*Bangladesh J. Nuclear Agric. 33 & 34: 19-26 (December, 2020)* *ISSN 0258-7130*

# EFFECT OF ROW SPACING AND DATES OF TRANSPLANTING ON YIELD PERFORMANCE OF KASALATH RICE MUTANT IN T. AMAN SEASON OF BANGLADESH

**M. I. Ali [1], M.M. Islam[1], M. S. Islam[1], M. A. K. Azad[2] and M. T. R. Mondal[3]**

**Abstract**

Proper time of transplanting and appropriate spacing are necessary for standardization the yield potential of advance kasalath rice mutants in Bangladesh climatic condition.Thefield experiments were conducted at BINA Headquarters farm, Mymensingh in T. Amanseason of 2017 and 2018 to see the performance of two mutant lines of Kasalath under different dates of transplanting and spacings. In 2017, two advanced mutant lines namely RM-Kas-60(C)-1, RM-Kas-80(C)-1were evaluated along with BRRI dhan49 at three levels of spacing, viz. 20cm×15cm, 20cm×20cm and 20cm×25cm. Mutant line RM-Kas-60(C)-1 produced statistically higher grain yield (4.8 t $ha^{-1}$) at 20cm×15cm spacing. In 2018, only RM-Kas-60(C)-1 was evaluated against Binadhan-11, at three row spacing (viz. 20cm×15cm, 20cm×20cm and 20cm×25cm) and three dates of transplanting such as July 15, July 30 and August 15. Among three transplanting dates, RM-Kas-60(C)-1 produced the highest grain yield of 4.86 t $ha^{-1}$ at 20cm×15cm spacing when transplanted on July 30. Overall observation showed that RM-Kas-60(C)-1 yielded the best at 20cm×15cm when transplanted on July 30 under rainfed condition of Bangladesh.

**Key words:** Spacing; dates of transplanting; yield; Kasalath rice mutants

## Introduction

The deficiency of phosphorus (P) in rice soil is a worldwide problem. Low P in soil may be due to the low P content of the parental material, low pH and/or soil with high P-fixing characteristics (Rose and Wissuwa 2012). Side by side with the application of costly P fertilizer, the development and use of less P uptake rice genotypes could offer a sustainable solution for such situation. Different genetic approaches have been taken to tackle this problem, and perhaps the most successful attempt was the identification and characterization of the major quantitative trait locus (QTL) Phosphorus uptake 1 (*Pup1*). *Pup1* was identified in the rice variety Kasalath (Wissuwa *et al.*, 2002), and near isogenic lines (NILs) carrying this QTL showed that *Pup1* conferred a significant yield advantage over the intolerant recurrent parent Nipponbare (Wissuwa 2005). Kasalath, the *Pup1* donor variety, was initially identified in a screening of 30 diverse rice genotypes in a P-deficient soil in Japan under rainfed conditions. Phenotypic data derived from Nipponbare contrasting near isogenic lines (NILs) with and without the QTL showed that *Pup*1 increased P uptake (Wissuwa *et al.*, 2002) and

[1]Agronomy Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202, Bangladesh
[2]Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202, Bangladesh
[3]Horticulture Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202, Bangladesh
*Corresponding author: ibrahimbd420@gmail.com

conferred a significant yield advantage (2 to 4-fold higher grain weight per plant) in p experiments using different P-deficient soil types and environments (Chin *et al.*, 2010).

The germplasm survey conducted with the above mentioned markers revealed that *Pup* is largely absent in modern irrigated rice varieties though highly conserved in drough tolerant breeding lines and upland varieties. This suggested that breeders are unknowingl selecting for *Pup1* in breeding programs that target drought-prone environments (Chin *et al* 2010).The impact of *Pup1* and other QTLs was the enhancement of grain yield in P-deficie soil and/or under drought stress (Bernier *et al.*, 2009). The mutant lines $M_6$, RM-Kas-60(C 1 and RM-Kas-80(C)-1 were discovered through carbon ion beam irradiation from 60 and Gy doses, respectively of indigenous Kasalath land races (A. K. Azad, 2018). Since most the Bangladesh rice soils are deficient in P, it is necessary to identify rice genotypes that a tolerant to P deficient soil environment. Moreover, it is also necessary to standardize th optimum planting time and planting spacing for exploiting the potential yield of the muta under Bangladesh conditions. This study was therefore, undertaken to study the yiel performance of the advanced mutant lines of Kasalath under different plant spacing an planting dates for growing under rainfed conditions in Bangladesh.

## Materials and Methods

Experiments were carried out at BINA Headquarters farm, Mymensingh during Ama season of 2017 and 2018.The experimental site was situated between 24.6°N and 90.5° latitude and at 18m high from the sea level. The soil of the experimental field was sand loam type and belongs to the Old Brahmaputra Flood Plain Alluvial Tract. The experiment plot was under the subtropical climate characterized by heavy rainfall during the month March to November. The advanced mutant lines RM-Kas-60(C)-1 and RM-Kas-80(C)- were collected from Plant Breeding Division of BINA and the check variety BRRI dhan 4 from Genetic Resource and Seed Division, Bangladesh Rice Research Institute.In 201 three levels of spacing, viz. 20cm×15cm ($S_1$), 20cm×20cm ($S_2$) and 20cm×25cm ($S_3$) we considered for transplanting on July 15. The fertilizer doses applied for the experiment we 80kg N $ha^{-1}$, 40kg P $ha^{-1}$, 50kg K $ha^{-1}$, 20kg S $ha^{-1}$ and 2kg Zn $ha^{-1}$. Twenty five days ol seedlings were transplanted in a randomized complete block design with three replicatio with single seedling per hill. The unit plot size was 3m×4m. The crop was harvested on O 15 and data on yield and yield components such as plant height, total number of tillers hill number of effective tillers $hill^{-1}$, panicle length, number of filled grains $panicle^{-1}$, number unfilled grains $panicle^{-1}$, thousand seed weight, grain yield, straw yield were recorded fro ten randomly selected plant. Yield data was taken from whole plot and converted into t hectare$^{-1}$ and analyzed statistically with statistix 10 data analysis software update versi 2018 and the means were compared.

In 2018, there were three transplanting dates such as July 15($D_1$) July 30($D_2$) an August 15($D_3$) and three line spacing's followed as 2017 were assigned for comparin

the performance of RM-Kas-60(C)-1 with check variety Binadhan-11. Twenty five days old seedlings were transplanted following split plot design with three replications with single seedling per hill. The application of herbicide (Bensulfuron methyl 4% + Acetachlor 14%) was necessary to keep the field free from weeds throughout the growing period along with a hand weeding at 35 days after transplanting (DAT). Furadan 5 G @ 10 kg $ha^{-1}$ was applied to control the infestation of stem borer. Three supplemental irrigations were needed due to less rainfall during the period from end of September to first week of October. After attaining 80% physiological maturity, the plants of Binadhan-11 were harvested on October 15, October30 & November 15and that of RM-Kas-60(C)-1 October 30, November 15 & November 30 for first, second and third dates respectively. The harvested plants were threshed, cleaned, and processed, and then yield and yield contributing characters, grain yield, straw yield were recorded. Weather parameters such as air temperature, soil temperature, relative humidity, rainfalland sunshine hours were also recorded for understanding the growing environment of the crop (Fig. 1).

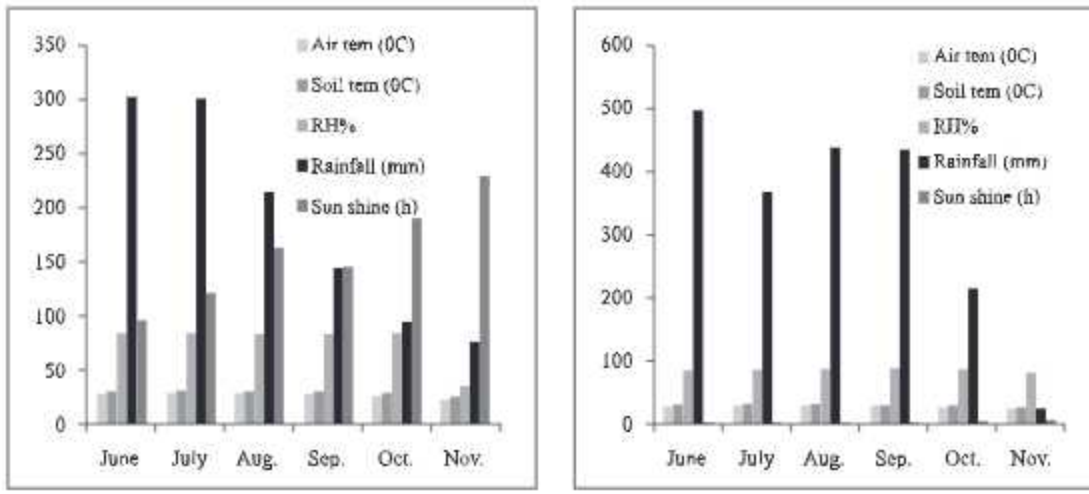


**Fig. 1.** Weather parameters during experimental period of 2017 and 2018 at BINA, Mymensingh

## Results and Discussion

***Effect of plant spacings on yield contributing characters of Kasalath rice mutant/variety in T. Aman season 2017:*** The effect spacings on plant height, total tillers and effective tillers $hill^{-1}$ and grain were significant (Table 1). The highest plant height (107.5cm) was observed at spacing of 20cm×15cm and the lowest (101.5cm) was observed at the spacing of 20cm×25cm. The highest plant height (104.3cm) was obtained in the mutant RM-Kas-60(C)-1 with spacing 20cm×20cm and 20cm×15cm. The highest number of total tillers $hill^{-1}$ (10.5) was observed at the spacing of 20cm×25cm and the lowest (9.7 $hill^{-1}$) was at the spacing of 20cm×20cm.

**Table 1. Effect of different spacing on the yield contributing characters and yield of rice mutants/variety in T. Aman season during 2017**

| Treatments | Plant height (cm) | Total tillers hill$^{-1}$ (no.) | Effective tillers hill$^{-1}$(no.) | Panicle length (cm) | Filled grains panicle$^{-1}$ (no.) | Unfilled grains panicle$^{-1}$ (no.) | 1000 seed wt. (g.) | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| **Spacing** | | | | | | | | | |
| 20cm×15cm ($S_1$) | 107.5 | 9.7 | 9.0 | 25.1 | 112.6 | 7.7 | 22.5 | 4.8 | 5.8 |
| 20cm×20cm ($S_2$) | 106.3 | 10.4 | 9.6 | 25.0 | 111.4 | 7.5 | 22.4 | 4.5 | 5.6 |
| 20cm×25cm ($S_3$) | 101.5 | 10.5 | 9.8 | 21.9 | 117.7 | 7.0 | 22.3 | 4.3 | 5.5 |
| $LSD_{0.05}$ | 1.5 | 0.3 | 0.3 | 2.73 | 8.33 | 0.80 | 2.55 | 0.2 | 0.36 |
| **Mutants/Varieties** | | | | | | | | | |
| RM-Kas-60(C)-1($V_1$) | 109.0 | 11.5 | 10.7 | 25.1 | 117.8 | 7.6 | 22.5 | 4.7 | 5.8 |
| RM-Kas-80(C)-1 ($V_2$) | 104.6 | 9.6 | 8.9 | 23.0 | 110.5 | 9.0 | 22.3 | 4.5 | 5.4 |
| BRRIdhan-49 ($V_3$) | 101.6 | 9.6 | 8.8 | 23.9 | 114.4 | 5.8 | 22.4 | 4.4 | 5.9 |
| $LSD_{0.05}$ | 4.5 | 1.92 | 0.8 | 1.1 | 8.88 | 3.00 | 0.48 | 0.38 | 0.50 |
| **Variety×Spacing** | | | | | | | | | |
| $V_1S_1$ | 103.7 | 9.1 | 8.2 | 25.3 | 107.4 | 4.0 | 22.1 | 4.8 | 6.2 |
| $V_1S_2$ | 104.3 | 10.0 | 9.0 | 25.0 | 110.5 | 6.1 | 22.2 | 4.5 | 6.1 |
| $V_1S_3$ | 103.3 | 10.5 | 9.6 | 24.7 | 116.3 | 5.7 | 22.4 | 4.3 | 5.5 |
| $V_2S_1$ | 104.3 | 8.3 | 8.0 | 24.9 | 108.1 | 7.1 | 22.4 | 4.6 | 6.1 |
| $V_2S_2$ | 103.0 | 9.4 | 8.5 | 25.1 | 112.7 | 7.0 | 22.3 | 4.5 | 6.0 |
| $V_2S_3$ | 102.7 | 10.0 | 9.4 | 24.4 | 115.5 | 7.9 | 22.4 | 4.2 | 5.3 |
| $V_3S_1$ | 98.0 | 8.8 | 7.9 | 21.9 | 118.2 | 5.7 | 22.4 | 4.6 | 6.5 |
| $V_3S_2$ | 97.7 | 9.8 | 9.2 | 22.2 | 121.6 | 4.1 | 22.8 | 4.4 | 5.7 |
| $V_3S_3$ | 97.7 | 10.5 | 9.8 | 21.8 | 119.1 | 4.7 | 22.9 | 4.2 | 5.5 |
| $LSD_{0.05}$ | 7.11 | 1.2 | 1.77 | 1.5 | 6.1 | 2.3 | 0.89 | 0.2 | 0.4 |
| CV% | 6.7 | 6.3 | 6.7 | 3.9 | 5.3 | 19.2 | 2.8 | 3.1 | 4.3 |

The highest number of total tillers hill$^{-1}$ (10.5) was obtained in the mutant RM-Kas-60(C)-1 and BRRIdhan49 with spacing of 20cm×25cm. The lowest number of total tillers hill$^{-1}$ (8.3) was observed in RM-Kas-80(C)-1 with spacing of 20cm×15cm.The highest number of effective tillers hill$^{-1}$ (9.8) was observed at the spacing of 20cm×15cm and the lowest number of effective tillers hill$^{-1}$ (9.0) at the spacing of 20cm×15cm. Amongst genotypes, the highest number of effective tillers hill$^{-1}$ (10.7) was observed at RM-Kas-60(C)-1 and the lowest was in BRRIdhan-49.There was no statistically significant difference of effective tillers hill$^{-1}$between spacing and genotypes. The interaction effect of genotype and spacing on effective tillers, panicle length, number of filled and unfilled grains panicle-1 and grain and straw yield was significant (Table 1). The highest panicle length (25.1 cm) was recorded at the mutant RM-Kas-60(C)-1 and the lowest (23.0 cm) was in RM-Kas-80(C)-1.For interaction, the highest panicle length (25.3 cm) was obtained in RM-Kas-60(C)-1 with spacing of 20cm×15cm and lowest panicle length (21.8 cm) was in the variety BRRI dhan49 with spacing of 20cm×25cm.The highest number of filled grains panicle$^{-1}$(121.6) was obtained in BRRI dhan49 with spacing of 20cm×20cm and lowest number of filled grains panicle$^{-1}$(107.4) in RM-Kas-60(C)-1 with spacing of 20cm×15cm. The highest number of unfilled grains panicle$^{-1}$(7.9) was obtained in the mutant RM-Kas-80(C)-1 with spacing of 20cm×25cm and the lowest was observed in RM-Kas-60(C)-1 with spacing.

20cm×15cm.The highest grain yield (4.8 t $ha^{-1}$) was recorded at the spacing of 20cm×15cmand the lowest grain yield (4.3 t $ha^{-1}$) was recorded at the spacing of 20cm×25cm (Table 1). Among the cultivars, highest grain yield (4.7 t $ha^{-1}$) was recorded in mutant RM-Kas-60(C)-1 and the lowest grain yield (4.4 t $ha^{-1}$) in the variety, BRRI dhan49. The highest grain yield (4.8 t $ha^{-1}$) was obtained in RM-Kas-60(C)-1 with spacing 20cm×15cm and the lowest grain yield (4.2 t $ha^{-1}$) was recorded in BRRI dhan49 under spacing of 20cm×25cm. The mutant RM-Kas-60(C)-1 produced the highest number of effective tillers/$m^2$, filled grains $panicle^{-1}$ and thousand grain weightunder the spacing of 20cm×15cm thereby showed the highest grain and straw yield. It might be due to maximum solar radiation interception by the mutant line RM-Kas-60(C)-1 which contributed to produce more assimilates and gives highest growth and development under the spacing of 20cm×15cm, thereby yield.

***Effect of plant spacing and transplanting date on yield contributing characters and yield of rice mutant/variety in T. Aman season 2018:*** Out of three transplanting dates, transplanted on July 30, 2018 produced the highest grain yield (4.71 t $ha^{-1}$)might be due to more filled grains $panicle^{-1}$ (139.7).Among the mutant line/variety, RM-Kas-60(C)-1 produced the highest grain yield (4.39 t $ha^{-1}$)might be due to more filled grains $panicle^{-1}$(136.5). The highest grain yield was recorded under the spacing of 20 cm×15 cm (4.54 t $ha^{-1}$). It might be due short stature of the plant and highest number of panicles $m^{-2}$ in (20 cm×15 cm) spacing congenial for growth and yield of the mutant. The wider spacing, 20 cm×25 cm showed the lowest grain yield (3.89 t $ha^{-1}$).

**Table 2. Effect of spacings and dates of transplanting on yield contributing characters and grain yield of rice mutant/variety in T. Aman season during 2018**

| Treatments | Plant height (cm) | Total tillers $hill^{-1}$ (no.) | Effective tillers $hill^{-1}$ (no.) | Panicle length (cm) | Filled grains $panicle^{-1}$ (no.) | Unfilled grains $panicle^{-1}$ (no.) | 1000 seed wt. (g.) | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| **Dates of transplanting** | | | | | | | | | |
| July. 15 ($D_1$) | 105.8 | 9.9 | 8.7 | 28.1 | 125.6 | 29.0 | 22.6 | 4.32 | 5.46 |
| July. 30 ($D_2$) | 102.3 | 9.2 | 8.3 | 25.9 | 139.7 | 17.1 | 22.5 | 4.71 | 5.45 |
| Aug. 15 ($D_3$) | 98.7 | 12.6 | 9.5 | 23.9 | 120.5 | 22.4 | 21.9 | 4.18 | 5.50 |
| $LSD_{0.05}$ | 3.0 | 3.4 | 0.8 | 1.5 | 18.2 | 3.1 | 0.9 | 4.8 | NS |
| **Mutant/Variety** | | | | | | | | | |
| RM-Kas-60(C)-1 | 107.6 | 13.2 | 8.8 | 26.5 | 136.5 | 23.5 | 22.2 | 4.39 | 5.39 |
| Binadhan-11 | 97.0 | 9.9 | 8.9 | 25.4 | 120.7 | 15.1 | 22.4 | 4.14 | 5.56 |
| $LSD_{0.05}$ | 9.70 | 3.0 | 0.3 | 1.4 | 14.8 | 6.4 | 0.3 | 0.25 | 0.27 |
| **Row spacing** | | | | | | | | | |
| 20cm×15cm ($S_1$) | 101.7 | 14.2 | 7.9 | 25.4 | 122.3 | 24.0 | 22.3 | 4.54 | 5.82 |
| 20cm×20cm ($S_2$) | 102.4 | 10.1 | 9.1 | 26.0 | 126.1 | 21.4 | 22.3 | 4.16 | 5.47 |
| 20cm×25cm ($S_3$) | 102.7 | 10.5 | 9.4 | 26.5 | 137.4 | 23.1 | 22.4 | 3.89 | 5.12 |
| $LSD_{0.05}$ | 3.85 | 4.2 | 0.7 | 0.5 | 6.2 | 2.8 | 0.2 | 0.16 | 0.18 |
| CV% | 5.1 | 11.1 | 10.3 | 6.4 | 9.6 | 14.6 | 2.99 | 4.56 | 6.80 |

The interaction effect of date and variety showed that RM-Kas-60(C)-1 produced the maximum yield (4.34 t $ha^{-1}$) when transplanted on July 30 (Table 3).There is a statistically significant difference on effect of date and variety. The highest filled grains $panicle^{-1}$(139.7) and lowest unfilled grains $panicle^{-1}$ produced in RM-Kas-60(C)-1 when on July 30.

Transplanting on July 30 produced the maximum yield (4.64 t $ha^{-1}$) at 20 cm×15 cm spacing. It might be due to the highest genetic expression for the mutant line in Mymensingh region where the rainfall was maximum during 15 June to September 15 when the raising of seedling, seedling transplanting, and tillering happened. Nonetheless, the bright sunshine at reproductive development phase was also congenial for optimum yield of the mutant line.The interaction effect between variety and spacing showed that RM-Kas-60(C)-1 produced maximum yield (4.63 t $ha^{-1}$) at 20 cm×15 cm spacing. It might be due to 20 cm×15 cm spacing congenial for suitable growth and development for more panicles produced $m^{-2}$ highest for the mutant RM-Kas-60(C)-1 and found maximum yield.

## Conclusion

The mutant line RM-Kas-60(C)-1 produced higher grain yield (4.8 t $ha^{-1}$) at 20cm×15cm spacing when transplanted on 30 July. Overall results suggest that yield of mutant line RM-Kas-60(C)-1 may express full potentialities in T. Aman season if favorable weather, edaphic conditions exist, proper management practices to control weeds, insects,diseases are provided at 20 cm×15 cm spacing and transplanted within 30 July.

## Acknowledgements

The authors would like to gratitude to staff of Agronomy field laboratory of Bangladesh Institute of Nuclear Agriculture for their co-operation during the period of experiment.

**Table 3. Interaction effect between spacing and transplanting dates on the yield and yield contributing characters of Kasalath rice mutant/variety in T. Aman season during 2018**

| Interaction | Plant height (cm) | Total tillers $hill^{-1}$ (no.) | Effective tillers $hill^{-1}$ (no.) | Panicle length (cm) | Filled grains $panicle^{-1}$ (no.) | Unfilled grains $panicle^{-1}$ (no.) | 1000 seed wt. (g.) | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| **Dates × Genotype** | | | | | | | | | |
| $D_1V_1$ | 110.6 | 9.8 | 8.6 | 29.1 | 131.6 | 29.3 | 22.8 | 4.15 | 5.38 |
| $D_1V_2$ | 100.9 | 9.9 | 8.8 | 27.1 | 119.6 | 28.7 | 22.4 | 4.08 | 5.53 |
| $D_2V_1$ | 104.5 | 9.4 | 8.6 | 25.5 | 149.6 | 19.0 | 22.5 | 4.34 | 5.35 |
| $D_2V_2$ | 100.2 | 9.0 | 8.0 | 26.3 | 129.7 | 15.2 | 22.4 | 4.21 | 5.56 |
| $D_3V_1$ | 107.6 | 20.4 | 9.1 | 25.0 | 128.2 | 22.1 | 21.3 | 4.22 | 5.43 |
| $D_3V_2$ | 89.9 | 10.8 | 9.9 | 22.9 | 112.8 | 22.8 | 22.4 | 4.13 | 5.58 |
| $LSD_{0.05}$ | 2.3 | NS | 1.4 | 1.1 | 14.2 | 10.1 | NS | NS | 0.20 |
| **Genotype × Spacing** | | | | | | | | | |
| $V_1S_1$ | 107.3 | 19.2 | 7.9 | 26.0 | 127.5 | 26.0 | 22.1 | 4.63 | 5.83 |
| $V_1S_2$ | 107.5 | 10.5 | 9.4 | 26.5 | 136.4 | 23.6 | 22.1 | 4.16 | 5.36 |
| $V_1S_3$ | 107.9 | 9.9 | 9.0 | 27.1 | 145.6 | 20.8 | 22.4 | 3.79 | 4.97 |
| $V_2S_1$ | 96.1 | 9.1 | 7.9 | 24.9 | 117.1 | 22.0 | 22.5 | 4.46 | 5.81 |
| $V_2S_2$ | 97.4 | 9.7 | 8.8 | 25.5 | 115.8 | 19.2 | 22.4 | 4.16 | 5.59 |
| $V_2S_3$ | 97.6 | 11.0 | 9.9 | 25.8 | 129.2 | 25.4 | 22.4 | 3.80 | 5.27 |
| $LSD_{0.05}$ | 3.1 | 2.1 | 1.7 | 1.3 | 15.3 | 13.7 | NS | 0.14 | 0.20 |
| CV% | 5.1 | 11.1 | 10.3 | 6.4 | 9.6 | 14.6 | 2.99 | 4.56 | 6.80 |

$D_1$ = 15 July, $D_2$ = 30 July and $D_3$ = 15 August; $S_1$ = 20cm×15cm, $S_2$ = 20cm×20cm and $S_3$ = 20cm×25cm; $V_1$ = RM-Kas-60(C)-1, $V_2$ = Binadhan-11

## References


Azad, A. K. 2018. Advance yield trial with $M_6$ Kasalath mutants. Bangladesh Institute of Nuclear Agriculture, Annual research report 2017-18. p.14.

Bernier, J., Kumar, A., Venuprasad, R., Spaner, D., Verulkar, S., Mandal, N.,P., Sinha, P.K., P eeraju, Dongre,P. and Mahto,P. R. 2009. Characterization of the effect of a QTL for drought resistance in rice, qtl12.1, over a range of environments in the Philippines and eastern India. Euphytica: 166: 207–217.

Chin, J.H., Lu, X., Haefele, S.M., Gamuyao, R., Ismail, A., Wissuwa, M. and Heuer, S. 2010.Development and application of gene-based markers for the major rice QTL *Phosphorus uptake 1*. Theor. Appl. Genet. 120: 1073–1086.

Rose, T. J. andWissuwa, M.2012. Rethinking internal phosphorus utilization efficiency: a new approach is needed to improve PUE in grain crops. Adv. Agron. 116:183–215.

Statistix 10 upgrade version 2018.Analytical Software for Statistix. Data analysis software for researchers. 2105 Miller Landing Rd, Tallahassee, FL 32312.

Wissuwa, M. 2002. Combining a modeling with a genetic approach in establishing associations between genetic and physiological effects in relation to phosphorus uptake. Plant Soil:269: 57-68.

Wissuwa, M., Wegner, J. A, N. and Yano, M. 2002. Substitution mapping of Pup1: a major QTL increasing phosphorus uptake of rice from a phosphorus deficient soil. Theor. Appl. Genet:6-7(890-897).

Wissuwa, M. 2005.Combining a modelling with a genetic approach in establishing associations between genetic and physiological effects in relation to phosphorus uptake.Plant Soil: 269: 57-68.