
Vallabh Basmati-21	7.1	7.2	7.4	7.3	2.0	2.1	2.5	2.3	3.3	2.1	2.4	2.9	301.4	285.4	306.3	281.1
Pusa Sugandh-2	6.9	7.1	7.2	7.2	2.4	2.2	2.5	2.5	4.1	2.3	2.7	3.2	276.4	270.1	296.2	265.4
Pusa Sugandh-3	6.5	6.4	6.9	6.6	2.5	2.3	2.7	2.4	3.6	2.3	2.6	3.1	277.8	269.3	301.6	261.0
Pusa Sugandh-5	6.2	6.3	6.7	6.5	2.4	2.2	2.6	2.5	3.8	2.1	2.9	3.4	268.1	255.7	298.2	251.9
Mugadh Sugandh	6.2	6.6	6.9	6.7	2.3	2.0	2.4	2.2	3.9	2.4	3.0	3.6	273.1	260.0	300.6	265.2
Pant Dhan-10	6.3	6.5	6.8	6.6	2.4	2.2	2.6	2.5	2.1	1.9	2.0	2.4	284.2	273.2	305.1	271.2
Pant Dhan-12	6.0	5.9	6.6	6.2	2.6	2.4	2.8	2.7	2.2	1.4	1.9	2.0	279.2	2.68	297.8	259.3
CSR-30	6.3	5.5	6.7	6.3	2.3	2.2	2.6	2.4	2.8	1.8	2.2	2.5	294.1	276.2	302.2	274.3
HKR-1	6.2	5.9	6.6	6.3	2.3	2.2	2.4	2.3	2.9	2.0	2.3	2.6	281.2	274.3	297.2	269.1
NDR-118	5.9	5.5	6.0	5.9	2.0	1.8	2.3	2.2	2.7	1.9	2.0	2.4	271.1	263.1	286.2	264.2

ZT-TPR- Zero till transplanted rice; RT-TPR- Reduced till transplanted rice; WBed-TPR- Transplanted rice on wide raised beds; CT-TPR- Conventional-till puddled transplanted rice

Cooking characteristics

The volume expansion ratio (VER) in aromatic traditional rice varieties ranged from 2.36-4.10, while in basmati varieties 2.73-3.63. 'Pusa Sugandh-5' showed the VER 3.63 and 'Mugadh Sugandh' with 2.73 (Table 4). It was reported that lower VER is preferred by the consumers than higher VER, on the other hand, a higher elongation ratio (ER) of the cooked rice is preferred than lower ER (Shahidullah *et al*., 2009). Kernel length after cooking (KLAC) ranged from 2.31-3.76 mm in aromatic traditionally cultivated rice and 4.62-5.88 mm in basmati rice. Minimum KLAC was observed in 'Tarori Basmati' and 'Basmati -370'. The kernel elongation ratio (ER) in aromatic traditional rice ranged from 1.01-1.42 and in basmati rice ranged from 1.02-1.12. The highest kernel ER was observed in 'Super Basmati' and the lowest in 'Pant Dhan-10' (Table 5).In basmati varieties, the water uptake ratio ranged from 260-377, and in aromatic rice varieties. The amount of water uptake during the cooking process is associated with the appearance of cooked rice (Tan *et al*., 2000).

Table 5: Effects of crop establishment techniques on grain cooking quality

Varieties	Kernel length (mm) after Cooking				Kernel width (mm) after Cooking				Elongation ratio				Gel consistency (mm)			
	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR
Pusa-2511	7.2	7.1	8.2	7.3	2.4	2.1	2.8	2.6	1.3	1.2	1.6	2.4	50.0	49.0	52.0	49.3
Type-3	7.4	7.2	7.9	7.7	2.7	2.4	3.1	2.8	1.2	1.3	1.4	1.2	51.3	43.0	53.3	47.7
Type- 9	7.5	7.1	8.1	7.9	2.6	2.2	3.1	3.1	1.3	1.2	1.6	1.4	53.0	48.6	53.3	50.3
Tarori Basmati	8.1	7.9	9.1	8.9	2.3	2.1	2.8	3.3	2.8	2.7	2.9	2.8	52.3	48.3	54.0	47.0
Haryana Basmati	7.8	7.6	9.0	8.8	2.6	2.4	3.0	2.9	2.2	2.1	2.4	2.3	49.9	44.6	48.0	49.0
Pusa Basmati-1	7.4	7.7	8.8	8.6	2.3	2.1	2.8	2.7	2.6	2.4	2.7	2.6	57.4	51.7	58.9	52.0
Basmati-370	8.5	8.4	8.1	8.1	3.0	2.9	2.8	3.0	3.0	2.9	2.8	2.8	59.6	55.0	53.3	48.5
Super Basmati	8.8	8.7	9.1	9.3	2.7	2.6	3.1	2.5	2.8	2.9	3.1	3.1	49.0	44.7	39.3	51.4
Basmati- 386	8.1	7.8	8.9	8.7	2.6	2.5	3.2	2.8	2.7	2.6	3.0	2.8	47.8	46.5	51.3	47.4
Ranbir Basmati	7.9	7.6	8.8	8.5	2.4	2.2	2.9	2.7	2.9	2.7	3.1	2.8	45.1	44.6	49.2	44.0
Vallabh Basmati-21	7.3	7.1	8.1	7.8	2.6	2.3	3.0	2.8	1.9	1.7	2.7	2.6	46.6	45.9	50.1	45.1
Pusa Sugandh-2	6.9	6.9	7.7	7.5	2.1	1.9	2.5	2.3	2.1	1.9	2.4	2.2	48.1	49.5	51.2	47.5
Pusa-Sugandh-3	7.1	7.3	7.8	7.7	2.3	2.1	2.8	2.6	1.8	1.7	2.0.	1.9	47.6	44.9	48.2	44.1
Pusa-Sugandh-5	7.3	7.5	8.0	7.9	2.7	2.6	3.0	2.9	1.6	1.5	1.9	1.7	45.9	45.0	49.1	44.8
Mugadh Sugandh	6.9	7.2	7.5	7.3	2.3	2.2	2.9	2.7	1.5	1.3	1.8	1.6	46.5	45.7	50.1	44.9
Pant Dhan-10	6.1	6.4	7.0	6.3	1.9	1.7	2.4	2.2	1.04	1.1	1.4	1.3	48.1	46.9	50.7	45.3
Pant Dhan-12	6.3	6.6	7.1	6.6	2.0	1.8	2.6	2.3	1.02	1.0	1.6	1.5	47.5	47.0	48.9	46.8
CSR-30	6.7	7.1	7.6	7.5	2.4	2.2	2.8	2.6	1.09	1.2	1.5	1.3	44.1	44.0	47.8	44.3
HKR-1	6.4	6.6	7.6	7.3	2.5	2.2	3.0	2.8	1.07	1.4	1.7	1.6	45.3	44.9	51.2	43.9
NDR-118	6.9	7.5	8.0	7.9	2.4	2.2	2.9	2.7	1.04	1.2	1.4	1.4	47.5	46.4	50.6	45.1

ZT-TPR- Zero till transplanted rice; RT-TPR- Reduced till transplanted rice; WBed-TPR- Transplanted rice on wide raised beds; CT-TPR- Conventional-till puddled transplanted rice

The value of the physico-chemical characteristic such as amylase of the grain among the 18 cultivars used in this study is shown in Table -----. The amylose content among the varieties studied ranged between 19.5-25.5%, with a mean value of 22.9±2.01%. "Super Basmati" and "Basmati-370" had the highest percentage of amylose, followed by Pusa Basmati-1, Tarori Basmati, Haryana Basmati, and Pusa 2511. On the other hand, Pant Dhan-10, Pant Dhan-12, NDR-118, CSR-30, and HKR-1 recorded the low value for percentage amylose (Table--). Most of the aromatic varieties showed low AC content in comparison with basmati rice varieties (Table ---). Shahidullah *et al*., 2009 reported that the AC in all grades of rice ranged between 20.7-21.4%. Cooked rice becomes moist and sticky due to low AC.

Table 6: Effects of crop establishment techniques on grain cooking characteristics

Varieties	Alkali spreading value				Amylose content (%)				Minimum cooking time (Min)				Gruel solid loss (%)			
	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR	ZT-TPR	RT-TPR	WBed-TPR	CT-TPR
Pusa-2511	5.6	5.2	5.7	5.9	18.6	18.2	20.2	21.8	15.1	16.2	14.8	14.3	4.8	6.2	3.7	2.9
Type-3	5.8	5.3	5.9	6.1	19.4	19.2	21.4	22.3	14.6	15.9	13.5	12.9	4.2	5.4	3.3	2.6
Type- 9	5.6	5.3	5.7	6.2	19.6	19.0	21.2	24.9	16.0	17.1	15.6	13.6	4.6	5.7	3.8	2.8
Tarori Basmati	6.0	5.9	6.5	7.1	19.8	19.3	23.1	24.5	9.2	11.0	7.5	6.7	3.7	4.8	2.8	1.6
Haryana Basmati	6.3	6.1	6.6	6.8	20.2	19.8	23.6	24.8	11.2	12.9	9.5	8.1	4.0	5.6	3.1	1.9
Pusa Basmati-1	6.4	6.0	6.4	6.6	20.3	19.9	24.1	25.1	12.8	14.5	11.1	9.7	3.9	4.5	2.6	1.7
Basmati-370	6.5	6.2	6.7	6.9	20.7	20.2	24.9	25.2	13.5	15.2	12.9	10.3	4.5	6.0	3.5	2.4
Super Basmati	5.7	5.5	5.8	6.2	21.4	21.1	25.1	25.5	16.2	18.9	13.2	11.1	4.3	5.8	3.4	2.2
Basmati- 386	6.0	5.8	6.2	6.4	20.9	20.6	24.1	25.3	14.3	16.0	12.2	9.5	4.1	5.3	2.2	1.3
Ranbir Basmati	5.9	5.7	6.0	6.3	21.9	21.4	25.4	27.1	14.9	17.9	12.	9.2	5.0	5.9	2.7	1.5
Vallabh Basmati-21	4.7	4.5	4.9	5.2	27.9	27.4	28.6	30.3	15.0	17.6	14.3	12.7	4.8	6.5	3.7	2.6
Pusa Sugandh-2	5.2	5.0	5.4	5.7	28.1	28.0	29.4	31.9	16.5	18.7	15.1	13.0	5.6	7.3	4.0	3.9
Pusa-Sugandh-3	5.4	5.1	5.6	5.8	23.5	23.2	24.2	25.0	18.1	19.3	15.2	13.6	5.1	7.0	4.2	3.7
Pusa Sugandh-5	5.6	5.2	5.5	5.9	22.5	21.8	22.9	23.8	17.5	18.5	16.1	13.9	4.9	6.6	4.1	3.4
Mugadh Sugandh	5.5	5.0	5.6	5.8	23.5	23.1	24.0	24.8	20.2	22.3	18.0	14.3	4.0	5.7	3.8	3.1
Pant Dhan-10	3.6	3.2	3.8	4.1	15.4	15.2	16.5	17.7	25.3	28.4	20.1	24.3	7.8	8.9	6.0	5.2
Pant Dhan-12	3.7	3.3	3.9	4.3	16.9	16.4	17.6	18.3	32.1	35.3	30.5	28.0	8.0	9.2	7.2	5.9
CSR-30	5.4	5.1	5.6	5.8	17.1	16.9	17.9	18.7	18.2	22.3	17.5	15.2	5.5	7.2	4.9	4.1
HKR-1	5.3	5.0	5.4	5.6	16.5	16.2	17.4	18.1	19.5	23.1	18.1	15.6	6.0	7.9	5.1	4.3
NDR-118	4.7	4.3	5.0	5.2	16.3	15.8	16.8	17.2	21.1	26.7	19.1	15.9	6.3	8.2	5.8	4.7

ZT-TPR- Zero till transplanted rice; RT-TPR- Reduced till transplanted rice; WBed-TPR- Transplanted rice on wide raised beds; CT-TPR- Conventional-till puddled transplanted rice

Table 7:Grade (Sp, A, B) specifications for Indian Basmati rice adopted by APEDA for export (Available at http://agmarknet.nic.in/amrscheme/punerice044.htm)

Specification	Permissible limits for exports for Indian Basmati											
	Milled			Milled parboiled			Brown			Brown parboiled		
	Sp	'A'	'B'	Sp	'A'	'B'	Sp	'A'	'B'	Sp	'A'	'B'
Length of pre-cooked rice (mm)	7.1	7.0	6.8	7.1	7.0	6.8	7.4	7.2	7.0	7.4	7.2	7.0
Min L/B ratio	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Max moisture content (%)	14	14	14	14	14	14	14	14	14	14	14	14
Max number of damaged/discolored grains (%)	0.5	0.7	1.0	0.5	0.7	1.0	0.5	0.7	1.0	0.5	0.7	1.0
Max chalky grain/ black kernels (%)	3	5	7	0.1	0.5	1.0	3	5	7	0.5	1.0	2.0
Max broken grains (%)	2	3	5	2	3	5	2	3	5	2	3	5
Max foreign matter (%)	0.1	0.25	0.4	0.1	0.25	0.4	0.2	0.5	1.00	0.2	0.5	1.0
Max grains of other crops and weeds etc. (%)	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2
Max grains of other rice varieties (%)	5	8	15	5	8	15	5	8	15	5	8	15
Max paddy grains (%)	0.1	0.2	0.3	0.1	0.2	0.3	0.2	0.5	0.8	0.1	0.2	0.3
Min elongation ratio	1.7	1.7	1.7	1.5	1.5	1.5	1.7	1.7	1.7	1.5	1.5	1.5
Max green grains (%)	nil	nil	nil	nil	nil	nil	2.0	4.0	6.0	2.0	4.0	6.0

Note: *Max- Maximum, Min- Minimum, Special grade,*
APEDA: *Agricultural Products Export Development Authority of India*

CONCLUSIONS

The study revealed the physical, chemical, and cooking characteristics of traditionally cultivated scented and basmati rice varieties. Among the varieties studied traditionally cultivated aromatic rice '------' and '-----' showed maximum hulling percentage. However, rice varieties viz. 'Pusa Basmati-1', 'Pusa Sugandh-2', 'Pusa Sugandh-3', 'Pusa Sugandh-5i with best cooking quality characteristics.

Puddling followed by transplanting is the most common and widely used practice of rice cultivation in the entire Indo-Gangetic Plain, India, however, it results in several constraints to the productivity and sustainability of rice-wheat systems. Five years of research work in western Uttar Pradesh, India has shown that puddling is unnecessary for achieving high grain yields. Transplanting under zero-till and dry-till situations may be suitable alternatives and farmers can adopt them if given proper guidelines and information. The study indicates that the rice crop grown with resource conservation technologies can save irrigation water, provided the irrigation scheduling is reworked for these techniques. Thus, for each resource conservation technology to grow rice crops, the water balance parameters need to be worked out under different soil and climatic scenarios as a pre-requisite to decide upon the most efficient irrigation scheduling. This study confirms that conservation agriculture-based alternative technologies seem to be promising options to sustain rice productivity on a long-term basis. Further evaluation of these technologies is strongly recommended under different agro-ecologies for their large-scale adoption in western Uttar Pradesh, India.

Rice varieties with a greater proportion of starch in the form of amylose tend to have a lower glycemic index. The amylose content of milled rice has been found to be positively correlated with the hardness values of cooked rice and negatively with stickiness values. Feeding cooked rice high in amylose instead of cooked rice low in amylose may be effective in controlling serum blood glucose and lipids.

FUTURE SCOPE:

There is great potential for future research and improvement in rice establishment techniques to guarantee food and nutritional security and enhance rice quality. Here's a thorough examination of how these developments might affect the future:

1. Advanced Techniques and Technologies

Precision agriculture: By adjusting rice establishment techniques to the unique requirements of each site, crop performance and quality can be increased. This is achieved by using GPS, drones, and remote sensing to monitor field conditions.

Automated Systems: Improving consistency and efficiency in rice establishment through automation in planting, irrigation, and nutrient management can result in higher-quality crops.

Biotechnological Approaches: Rice varieties with enhanced quality features and optimum biochemical compositions can be created through genetic engineering and molecular breeding.

2. Impact on Biochemical Composition

Enhanced Nutrient Profiles: By addressing nutritional inadequacies, techniques that enhance nutrient uptake and soil health can produce rice with higher concentrations of vital vitamins and minerals.

Stress Resistance: More consistent nutrient levels and higher-quality rice can result from cultivating rice types that can resist environmental stressors (such as salinity or drought) without sacrificing biochemical quality.

3. Eating Quality

Enhancement of Flavor and scent: Studies on the effects of various establishment practices on the flavor and scent of rice can result in rice types that are more palatable and satisfy customer preferences.

Texture Optimization: Technological developments in rice cultivation can improve the texture of rice, adapting it to a wider range of culinary applications and raising the standard of eating.

4. Cooking Quality

Consistency and Performance: Cooking characteristics like cooking time and textural consistency can be enhanced by establishment processes that guarantee consistent grain growth.

Quality Control: Rice establishments can maintain excellent cooking quality and match market expectations by putting rules and guidelines into place.

5. Food and Nutritional Security

Sustainability: By raising rice yields while reducing their negative effects on the environment, improved establishment procedures help promote sustainable food production.

Adaptation to Climate Change: Safeguarding food supplies in the face of global challenges can be achieved by cultivating robust rice varieties and methods.

6. Integration with Supply Chains

Traceability and Quality Assurance: By putting in place technology that monitor and confirm rice quality from the field to the table, you can boost consumer confidence and guarantee that strict requirements are fulfilled.

Policy and Education: By supporting best practices with policy and educating farmers, we may encourage the adoption of cutting-edge methods and bring about significant changes in the quality of rice.

The future scope of rice establishment techniques involves leveraging technology and research to enhance biochemical, eating, and cooking quality, all while ensuring sustainability and security in the global food system.

Declarations

Conflict of Interest: The authors declare no competing interests.

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