Advances in Kalanamak Rice Improvement and Protection to Benefit Farmers, Global Consumers and India

R. C. Chaudhary, Pushker Chaudhary, P. K. Yadav, A. K. Srivastava, R. Kumar

Kalanamak rice (*Oryza sativa* L.), sometimes referred to as "Buddha Rice" or 'Buddha Home Rice,' holds a significant place in the religious and agricultural history of India. This heritage rice variety is believed that Lord Buddha himself gave to the farmers of Bajaha village in Siddharth Nagar district of U. P., some 3000 years ago. Facing extinction but due to the Bhagirath Prayas of the Dr. Ram Chet Chaudhary, the Chairman of PRDF and his team not only saved Kalanamak from extinction but made it distinction by exporting to the world market. Historically prized for its unique fragrance, taste, and nutritional benefits, Kalanamak rice saw a decline during the Green Revolution period due to its lower yield compared to HYV varieties and absence of improved varieties. The programme involved germplasm collection, followed by the pureline selection, hybridization and selection to develop improved varieties like KN 3, Bauna Kalanamak 101, Bauna Kalanamak 102 and Kalanamak Kiran. Seed of these varieties are available to farmers produced using Nucleus, Breeder, Foundation, and Certified seed system. PRDF also protected Kalanamak through registering it under PPV & FRA, and also Geographical Indications (GI). Success of Kalanamak rice however, faces challenges, particularly in the availability of quality seed, ensuring authenticity and quality control amidst the proliferation of counterfeit products. Advanced technologies such as blockchain, QR code-based tools and modern 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. Government is also supporting organic and natural farming systems to ensure quality products.

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

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Historical Significance and Cultural Tale of Kalanamak rice

The history of Kalanamak rice is not a mystery but deeply intertwined with the local myths and cultural practices of the region. According to the legend (Chaudhary, 2023; Legge, 2021; Watters, 1904), Gautam Buddha, after receiving enlightenment, was returning from Bodha Gaya to his father's kingdom in Kapilvastu. On the way, 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 advised them to grow these in the lowland. The fragrance of the rice, he said, will remind them of Him and the nutritive value of the grain 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 (Chaudhary, 2014; Chaudhary, 2023).

Kalanamak Declined to near Extinction

After the advent of Green Revolution and development of High Yielding Varieties (HYV), the area under Kalanamak started declining. It may 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 HYV of rice in 1965, which yielded double of Kalanamak. The second was the absence of any improved variety of Kalanamak which had become a Land Race and admixture. The next reason was the neglect of Kalanamak by the research institutions (Chaudhary and Tran, 2001a; Chaudhary and Tran, 2001b). The fourth reason was the reduced aroma and poor grain quality due to unscientific seed production. Production of Kalanamak was a net loss to the farmers. The sum of all the above factors resulted in the reduction of the Kalanamak area (Table 1).

Organized Improvement of Kalanamak rice

Organized efforts to improve Kalanamak did not start until 1974 (Nanda et al. 1974), though the Department of Agriculture did try to test some Kalanamak germplasm at their research centres. The first organized efforts started at G. B. Pant University of Agriculture and Technology, Pantnagar (then in U. P. and now in U.K.) through Mutation Breeding (Chaudhary 1979a, 1979b). Not much could be achieved except getting some mutants of academic interest in Kalanamak (Chaudhary 1979a, Chaudhary, 1979b, Chaudhary and Chauhan, 1979, Chaudhary et al, 2012). Later Pantnagar did try testing some germplasm but nothing of economic use could come out.

Germplasm Collection and Evaluation of Kalanamak

Organized germplasm collection was done with the financial assistance from the U. P. Council of Agricultural Research (UPCAR) described below (Chaudhary, 2023).

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 (Chaudhary, 2005; Chaudhary and Mishra, 2016; Chaudhary and Prajapati, 2007). The single panicle collections were used for developing purelines and bulk collections were tested for yield potential.

2. Single Panicle Collection: Total 1,455 panicles were collected from farmers' fields of Maharajganj, Sant Kabir Nagar, and Siddharth Nagar districts. These panicles were tested organoleptically for classifying as aromatic and non-aromatic types. From 5 accessions, only 12.57% of panicles were found aromatic, 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. 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 from each. The frequency of aromatic lines for each accession is provided in Table 2.

As will be clear from the Table 2, that from the 226 lines out of five accessions only 70 lines were found to be aromatic (33.58%) in the subsequent 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.

3. Bulk Collection: Total of 39 bulk collections were collected from different sources. Out of these, 16 collections were from PRDF Gorakhpur; 8 collections from ANDUAT, Ayodhya, and 15 collections from CRRI (now National Rice Research Institute), Cuttack (Odisha). These collections were tested in a randomized block design with 2 replications in 4 districts given below:

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, KN 41, and KN 42 were more vigorous. Since the experiment could be planted late, initial flowering ranged between 87 to 93. Maturity duration ranged between 121 to 131 days (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, KN 55, and KN 56 were found significantly superior at all the locations over the rest of the accessions. However, KN 48, KN 54, and KN 58 were found significantly superior only at two locations. Thus, finally KN 48, KN 53, KN 54, KN 55, KN 56, and KN 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 (Chaudhary et al. 2007) as these were sent to National Gene Bank located at National Bureau of Plant Genetic Resources, New Delhi for long term storage. Details are described in the Catalogue and other publications (Chaudhary, 2005; Chaudhary et al. 2007; Chaudhary and Prajapati, 2007; Chaudhary et al. 2010b; Chaudhary and Mishra, 2010; Chaudhary and Mishra, 2016; Chaudhary and Prajapati, 2007, and Chaudhary, 2014). One set of these collections were also sent to Directorate of Rice Research (DRR) Hyderabad and Central (now National) Rice Research Institute (NRRI), Cuttack for conservation and use at their ends (Chaudhary et al. 2008a; (Chaudhary et al. 2008a).

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 could be notified by the Central Sub Committee on Varietal Release and Notification in 2010. KN 3 was the first Kalanamak rice variety notified setting a historic platform with original aroma and grain quality (Chaudhary et al. 2014; Chaudhary, 2016). 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 been recovered back in KN 3 (Chaudhary, 2016; Chaudhary, 2019; Chaudhary, 2020a; Chaudhary, 2020b; Chaudhary, 2020c, Chaudhary, 2020d; Chaudhary, 2020e), and Chaudhary, 2022). Since the variety N3 was released and notified on the proposal of PRDF Gorakhpur, we retain the exclusive right to produce Nucleus Seed and Breeder Seed (Chaudhary, 2019). Other organizations like National Seeds Corporation, U. P. Beej Vikas Nigam, and others produce Certified Seed of it. Package of practices for the cultivation of Kalanamak was standardized and publicised by All India Radio, Door Darshan, in addition by the print media like Indian Farming, Kheti, Rice India, etc. (Chaudhary, 2009; Chaudhary; Chaudhary et al., 2008a; Chaudhary et al., 2008b; Chaudhary et al., 2008c; Chaudhary et al. 2008d; Chaudhary et al. 2008e; Chaudhary et al. 2008f; Chaudhary et al. 2008g, and (Chaudhary, 2019).

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 (Chaudhary and Kumar, 2018). 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 (Kumar et al. 2018a; Kumar et al. 2018b; Chaudhary et al. 2016; Chaudhary et al. 2017a; Kumar et al. 2024). The aroma quantification was done by Indian Institute of Technology (IICT), Hyderabad and the results are reproduced below.

Breeding of Bauna Kalanamak 102

A proposal for the release of Bauna Kalanamak 102 was put up to the U. P. State Variety Release Committee released 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 (Kumar et al. 2018a; Kumar et al. 2018b; Kumar et al. 2024).

Breeding of Kalanamak Kiran

Kalanamak Kiran was derived from a cross of Swarna Sub1 and KN31. The segregating generations were handled by the Pedigree method of breeding followed by selection. The breeding line was designated as PRDF-2-14-10-1-1 and tested as PRDF-2-14-10. 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 an 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, 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). The date of the planting trial was conducted. It was observed 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 KN3 parent. Its pests and disease resistance is acceptable, as compared to the other varieties of the group (Table 9).

Its quality of the grain 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 tested by the IICT, Hyderabad through sophisticated tests and was confirmed as aroma equal to KN3. Kalanamak Kiran has the same level of Iron and Zinc as its original parent KN3 (Chaudhary et al. 2020a; Chaudhary et al. 2020b; Chaudhary et al. 2020c; Chaudhary et al. 2020d; Chaudhary et al. 2020e).

Compared to its 200 cm tall parent KN3 (Figure 1), PRDF-2-14-10 (Kalanamak Kiran) is semi-dwarf (height 95 cm (Figure 2), highly resistant to lodging and shattering, and is suitable for combine harvesting. 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. Therefore, PRDF-2-14-10 was found superior to the checks 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 proposed that it should be released as Kalanamak Kiran for eastern Uttar Pradesh. It was notified by the Government of India under Gazette No. 3220 (Part II (3) dated 06 08.2019.

Figure 1. Polished rice of Kalanamak

Figure 2. Unpolished Kalanamak Kiran rice

Key Feature of Kalanamak Kiran

1. Unique grain Quality

Kalanamak rice is distinguished by its black husk and white rice (Figure 3), and greenish kernel if unpolished (Figure 4). extraordinary fragrance. Name "Kalanamak" is derived from two words: "Kala" meaning black and "Namak" meaning salt, referring to the black husk, and Namak referring to its adaptation even to the saltish soils. Its palatability is excellent when cultivated in this particular area. The aroma 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 (Kumar et al. 2024). The grain size of Kalanamak rice is medium slender (MS), and it has a high elongation ratio when cooked. This rice grains expand significantly upon cooking, resulting in a fluffy and soft texture. The combination of its unique fragrance, texture, and mouthwatering feel is the unique quality of Kalanamak. Kalanamak rice is 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 and Blue Bull (Neelgay) 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.

Figure 3. Kalanamak KN 3 (2m tall) as the first variety of Kalanamak

Figure 4. My grandson Kiran in the field of Kalanamak Kiran variety (95 cm dwarf)

2. Nutritional Properties

Kalanamak rice is not only prized for its aroma but also for its nutritional benefits. Studies have shown that Kalanamak rice has 3 times more iron and 4 times more zinc than much acclaimed Basmati. . The iron content

in Kalanamak rice is 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, particularly in regions where protein intake might be limited. Kalanamak has a low glycemic index (GI), ranging between 49% to 52%, making it suitable for people with diabetes as it does not cause a rapid spike in blood sugar levels (Pandey et al. 2022; Singh et al. 2005; Chaudhary, 2023).

Kalanamak 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 unique, adds to its nutritional profile by providing Vitamin A, important for vision and immune function (Chaudhary et al. 2022a; Chaudhary et al. 2022b; Chaudhary et al. 2022c; Kumar et al. 2022a; Kumar et al. 2022b; Kumar et al. 2022c). The nutritional benefits of Kalanamak rice, highlight its superiority and value as a heritage crop variety (Table 10) over the other rices.

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Dr. Sanjay Saxena
Hon. Secretary
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To,
Dr.Raja Ganapathy R.
I.A.S.
District Magistrate
Chairman,Kalanamak Rice Export Development Foundation
Siddharthnagar (U.P.)

I,Dr.Sanjay Saxena MBBS MS,an EyeSurgeon, Hon. Secretary ,IMA Lucknow here by certify the nutritive qualities of Kalanamak Rice on the basis of the detailed analysis carried out by UP Govt. & Agriculture dept. through ICAR-IIRR, IICT Hyderabad, Eastern Pacific Lab Singapore and Regional Food & Research Analysis Centre Lucknow (R-FRAC, Lucknow, 2020) that this kalanamak rice contains 16.97% of Zinc , Iron 4.5 mg, Protein 10.6%, Beta carotene 0.42mg ,Omega 3 fatty acids 0.01 gm, Omega 6 fatty acids 0.06 gm, high amount of Lysine an essential amino acid with a low glycemic index of 49-52%. Apart from health benefits this rice has a unique aroma, highly nutritive, diabetic friendly, easily digestible,rich in antioxidant Anthocyanin, prevents Coronary heart disease, Alzheimer's disease, Obesity and Skin diseases.

Dr.Sanjay Saxena,MS.
Hon.Secretary, IMA. Lucknow(U.P.)

Figure 7. Indian Medical Association confirmed the sugar free status & nutritive qualities of Kalanamak

3. Comparison with Other Rice Varieties

When compared to other popular rice varieties, such as Basmati, Kalanamak rice holds its superiority 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 (Khao Dawk Mali) rice, another aromatic variety from Thailand, is popular in Southeast Asia (Chaudhary et al. 2022a; Chaudhary et al. 2022b). While both these varieties are highly regarded for their long grain, flavour and texture, Kalanamak rice surpasses them.

Firstly, the fragrance of Kalanamak rice is stronger and more lingering than that of Basmati and 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 protein, iron and zinc, provides health benefits that are not as prominent in Basmati or Jasmine rice (Tables 11, 12). Besides Kalanamak is sugar free due to its low Glycemic Index and has a good amount of Vitamin A in the form of Beta Carotene. The quantity is more than that of much hyped Golden rice (Chaudhary, 2022). Besides, Kalanamak can be milled in any rice mill due to its medium size grain compared to Basmati which can be milled only in rubber roll mills. In terms of texture, Kalanamak rice is softer and fluffier due to its lower amylose content when cooked, compared to the slightly firmer texture of Basmati. Due to this property, Kalanamak is liked more in South East Asia. This also 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 (Singh and Singh, 2005; Singh et al. 2001, Singh et al. 2005 and Chaudhary, 2023).

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 of 3 divisions, Gorakhpur Division (Deoria, Kushinagar, Gorakhpur, and Maharajganj), Basti Division (Sant Kabir Nagar, Basti and Siddharthnagar), Devi Patan Division (Bahraich, Balrampur and Shrawasti) depicted in Figure 5. These 3 Divisions are located in Agroclimatic Zone 7. 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 where its grain quality is superb, thereby ensuring that only rice grown in this area can be marketed under the name 'Kalanamak' (Yadav et al. 2017a, Yadav et al. 2017b; Yadav et al. 2018; Yadav et al. 2019).

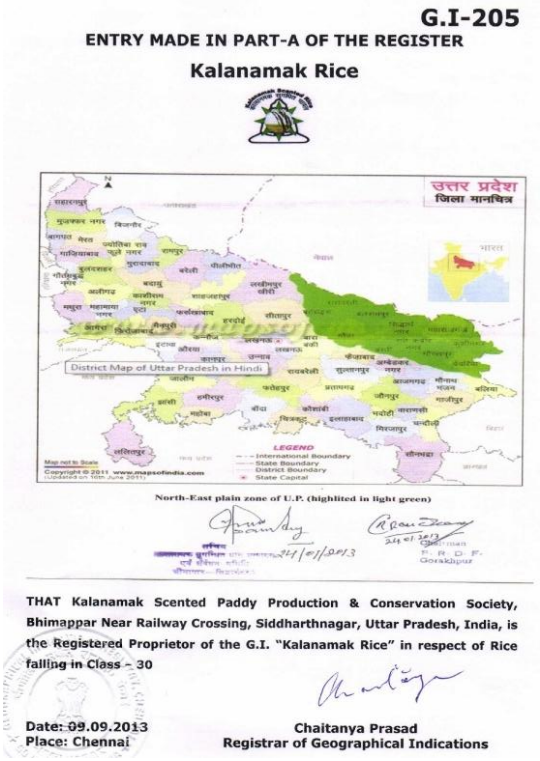

Figure 5. Geographical Indication area of Kalanamak rice indicating 11 districts of U.P.

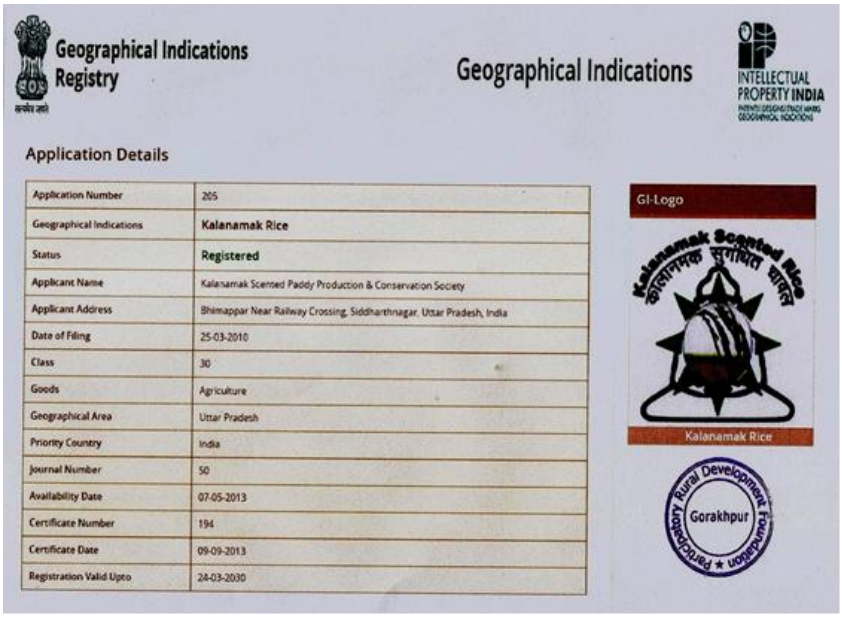

Figure 6. Geographical Indication of Kalanamak submitted in 2010 valid till March 2030

The GI tag (Figure 5) awarded to Kalanamak rice in 2010, and has extended validity until 2030 (Figure 6). The GI tag protects the authenticity of the rice and serves as an inspiration for other regions and products (Singh et al. 2001; Yadav et al. 2017b; Yadav et al. 2018; Yadav et al. 2019).

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 high yielding varieties like Kalanamak Kiran with double or triple yield and as good grain quality those negatives have been annulled. Government announces a Minimum Support Price (MSP) for fine rice of above Rs. 2,300 per quintal yet most farmers can't get that rate due to various reasons and are compelled to sell their paddy at lower prices, around Rs. 1,900 per quintal. Compared to that, Kalanamak paddy sells between Rs. 3,500 to Rs. 5,000/- per quintal. Thus, now Kalanamak farmers are tripling their income. Protocol for producing Organic Kalanamak has been developed (Chaudhary et al, 2010a; Chaudhary et al. 2010b; Chaudhary et al. 2013 that fetches 20 percent higher price at least. Common rice with an average yield of 40 qtl / ha can gives 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 as depicted in Table 13 (Chaudhary et al. 2018).

Socio-Economic Impact
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 2025.

This expansion has been driven by the adoption of improved varieties, better agricultural practices, and increased market demand (Chaudhary, 2023). 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 resistant to lodging and pests, offer higher yields, and are better suited to mechanical harvesting.

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 (Kumar et al. 20181; Kumar et al. 2018b; Kumar et al. 2024.

Overall Enthusiasm

In 1998, when PRDF had taken pledge to save Kalanamak from extinction, it was the lone tune. The accomplishments described in this article were the results of single-minded effort and devotion of Dr. Ram Chet Chaudhary Chairman of PRDF. Now, there are dozens of organizations working on promoting Kalanamak and thousands of people joined the bandwagon, Support of Government of India came in for improving the old irrigation structure in Siddharthnagar. Department of MSME provided a grant of about Rs, 8 crores to establish modern rice mill with most modern milling and packaging machineries and cold storage. This Common Facility Centre (CFC) has helped thousands of farmers to get their rice processed and get good quality rice. Department of Agriculture of U. P. helped train to produce organic Kalanamak rice certified under Participatory Guarantee System of NCONF. IARI also developed and got notified 2 varieties of Kalanamak namely Pusa-Narendra-KN1, and Pusa-CRD-KN2 which they claimed are higher yielding than KN3. IRRI South East Asia centre developed several products of Kalanamak rice.

They also started basic research on direct seeding and aroma retention. Researchers at ICAR – IIRR Hyderabad also developed agronomic practices for improving aroma content. Export to Nepal, Dubai, Germany, USA and Singapore was initiated to open foreign markets and get better price for farmers. Business houses, FPOs and universities joined hands. As the result Kalanamak rice which was destined to be extinct became distinct. Farmers are benefitting from its very high price and doubling or tripling their incomes.

Consumers including diabetics are able to eat rice and take advantage of its sugar free status. Other consumers are taking advantage of its high protein, iron and zinc to improve their health and save themselves from diseases. Local consumption has increased several folds. Future is bright for Kalanamak to brighten rice export from India.

In 2024, President of India awarded me of the highest Civilian award called “Padma Shri” to the Chairman of PRDF, Dr. Ram Chet Chaudhary (Figure 14) for “Protecting and Promoting Kalanamak” (Figure 9). This has boosted moral of the Kalanamak scientists, producers and marketeers.

Figure 9. "Padma Shri" award by the President of India to Dr. RC Chaudhary for saving and promoting Kalanamak rice.

Figure 10. Prime Minister, Sri Narendra Modi Ji admired Dr. Chaudhary for exemplary R & D on Kalanamak rice.

Challenges for Future

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 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 rice. PRDF also helped Kalanamak to get a Geographical Indication (GI) in 2010 covering 11 districts of eastern U. P. (Figure 4). It expired in 2020 and once again, PRDF helped get the GI protection extended (Figure 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 (Chaudhary, 2003). 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 (Chaudhary, 2002, Yadav et al. 2017b; Yadav et al. 2018; Yadav et al. 2019; Chaudhary et al. 2017a and Chaudhary et al. 2017b). 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 Ghaghara River in the south, Bahraich in the west to Deoria in the east (Figures 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. However, implementing GI is a hard task and the government must be vigilant.

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. The proposed "Kalanamak Promotion Board" must come into being.

Efforts to combat counterfeit and adulterated products include the use of advanced technologies such as blockchain, Authorised Producers 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 (Chaudhary, 2023).

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 its authenticity, 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 must 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 avoiding 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 (Chaudhary, 2022; Chaudhary, 2023). 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.

Expanding Market Reach

Expanding the market reach of Kalanamak rice in 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. Operationalization of Kushinagar International Airport will open up the Kalanamak market access to the Buddhist countries. 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 Kalanamak's exceptional culinary qualities (Pandey et al. 2022). 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 (Chaudhary, 2023; Chaudhary and Mishra, 2010).

Figure 8. Packaging of Kalanamak rice for the domestic and the export markets.

Summary of the Journey from Legend to Modern Revival

Kalanamak rice, also referred to as the "Buddha Rice" boasts a fascinating journey that intertwines legend, history, and modern agricultural science. This unique aromatic rice variety, native to the Tarai region of Uttar Pradesh, India, has a 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 villager's seeds of Kalanamak rice, blessing them with the promise that the rice would carry a fragrance that would remind them of Him (Chaudhary, 2023). 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 Kalanamak. Farmers began to abandon Kalanamak rice due to its lower yield and declining grain quality, leading to a drastic decline in its acreage (Singh et al. 2001; Singh et al. 2005). 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 yield through new improved varieties, 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 Kalanamak102, 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 (Chaudhary, 2014; Chaudhary, 2023). The Geographical Indication (GI) tag awarded to Kalanamak rice in 2013 marked a significant milestone, protecting its authenticity and boosting its market. 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 its distribution, ensuring better returns for farmers and defying the myth of "Paddy and Poverty Go Together". Revealing the nutritional qualities attracting the consumers was the other milestone.

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 Chaudhary, 2020a; Chaudhary, 2020b; Chaudhary, 2020c; Chaudhary, 2020d; Chaudhary, 2020e and (Chaudhary et al. 2012)

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. Draupadi 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 (45^0)	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 (45^0)	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 (45^0)	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 (45^0)	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 (Chaudhary et al. 2014)

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 (analysed at NRRI 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 Fibber	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 (ß 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 (Chaudhary, 2022)

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

References

Chaudhary, R. C. (1979a). Productive mutants in scented rice in Uttar Pradesh. In Proceedings of the Symposium on the Role of Induced Mutations in Crop Improvement (September 10–13, 1979, p. 60). BARC–OU, Hyderabad, India.

Chaudhary, R. C. (1979b). Increasing the mutagenic efficiency of EMS in rice. In Proceedings of the Symposium on the Role of Induced Mutations in Crop Improvement (September 10–13, 1979). BARC–OU, Hyderabad, India.

Chaudhary, R. C. (2002). Consequences of WTO and geographic indicators on economics, production trend, and marketing of speciality rices. In Proceedings of the World Rice Commerce 2002 Conference (pp. 1–20), Beijing, China, September 16–18, 2002.

Chaudhary, R. C. (2003). Speciality rice of the world: Effect of WTO and IPR on its production trend and marketing. Journal of Food, Agriculture and Environment, 1(2), 34–41.

Chaudhary, R. C. (2005). India: The great cradle of rice. In A. Ferrero & G. M. Scansetti (Eds.), Rice landscapes of life (pp. 161–175). Edizioni Mercurio.

Chaudhary, R. C. (2009). Prospects of promoting traditional scented rice varieties of eastern Uttar Pradesh for local consumption and export. Rice India, 19(8), 22–24.

Chaudhary, R. C. (2014). Augmenting traditional knowledge for nature conservation and nutrition security in eastern India. In International Knowledge Sharing and Summer School Workshop (Abstract). Organized by DAAD, Germany, and University of Chiang Mai, Thailand.

Chaudhary, R. C. (2016). Story of heritage rice Kalanamak: Extinction to distinction in eastern Uttar Pradesh. In C. Prasad (Ed.), Research interface: Promoting exportable rice varieties and evolving a sustainable development model (pp. 49–67). VARDAN.

Chaudhary, R. C. (2019). Intellectual property and breeders' rights in India. In Proceedings of the Conference on Protecting Plant Breeders' Rights in Agricultural Research and Development (pp. 1–25). Bihar Agricultural University, Sabour, Bhagalpur, India.

Chaudhary, R. C. (2020a, July 25). Scent of Kalanamak paddy is returning: There is tremendous boom in the area. First Eye News, pp. 1–2.

Chaudhary, R. C. (2020b). Aroma of Kalanamak rice is returning back: Big jump in area. TFI Post, pp. 1–2.

Chaudhary, R. C. (2020c). Rice price today: Aroma of Kalanamak rice is returning and big jump in area. News Nation, p. 1.

Chaudhary, R. C. (2020d). Aroma of Kalanamak rice is returning back: Big jump in area. India Narrative, pp. 1–2.

Chaudhary, R. C. (2020e). Aroma of Kalanamak rice is returning back: Big jump in area. Amrit Vichar, pp. 1–3.

Chaudhary, R. C. (2022). Story of Kalanamak rice: Past, present and future. BFC Publications. ISBN 978-93-5632-355-1.

Chaudhary, R. C. (2023). Kalanamak dhan: Atit se vartman (in Hindi). Army Press.

Chaudhary, R. C., & Chauhan, J. S. (1979). Note on isozyme pattern of monogenic recessive vegetative mutant in Kalanamak rice. In Proceedings of the Symposium on the Role of Induced Mutations in Crop Improvement (September 10–13, 1979). BARC–OU, Hyderabad, India.

Chaudhary, R. C., & Kumar, S. (2018). Bauna Kalanamak 101: New aromatic variety of heritage rice. FARM Journal, 2(1), 31–37.

Chaudhary, R. C., & Mishra, S. B. (2010). Collection of unique rice germplasm from the cradle of rice (Oryza sativa L.) in eastern Uttar Pradesh. In S. D. Sharma (Ed.), Genetic resources of rice in India: Past and present (pp. 587–594). Today & Tomorrow's Printers.

Chaudhary, R. C., & Mishra, S. B. (2016). Development and use of organic protocol to promote Kalanamak rice (Oryza sativa L.) and its certification under PGS mode. Current Advances in Agricultural Sciences, 8(1), 28–31.

Chaudhary, R. C., & Prajapati, S. C. (2007). Rice in its original home: Interwoven diversity of rice varieties, agro-ecosystems and farmers in Uttar Pradesh (India). In A. Ferrero & F. Vidotto (Eds.), Agro-economical traits of rice cultivation in Europe and India. Edizioni Mercurio.

Chaudhary, R. C., & Tran, D. V. (2001b). Speciality rices of the world: A prologue. In R. C. Chaudhary & D. V. Tran (Eds.), Speciality rices of the world: Breeding, production and marketing (pp. 3–12). FAO.

Chaudhary, R. C., & Tran, D. V. (Eds.). (2001a). Speciality rices of the world: Breeding, production and marketing. FAO.

Chaudhary, R. C., Gandhe, A., & Mishra, S. B. (2010a). Manual on organic production of Kalanamak rice. PRDF.

Chaudhary, R. C., Gandhe, A., & Mishra, S. B. (2014). Revised manual on organic production of Kalanamak rice (English & Hindi). PRDF.

Chaudhary, R. C., Kumar, S., & Mishra, S. B. (2016). New variety of aromatic rice: Bauna Kalanamak 101 (in Hindi). Kahaar, Vols. 1–2, 1–5.

Chaudhary, R. C., Kumar, S., & Mishra, S. B. (2017c). Recent variety of aromatic rice: Bauna Kalanamak 102 (in Hindi). Kahaar, Vols. 1–2, 9–13.

Chaudhary, R. C., Kumar, S., & Mishra, S. B. (2018). Sustainable tripling of farmers' income by improving heritage rice Kalanamak. In International Conference on Climate Change, Biodiversity and Sustainable Agriculture, Assam Agricultural University, Jorhat, India (December 13–16, 2018).

Chaudhary, R. C., Mishra, S. B., & Dubey, D. N. (2008b). Cultivation of new variety of rice Kalanamak. Indian Farming, 58(6), 21–24.

Chaudhary, R. C., Mishra, S. B., & Dubey, D. N. (2008c). Scented rice variety of new Kalanamak and its cultivation package (in Hindi). Kheti, 61(6), 10–12.

Chaudhary, R. C., Mishra, S. B., & Dubey, D. N. (2008d). Scented rice variety Kalanamak and its cultivation for better quality and high yield. Rice India, 18(8), 23–25.

Chaudhary, R. C., Mishra, S. B., & Dubey, D. N. (2008f). Scented rice variety of new Kalanamak and its cultivation package (in Hindi). Kheti, 61(6), 10–12.

Chaudhary, R. C., Mishra, S. B., & Dubey, D. N. (2008g). Scented rice variety Kalanamak and its cultivation for better quality and high yield. Rice India, 18(8), 23–25.

Chaudhary, R. C., Mishra, S. B., & Kumar, D. (2013). Organic farming of Kalanamak rice (in Hindi). Kheti, 66(1), 3–6.

Chaudhary, R. C., Mishra, S. B., & Sahani, A. (2020b). Sugar-free, aromatic and nutritious rice variety Kalanamak Kiran notified in 2019. Nature Times Magazine, 1(April), 31–36.

Chaudhary, R. C., Mishra, S. B., Dubey, D. N., & Chaudhary, P. (2008a). Short-grained aromatic rice Kalanamak: Its export potential. Commodity Today, 1(9), 28–29.

Chaudhary, R. C., Mishra, S. B., Dubey, D. N., & Chaudhary, P. (2008e). Short-grained aromatic rice Kalanamak: Its export potential. Commodity Today, 1(9), 28–29.

Chaudhary, R. C., Mishra, S. B., Yadav, S. K., & Ali, J. (2012). Extinction to distinction: Current status of Kalanamak, the heritage rice of eastern Uttar Pradesh and its likely role in farmers' prosperity. LMA Convention Journal, 8(1), 7–14.

Chaudhary, R. C., Pandey, A., Mishra, S. B., Dubey, D. N., Chaudhary, P., & Kumar, D. (2010b). Catalogue of aromatic rices of eastern Uttar Pradesh. In R. S. Rathor & C. Prasad (Eds.), Catalogue of aromatic rices of eastern Uttar Pradesh (p. 180). Uttar Pradesh Council of Agricultural Research.

Chaudhary, R. C., Prajapati, S. C., Chaudhary, N., Anita, & Shukla, A. K. (2007). Diversity in rice, its cultivation and its uses in the area of its origin: Eastern Uttar Pradesh, India. In D. Papotti & C. Brusa (Eds.), Geographical researches on rice: A comparative analysis of rice districts in the European Union and India (pp. 165–176). Edizioni Mercurio.

Chaudhary, R. C., Sahani, A., & Mishra, S. B. (2020a). Kalanamak chawal ke jaivik kheti ke anubhav. Krishi Manjusha, 2(2), 13–17.

Chaudhary, R. C., Sahani, A., & Mishra, S. B. (2022b). Improvement of local germplasm of Kalanamak rice to benefit environment, health and wealth. Scientific Research Journal of Agriculture and Life Sciences, 2(1).

Chaudhary, R. C., Sahani, A., & Mishra, S. B. (2022c). Gem from local germplasm of Kalanamak rice for environment, health and wealth. International Journal of Multidisciplinary Research and Development, 3(2), 427–432.

Chaudhary, R. C., Sahani, A., Mishra, S. B., & Kumar, R. (2020c). Kalanamak Kiran: Dhaan sugandhit, loha aur zasta se bharpur. Krishi Jagran, April 27, p. 4.

Chaudhary, R. C., Sahani, A., Mishra, S. B., & Kumar, R. (2020d). Kalanamak Kiran variety of rice developed as aromatic, nutritious and sugar free. Indian Farmers' Digest, 53, 4–8.

Chaudhary, R. C., Sahani, A., Mishra, S. B., & Kumar, R. (2020e). Kalanamak Kiran: Dhaan sugandhit, loha aur zasta se bharpur. Krishi Jagran, April 27, p. 4.

Chaudhary, R. C., Singh, S., Yadav, R., Das, S., & Sahani, A. (2022a). High beta carotene discovered in Kalanamak rice. Journal of AgriSearch, 8(4), 379–380.

Chaudhary, R. C., Yadav, S. K., & Kumar, S. (2017a). Geographical indications in Indian agriculture on the anvil. Journal of Bioinnovation, 6(5), 790–816.

Chaudhary, R. C., Yadav, S. K., & Sahani, A. (2017b). Present status and potentiality of geographical indications registration in Uttar Pradesh. In National Symposium on IPRs in Agriculture Sector (pp. 4–14). Babasaheb Bhimrao Ambedkar University & UPCAR.

Kumar, D., Chaudhary, R. C., & Singh, Y. (2024). Kalanamak rice: A heritage variety. Asian Journal of Agricultural Extension, Economics & Sociology, 42(2), 189–199. https://doi.org/10.9734/ajaees/2024/v42i218327

Kumar, S., Mishra, S. B., & Chaudhary, R. C. (2018a). Breeding Bauna Kalanamak 101 as a new aromatic variety of heritage rice for Uttar Pradesh. International Journal of Science, Environment and Technology, 7(2), 580–590.

Kumar, S., Mishra, S. B., & Chaudhary, R. C. (2018b). Breeding Bauna Kalanamak 102 as a new aromatic variety of heritage rice from Uttar Pradesh. International Journal of Science, Environment and Technology, 7(5), 1690–1699.

Legge, J. (2021). A record of Buddhistic kingdoms. Project Gutenberg. (Original work published 1886)

Nanda, J. S., Chaudhary, R. C., Singh, J. P., Singh, H. P., & Gupta, M. D. (1974). Breeding for quality rice through induced mutation. In Proceedings of the Symposium on Use of Radiations and Radioisotopes in Studies of Plant Productivity (pp. 24–32), Pantnagar, India, April 12–14, 1974.

Pandey, S., Tripathi, V., Sahin, A., & Dubey, P. (2022). Food products of broken Kalanamak rice (PRDF Manual No. 22-1, 38 pp.). Plant Research and Development Foundation (PRDF). https://www.prdf-agri.com

Singh, R. K., & Singh, U. S. (2005). Scented rices of Uttar Pradesh and Uttaranchal. Kalyani Publishers.

Singh, R. K., Sahai, V. N., Sharma, R. N., Singh, U. S., Singh, S., & Singh, O. N. (2001). Current status and future prospects of improving traditional aromatic rice varieties in India. In R. C. Chaudhary & D. V. Tran (Eds.), Speciality rices of the world: Breeding, production and marketing (pp. 80–87). FAO.

Singh, U. S., Singh, N., Singh, H. N., Singh, O. P., & Singh, R. K. (2005). Rediscovering scented rice cultivar Kalanamak. Asian History Foundation Journal, 9(3), 211–219.

Watters, T. (1904). On Yuan Chwang’s travels in India (Vols. 1–2). Royal Asiatic Society.

Yadav, S. K., Chaudhary, R. C., & Sahani, A. (2017a). Registration for geographical indication in Uttar Pradesh: Present status and future potential. International Journal of Trend in Research and Development, 4(6), 48–57.

Yadav, S. K., Chaudhary, R. C., & Sahani, A. (2017b). Geographical indication and registration in Uttar Pradesh, India: Present and future potential. Journal of Bioinnovation, 6(5), 790–801.

Yadav, S. K., Chaudhary, R. C., & Sahani, A. (2018). Geographical indication and registration in Uttar Pradesh, India: Present and future potential. International Journal of Research in Agricultural Sciences, 5(1), 48–57.

Yadav, S. K., Chaudhary, R. C., Kumar, S., & Mishra, S. B. (2019). Breakthrough in tripling farmers’ income sustainably by producing Kalanamak rice. Journal of AgriSearch, 6(1), 1–5.