

Distinction from Near Extinction of Kalanamak: A Heritage Rice's Journey from a Remote Village to the Globe

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ABSTRACT

Kalanamak, a landrace of rice (*Oryza sativa* L.), often referred to as "Buddha Home Rice" or 'Buddha Rice,' holds a significant place in the cultural and agricultural history of India. This heritage rice variety is believed to be blessed by Lord Buddha himself to the farmers of Bajaha village in Siddharthnagar district of U. P., some 3000 years ago. Facing extinction but due to the Bhagirath Prayas of one scientist, now touching the world market. parts of programme involved germplasm collection, followed by the pureline selection, hybridization and selection, and modern revival to reach to global level. Historically prized for its unique fragrance, taste, and nutritional benefits, Kalanamak rice saw a decline during the Green Revolution due to its lower yield compared to modern rice varieties.

However, the success of Kalanamak rice faces challenges, particularly in ensuring authenticity and quality control amidst the proliferation of counterfeit products. Advanced technologies such as blockchain and QR code-based traceability systems are proposed to combat these issues. Sustainable agricultural practices, ongoing research, and innovations are emphasized as crucial for the continued growth and environmental viability of Kalanamak rice cultivation.

Keywords: Kalanamak rice, sustainable agriculture, heritage rice, germplasm collection, nutritional benefits, export potential, tripling farmer's income.

1. Historical Significance and Cultural Tale of Kalanamak rice

The history of Kalanamak rice is deeply intertwined with the local myths and cultural practices of the region. According to legend [16], [53]; [59], Lord Gautam Buddha, after he received enlightenment, was returning from Bodha Gaya to his father's kingdom in Kapilvastu, he was requested by the villagers of Bajaha jungle (now Bajaha and Mathala villages) to bless them. He then took out a fist of paddy seeds from his bag and asked them to grow these in the lowland. The fragrance of the rice will remind them of Him and the nutritive value as His blessing. This story has not only persisted but has also become a part of the local folklore, enhancing the cultural significance of Kalanamak rice [7], [16].

2. Decline to near extinction of Kalanamak

The decline of Kalanamak rice cultivation can be attributed to several socio-economic and technical factors. Basically, there were four major reasons for the decline of the Kalanamak area. First was the advent of High Yielding Varieties (HYV) of rice in 1965, which yielded double Kalanamak.

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The second reason was the absence of any improved variety of Kalanamak which had become a Land Race and admixture. The third reason was the neglect of Kalanamak by the research and academic institutions [21], [22]. The fourth reason was the loss of aroma and grain quality due to unscientific seed production. The sum of all the factors reduced the Kalanamak area (Table 1).

3. Organized Improvement of Kalanamak rice

Organized efforts to improve Kalanamak did not start until 1974 [54], though the Department of Agriculture did try to test some Kalanamak germplasm at their research centers. The first organized efforts started at G. B. Pant University of Agriculture and Technology, Pantnagar with the start of Mutation Breeding [1], [2]. Not much could be achieved except getting some mutants of academic interest in Kalanamak [17]. Later Pantnagar did try testing some germplasm of Kalanamak but nothing of use could come out.

3. Germplasm Collection and Evaluation of Kalanamak

Before the germplasm collection of Kalanamak was formally started, some preliminary work on inducing mutation in Kalanamak rice was done at G. B. Pant University of Agriculture and Technology, Pantnagar [1], [2], [34]. Organized germplasm collection was done with financial assistance from the U . P. Council of Agricultural Research (UPCAR) described below [16].

3.1 Germplasm Collection

A collection of Kalanamak germplasm was done in order to get some superior types for further varietal improvement programmes. The germplasm was collected as a single panicle collection and bulk collection from sources like farmers' fields and research institutions [5], [20], [18], [19]

The single panicle collections were used for developing purelines and bulk collections were tested for yield potential.

3.2 Single Panicle Collection

A total of 1,455 panicles were collected from farmers' fields of Maharajganj, Sant Kabir Nagar, and Siddharth Nagar districts. These panicles were tested organoleptically for aroma and classified as aromatic and -non-aromatic types. Only 12.57% of panicles were found aromatic (belonging to 5 accessions), and the rest 87.43% were non-aromatic. Aromatic types were sown in nursery beds using the concept of the panicle-to-row method. Seedlings from one panicle were transplanted in a single row. Observations on initial and 50% flowering, tillering ability, maturity, etc. were recorded. Initial flowering ranged between 100 to 108 days and 50% flowering ranged between 104 to 114 days. Maturity duration ranged between the ranges of 134 to 144 days. Superior performing and scented lines were identified, and 5 single plants were harvested separately. The frequency of aromatic lines for each accession is provided in Table 2.

Table 2 reveals that from the 226 lines out of five accessions only 70 lines were found to be aromatic (33.58%) in the current cropping season. Thus there has been improvement as the frequency of aromatic lines has been doubled in one cycle of selection only. Therefore, it is expected that in the next two cycles, pure aromatic lines could be developed. Further, the stability of the aroma of such pure lines of Kalanamak in various locations could then be tested.

3.3 Bulk Collection

A total of 39 bulk collections were collected from different sources. Out of these, 16 collections were from PRDF Gorakhpur; 8 collections from NDUAT, Ayodhya, and 15 collections from CRRI, Cuttack. These collections were tested in a randomized block design (RBD) using a multi-location trial with 2 replications in 4 districts. The trials were arranged at the following locations.

PRDF experimental plot (Gorakhpur)

Sampatiha (Maharajganj)

Jhingurapar (Sant Kabir Nagar)

Ghoswa (Siddharthnagar)

In these purposely delayed sowing trials, observations for seedling height, and seedling vigour were recorded at the seedling stage. Just before transplanting, average heights ranged from 33 to 38 cm. Vigour was normal but KN 38, 41, and 42 were more vigorous. Since the experiment could be planted late, initial flowering ranged between 87 to 93 and 50% flowering ranged between 91 to 101 days. Maturity duration ranged between 121 to 131 days and other characters ranged too (Table 3).

The mature crop was harvested and yield data of each accession for each location was recorded. The data were analyzed to find out accessions with superior yield potential using ANOVA. After analysis, KN 53, 55, and 56 were found significantly superior at all the locations over the rest of the accessions. However, KN 48, 54, and 58 were found significantly superior only at two locations. Thus finally KN 48, 53, 54, 55, 56, and 58 had been selected for better yield potential from a total of 39 accessions. Also, visually superior panicles from each accession were collected for further study.

All these accessions have National Accession Number [24]. Details are described in the Catalogue and publications [5], [24]; [20], [33], [18], [19], and [7]. One set of these collections were also sent to Directorate of Rice Research (DRR) Hyderabad and Central Rice Research Institute (CRRI), Cuttack for conservation and use at their ends [25], [26], [27], and [28].

4. Breeding of Kalanamak KN 3

As per procedure, any crop variety to be released for general cultivation in Uttar Pradesh must be tested by the Department of Agriculture at their Regional Agricultural in Testing and Demonstration Stations (RATDS) for three years. Pureline selection of Kalanamak (KN3-27-3 -3) was tested from 2004 to 2007. Based on its superior performance it was released by U. P. State Variety Recommendation Committee in 2007 as Kalanamak KN3. However, it was notified by the Central Sub Committee on Varietal Release and Notification in 2010. KN 3 was the first Kalanamak rice variety developed through Pureline selection and set a historic platform with original aroma and grain quality [36], [8]. KN 3 became popular with farmers and will remain popular in the low-lying areas where water stagnates for more than half a meter. Its characters are summarised in Table 4.

Farmers and consumers realized that the aroma and grain quality of Kalanamak have returned back in KN 3 [8], [9], [10], [11], [12], [13], [14], and [15]. Since the variety Kalanamak KN3 was released and notified on the proposal of PRDF Gorakhpur, we retain the exclusive right to produce Nucleus Seed and Breeder Seed [9]. Other organizations like National Seeds Corporation, U. P. Beej Vikas Nigam, and others produce Certified Seed of it. A package of practices for the cultivation of Kalanamak was standardized and publicity was done by All India Radio, Door Darshan, in Indian Farming, Kheti, Rice India, and other popular magazines [6], [25], [26], [27], [28]; and [9].

5. Breeding of Bauna Kalanamak 101

Regional Agricultural Technology Demonstration & Testing Station (RATDS) of the Department of Agriculture conducts varietal trials annually on the new varieties to be considered for release. PRDF had proposed a number of semi-dwarf breeding lines of Kalanamak. These breeding lines were tested at RATDS during the years 2012 to 2014 in a state trial called "Paddy standard varietal trial: Sthaniy Sugandhit". The yields and morpho-agronomic characters taken from the three RATDS located in the Eastern Region of U. P. are given in Table 5 [23].

Based on the superior performance of UPCARKN-2-19-14 was proposed for release in the State Variety Release Committee in 2015. Farmers have liked it and it was already cultivated in more than 2,000 acres during Kharif 2014. Yields were very high but the grain quality characters of Bauna Kalanamak 101 were analyzed and found to be a bit different from the tall Kalanamak KN3. The husk colour was brownish, not black, and also grain was a bit coarser than KN3. However, due to yield advantage farmers liked it and expanded the area [50], [51], [52], [37], [38]. The aroma quantification was done by IICT Hyderabad and the results are reproduced below.

6. Breeding of Bauna Kalanamak 102

A proposal for the release of Bauna Kalanamak 102 was put up once the U. P. State Variety Release Committee released it in 2017. Yields obtained at RATDS and morpho-agronomic characters observed from 2013 to 2015 are summarised in Table 6. Bauna Kalanamak 102 was a definite improvement on the grain characters of Bauna Kalanamak 101. That is how it became more popular with the farmers and consumers [50], [51], [52].

7. Breeding of Kalanamak Kiran

Kalanamak Kiran was derived from a cross of KN 3 and Swarna Sub₁. The segregating generations were handled by the Pedigree method of breeding and selection.

The breeding line was purified as PRDF-2-14-10-1-1 and tested as PRDF-2-14-10 and the pedigree line PRDF-2-14-10 was tested at RATDS of the Department of Agriculture during 2013 – 2016. It stood at first rank with an average yield of 32.95 quintal/ha. It out-yielded the check variety Kalanamak KN3 by 26.58 %. On average PRDF-2-14-10 out-yielded the check variety Kalanamak KN3 by 26.58%. Over the second check variety Lalmati, it out-yielded by 25.23 %. In AICRIP trials as the IET No. 27453 in AICRIP trials, it out-yielded the check variety Kalanamak KN3 by 33.35% across the country. It is semi-dwarf, lodging resistant, and suitable for harvesting by combine harvester (Table 7). On the date of the planting trial, it was established that a seed sown in the -mid-June and transplanted in -mid-July is the best for its performance and yield (Table 8) as it is a highly photoperiod sensitive variety, and inherited from its Kalanamak parent. The resistance to pests and disease is acceptable, as compared to the other varieties of the group (Table 9).

The grain quality was tested in the Regional Food Analysis and Research Centre (R-FRAC) at Lucknow, and in the Asia Pacific Lab in Singapore (Table 10). PRDF-2-14-10 has the same black husk, white and aromatic rice grain with excellent cooking quality, as the original Kalanamak KN3. Its aroma content was confirmed by the Indian Institute of Chemical Technology (IICT), Hyderabad through sophisticated tests. Its aroma content was confirmed by the Indian Institute of Chemical Technology (IICT), Hyderabad confirmed its aroma equal to KN3. Kalanamak Kiran has the same level of Iron and Zinc as its original parent Kalanamak KN3 [42], [43], [44], [45], and [46]. Compared to its 200 cm tall parent KN3 (Fig. 1), PRDF-2-14-10 (Kalanamak Kiran) is semi-dwarf (height 95 cm (Fig. 2), highly resistant to lodging and shattering, and is suitable for harvesting by combine harvester. PRDF-2-14-10 (Kalanamak Kiran) matures earlier than Kalanamak KN3 by about 10 days. This early maturity enables planting of the following Rabi crop earlier, by 10 days. Therefore, PRDF-2-14-10 was found superior to the checks in all these tests and was recommended for release as Kalanamak Kiran by the U. P. State Variety Release Sub-Committee in its 56th meeting held on 19th May 2017 at Lucknow. Based on the above superior features of PRDF-2-14-10, the U. P. State Variety Release Sub-Committee proposes that PRDF-2-14-10 should be released and notified as Kalanamak Kiran for eastern Uttar Pradesh. It was notified by the Government of India Gazette of India under Gazette No. 3220 (Part II (3) dated 06 08.2019.

8. Kalanamak Rice: Key Feature

8.1 Unique grain Quality attributes and pleasant Aroma

Kalanamak rice is distinguished by its unique black husk and white rice (Fig. 3), and greenish kernel if unpolished (Fig.4). extraordinary fragrance. The name "Kalanamak" is derived from two words: "Kala" meaning black and "Namak" meaning salt, referring to the black husk, and Namak referring to marshy soils that contain salt. Its palatability is excellent when cultivated in this particular soil. The aromatic quality of Kalanamak rice is one of its most celebrated features. This fragrance is attributed to the presence of a compound called 2-acetyl-1-pyrroline, which is also found in other aromatic rice varieties like Basmati and Jasmine. However, the concentration of this compound is higher in Kalanamak, making its aroma more pronounced [52].

The grain size of Kalanamak rice varies from short to medium, and it has a high elongation ratio when cooked. This means that the rice grains expand significantly upon cooking, resulting in a

fluffy and soft texture. The combination of its unique fragrance, texture, and mouth feel is the unique quality of Kalanamak. Kalanamak rice is a gourmet product, often sought after by connoisseurs of fine foods (Table 10).

The rice's aroma is so distinctive that it has been described in historical texts and local folklore as capable of attracting herds of deer from the jungle. This legend is not only a testament to its fragrance but also highlights the cultural importance of Kalanamak rice in the region.

8.2 Nutritional Properties

Kalanamak rice is not only prized for its aromatic qualities but also for its nutritional benefits. Studies have shown that Kalanamak rice is rich in micronutrients such as iron and zinc, which are essential for human health. The iron content in Kalanamak rice is significantly higher compared to other rice varieties, making it beneficial for preventing anaemia and other iron-deficiency disorders. The zinc content is also noteworthy, contributing to the rice's role in boosting the immune system and supporting metabolic functions (Table 10).

In addition to its micronutrient content, Kalanamak rice has a higher protein content than many common rice varieties. It contains about 11% protein, which is nearly double that of Basmati. This makes it a valuable food source, particularly in regions where protein intake might be limited. The rice also has a low glycemic index (GI), ranging between 49% and 52%, making it suitable for people with diabetes as it does not cause a rapid spike in blood sugar levels [55], [56], and [16].

The rice is also rich in antioxidants, which help in combating oxidative stress in the body. These antioxidants are crucial for preventing chronic diseases and promoting overall health. The presence of beta-carotene in Kalanamak rice, which is not found in many other rice varieties, adds to its nutritional profile by providing Vitamin A, important for vision and immune function [47], [48], [49], [50], [51], [52]. The nutritional benefits of Kalanamak rice, highlight its superiority and value as a heritage crop variety (Table 10).

8.3 Comparison with Other Rice Varieties

When compared to other popular rice varieties, such as Basmati, Kalanamak rice holds its own due to its unique qualities. Basmati rice, known for its long grains and distinctive aroma, is often used in Indian and Middle Eastern cuisines. Jasmine rice, another aromatic variety, is popular in Southeast Asia [47], [48], and [49]. While both these varieties are highly regarded for their flavour and texture, Kalanamak rice surpasses them.

Firstly, the fragrance of Kalanamak rice is stronger and more lingering than that of Basmati or Jasmine. The higher concentration of 2-acetyl-1-pyrroline in Kalanamak rice gives it a more robust aroma. Secondly, the nutritional content of Kalanamak rice, particularly its higher levels of iron and zinc, provides health benefits that are not as prominent in Basmati or Jasmine rice (Tables 11, 12). Besides Kalanamak has a good amount of Vitamin A in the form of Beta Carotene. The quantity is more than that of Golden rice [15].

In terms of texture, Kalanamak rice is softer and fluffier when cooked, compared to the slightly firmer texture of Basmati. This makes it suitable for a variety of dishes, from simple boiled rice to more elaborate preparations. The elongation ratio of Kalanamak rice, although significant, is not as high as that of Basmati, which makes it less prone to breaking during cooking, thus retaining its shape and integrity better [56], [57], [58], and [16].

Economic factors also played a role in the decline. The lack of market support and the absence of premium pricing for Kalanamak rice made it less attractive for farmers. Over time, the focus shifted to more commercially viable varieties, leading to the near extinction of Kalanamak rice by the 1990s [15].

9. Geographic Indication (GI) Tag

In recognition of its unique qualities and historical significance, Kalanamak rice was awarded the Geographic Indication (GI) tag in 2013. This GI tag has been given for its association with 11 districts - Siddharthnagar, Kushinagar, Maharajganj, Gorakhpur, Bahraich, Balrampur, Basti, Deoria, Gonda, Sant Kabir Nagar, and Shrawasti (Fig. 5). This tag is crucial as it helps in preserving the authenticity of the Kalanamak rice and protecting it from counterfeit products. The GI tag identifies Kalanamak rice with the specific region of Siddharth Nagar and its adjacent districts, thereby ensuring that only rice grown in this area can be marketed under the name 'Kalanamak'. [60], [61], [62], and [63].

The GI tag (Fig. 5) awarded to Kalanamak rice in 2010, and valid until 2030 (Fig.6), has also played a crucial role in its revival [35]. The GI tag protects the authenticity of the rice and serves as an inspiration for other regions and products [57], [60], [61], [62], [63].

10. Prosperity of Kalanamak Farmers

Due to poor yield, poor quality, and lesser income as compared to HYV rice, the area under Kalanamak had declined (Table 1). However, now with the availability of a better quality variety of Kalanamak KN3 and high-yielding ones like Bauna Kalanamak 101, 102, and Kalanamak Kiran, those negatives have been annulled. The government announces a Minimum Support Price (MSP) for fine rice of around Rs. 2,020/ per quintal. However, most farmers can't get that rate due to various reasons and are compelled to sell their paddy at lower prices, around Rs. 1,500 per quintal. Compared to that, Kalanamak paddy sells between Rs. 3,500 to Rs. 4,500 /- per quintal. Thus, now Kalanamak farmers are tripling their income. Protocol for producing Organic Kalanamak has been developed [32], [33], [35] that fetches 20 percent higher price. Common rice with an average yield of 40 qtl/ha can give a net profit of Rs.35,500. Kalanamak KN3 and Bauna Kalanamak can give an average yield of 25 and 55 quintals per ha respectively. This amounts to a net profit of Rs. 56,875 for KN3 and for Bauna Kalanamak varieties Rs. 88,750. The net profit thus will be double to triple (Table 13). This should bring prosperity to the farmers of eastern U.P., where Basmati cannot be grown legally due to GI restriction. Production of Organic Kalanamak further benefits organic farmers by as much as Rs. 1,10,000/- per ha, which amounts to tripling the Kalanamak farmers' income (Table 13).

11. Socio-Economic Impact

11.1 Increase in Cultivation Area and Production

The concerted efforts by farmers, scientists, and the government have led to a significant increase in the cultivation area and production of Kalanamak rice. From a mere few thousand hectares in the early 2000s, the area under Kalanamak rice cultivation has expanded to tens of thousands of hectares by 2023. This expansion has been driven by the adoption of improved varieties, better agricultural practices, and increased market demand [16].

The development of dwarf varieties like Bauna Kalanamak 101, Buna Kalanamak 102, and Kalanamak Kiran has been particularly instrumental in this increase.

These varieties are more resistant to lodging and pests, offer higher yields, and are better suited to modern farming techniques. The introduction of these varieties, along with training and support provided by government and non-governmental organizations, has encouraged more farmers to switch to Kalanamak rice cultivation.

The increase in production has also been supported by improved government policies, infrastructure and market access. The establishment of processing and packaging centres, often managed by FPOs, has ensured that the rice is processed and packaged efficiently, maintaining its quality and appeal. Enhanced market access through both traditional and e-commerce platforms has provided farmers with broader markets, ensuring better returns on their produce [50], [51], and [52].

12. Challenges for Future

12.1 Legal Protection to Kalanamak

The Protection of Plant Varieties and Farmers Rights Act (PPV & FRA) came into being in 2001. The scope and importance of the act is amply clear from its name. This gives the right to farmers to own, retain, sow, re-sow, and sell the seed of their varieties. Accordingly, we at PRDF helped the farmers of Siddharthnagar to get the registration of Kalanamak done under PPV & FRA on 8th April 2009. The registration assures that no individual or organization can steal the rights of the farmers of Kalanamak KN3 rice. It is protected until 30th August 2025 [8], [16].

PRDF also helped Kalanamak to get a Geographical Indication (GI) in 2010 covering 11 districts of eastern U. P. (Fig. 4). It expired in 2020 and once again, PRDF helped get the GI protection extended (Fig. 5) until 2030. Geographical Indication of Goods (GI) as the name implies, is an indication, in the form of a name or sign, used on the goods that have a specific geographical origin and possess qualities or a reputation that are due to the place of its origin. This was signed into an Act on 30th December 1999 by the President of India and enacted on 15th September 2003 [4]. GI protects the consumer and also safeguards the interests of the producers. The GI is perceived as both an origin and quality indicator because of which the consumer willingly pays a premium price, and producers make a bigger profit that leads to the growth of the regional economy. The importance and benefits of GI have been described well in the publications emanating from PRDF [3], [60], [61], [62], [63], [38], and [39]. Looking into all the benefits it would bring to Kalanamak as a commodity and Agro-climatic Zone No. 7 of Uttar Pradesh, its impact can well be imagined. GI for Kalanamak covers 11 districts namely Bahraich, Balrampur, Basti, Deoria, Gonda, Gorakhpur, Kushinagar, Maharajganj, Sant Kabir Nagar, Siddharth Nagar, and Shrawasti, located between Nepal border in the north to Ghaghra river in the south, Bahraich in the west to Deoria in the east (Figs. 4, 5). GI was registered for Kalanamak in August 2010 and published in the GI Journal of the Government of India, is now validated until 2030

12.2 Counterfeit and Adulterated Products

Despite the successful branding and commercialization efforts, Kalanamak rice faces significant challenges related to counterfeit and adulterated products. The high demand and premium pricing of Kalanamak rice have led to the proliferation of fake products in the market. Unscrupulous traders often mix Kalanamak rice with lower-quality varieties, or entirely counterfeit the product, misleading consumers and undermining the brand's reputation. The problem stems from the lack of any regulation to control it.

Efforts to combat counterfeit and adulterated products include the use of advanced technologies such as blockchain and QR code-based traceability systems. These technologies enable consumers to verify the authenticity of Kalanamak rice by scanning codes on the packaging, which provide detailed information about the product's origin, processing, and distribution. Such measures are essential to protect the integrity of the brand and ensure that consumers receive genuine Kalanamak rice [16].

12.3 Ensuring Authenticity and Quality Control

One of the most significant challenges facing Kalanamak rice is ensuring its authenticity and quality control. The high market value and growing demand for Kalanamak rice have led to an increase in counterfeit and adulterated products. These fake products undermine consumer trust and can severely damage the reputation of this heritage rice.

To combat this, advanced technologies such as blockchain and QR code-based traceability systems can be employed. Blockchain technology can provide a secure and immutable ledger of the entire supply chain, from farm to fork. By using blockchain, every transaction involving Kalanamak rice can be recorded, ensuring transparency and traceability. Consumers can scan QR codes on the packaging to verify the authenticity of the rice, and obtain detailed information about its origin, cultivation practices, and supply chain journey.

In addition to technological solutions, strengthening regulatory frameworks is crucial. Governments and regulatory bodies need to enforce stringent quality control standards and conduct regular inspections to ensure compliance. Certification schemes, such as the GI tag, must be rigorously implemented and monitored to prevent misuse. Public awareness campaigns can educate consumers about the importance of purchasing authentic Kalanamak rice and recognizing counterfeit products. To handle all these issues, the establishment of the Kalanamak Promotion Board has been mooted to the government in 2022. Their decision is long awaited [15], [16].

Collaboration between stakeholders, including farmers, government agencies, researchers, and businesses, is essential to develop and implement these measures effectively. Creating a robust system of checks and balances will help maintain the integrity of Kalanamak rice and protect it from fraudulent practices.

13. Expanding Market Reach

Expanding the market reach of Kalanamak rice involves both domestic and international efforts. While the rebranding as 'Buddha Rice' has been successful in attracting attention, continuous marketing and outreach are necessary to maintain and grow its consumer base. Targeted marketing campaigns that emphasize the unique qualities and historical significance of Kalanamak rice can help attract new customers. Participating in international food exhibitions and trade fairs can also showcase Kalanamak rice to a global audience.

In the domestic market, promoting Kalanamak rice through local and regional festivals, culinary events, and organic food markets can enhance its visibility and appeal. Collaborations with renowned chefs and food bloggers can create a buzz and highlight the rice's exceptional culinary qualities [55]. Developing partnerships with retail chains and specialty stores can ensure that Kalanamak rice is available in premium outlets, catering to health-conscious and gourmet consumers [16], [18].

14. Summary of the Journey from Legend to Modern Revival

Kalanamak rice, often referred to as the 'Buddha rice,' boasts a fascinating journey that intertwines legend, history, and modern agricultural science. This aromatic rice variety, native to the Tarai region of Uttar Pradesh, India, has a storied past linked to Gautam Buddha, who is believed to have bestowed the rice upon the region's farmers. The legend says that Buddha, during his travels, gifted the villagers seeds of Kalanamak rice, blessing them with the promise that the rice would carry a fragrance that would remind them of him [16]. The historical cultivation of Kalanamak rice flourished for centuries, known for its distinct aroma, taste, and health benefits. However, the advent of the Green Revolution in the mid-20th century brought high-yielding, modern rice varieties that overshadowed traditional types like Kalanamak. Farmers began to abandon Kalanamak rice due to its lower yield and the intensive labour required for its cultivation, leading to a drastic decline in its acreage [57], [58].

The revival of Kalanamak rice began in the late 20th century, spearheaded by dedicated agricultural scientists and supported by government initiatives. Efforts focused on enhancing the rice's agronomic traits while preserving its unique qualities. Dr. Ram Chet Chaudhary's pioneering work in developing improved varieties such as KN3 and dwarf versions like Bauna Kalanamak 101, Bauna Kalanamak 102, and Kalanamak Kiran played a crucial role in this revival. These varieties addressed issues of low yield and lodging, making Kalanamak rice more viable for modern agriculture [7], [16]. The Geographical Indication (GI) tag awarded to Kalanamak rice in 2013 marked a significant milestone, protecting its authenticity and boosting its market appeal. Branding initiatives, particularly the rebranding as 'Buddha Rice,' and export efforts under schemes like the One District One Product (ODOP) have expanded its reach to international markets. Farmer Producer Organizations (FPOs) and e-commerce platforms have further facilitated the commercialization and distribution of Kalanamak rice, ensuring better returns for farmers and contributing to the regional economy.

In conclusion, the journey of Kalanamak rice from legend to modern revival is a powerful example of how traditional knowledge and modern science can come together to create sustainable solutions. By preserving the heritage of Kalanamak rice and promoting innovation, this unique rice variety continues to thrive and contribute to the well-being of farmers, consumers, and the environment.

Table 1. Area under Kalanamak rice [10],[11],[12],[13],[14], and [34]

S.N.	Year	Kalanamak area (ha) estimate	Remark on technology and support
1	1960	50,000	The traditional area under Kalanamak
2	1970	40,000	The traditional area under Kalanamak
3	1980	10,000	Spread of HYV rice
4	1990	2,000	Spread of HYV rice
5	2000	2,000	Spread of HYV rice
6	2010	3,000	Release & Notification of Kalanamak KN3
7	2015	10,000	Release & Demonstration of Kalanamak KN3
8	2016	20,000	Release & Notification of Bauna Kalanamak 101
9	2017	25,000	Release & Notification of Bauna Kalanamak 102
10	2018	35,000	Release & Notification of Bauna Kalanamak 102
11	2019	40,000	Release & Notification of Kalanamak Kiran
12	2020	45,000	Release & Notification of Kalanamak Kiran
13	2021	50,000	Notification of Kalanamak Kiran, Govt. support as FPO, CFC, Mahotsav, exhibitions
14	2022	70,000	Govt. support, inspiration from the President Sri Ram Nath Kovind, PM Sri Modi Ji and CM Sri Yogi Adityanath Ji, MSME, Dept. Agriculture
15	2023	80,000	Govt. support, inspiration from the President Smt. Droupadi Murmu, PM Sri Narendra Modi and CM Sri Yogi Adityanath, MSME, Dept. Agric. U. P.

Table 2. Frequency of aromatic lines for each accession

S.N.	Designation of the accession	Number of lines		% aromatic lines
		Total	Aromatic	
1	KN 2	75	20	26.66
2	KN 3	34	14	41.17
3	KN 7	21	7	33.33
4	KN 20	29	12	41.37
5	KN 29	67	17	25.37
	Total	226	70	167.90
	Average			33.58

Table 3. Range of variation for different characters in bulk collection

S. N.	Characters	Range
1.	Initial flowering (no. of days)	87 – 96
2.	50% flowering (no. of days)	91 – 101
3.	Maturity (no. of days)	121 – 131
4.	Plant height (cm)	125 – 174.5
5.	Panicle length (cm)	22.6 – 29.6
6.	Yield (q/ha)	10.7 – 169
7.	No. of grain per panicle	141 – 262
8.	100-grain weight (gm)	1.4 – 2.5
9.	Grain length (mm)	6.0 – 7.8
10.	Grain width (mm)	2.0 – 3.0
11.	L/B ratio	2.1 – 3.5

Table 4. Morpho-agronomic and grain quality characters of Kalanamak Kn3

Morpho-agronomic traits	Description	Grain Traits	Description
Basal leaf sheath colour	Green	Kernel length	5.76 mm
Tillering ability	Medium (20 tiller/hill)	Kernel width	2.18 mm
Days to 50% flowering	115 days (Photosensitive)	L/B Ratio	2.64 mm
Days to maturity	155 days (Photosensitive)	Grain type	Medium Slender
Culm angle	Slightly Open (45°)	Kernel colour	White
Leaf length	59 cm.	1,000-grain weight	15 grams
Leaf width	1.4 cm.	Hulling	80 %
Panicle length	31 cm.	Milling	75 %
Panicle type	Open	Head rice	70 %
Plant height	142 cm.	Alkali value	6 - 7
Aroma in plant	Highly scented	Volume Expansion	4.5 times
Apiculus colour	Brown (tawny)	Gel consistency	80 mm
Awning	Absent	Amylose content	22 %
Lemma, Palea colour	Purplish Black	Aroma in grain	Strong
Stigma colour	Purplish Black	Taste	Superb

Table 5. Morpho-agronomic and grain quality characters of Bauna Kalanamak 101 (UPCAR KN2-19-14)

Morpho-agronomic traits	Description	Grain Traits	Description
Basal leaf sheath colour	Green	Kernel length	5.76 mm
Tillering ability	Medium (20 tiller/hill)	Kernel width	2.18 mm
Days to 50% flowering	110 days (Photosensitive)	L/B Ratio	2.64 mm
Days to maturity	145 days (Photosensitive)	Grain type	Medium Slender
Culm angle	Slightly Open (45°)	Kernel colour	White
Leaf length	59 cm.	1,000-grain weight	15 grams
Leaf width	1.4 cm.	Hulling	80 %
Panicle length	29 cm.	Milling	75 %
Panicle type	Open	Head rice	70 %
Plant height	95 cm.	Alkali value	6 - 7
Aroma in plant	Highly scented	Volume Expansion	4.5 times
Apiculus colour	Brown (tawny)	Gel consistency	80 mm
Awning	Tip-awned	Amylose content	22 %
Lemma, Palea colour	Purplish Black	Aroma in grain	Strong
Stigma colour	Purplish Black	Taste	Superb
Stem strength	Very strong (non-lodging)	Yield	50 q/ha

Table 6. Morpho-agronomic and grain quality characters of Bauna Kalanamak 102 (UPCAR KN1-5-1)

Morpho-agronomic traits	Description	Grain Traits	Description
Basal leaf sheath colour	Green	Husk colour	Light-black
Tillering ability	Medium (20 tiller/hill)	Kernel length	5.76 mm
Days to 50% flowering	110 days (Photosensitive)	Kernel width	2.18 mm
Days to maturity	135 days (Photosensitive)	L/B Ratio	2.64 mm
Culm angle	Slightly Open (45°)	Grain type	Medium Slender
Leaf length	59 cm	Kernel colour	White
Leaf width	1.4 cm	1,000-grain weight	15 grams
Panicle length	31 cm	Hulling	80 %
No. of grains/panicles	400	Milling	75 %
Plant height	102 cm	Head rice	70 %
Aroma in plant	Highly scented	Alkali value	6 - 7
Apiculus colour	Brown (tawny)	Volume Expansion	4.5 times
Awning	Few spikelets tip-awned	Gel consistency	80 mm
Lemma, Palea colour	White - Green - P. Black	Amylose content	20 %
Stigma colour	White	Aroma in grain	Strong

Table 7. Morpho-agronomic and grain quality characters of Kalanamak Kiran (PRDF-2-14-10)

Morpho-agronomic traits	Description	Grain Traits	Description
Basal leaf sheath colour	Green	Kernel length	5.76 mm
Tillering ability	Medium (20 tiller/hill)	Kernel width	2.18 mm
Days to 50% flowering	110 days (Photosensitive)	L/B Ratio	2.64 mm
Days to maturity	135 days (Photosensitive)	Grain type	Medium Slender
Culm angle	Slightly Open (45°)	Kernel colour	White
Leaf length	59 cm	1,000-grain weight	15 grams
Leaf width	1.4 cm	Hulling	80 %
Panicle length	31 cm	Milling	75 %
No. of grains/panicles	400	Head rice	70 %
Plant height	95 cm	Alkali value	6 - 7
Aroma in plant	Highly scented	Volume Expansion	4.5 times
Apiculus colour	Brown (tawny)	Gel consistency	80 mm
Awning	Absent	Amylose content	20 %
Lemma, Palea colour	Green – Purple Black	Aroma in grain	Strong
Stigma colour	White	Taste	Soft, aromatic

Table 8. Effect of date of planting, date of flowering, and duration of KN3 and Kalanamak Kiran

S.N.	Date of sowing	Kalanamak Kiran		Kalanamak KN3	
		Date of flowering	Days to flowering	Date of flowering	Days to flowering
1	15 May	19 October	157	27 October	165
2	30 May	19 October	142	27 October	150
3	15 June	19 October	126	27 October	134
4	30 June	19 October	111	27 October	119
5	15 July	22 October	100	30 October	108
6	30 July	23 October	84	30 October	91

Table 9. Reaction of Kalanamak Kiran to major pests & diseases, Kharif 2014, 2015 [36]

S.N.	Diseases	Reaction	S.N.	Pests	Reaction
1	Bacterial blight	Mod. Resistant	1	Stem borer	Mod. Susceptible
2	Blast	Mod. Resistant	2	Brown Plant Hopper	Mod. Resistant
3	Sheath blight	Mod. Susceptible	3	Green Leaf Hopper	Mod. Resistant
4	Sheath rot	Mod. Susceptible	4	Gundhi bug	Susceptible
5	Tungro	Resistant	5	Leaf folder	Mod. Resistant
6	Bacterial Leaf Streak	Resistant	6	Caseworm	Mod. Resistant
7	Brown spot	Resistant	7	Root weevil	Resistant

Table 10. Grain quality characters of Kalanamak KN 3, Bauna Kalanamak 101, Bauna Kalanamak 102, and Kalanamak Kiran rice varieties (analyzed at NRRRI Cuttack, NDUAT Ayodhya, ICAR-IIRR Hyderabad, IICT Hyderabad, and R-FRAC, Lucknow).

S. N.	Traits	Description of the variety			
		Kalanamak KN3	Bauna Kalanamak 101	Bauna Kalanamak 102	Kalanamak Kiran
1	Method of Breeding	Germplasm / Pureline selection	Hybridization and selection	Hybridization and selection	Hybridization and selection
2	Year of release/notification	2007 / 2010	2015 / 2016	2016 / 2017	2019 / 2019
3	Published in the Govt. Gazette	No. 1816, (1), August 31, 2010	No. 2771, (23), November 24, 2016	No. 2458, (12), August 29, 2017	No. 2948, (8), September 6, 2019
4	Kernel length	5.76 mm	5.76 mm	5.76 mm	5.76 mm
5	Kernel width	2.18 mm	2.18 mm	2.18 mm	2.18 mm
6	L/B Ratio	2.64 mm	2.64 mm	2.64 mm	2.64 mm
7	Grain type	Medium slender	Medium slender	Medium slender	Medium slender
8	Kernel colour	White	White	White	White
9	1,000-grain weight	15 grams	15 grams	15 grams	15 grams
10	Hulling	80 %	80 %	80 %	80 %
11	Milling	75 %	75 %	75 %	75 %
12	Head rice	70 %	70 %	70 %	70 %
13	Alkali value	6 - 7	6 - 7	6 - 7	6 - 7
14	Volume Expansion Ratio	4.5	4.5	4.5	4.5
15	Gel consistency	80 mm	80 mm	80 mm	80 mm
16	Amylose content	21 %	22 %	22 %	21 %
17	Aroma	Highly aromatic	Aromatic	Highly aromatic	Highly aromatic
18	Iron (ppm) *	4.82	4.35	4.55	4.81
19	Zinc (ppm)*	16.97	14.35	14.55	16.37
20	Protein	10.64 %	10.50 %	10.64 %	10.64 %
21	Beta Carotene**	0.52 mg/100g	0.50 mg/100g	0.52 mg/100g	0.53 mg/100g

*All India average of 15 locations from AICRIP trials

**Analysis done at R-FRAC, Dept. of Horticulture, Govt. of U. P., Lucknow

Table 11. The nutritional benefits of Kalanamak rice (Source: IRRI – ISAEC, Varanasi)

Nutrients	Quantity per 100g	Health Benefits
Protein	11%	Essential for muscle growth, tissue repair, and enzyme/hormone production.
Iron	3.9 mg (too high conc.)	Vital for the formation of haemoglobin and prevention of anaemia.
Zinc	16.97 ppm	Supports immune function, DNA synthesis, and cell division.
Carbohydrates	68%	Provides a primary source of energy.
Dietary Fiber	3.50%	Aids in digestion and helps maintain bowel health.
Fat	0.50%	Essential for absorbing fat-soluble vitamins and providing energy.
Beta-carotene (brown rice)	0.53 mg (claiming more than golden rice)	Converted to Vitamin A in the body, important for vision and immune function.
Glycemic Index	49-52	A low glycemic index helps in maintaining stable blood sugar levels, making it suitable for diabetics.
Magnesium	25 mg	Important for muscle and nerve function, blood sugar control, and bone health.
Phosphorus	95 mg	Crucial for the formation of bones and teeth, as well as the body's use of carbohydrates and fats.
Vitamin B1 (Thiamine)	0.1 mg	Necessary for glucose metabolism and plays a key role in nerve, muscle, and heart function.
Vitamin B2 (Riboflavin)	0.03 mg	Important for growth, energy production, and the breakdown of fats, drugs, and steroid hormones.
Vitamin B3 (Niacin)	1.6 mg	Helps convert food into energy and is essential for healthy skin, nerves, and digestion.
Vitamin B6 (Pyridoxine)	0.5 mg	Involved in the creation of neurotransmitters and red blood cells, and helps maintain normal brain development and immune system function.

Table 12. Comparative grain quality characters of Kalanamak rice and Basmati rice. (Analysed at R-FRAC, Dept. of Horticulture, Government of U. P., Lucknow)

S.N.	Parameter	Kalanamak	Basmati	Test method
1	Fat %	0.51	0.50	IS12711: 1989 RA2005
2	Protein %	10.6	5.8	IS 7219: 1973 RA
3	Total Ash %	0.32	0.32	FSSAI Manual 2016
4	Iron mg / 100 g	3.0	1.0	FSSAI Manual 2016
5	Zinc mg / 100 g	16.37	4.23	FSSAI Manual 2016
6	Amylose %	18.86	24.50	ICAR – IIRR Hyderabad
7	Glycemic Index	49 – 52 %	80 – 85 %	ICAR – IIRR Hyderabad
8	Vitamin A (β Carotene)	0.53	0.0	R-FRAC, Lucknow
9	Cooked rice softness	Soft	Hard	

Table 13. Comparative profitability of Kalanamak KN3, Bauna Kalanamak and Common rice, 2022-23 [15]

Item	Common rice	Kalanamak KN3	Bauna Kalanamak*	Organic Kalanamak*
Rice area (ha)	9,24,976	5,000	63,000	2,000
Average Yield (qtl/ha)	40	25	35	35
Selling price of paddy (Rs./qtl)	2,020	3,500	3,500	4,000
Gross Profit	80,000	87,500	1,22,500	1,40,000
Cost of Cultivation (Rs./ha)	44,500	30,625	33,750	30,000
Net profit (Rs./ha)	35,500	56,875	88,750	1,10,000
Incremental income in (Rs/ha)	0	21,375	53,250	74,750

*Bauna Kalanamak 101, Bauna Kalanamak 102, Kalanamak Kiran



Fig.1. Paddy, polished rice of Kalanamak



Fig. 2. Unpolished Kalanamak rice



Fig. 3. Kalanamak KN 3 (2m tall)



Fig. 4. Dwarf Kalanamak Kiran (0.9m tall)

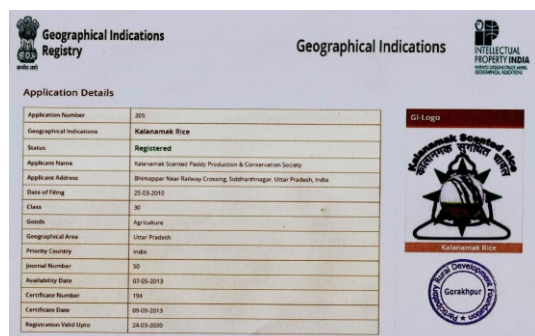


Fig. 6 Geographical Indication of Kalanamak submitted in 2010 valid till March 2030

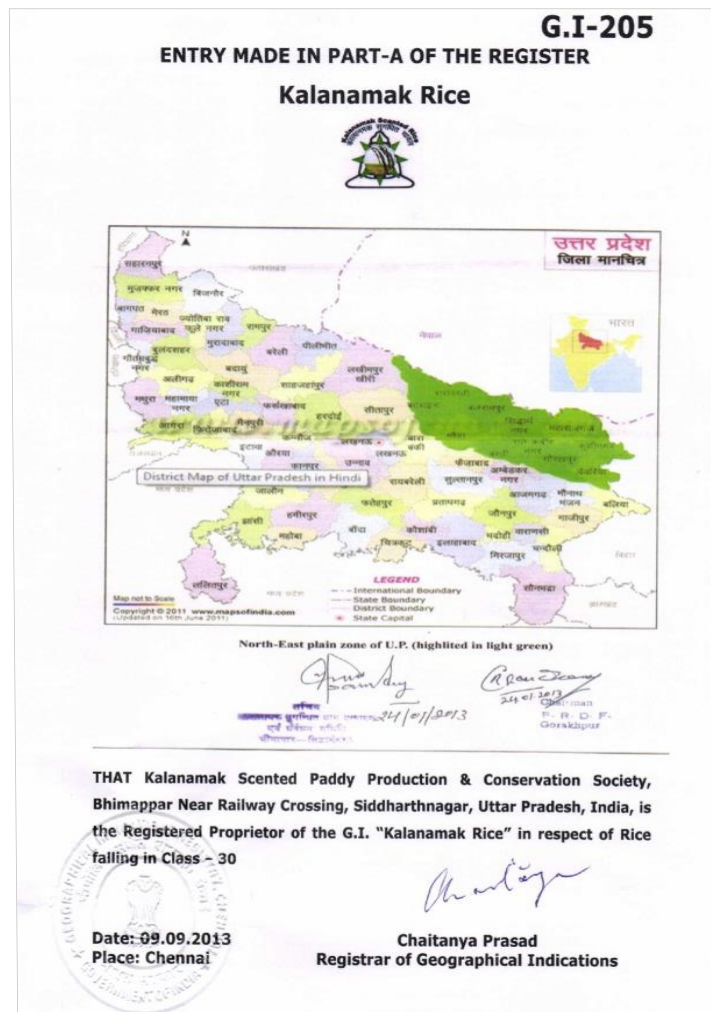


Fig. 5 Geographical Indication area of Kalanamak rice indicating 11 districts of U.P.

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