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# Achievements in Rice Research at BINA through Induced Mutation

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## ABSTRACT

The Bangladesh Institute of Nuclear Agriculture (BINA), since its inception in 1961 as a radio tracer laboratory under the then Pakistan Atomic Energy Commission (PAEC), has released so far 9 improved varieties of rice through induced mutation technique. Of the 9 varieties 'Iratom-24' and 'Iratom-38' were developed by irradiating the seeds of the rice 'IR 8' and released by the National Seed Board (NSB) of Bangladesh in 1974 for *boro* (December to May) and *aus* (March to June) seasons. The mutated characteristics of these varieties are shorter crop duration, resistance against bacterial leaf blight (BLB) and medium fine grain size. 'Binasail' was also developed by irradiating the seeds of 'Naizersail' and released in 1987 for *aman* (July to December) season with mutated characters like long panicles, more number of grains, medium fine grains with higher weight, early maturing with photo-insensitivity and higher grain and straw yields. 'Binadhan-4', 'Binadhan-5' and 'Binadhan-6' were developed by irradiating $F_2$ seeds of the parents 'BR-4' and 'Iratom-38' and released in 1998, 'Binadhani-4' for *aman* and 'Binadhan-5' and 'Binadhan-6' for *boro* season. 'Binadhan-7' was developed from $M_3$ seeds of the cv. 'Tai Nguen' of Vietnam. This variety was released in 2007 for *aman* season with earliness, long fine grain and high yield. Early maturing character of this variety helps to escape drought and insect attack during flowering and dough stages. Moreover, it helps increasing cropping intensity by facilitating timely cultivation of following winter crops. 'Binadhan-9' was developed by hybridizing between the local cv. 'Kalozira' and an exotic mutant line Y-1281. It was released in 2012 for *aman* season, also can be grown in *boro* season. Unlike the parent 'Kalozira'it has short duration, long and slender grains with slight aroma. Using recent ion beam irradiation technique BINA has already developed two mutant lines that can be grown after harvest of mustard or rapeseed during the first week of February to first week of March and can be harvested after 121-134 days. These mutant lines produce high yield.

**Keywords:** *aman* rice, *aus* rice, *boro* rice, mutant variety, mutation breeding
**Abbreviations: BINA**, Bangladesh Institute of Nuclear Agriculture; **PAEC**, Pakistan Atomic Energy Commission; **BAU**, Bangladesh Agricultural University; **t/ha**, Metric ton/hectare, **INA**, Institute of Nuclear Agriculture; **NSB**, National Seed Board; **IRRI**, International Rice Research Institute

## CONTENTS



## INTRODUCTION

Mutations are the tools used to study the nature and functions of genes and to create raw materials for genetic improvements of crop plants (Adamu and Aliyu 2007). It has been used to develop many crop varieties with improved quantitative, qualitative and economic value (Hamid *et al.* 2006; Latado *et al.* 2006; Nayeem *et al.* 2006; Rutger 2006; Azad *et al.* 2010). Realizing the importance of this technique in agricultural development of a country, research work was initiated in 1961 in the then Pakistan Atomic Energy Commission at Dhaka. After independence in 1972, the Institute of Nuclear Agriculture (INA) comprising of several disciplines was established. This was shifted to the present campus of Bangladesh Agricultural University at Mymensingh in 1975. Considering the greater role of nuclear research in agriculture, the status of INA was upgraded to an independent national agricultural research institute in 1982 and placed under the Ministry of Agriculture and was named as "Bangladesh Institute of Nuclear Agriculture" (BINA) in 1984. BINA has been working on rice from its very inception as it is the staple food for more than half of the world population including Bangladesh. Induced mutations have played significant role for the improvement of rice (Azam and Uddin 1999; Maluzinski *et al.* 1986; Baloch *et al.* 1999; 2001a; 2001b; 2002; 2003). BINA in its short lifetime has released or registered 59 improved crop varieties including 9 rice varieties. Of the rice varieties, 8 were

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Invited Mini-Review

**Table 1** Mutagen used/method of development, parent used and key mutated characters of the BINA released mutant varieties of rice.

| Mutant variety | Mutagen used/method of development | Parent | Suitable growing season in Bangladesh | Year of release by NSB | Mutated key characters |
|---|---|---|---|---|---|
| Iratom-24 | Seed irradiation with 300Gy dose of gamma rays | IR-8 | *Boro* December to May) and *Aus* (March-June) | 1974 | Shorter crop duration by 20-25 days than the parent, dwarf, resistance against bacterial leaf blight (BLB) and medium fine grains. |
| Iratom-38 | Seed irradiation with 300Gy dose of gamma rays | IR-8 | *Boro* (December to May) and *Aus* (March- June) | 1974 | Shorter crop duration by 30-35 days than the parent, dwarf, resistance against bacterial leaf blight (BLB) and medium fine grains. |
| Binasail | Seed irradiation with 250Gy dose of gamma rays | Nizersail | *Transplant aman* (July to December) | 1987 | Improved plant type, longer panicles with more number of grains, medium fine grains, early maturing (135-140 days from seed to seed) with photo-insensitivity and higher grain and straw yields. |
| Binadhan-4 | $F_2$ seed irradiation with 250Gy dose of gamma rays | BR 4 and Iratom-24 | *aman* (July to December) | 1998 | Shorter crop duration (130-135 days) and long slender grain. |
| Binadhan-5 | $F_2$ seed irradiation with 250Gy dose of gamma rays | Iratom-24 and Dular | *Boro* | 1998 | Taller and stiffer plant with long slender grain and higher yield (7.0-7.5 t/ha), easy to thresh. |
| Binadhan-6 | $F_2$ seed irradiation with 250Gy dose of gamma rays | Iratom-24 and Dular | *Boro* | 1998 | Taller and stronger plants; moderate bold grain size, high yield (>8.0 t/ha). |
| Binadhan-7 | Seed irradiation with 250Gy dose of gamma rays | Tai Nguen | *aman* | 2007 | Shorter crop duration (115-120 days), medium long fine grain, tolerant to brown plant hopper (BPH) and higher yield (4.8 t/ha). |
| Binadhan-9 | Hybridization between a mutant line and a local cultivar | Y-1281 (mutant) and Kalozira (local cv.) | *aman* | 2012 | Shorter duration (118-123 days), shorter height, lodging resistant, aromatic, long fine grains. |

bred through mutation breeding. In this paper the method of development of the 8 rice mutant varieties along with their mutated key characters (**Table 1**) and benefits towards acceptability by the farmers are discussed.

## IRATOM-24 and IRATOM-38

Mutation breeding work on rice was started at BINA with the *boro* rice variety 'IR-8'. The variety has some disadvantages like longer crop duration (170 days, seed to seed) related to higher cost of cultivation, susceptible to lodging, diseases and insect pests. To overcome these disadvantages dry seeds of 'IR-8' were exposed to 300 Gy of gamma rays (**Table 1**) and four early maturing lines were finally selected. Among these four mutant lines, Mutant 24 and Mutant 38 performed better. These 2 mutant lines were further tested at various locations including IRRI, Philippines in subsequent years. Finally, in 1974, the NSB of Bangladesh approved these two mutant lines under the commercial names 'Iratom-24' (**Fig. 1A**) and 'Iratom-38', respectively, for cultivation in *boro* (December–May) and *aus* (March – July) seasons. The mutated key characteristics of these varieties are shorter crop duration ('Iratom-24' by 20-25 days and 'Iratom-38' by 30-35 days) than the parent, resistance against BLB and medium fine grain size (**Table 1**). Early maturity of these two varieties offer lower cost of cultivation compared to the parent, increased cropping intensity and avoiding hailstorm and other natural hazards at the end of *boro* season. The variety, Iratom-24 gained much popularity particularly in the northern districts of Bangladesh where it is mostly known as "Tom dhan". It does not lodge because of its dwarfness. Grain yield potential of the variety is 6.0-6.5 tons (t) in *boro* and 3.5-4.0 t/ha in *aus* season.

## BINASAIL

In 1973, induced mutagenesis programme was undertaken with a popular local rice cultivar 'Nizersail' which was introduced from Nizeria in 1941. 'Nizersail' has the excellent grain quality despite having the disadvantages of longer crop duration (150 days, seed to seed) in *aman* (July–December) season, highly photo-sensitive, tall and inferior type of plants with lodging habit and comparatively lower grain yield. To overcome these shortcomings dry seeds of 'Nizersail' were treated with 250 Gy dose of gamma rays (**Table 1**) and finally one tall mutant, Mut. NS-1, having a number of desirable traits was selected in 1983 and subjected to evaluation trial in 1985. In 1987, the NSB approved this mutant for commercial cultivation in the *aman* season as 'Binasail'. This variety exhibited multiple mutated traits like (i) improved plant type, comparatively taller and more lodging resistance (**Fig. 1B**), (ii) longer panicles bearing more number of grains (iii) medium fine grains with higher weight, (iv) early maturing (135-140 days from seed to seed) with photo-insensitivity and (v) higher grain and straw yields (**Table 1**). It is known that in Bangladesh, all the landraces or even the modern rice cultivars show partial to total crop failure at late planting. It is a matter of satisfaction that 'Binasail' can be planted late up to mid September when floodwater recedes. This is a low input variety, very popular across the flood prone areas of the country. Planting of 'Binasail' in optimum time can give 20% higher yield (up to 5 tons) than 'Nizersail' while in late planting, yield ranges between 3.5-4.0 t/ha. The plant is tall; grains are slender and tasty with high protein content.

## BINADHAN-4

$F_2$ seeds of two crosses of 'BR-4' with 'Iratom-24' were subjected to gamma irradiation with 250, 300 and 350 Gy doses of gamma rays in 1985 to develop tall, high yielding and early maturing variety for *aman* season. Finally, after selection and yield trials, the mutant line BINA6-84-4-115 originated from 250 Gy dose (**Table 1**) was released by NSB in 1998 in the commercial name of 'Binadhan-4' for cultivation in *aman* season. The most prominent mutated characters are taller plants (**Fig. 1C**), shorter crop duration (130-135 days, seed to seed) and long slender grain (**Table 1; Fig. 1C**). Early maturity trait of this variety helped in increasing cropping intensity by facilitating cultivation of winter crops like wheat, oil seeds, potato, etc. in time.

## BINADHAN-5 and BINADHAN-6

$F_2$ seeds of a cross between 'Iratom-24' and 'Dular' (a local cultivar) were irradiated with 250, 300 and 350 Gy doses of gamma rays in 1985. Finally, two mutant lines BINA4-39-15-13 and BINA4-5-17-19 were selected from 250 Gy dose for release. NSB approved these two mutant lines as 'Binadhan-5' and 'Binadhan-6' in 1998. The most important mutated characters for 'Binadhan-5'are taller and stiffer plants (**Fig. 1D**) and long slender grain (**Table 1**). It matures one week earlier than 'BRRI dhan29' but with similar yield (7.0-7.5 t/ha). Moreover, this variety is easy to thresh. For

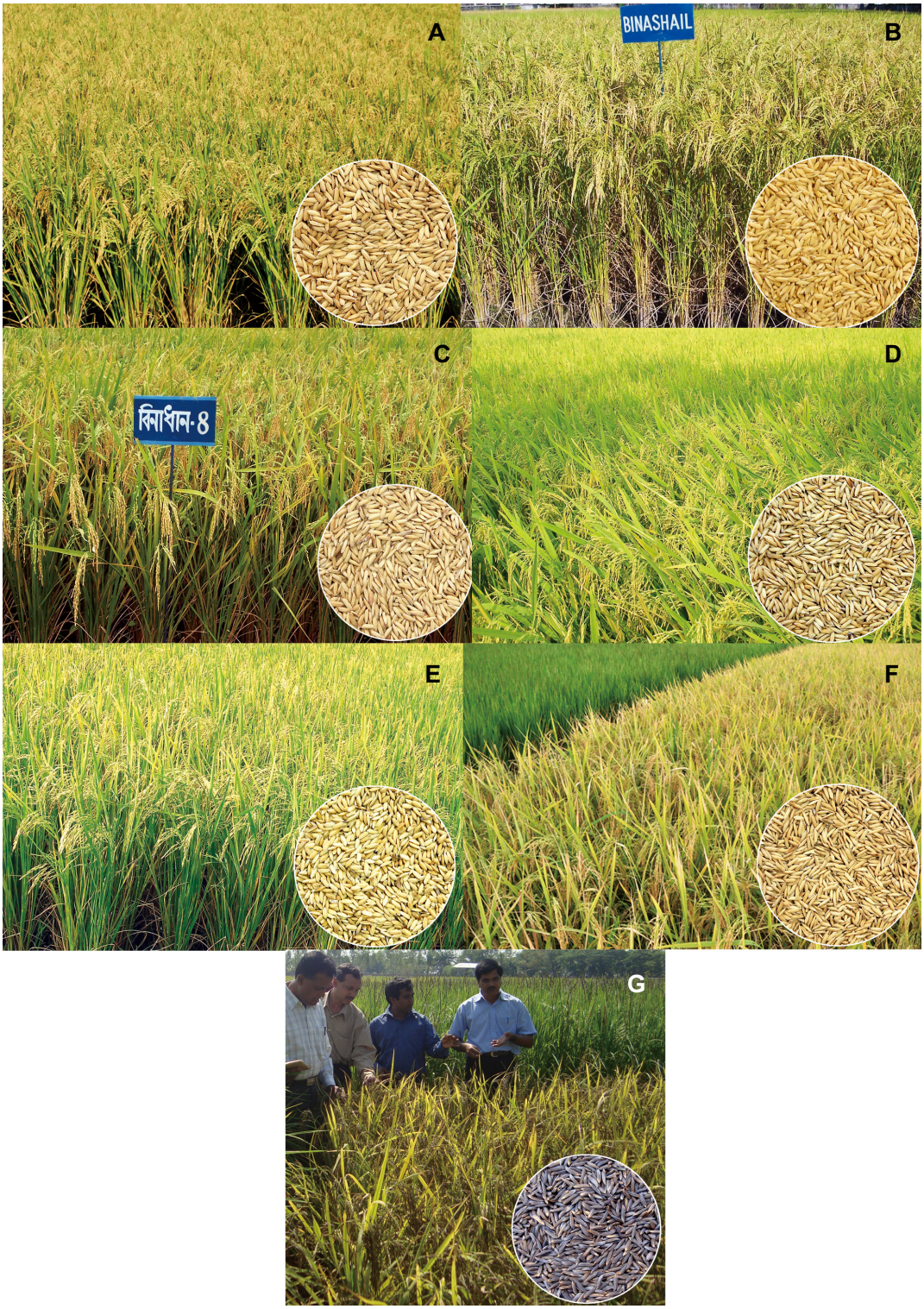


**Fig. 1 Field view of various BINA rice varieties.** (**A**) Iratom-24; (**B**) Binasail; (**C**) Binadhan-4; (**D**) Binadhan-5; (**E**) Binadhan-6; (**F**) Binadhan-7 showing its early maturity in comparison with a standard check variety; (**G**) field view showing earliness and relatively shorter height of aromatic Binadhan-9 compared to parent Kalozira.

this, it has become popular in some places of Bangladesh like Mymensingh and Rangpur. Additionally, it has proven potential to perform well in Narsingdi and many other regions. In case of 'Binadhan-6', plants became taller and stronger (**Table 1; Fig. 1E**); grain size became moderate bold and grain as well as straw yields increased. 'Binadhan-6' is now the topmost high yielding *boro* rice variety (produce above 8.0 tons/ha in average) in Bangladesh. This variety is gaining popularity in the southern districts particularly Jhalakathi and Barisal because of its coarse grain and highest yield.

## BINADHAN-7

$M_3$ seeds of 'Tai Nguen', irradiated with 250 Gy dose of gamma rays (**Table 1**), were collected from Vietnam under a Regional Cooperation (RC) Project of International Atomic Energy Agency (IAEA). The collected $M_3$ seeds were grown during the *aman* season in 2000 and quite a few numbers of similar plants were selected based on desired plant type. The harvested seeds from these plants were bulked. Selections during $M_4$ to $M_7$ generations in *aman* and *boro* seasons of 2001 to 2003 showed the mutant line TNDB-100 as performing better in *aman* season and thus NSB approved it as 'Binadhan-7' for *aman* season in 2007.

**Table 2** Year wise yield of grain rice of three ecotypes during 2003-04 to 2009-10 in Bangladesh.

| Rice ecotypes | 2003-04 (t/ha) | 2004-05 (t/ha) | 2005-06 (t/ha) | 2006-07 (t/ha) | 2007-08 (t/ha) | 2008-09 (t/ha) | 2009-10 (t/ha) |
|---|---|---|---|---|---|---|---|
| *Aus* | 2.03 (7.00) | 1.86 (5.96) | 1.99 (6.58) | 1.67 (5.54) | 1.64 (5.21) | 1.78 (6.05) | 1.74 (5.35) |
| *Aman* | 2.03 (43.99) | 1.86 (39.03) | 1.99 (40.75) | 2.00 (39.68) | 1.91 (33.40) | 2.11 (37.08) | 2.15 (38.18) |
| *Boro* | 3.25 (49.01) | 3.40 (55.01) | 3.44 (52.67) | 3.51 (54.78) | 3.85 (61.39) | 3.77 (56.87) | 3.84 (56.47) |
| Total | 2.42 | 2.43 | 2.52 | 2.58 | 2.73 | 2.78 | 2.82 |

Figures in the parentheses indicate percentages of total rice production; Source: Statistical Yearbook of Bangladesh, 2011

After release of 'Binadhan-7' in 2007, it has become very popular throughout the country particularly for its earliness, long fine grain and high yield (Maximum 5.5 t/ha and average 4.8 t/ha) (**Fig. 1F**). Early maturing character of this variety helps to escape drought and insect attack during flowering and dough stages. Moreover, it help increasing cropping intensity by facilitating timely cultivation of mustard, potato, wheat and winter vegetables. The most important point is that the introduction of this variety in the Rangpur region has a tremendous effect in eradicating the unemployment driven hunger during October to mid November. This variety is also tolerant to brown plant hopper commonly known as 'current poka' (**Table 1**).

## BINADHAN-9

A hybridization program between the long duration aromatic Kalozira (with short and coarse grain) and a long fine grain non-aromatic mutant line Y-1281 gave birth to RC-43-28-5-3-3 'Binadhan-9'. This aromatic long fine grain rice line matures within 118-123 days (seed to seed), 17-32 days earlier than its parent Kalozira, and produces more than double yield (3.0 to 4.15 t/ha) in *aman* season (**Table 1**). It does not lodge because of its relatively shorter height. Like 'Binadhan-7', cultivation of this variety will facilitate timely cultivation of mustard, potato, wheat and winter vegetables. NSB has approved this variety in 2012 (**Fig. IG**).

## ADVANCED LINES: RM-200 (C)-1-10 and RM-200 (C)-1-17

In Bangladesh, more than two-third of required edible oil is being imported in exchange of heard earned foreign currency. To reduce this import, more oil seeds particularly high yielding mustard/rapeseed varieties should be produced. But the high yielding varieties of mustard/rapeseed are relatively long duration; do not fit in our existing cropping pattern. To fit these mustard/rapeseed varieties in the existing cropping pattern short duration, high yielding (6.0 to 6.5 t/ha) *boro* rice varieties are needed that can be transplanted during the first week of February to the first week of March and can be harvested in early days of May. BINA has already developed two such mutant lines that mature within 121-134 days (seed to seed) and produce 6.0 to 6.5 t/ha yield.

## DISCUSSION

Mutation induction has become a proven way of creating variation within a crop variety (Novak and Brunner 1992). It offers possibility of inducing desired attributes that either cannot be found in nature or have been lost during evolution. The *boro* variety 'IR-8' has the disadvantages like susceptible to lodging and longer crop duration. These two characters were induced in 'Iratom-24' and 'Iratom-38' by irradiating the seeds of 'IR-8' with 300 Gy dose of gamma rays (**Table 1**). These results are in conformity with that of many working with rice and other crops (Shamsuzzaman *et al.* 1998; Hamid *et al.* 2006; Kihupi *et al.* 2009; Tulmann Neto *et al.* 2011). They also reported induced mutations for shorter crop duration and lodging resistance through reduced plant height in their studies with rice and other crops. In 'Binasail' yield was increased through increased panicle length and more number of grains (**Table 1**). Moreover, it was induced as photo insensitive unlike its parent 'Nizershail'. These results also corroborate with those of many groups (Morinaka *et al.* 2006; Bughio *et al.* 2007; Li *et al.* 2011). They also observed increased yield in the mutant than the parents in rice. Mutation breeding also improves quality parameters in rice. 'Iratom-24', 'Iratom-38' and 'Binasail' have higher protein contents than their respective parents (Dutta *et al.* 1998). For food and nutritional security of a big population of Bangladesh it was felt seriously to develop a high yielding short duration variety of *aman* rice. With that objective, a hybridization program between the mutant variety 'Iratom-24' and 'BR-4', a Bangladesh Rice Research Institute (BRRI) developed *aman* variety gave birth to 'Binadhan-4' with long fine grain and shorter duration (130-135 days, seed to seed). But this variety could not satisfy fully the farmer's need. The variety 'Binadhan-7' is that variety that could satisfy the needs of the farmers' fully. They are able to grow mustard/rapeseed, wheat, potato, vegetables and even pulses after harvest of 'Binadhan-7'.

In the northern districts of Bangladesh, aromatic rice local cultivars are grown in *aman* season from time immemorial but these require long period to mature and have coarse grain. To develop a short duration and long fine grain aromatic variety another hybridization programme between a non aromatic short duration mutant line Y-1281 and a long duration (>150 day, seed to seed) aromatic cultivar with short grains, yielded RC-43-28-5-3-3 ('Binadhan-9') which is early maturing (118-123 days, seed to seed), aromatic long fine grain can be grown in *aman* and also in *boro* season.

Recently, ion beams irradiation has been established as an effective method of inducing mutations. The biological effects of ion beams have been investigated and observed to be shown a high relative biological effectiveness (RBE) in lethality, mutation and so on, compared to low linear energy transfer (LET) radiation like Gamma-rays, X-rays and electrons (Blakely 1992). As ion beams deposit high energy on a local target, it has been suggested that ion beams induce predominantly single or double strand DNA breaks with damaged end groups that are unable to be repaired easily (Goodhead 1995). Therefore, it seems plausible that ion beams frequently produce large DNA alterations, such as inversions, translocations and large deletions rather than point mutations. It has been also demonstrated that ion beams induce mutations at high frequency and induce novel mutants in *Arabidopsis* (Tanaka *et al.* 1997; Hase *et al.* 2000; Tanaka *et al.* 2002; Shikazono *et al.* 2003). Using this technique BINA has already developed some mutant lines that can be grown after harvest of mustard/rape-seed during the first week of February to the first week of March and can be harvested after 121-134 days. These mutant lines produce 6.0 to 7.0 t/ha yield.

## FUTURE PROSPECT

Yield of *boro* rice has reached a plateau in 2007-08 in Bangladesh (**Table 2**). For further increase in yield of rice mutation breeding is one of the best option. It is easy and straight forward to develop varieties with at least 15-20% higher yield than a top cultivar.

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