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Evaluation of nitrogen use efficiency of mutant and parental varieties of rice in Chhattisgarh

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Abstract
The present study was conducted during the year 2019 - 2020 with objectives to study the effects of nitrogen application in yield and yield attributes of mutant and parent rice varieties and to estimate the nitrogen uptake and use efficiency of mutant and parent rice varieties. The soil of the experimental field exhibited neutral soil pH i.e. 7.29, Electrical conductivity 0.16 dS/m, low organic carbon content (0.35), low soil available nitrogen (210.62 kg/ha), high soil available phosphorus (31.53 kg/ha) and high soil available potassium (437.68 kg/ha). The experiment was conducted in split-plot design and replicated thrice, consisting four nitrogen levels (0, 60, 80 and 100 kg N / ha) as main factor and four varieties as sub factor. There were total 16 treatment combinations. Two new high-yielding mutant varieties of paddy i.e. C.G. Javaphool Trombay and Sonagathi Mutant-1 were developed from two traditional varieties of paddy Javaphool and Sonagathi by gamma irradiation method of inducing mutation. Morpho-physiological parameters and nutrient content were analyzed plot wise and calculated to hectare basis. Likewise, soil samples were collected, processed and utilized for determining physico-chemical properties of soil. Among all varieties, Sonagathi mutant-1 (30.12%) and C.G. Javaphool Trombay (27.04%) were more efficient in utilizing nitrogen than Sonagathi parent (26.93%) and Javaphool parent (23.28%). Nitrogen use efficiency increased up to 80 kg N / ha then it further decreased at 100 kg N / ha. The treatment combination $N_{80}V_3$ *viz*., Sonagathi Mutant-1 with 80 kg N/ha application was found to be superior among all combinations in terms of nitrogen use efficiency.

Keywords: Javaphool trombay, sonagathi mutant-1

Introduction

Nitrogen-use efficiency (NUE) is a parameter which indicates the extent of utilization of applied N by the crop and evaluates a crop cultivar. It is also defined as the ratio of grain yield to supplied N. Since, one of the major challenges faced by us is to ensure adequate availability of nutrients and rational use of appropriate fertilizers for agriculture, in view of preventing the unwanted accumulation of reactive N from different sources and improving nutrient use efficiency of crops. Therefore, vital factor for crop improvement in agriculture is improving nitrogen use efficiency for achieving sustainability.

Mutation breeding is the process of exposing seeds to mutagens (such as chemicals or radiation) to produce mutants with desired characteristics. It is the most effective and simple way to generate variability in crop plants to select the desired plant phenotype. Compared with other traditional breeding methods, it takes less time to develop varieties through mutation breeding.

Indira Gandhi Agriculture University (IGAU) was developed two new high-yielding mutant varieties of paddy (C.G. Javaphool Trombay and Sonagathi Mutant-1) in collaboration with Bhabha Atomic Research Centre (BARC), which are shorter in height and take less duration to ripe. Both the varieties were developed by using physical mutagen gamma rays (300 Gy) through genetic mutation of traditional varieties of paddy Sonagathi and Javaphool.

Higher grain yield and higher nitrogen use efficiency are associated with understanding plant traits like root-shoot biomass, root length, root length density, root oxidation activity and crop growth rate, photosynthetic NUE etc. These traits are important in breeding program to develop N-efficient varieties (Ju *et al*., 2015) [8]. Improvement of dry matter weight, nitrogen uptake ability per panicle and nitrogen uptake intensity per panicle are helpful to improve the amount of nitrogen uptake.

Increase in nitrogen translocation from vegetative organs to reproductive organs (panicles) and decrease of the nitrogen content in sheath, stem and leaves are beneficial for the improvement of nitrogen use efficiency in *Indica* and *Japonica* rice varieties with longer growth duration (Hong-cheng *et al*., 2013) [5].

Materials and Methods

The experimental site "Research Farm of Indira Gandhi Krishi Vishwavidyalaya" lies at 21º 16.885'' N latitude and 81º 42.117''E longitudes with an altitude of 298.56 meter above the mean sea level. Two traditional varieties of paddy and their mutant varieties were laid out in split plot design with varying doses of nitrogen. Grain and straw yields were recorded plot wise and estimation was done on hectare basis. The representative 5 plant samples were selected randomly for taking observations of various morpho-physiological parameters like plant height, panicle length, number of effective tillers per plant, number of filled grains per panicle, test weight, grain and straw yield. Nutrient content analysis of plant samples was also done. Likewise, soil samples were pooled and collected from three different sites of plot.

Soil pH was determined by electrode pH meter as suggested by Piper (1966) [14]. Electrical Conductivity of soil sample was determined by EC meter by dipping the electrode without stirring as described by Black (1965) [2]. Organic carbon was determined by Walkley and Black's (1934) [18] rapid titration method as described by Piper (1966) [14]. Available N was determined by alkaline permanganate method as suggested by Subbiah and Asija (1956) [17]. Available soil phosphorus was extracted by 0.5 M $NaHCO_3$ at pH 8.5 using Double beam Spectrophotometer as described by Olsen *et al*., (1954) [12]. Soil available potassium was extracted by 1 N (neutral) ammonium acetate and determined with the help of flame photometer as described by Jackson, (1967) [6].

Total Nitrogen content of plant samples were determined by Kjeldahl's digestion method using automatic KEL plus distillation described by Chapman and Pratt (1961) [3]. Phosphorus content was determined by vanado-molybdate yellow color complex method as described by Jackson (1973) [7]. Potassium content was determined by Flame photometer as described by Chapman and Pratt (1961) [3].

Nutrient uptake was calculated by using the following formula:

$$\text{Uptake (kg/ha)} = \frac{\text{Nutrient content (\%) x Yield (kg/ha) or oven dried biomass}}{100}$$

The easiest way to calculate NUE is Apparent Nitrogen Recovery (ARN)

$$AR_N\,(\%) = \frac{TU_N - CU_N}{AF_N} \times 100$$

Where,

TU_N- total N uptake from fertilized plot (kg/ha)

CU_N- total N uptake from unfertilized plot (kg/ha)

AF_N- amount of applied N fertilizer (kg/ha)

Results and Discussion

The results of the study area are presented and discussed as follows:

Effect of different nitrogen levels on growth and yield parameters

Plant height (cm)

As per the data recorded, plant height increased with increasing nitrogen levels. This result is in accordance with an experiment conducted by Gewaily *et al*., (2018) [4]. This may be because of its role in promoting rapid leaf, stem and other vegetative part's growth and development. Among four nitrogen levels, N_{100} produced highest plant height (149.59 cm), whereas, lowest (129.24 cm) by N_0. In case of varieties, highest plant height (155.49 cm) was recorded by V2 (Javaphool parent), whereas lowest (130.97 cm) by V3 (Sonagathi mutant-1). On comparing parent varieties to their mutant types, parent varieties showed significantly higher plant height. The plant height was significantly reduced due to mutation in both varieties. Interaction effect of nitrogen levels and varieties on plant height was found to be non-significant.

Table 1: Effect of different nitrogen levels on plant height (cm) of mutant and parent rice varieties

Treatments	N_0	N_{60}	N_{80}	N_{100}	Mean
V1 (C.G. Javaphool Trombay)	129.72	140.18	145.23	148.22	140.84
V2 (Javaphool parent)	147.11	153.55	160.15	161.17	155.49
V3 (Sonagathi mutant-1)	114.05	131.81	137.90	140.11	130.97
V4 (Sonagathi parent)	126.07	142.99	148.16	148.89	141.53
Mean	129.24	142.13	147.86	149.59	-
SEm ±	N - 2.14, V- 2.08, N X V -4.16				
CD (p = 0.05)	N -7.39, V -6.07, N X V – NS				

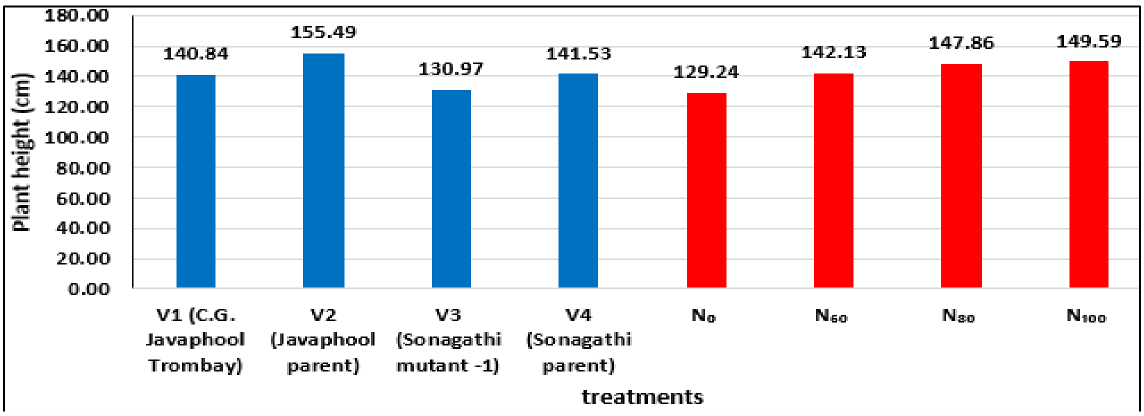

Fig 1: Effect of different nitrogen levels on plant height (cm) of mutant and parent rice varieties

Number of effective tillers per hill

The results revealed that variety V3 (Sonagathi mutant-1) recorded highest number (6.46) of effective tillers. Among nitrogen levels, application of N_{100} produced maximum number of effective tillers (6.27). This clarifies that on increasing nitrogen levels, number of effective tillers per hill increases. This is because nitrogen application increases the cytokinin content within tiller nodes and thus enhanced the germination of the tiller primordium (Liu *et al*., 2011) [10]. On comparing parent varieties to their mutant types, mutant varieties showed significantly higher number of effective tillers per hill than parent varieties.

Table 2: Effect of different nitrogen levels on no. of effective tillers/hill of mutant and parent rice varieties

Treatments	N_0	N_{60}	N_{80}	N_{100}	Mean
V1 (C.G. Javaphool Trombay)	3.87	4.33	4.67	5.40	4.57
V2 (Javaphool parent)	3.67	4.47	4.27	4.80	4.30
V3 (Sonagathi mutant-1)	4.96	6.32	6.56	8.00	6.46
V4 (Sonagathi parent)	4.96	5.52	6.32	6.88	5.92
Mean	4.36	5.16	5.45	6.27	-
SEm ±	N - 0.14, V- 0.23, N X V – 0.46				
CD (p = 0.05)	N – 0.47, V -0.67, N X V - NS				

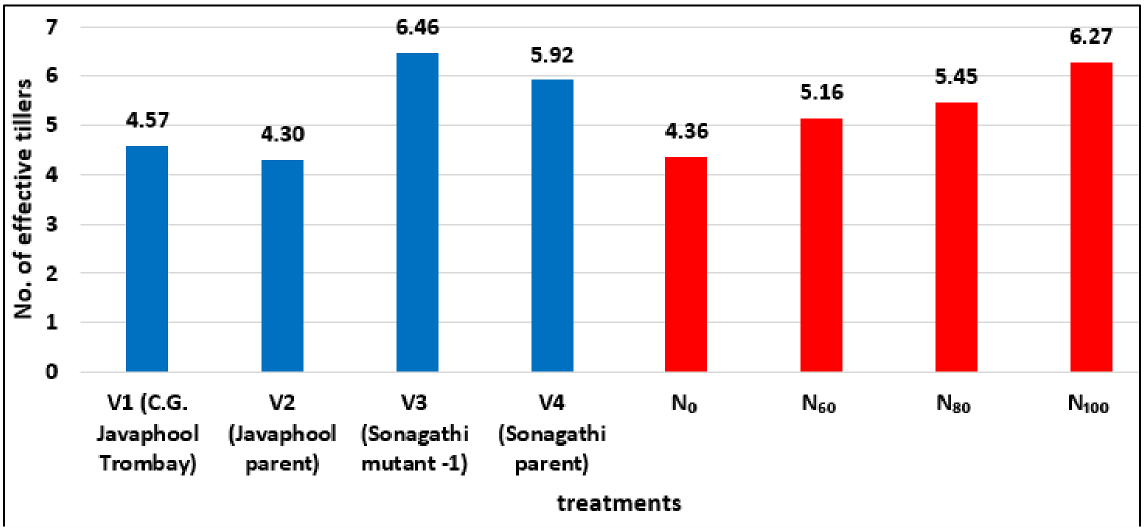

Fig 2: Effect of different nitrogen levels on no. of effective tillers/hill of mutant and parent rice varieties

Panicle length (cm)

Panicle length tends to increase with increasing nitrogen level up to N_{80} and after that it was decreased. Similar trend was also reported by Aparna (2017) [1]. Among all varieties, V1 (C.G. Javaphool Trombay) produced highest panicle length i.e. 27.44 cm whereas, lowest i.e. 24.94 cm by V4 (Sonagathi parent). Application of N_0 resulted in minimum panicle length (Salman *et al*., 2012) [15]. On comparison, mutant varieties showed higher panicle length and which was at-par with their parents.

Table 3: Effect of different nitrogen levels on panicle length (cm) of mutant and parent rice varieties

Treatments	N_0	N_{60}	N_{80}	N_{100}	Mean
V1 (C.G. Javaphool Trombay)	25.00	27.99	28.33	28.44	27.44
V2 (Javaphool parent)	25.13	26.75	27.80	26.73	26.61
V3 (Sonagathi mutant-1)	23.13	25.27	26.84	26.47	25.43
V4 (Sonagathi parent)	23.20	24.91	25.57	26.07	24.94
Mean	24.12	26.23	27.14	26.93	
SEm ±	N - 0.65, V- 0.41, N X V – 0.81				
CD (p = 0.05)	N – 2.08, V -1.18, N X V - NS				

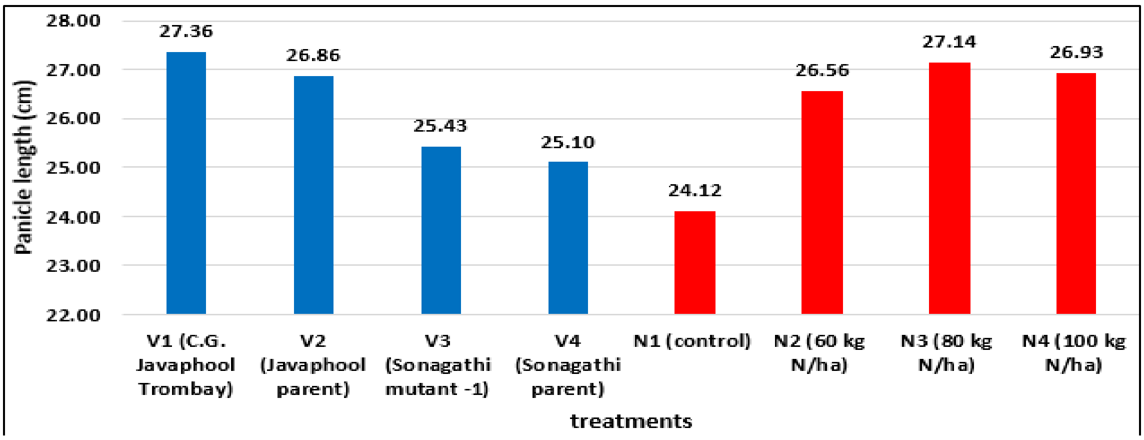

Fig 3: Effect of different nitrogen levels on panicle length (cm) of mutant and parent rice varieties

Number of filled grains per panicle

V1 (C.G. Javaphool Trombay) and V4 (Sonagathi parent) had the highest (209.96) and lowest (157.59) number of filled grains per panicle, respectively among all varieties. The highest number of filled grains per panicle (196.43) was produced under N_{100} and lowest in N_0. Result revealed that on increasing N levels, number of filled grains also increased. This is due to adequate supply of photosynthates from the source to the sink (grain). Accumulation of photosynthates to sink depends on the availability of nutrients and genetic potentiality of the crops (Yesuf and Balcha, 2014) [19].

Table 4: Effect of different nitrogen levels on no. of filled grains/panicle of mutant and parent rice varieties

Treatments	N_0	N_{60}	N_{80}	N_{100}	Mean
V1 (C.G. Javaphool Trombay)	179.93	211.67	222.92	225.33	209.96
V2 (Javaphool parent)	173.85	199.48	208.73	214.53	199.15
V3 (Sonagathi mutant-1)	151.16	162.28	172.47	178.07	165.99
V4 (Sonagathi parent)	146.18	153.06	163.33	167.80	157.59
Mean	162.78	181.62	191.86	196.43	
SEm ±	N - 0.70, V- 2.05, N X V – 4.10				
CD (p = 0.05)	N – 2.42, V -5.99, N X V - NS				

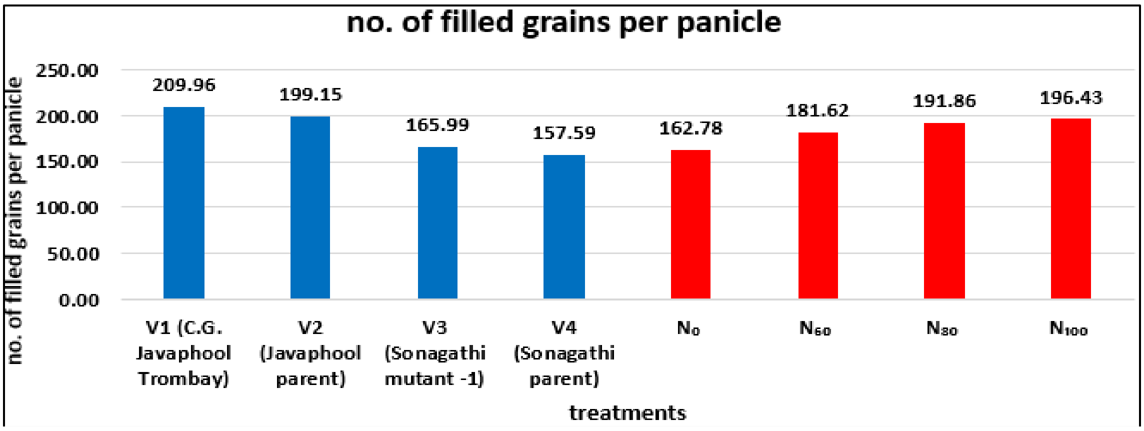

Fig 4: Effect of different nitrogen levels on no. of filled grains/panicle of mutant and parent rice varieties

Test weight (1000 seed weight in gm.)

The test weight was not affected due to mutation; therefore Sonagathi varieties had greater test weight than Javaphool. Highest test weight (23.24 gm) was found for V3 (Sonagathi mutant-1) and lowest test weight (10.46gm) was found for V2 (Javaphool parent). Significant differences were observed among two varieties but differences among various nitrogen levels were found to be non-significant. This may be because test weight of variety is genetically inherent character. Interaction effect of varieties with nitrogen levels on test weight was also found to be non-significant.

Table 5: Effect of different nitrogen levels on test weight (gm) of mutant and parental rice varieties

Treatments	N_0	N_{60}	N_{80}	N_{100}	Mean
V1 (C.G. Javaphool Trombay)	10.96	10.75	10.78	11.01	10.87
V2 (Javaphool parent)	10.54	10.55	10.30	10.45	10.46
V3 (Sonagathi mutant-1)	23.13	23.11	23.41	23.29	23.24
V4 (Sonagathi parent)	23.30	23.18	23.30	23.15	23.23
Mean	16.98	16.90	16.95	16.98	
SEm ±	N - 0.28, V- 0.29, N X V – 0.57				
CD (p = 0.05)	N – NS, V - 0.84, N X V - NS				

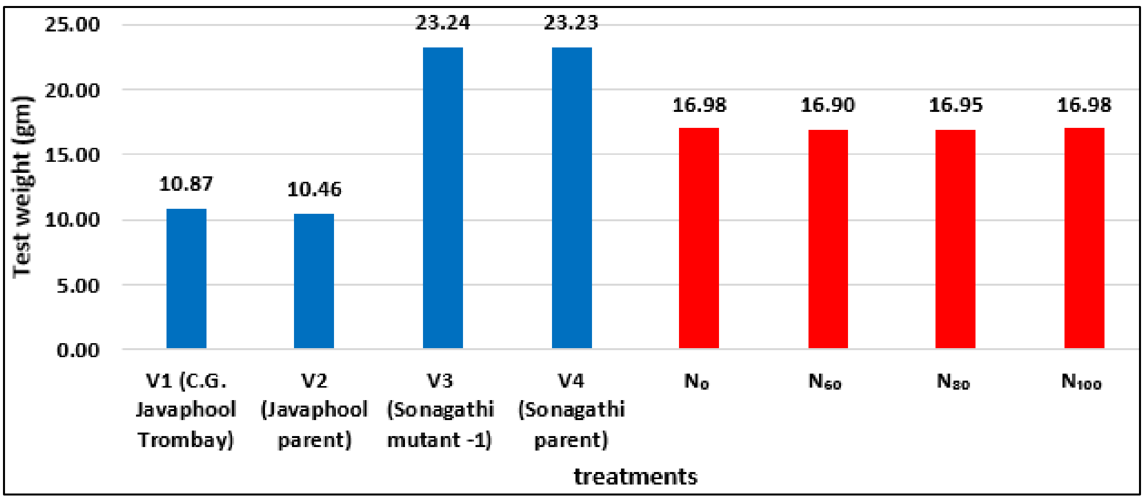

Fig 5: Effect of different nitrogen levels on test weight (gm) of mutant and parental rice varieties

Grain yield

Grain yield ranged from 20.45 q / ha under N_0 to 68.22 q / ha under N_{100}. Among all varieties, V3 (Sonagathi mutant-1) gave the significantly best performance with respect to grain yield. As per data, it is recognized that increasing nitrogen levels significantly increased grain yield up to the application of 80 kg N / ha and it was at par with 100 kg N / ha. Among the varieties, highest grain yield was found by V3 (Sonagathi mutant-1) under N_{100} i.e. 68.22 q / ha and it was at par with 80 kg/ha of N application followed by V4 (Sonagathi parent), C.G. Javaphool Trombay and Javaphool parent. Similarly, C.G. Javaphool Trombay (V1) and Javaphool parent (V2) responded only up to 60 kg N / ha. Overall maximum grain yield (68.22 q / ha) was observed in interaction of Sonagathi mutant-1 with 100 Kg N / ha level ($V3\times N_{100}$) and lowest (20.45 q / ha) with Javaphool parent in control. ($V2\times N_0$). Nitrogen plays an important role in photosynthesis, biomass accumulation, effective tillering, spikelets formation and translocation of photosynthates to grain via source-sink interaction. (Yoshida *et al*., 2006) [21].

Table 6: Effect of different nitrogen levels on grain yield (q/ha) of mutant and parent rice varieties

Treatments	N_0	N_{60}	N_{80}	N_{100}	Mean
V1 (C.G. Javaphool Trombay)	24.20	30.30	31.72	32.05	29.57
V2 (Javaphool parent)	20.45	26.73	28.45	29.58	26.30
V3 (Sonagathi mutant-1)	30.20	51.81	64.52	68.22	53.69
V4 (Sonagathi parent)	29.60	48.48	60.40	63.92	50.60
Mean	26.11	39.33	46.27	48.44	
SEm ±	N - 1.21, V- 1.07, N X V – 2.15				
CD (p = 0.05)	N – 4.19, V - 3.13, N X V - 6.26				

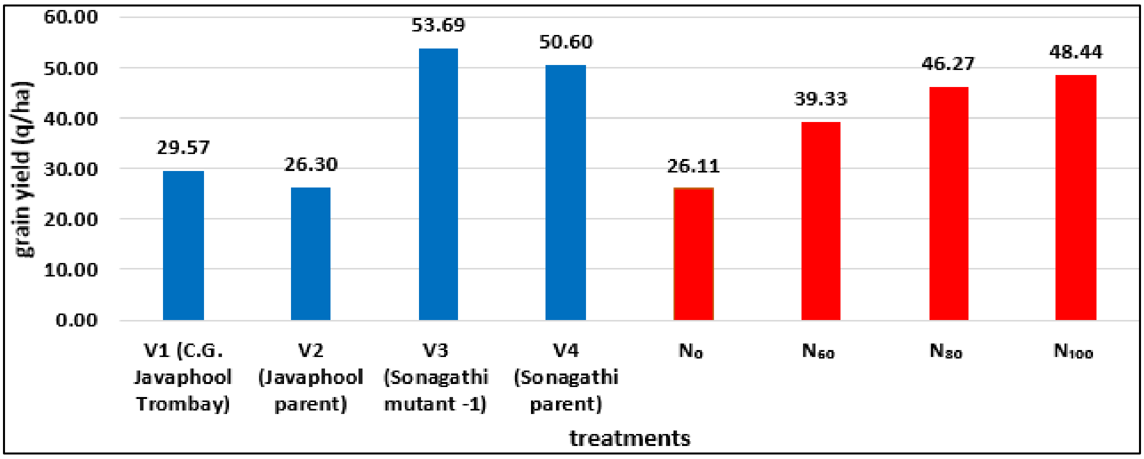

Fig 6: Effect of different nitrogen levels on grain yield (q/ha) of mutant and parent rice varieties

Straw yield (q / ha)

Highest straw yield i.e. 95.25 q / ha was observed for V2 (Javaphool parent) under N_{100}, while lowest (41.67 q / ha) was for V3 (Sonagathi mutant-1) under N_0. Trend followed by the data recorded is that, on increasing nitrogen levels, straw yield also increased. Similar trend was also observed by Singh *et al*., (2020) [16]. Nitrogen is responsible for improving rice vegetative growth i.e. height, number of tillers etc. which might have increased straw yield. (Krupnik *et al*., 2004) [9]

Table 7: Effect of different nitrogen levels on straw yield (q/ha) of mutant and parent rice varieties

Treatments	N_0	N_{60}	N_{80}	N_{100}	Mean
V1 (C.G. Javaphool Trombay)	53.56	63.03	79.67	84.25	70.13
V2 (Javaphool parent)	55.68	82.60	95.22	95.25	82.19
V3 (Sonagathi mutant-1)	41.67	55.20	82.82	84.78	66.12
V4 (Sonagathi parent)	43.83	62.18	85.00	85.08	69.02
Mean	48.69	65.75	85.68	87.34	
SEm ±	N - 3.21, V- 2.48, N X V – 4.95				
CD (p = 0.05)	N – 11.11, V - 7.23, N X V - NS				

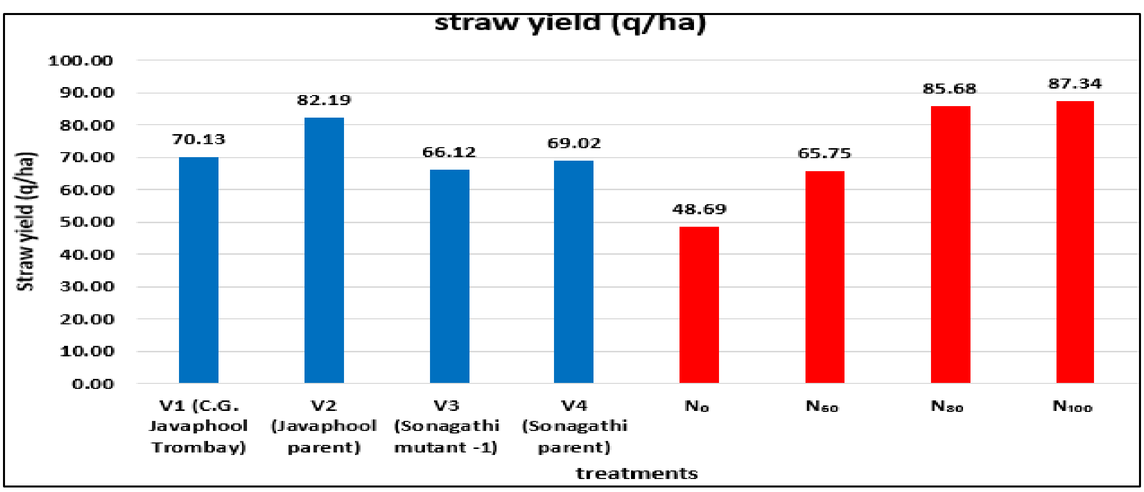

Fig 7: Effect of different nitrogen levels on straw yield (q/ha) of mutant and parent rice varieties

Effect of different nitrogen levels on plant nutrient uptake and nitrogen use efficiency

Plant nitrogen uptake (kg/ha)

Different nitrogen levels had significant influence on nitrogen uptakes (grain + straw) of all varieties. Interaction effect of nitrogen levels and varieties was found to be non-significant on grain, straw and total N. Maximum grain N uptake (63.91 kg/ha) was recorded for V3 (Sonagathi mutant-1) i.e. 55.22 kg/ ha followed by V4 (Sonagathi parent) i.e., whereas lowest for V2 (Javaphool parent) i.e. 28.99 kg/ha. Highest straw nitrogen uptake was recorded for V2 (Javaphool parent) i.e. 39.93 kg/ha, followed by V1 (C.G. Javaphool Trombay) i.e. 39.62 kg/ha, whereas lowest for V4 (Sonagathi parent) i.e. 28.51 kg/ha. If total nitrogen uptake was considered then result was same as grain nitrogen uptake. Total N uptake ranged from 68.92 kg/ha by V2 to 86.38 kg/ha by V3 (Sonagathi mutant-1). N_{100} resulted in highest total N uptake i.e. 90.14 kg/ha whereas, N_0 resulted in lowest total N uptake i.e. 61.23 kg N / ha. Data on table revealed that nitrogen uptake by grain and straw increased with increasing nitrogen levels. Metwally *et al*., (2011) [11] and Oo *et al*., (2007) [13] also reported similar findings. This might be because of increased N assimilation and biomass production.

Plant phosphorus uptake (kg/ha)

Highest grain P uptake (25.37 kg/ha) was recorded for V3 (Sonagathi mutant-1), followed by V4 (Sonagathi parent) i.e. 23.08 kg/ha, while lowest for V2 (Javaphool parent) i.e. 12.82 kg/ha. Similar result was recorded for total phosphorus uptake ranging from 16.99 kg/ha by V2 (Javaphool parent) to 29.38 kg/ha by V3 (Sonagathi mutant-1). In case of straw phosphorus uptake, highest recorded for V4 (Sonagathi parent) i.e. 4.53 kg/ha followed by V2 (Javaphool parent) i.e. 4.17 kg/ha. N_{100} resulted in highest grain, straw and total P uptake i.e. 22.50, 5.00 and 27.49 kg/ha, respectively whereas lowest uptakes were observed by N_0. Results revealed that P uptake and accumulation increased on increasing N level.

Plant potassium uptake (kg/ha)

Grain, straw and total potassium uptake was significantly affected by varying nitrogen levels among different varieties. But, interaction effect of both factors was found to be non-significant on K uptake. Maximum total K uptake (96.02 kg/ha) was found for V2 (Javaphool parent), followed by V4 (Sonagathi parent) i.e. 88.54 kg/ha, whereas minimum total K uptake (83.90 kg/ha) was found for V3 (Sonagathi mutant-1). Lowest (14.12 kg/ha) and highest (21.21 kg/ha) grain K uptake were recorded for V2 (Javaphool parent) and V3 (Sonagathi mutant-1), respectively while, the lowest (62.69 kg/ha) and highest (81.90 kg/ha) straw K uptake were recorded for V3 (Sonagathi mutant-1) and V2 (Javaphool parent) respectively.N_{100} (100 kg N / ha) resulted in highest grain, straw and total K uptake i.e. 21.99, 87.10 and 109.09 kg/ha, respectively whereas lowest uptakes were observed by N_0.

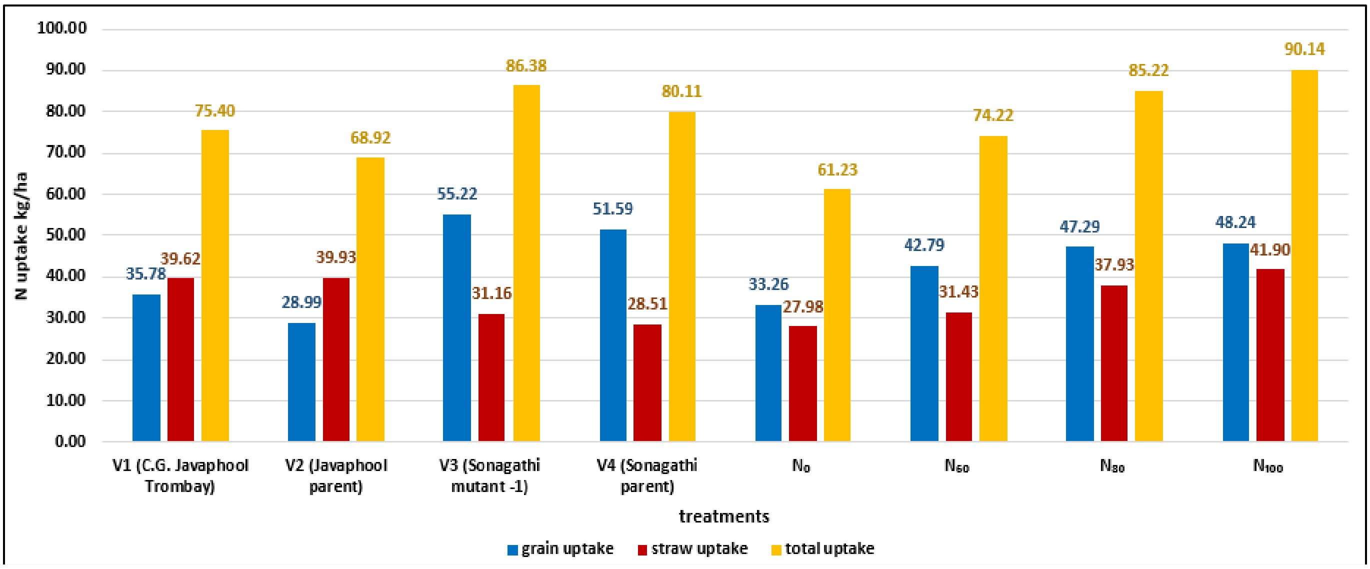

Fig 8: Effect of different nitrogen levels on grain, straw and total nitrogen uptake (kg/ha) by mutant and parent rice varieties

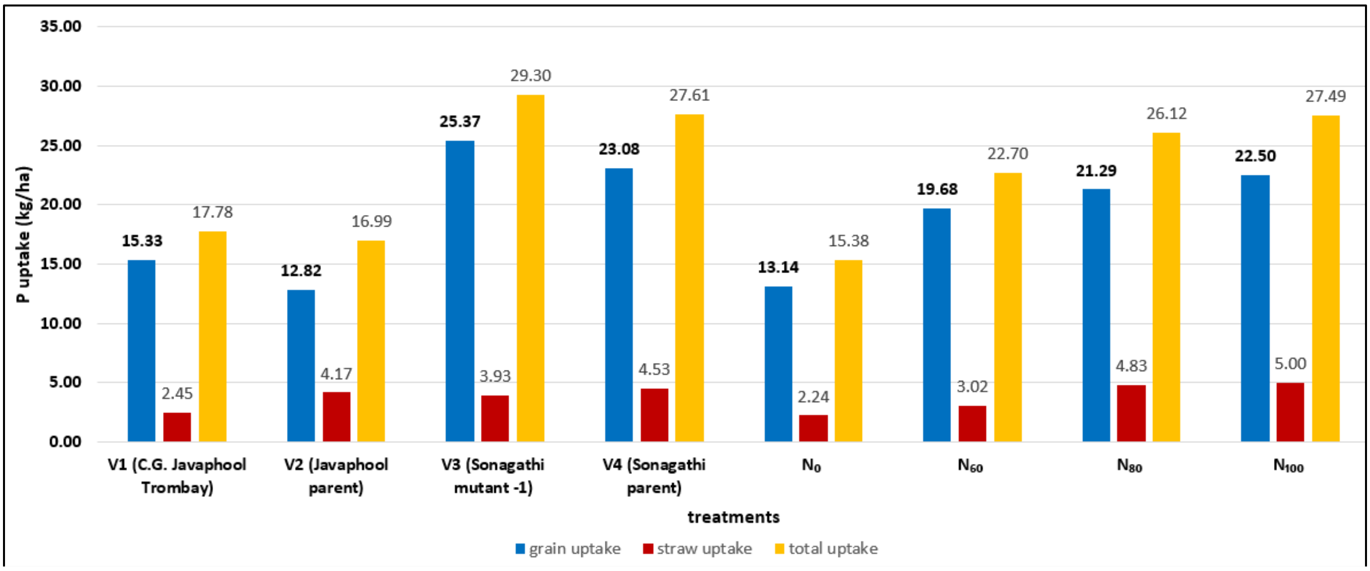

Fig 9: Effect of different nitrogen levels on grain, straw and total phosphorus uptake (kg/ha) by mutant and parent rice varieties

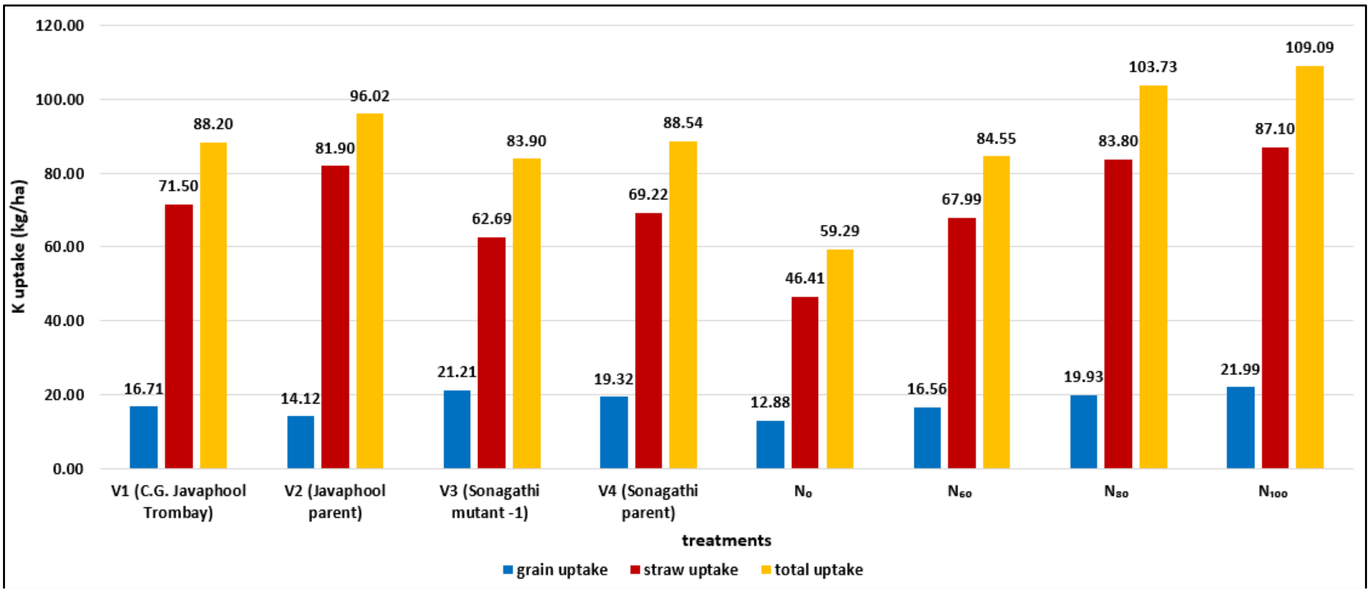

Fig 10: Effect of different nitrogen levels on grain, straw and total potassium uptake (kg/ha) by mutant and parent rice varieties

Nitrogen use efficiency

Among four varieties, V3 (Sonagathi mutant-1) (30.12%) was found to be superior with respect to N-use efficiency over others. In case of nitrogen applications, the highest NUE (29.98%) was observed in N_{80} (80 kg/ha) levels. Data revealed that NUE firstly increased with increasing N doses up to N_{80} (80 kg/ha) levels, after that, it decreased at N_{100}. Similar results were found by Shivay Y.S. *et al*., (200) [13]. Interaction effect of varieties with nitrogen levels (N×V) influenced the grain yield. Varieties Sonagathi mutant-1 (V3) and Sonagathi parent (V4) significantly increased the grain yield up to 80 kg N / ha whereas C.G. Javaphool Trombay (V1) and Javaphool parent (V2) responded only up to 60 kg N / ha. This might be due to higher nitrogen uptake at higher nitrogen supply which ultimately led to biomass production through enzymatic activities like glutamine synthetase, glutamate synthase and glutamate dehydrogenase. (Miflin and Habash., 2002) [22]

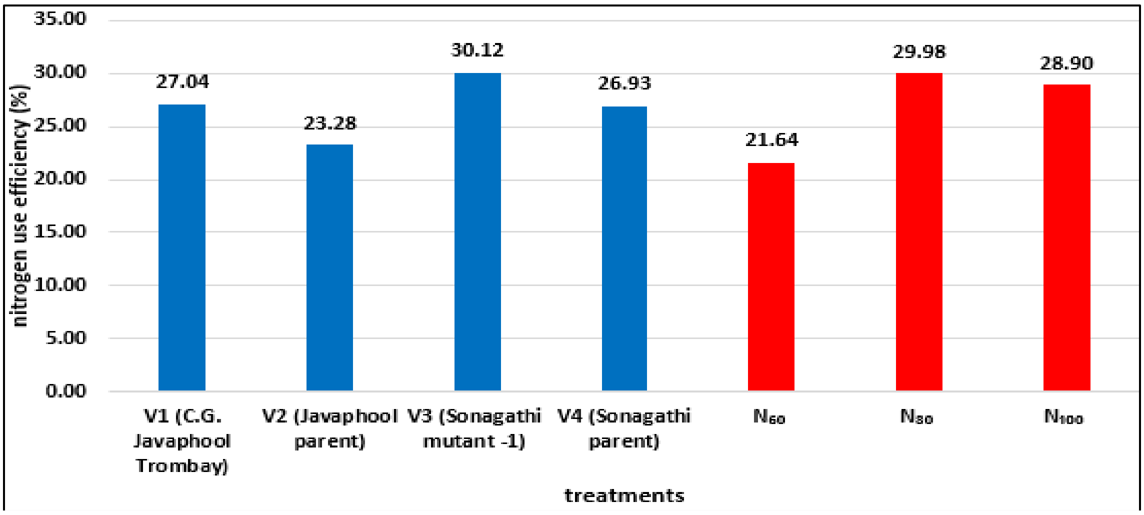

Fig 11: Nitrogen use efficiency (%) of mutant and parent rice varieties

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