Radiation induced mutation for resistance/tolerance against *Fusarium oxysporum* f. sp. *ciceri* in chickpea (*Cicer arietinum* L.)

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Abstract

Chickpea (*Cicer arietinum* L.) is the third most important pulse crop grown throughout the world. *Fusarium oxysporum* f. sp. *ciceri* is a soil-borne as well as seed-borne fungus that is a serious threat, thereby inflicting heavy quantitative as well as qualitative losses in chickpea crop. In India, during 2017-18 Chickpea was cultivated on an area of 105.73 Lakh hectares with a production of 111.58 Lakh tonnes and productivity of 1056 kg/ha (Anonymous, 2018). Wilt of chickpea caused by *Fusarium oxysporum* f. sp. *ciceri* which one of the most prevalent and widely spreading disease in India. The pathogen is facultative saprophytic and it can survive as mycelium and chlamydospores in seed, soil and also on infected crops residues, buried in the soil for up to five to six years. The utilization of mutation breeding is a simple, cost effective and time saving method. Therefore, present investigation on “Radiation induced mutation for resistance against *Fusarium oxysporum* f. sp. *ciceri (Cicer arietinum L.*)” was aimed at identification of suitable mutant or a combination of mutants influencing resistance to Fusarium wilt in chickpea. The experimental material was consisted of the population of four selected cultivars of chickpea on the basis of popularity, high yield and disease reaction (JG 62, BDNG 798, JAKI 9218 and Vijay) grown in randomized block design at College of Agriculture Golegaon, during Rabi 2018-19. Dry seeds (10-12% moisture content) of JG 62, BDNG 798, JAKI 9218 and Vijay these varieties were irradiated with different doses of gamma rays (20 KR, 30 KR and 40 KR). Another set of presoaked seeds in distilled water (12 hrs.) were treated with ethyl methane sulphonate at different concentration (0.2%, 0.3% and 0.4%) prepared for 6 hrs. A portion of seeds irradiated at 20 KR and 30 KR gamma-ray doses were also treated with 0.2% and 0.3% EMS independently for 6 hrs. Present findings revealed that mutagenic treatments (20 KR, 30 KR, 0.2% EMS, 0.3% EMS, 20 KR+0.2% EMS, 30 KR+0.2% EMS) showed significant impact on various morphological and biological parameters of the plant habit. The effect of different doses of Gamma rays, EMS and combination of these treatments on the number of pods per plant, number of seeds per plant, seed yield per plant and 100 seed weight in M1 population of chickpea reveals that sufficient variability induced in genotypes for this character across the various treatments.

**Keywords:** *Fusarium oxysporum*, *Cicer arietinum* L.

Introduction

Chickpea (*Cicer arietinum* L.) is the third most important pulse crop grown throughout the world. About 65 per cent of the global area and 68 per cent of global production of chickpea is contributed by India. Fusarium wilt caused by *Fusarium oxysporum* f. sp. *ciceri* is one of the major disease causes up to 90% losses depending on weather conditions. The incidence is more if the crop is subjected to sudden temperature rise and water stress (Venkataramanamma et al., 2018) [8]. Physical mutagens such as ionising radiations and chemical mutagens that show resistance to pathogen and disease outbreak utilized for the development of elite crop varieties. Mutagenesis enables identification of wild genes or the creation of novel genes that impart disease resistance in cereals, legumes and economically important crops (Raina and Danish 2018) [9]. Different applications of induced mutagenesis have been released numerous cultivars of rice, maize, wheat, cotton, chickpea, rapeseed, mungbean, sesame, apple and durum wheat that are resistant to different bacteria, viruses and pathogen (Oladosu et al., 2016) [10].

Materials and Methods

The experiment was carried out at the College of Agriculture, Golegaon and Department of Plant Pathology, VNMKV, Parbhani (MH) during Rabi 2018-2019. Temperature extremes
vary between minimum temperature of 4.1 °C in December and January months to maximum temperature of 39 °C in March month. The average annual rainfall is 1011 mm. Chickpea seeds of JG 62, BDNG 798, JAKI 9218 and Vijay Genotype were collected from healthy plants at maturity stage of the crop. Chickpea seeds of different Genotype JG 62 were collected from AICRP on Chickpea, College of Agriculture Sehore, R.V.S.K.V.V., Gwalior (M.P) and remaining three Genotypes from ARS, Badnapur (MH). Gamma irradiation has been performed (Nuclear Research Laboratory RTMNU, Nagpur) in gamma chamber by exposing the seeds to the gamma rays from $^{60}$Co source was filled and handpicked uniform sized seeds with moisture content of 10-12% were chosen for irradiation. A sample of 150 seeds per treatment were packed in the butter paper cover and placed in 100 curie $^{60}$Co gamma cell. The treatments were given to various duration depending on the doses required (20 KR, 30 KR and 40 KR) with the dose rate of 12.2 KRads/seconds. The seeds were presoaked in water for 12 hours before treated with ethyl methane sulphonate at different concentration by using magnetic stirrer (0.2, 0.3 and 0.4%) for 6 hrs. A portion of seeds irradiated at 20 KR and 30 KR Gamma rays doses were also treated with 0.2 and 0.3% EMS independently for 6 hrs. with constant intermitted shaking in shaker and after that washed under running tap water. The treated seeds were sown in of 11-treatment combinations (including control) were evaluated separately for each Genotype planted in Randomized Block Design with three replication following biological parameters of observation during Rabi season 2018-19 at College of Agriculture, Golegaon., VNMKV, Parbhani.

Results and Discussion
Impact of mutagenic treatments on seed germination and some morphological parameters on chickpea genotypes

**JG-62, BDNG 798, JAKI 9218 and Vijay**

The varieties used for this comparative study are selected on the basis of popularity, high yield and disease reaction viz., JG 62, BDNG 798, JAKI 9218 and Vijay were selected to study the impact of the mutagenic treatments and all the results are compared on percentile average basis and presented below.

**Germination (%)**

The mean seed germination percentage in JG 62 was reported to be 83.42% at 20 and 30 KR, 75.78% at 40 KR respectively as compared to control. Similarly, the germination (%) was also reduced by using chemical mutagens. The germination (%) was noted to be 75.92% at 0.2% EMS followed by 57.40% at 0.4% EMS and 53.15% at 0.3% EMS treatments respectively. Whereas, germination (%) in combination of Gamma irradiation and EMS at treatment was reported as 77.94% at 20 KR+0.2% EMS and lowest 67.29% at 30 KR+0.2% EMS as compared to control (83.42%).

The mean seed germination percentage in BDNG 798 was reported to be 78.90% at 20 KR, 68.70% at 30 KR and 61.80% at 40 KR respectively as compared to control. Similarly, the germination (%) in chemical mutagens was noted to be 64.14% at 0.2% EMS followed by 65.20% at 0.4% EMS and 52.32% at 0.3% EMS treatments respectively. Whereas, germination (%) in combination of Gamma irradiation and EMS at treatment was reported as 64.99% at 20 KR+0.2% EMS and lowest 54.74% at 30 KR+0.3% EMS as compared to control (79.82%).

The mean seed germination percentage in JAKI 9218 was reported to be 83.42% at 30 KR, 81.41% at 20 KR, 74.67% at 40 KR, 62.06% at 0.2% EMS, 57.75% at 0.3% EMS and 48.44% at 0.4% EMS treatments, respectively. Whereas, the mean seed germination percentage in combination of Gamma irradiation and EMS at treatment were reported 68.14% at 30 KR+0.3% EMS and lowest germination at 30 KR+0.2% EMS i.e., 51.21% respectively as compared to control (82.54%).

The mean seed germination percentage in Vijay was reported to be 81.41% at 20 KR, 77.94% at 40 KR and 71.24% at 30 KR respectively as compared to control. Similarly, the germination (%) was also reduced by using chemical mutagens was noted to be 69.21% at 0.2% EMS followed by 59.48% at 0.3 and 0.4% EMS treatments respectively. Whereas, germination (%) in combination treatments was reported as 76.66% at 20 KR+0.3% EMS and lowest 52.34% at 30 KR+0.2% EMS as compared to control (83.42%).

| Variety* | JG 62 | BDNG 798 | JAKI 9218 | VIJAY |
|----------|-------|----------|-----------|-------|
| Gamma rays (KR) | | | | |
| 20 KR | 98.00 (83.42) | 93.33 (78.90) | 96.67 (81.41) | 96.67 (81.41) |
| 30 KR | 98.00 (83.42) | 86.67 (68.70) | 98.00 (83.82) | 89.33 (71.24) |
| 40 KR | 93.33 (75.78) | 77.33 (61.80) | 92.00 (74.67) | 95.33 (77.94) |
| Ethyl Methane sulphonate (%) | | | | |
| 0.2% EMS | 94.00 (75.92) | 80.67 (64.14) | 78.00 (62.06) | 87.33 (69.21) |
| 0.3% EMS | 64.00 (53.15) | 62.67 (52.32) | 71.33 (57.75) | 74.00 (59.48) |
| 0.4% EMS | 70.67 (57.40) | 82.00 (65.20) | 56.00 (48.44) | 74.00 (59.49) |
| Gamma rays + Ethyl methane sulphonate | | | | |
| 20 KR+0.2% EMS | 95.33 (77.94) | 81.33 (64.99) | 81.33 (64.90) | 78.00 (62.54) |
| 30 KR+0.2% EMS | 84.67 (67.29) | 72.67 (58.54) | 60.67 (51.21) | 62.67 (52.34) |
| 20 KR+0.3% EMS | 92.67 (74.50) | 79.33 (63.11) | 76.67 (62.17) | 94.00 (76.66) |
| 30 KR+0.3% EMS | 88.00 (70.25) | 66.67 (54.74) | 86.00 (68.14) | 74.67 (59.89) |
| Untreated | Control | 98.00 (83.42) | 96.67 (79.82) | 97.33 (82.54) | 98.00 (83.42) |
| Mean | 88.78 | 79.93 | 81.27 | 84.00 |
| CV | 6.15 | 8.52 | 7.95 | 7.00 |
| CD 5% | 9.31 | 11.62 | 11.02 | 10.03 |
| S.E+ | 3.15 | 3.93 | 3.73 | 3.39 |
| F. cal | 13.30 | 6.76 | 15.15 | 12.18 |

* Mean of three replications
Figures in parenthesis are angular arc sine transformation

**Seedling height (cm)**

In genotype JG 62 results revealed that mean seedling height (cm) after 14 days of sowing was reported to be in Gamma rays dose 30 KR i.e., 11.67 cm followed by 11.47 cm at 20 KR and 11.32 cm at 40 KR. Similarly in chemical mutagenic treatments the seedling height was 9.87 cm at 0.2% EMS,
9.27 cm at 0.3% EMS and 9.00 cm at 0.4% EMS respectively. Whereas in combination treatments the mean seedling height was noted to be 11.00 cm at 30KR+0.2%EMS followed by 10.20 cm at 20KR+0.2% EMS, 10.00 cm at 30KR+0.3%EMS and 9.47 cm at 20KR+0.3%EMS respectively, as compared to control.

Mean seedling height (cm) in BDNG 798 was noted in genotype BDNG 798 was 30.00 cm at 30 KR, 34.50 cm in 0.2% EMS and 35.73 cm in combination treatment 20 KR+0.3%EMS and 9.47 cm at 20KR+ 0.3%EMS respectively, as compared to control.

The maximum mean plant height (cm) was noted to be in JAKI 9218 i.e., 35.60 cm at 30 KR, 35.00 cm in 0.2% EMS and 38.37 cm in combination treatment 20 KR+0.2% EMS respectively, among the all treatments as compared to control. The mean plant height (cm) was noted in genotype Vijay i.e., 35.00 cm at 30 KR, 34.50 cm in 0.2% EMS and 35.73 cm in combination treatment 30 KR+0.2% EMS respectively, which was maximum among all the treatments as compared to control.

| Treatment | Doses | Variety* |
|-----------|-------|----------|
| Gamma     | 20 KR | JG 62    |
|           |       | BDNG 798 |
|           |       | JAKI 9218|
|           |       | VIJAY    |
| rays (KR) | 30 KR | JG 62    |
|           |       | BDNG 798 |
|           |       | JAKI 9218|
|           |       | VIJAY    |
| Ethyl     | 0.2% EMS | 30 KR+0.3% EMS |
| methane   | 0.3% EMS | 30 KR+0.3% EMS |
| Sulphonate | 0.4% EMS | 30 KR+0.3% EMS |
| Gamma rays | 20 KR+0.2% EMS | 30 KR+0.3% EMS |
| + Ethyl methane | 30 KR+0.2% EMS | 30 KR+0.3% EMS |
| Sulphonate | 0.3% EMS | 30 KR+0.3% EMS |
| Untreated | Control | 30 KR+0.3% EMS |
| Mean      | CV    | 30 KR+0.3% EMS |
|           | CD 5% | 30 KR+0.3% EMS |
|           | S.Em+ | 30 KR+0.3% EMS |
|           | F. cal | 30 KR+0.3% EMS |

* Mean of three replications

Number of pods/plants

The highest number of mean pods per plants in JG 62 i.e., 94.07 was noted at 30 KR, followed by 92.40 at 40 KR and 90.90 at 20 KR. Minimum number of pods per plants was also increased using chemical mutagens, the highest pods per plant in EMS treatment was noted at 0.2% EMS (91.50), whereas in combination treatment highest mean pods per plants was reported to be 90.13 at 30KR+0.2% EMS as compared to control.

The number of pods per plants in genotype BDNG 798 was reported to be to be 69.30 at 40 KR, followed by 65.67 at 20 KR, 63.17 at 30 KR and in chemical mutagens 75.20 at 0.4% EMS. Whereas, in the combination treatment highest mean pods per plants was reported to be 90.00 at 30KR+0.2% EMS as compared to control.

In genotype JAKI 9218 the maximum number of mean pods per plants was reported to be 91.87 at 30 KR and 90.97 at 20 KR respectively. Similarly, in chemical mutagens maximum number of mean pods per plants was noted to be 89.37 at 0.2% EMS. Whereas in combination treatment highest mean pods per plant percentage was reported to be 81.27 at 20KR+0.2% EMS as compared to control.
Number of seeds/plant

The mean seeds per plant in genotype JG 62 were noted to be 90.63 at 30 KR followed by 88.33 at 40 KR and 87.33 at 20 KR. Similarly in chemical mutagenic treatments the mean seeds per plant percentage were noted to be 88.00 at 0.2% EMS followed by 86.50 at 0.4% EMS and 85.00 at 0.3% EMS respectively. Whereas the combination treatment showed highest mean seeds per plant percentage among the all mutagenic treatments which was noted to be 86.50 at 30KR+0.2% EMS as compared to control.

In genotype BDNG 798 minimum mean seeds per plant were noted to be 61.10 at 30 KR. Similarly in chemical mutagenic treatments the mean seeds per plant were noted to be 73.20 at 0.4% EMS followed by 70.33 at 0.3% EMS and 63.53 at 0.2%EMS respectively. In the combination treatment highest number of mean seeds per plant among all the mutagenic treatments was found 69.13 at 20KR+0.2% EMS as compared to control.

The highest mean seeds per plant in JAKI 9218 were noted to be 86.07 at 30 KR in gamma rays doses and in chemical mutagens 85.03 at 0.2% EMS, respectively. Whereas, the combination treatment (20 KR+0.2% EMS) showed highest mean seeds per plant percentage among the all mutagenic treatments which was noted to be 77.50 as compared to control.

The mean seeds per plant in genotype Vijay were noted to be maximum 88.37 at 30 KR in Gamma rays respectively. Similarly in chemical mutagenic treatments the highest mean seeds per plant were noted to be 79.00 at 0.3% EMS respectively. In the combination treatment highest number of mean seeds per plant among all the mutagenic treatments was found at 20KR+0.2% EMS (76.27) as compared to control.

Seed yield/plant (gm)

The mean seed yield per plant (gm) in genotype JG 62 was noted to be 15.02 gm at 30 KR followed by 13.00 gm at 40 KR and 12.99 gm at 20 KR. Similarly in chemical mutagenic treatments the highest mean seed yield per plant (gm) was 14.88 gm at 0.2%EMS, whereas in combination treatments (30 KR+0.2% EMS) the highest of mean seed yield per plant (gm) was noted to be 15.18 gm respectively.

Genotype BDNG 798 showed that the mean seed yield per plant (gm) was recorded to be highest 16.15 gm at 40 KR followed by 15.15 gm at 30 KR doses of Gamma rays treatments. Similarly in chemical mutagenic treatments the highest mean seed yield per plant (gm) was reported to be 16.40 gm at 0.3% EMS followed by 16.36 gm at 0.4% EMS. In combination treatments 20 KR+0.2% EMS the highest mean seed yield per plant was noted to be 17.76 gm followed by 17.69 gm at 30 KR+ 0.2% EMS respectively as compared to control.

In genotype JAKI 9218 was noted to be 15.61 gm at 40 KR followed by 14.86 gm at 30 KR, 13.73 gm at 20 KR and highest 17.27 gm at 0.2%EMS, whereas in combination treatments the highest mean seed yield per plant (gm) was noted to be 16.75 gm at 20 KR+0.2%EMS treatment, followed by 13.67 at 30KR+0.2% EMS respectively. The mean seed yield per plant (gm) in Vijay was noted to be 14.14 gm at 40 KR followed by 14.06 gm at 20 KR, 13.98 gm at 30 KR and highest 15.81 gm at 0.3%EMS, whereas in combination treatments the highest mean seed yield per plant (gm) was noted to be 15.25 gm at 20 KR+0.2%EMS treatment, followed by 12.44 gm at 30KR+0.2% EMS respectively.

Table 4: Effect of mutagenic treatments on number of pods per plants in M1 generation

| Treatment         | Doses | Variety*       |
|-------------------|-------|----------------|
|                   | JG 62 | BDNG 798       | JAKI 9218 | VIJAY |
| Gamma             | 20 KR | 90.90          | 65.67     | 90.97 | 90.80 |
| rays (KR)         | 30 KR | 94.07          | 63.17     | 91.87 | 92.27 |
|                   | 40 KR | 92.40          | 69.30     | 86.10 | 90.27 |
| Ethyl             | 0.2% EMS | 91.50      | 65.90     | 89.37 | 83.00 |
| Methane           | 0.3% EMS | 88.00        | 71.97     | 82.53 | 85.20 |
| Sulphonate (%)    | 0.4% EMS | 89.43        | 75.20     | 78.30 | 71.33 |
| Gamma rays        | 20 KR+0.2% EMS | 88.33     | 71.97     | 81.27 | 81.33 |
| +Ethyl methane    | 30 KR+0.2% EMS | 90.13    | 67.98     | 71.90 | 70.17 |
| Sulphonate        | 20 KR+0.3% EMS | 82.20    | 57.28     | 70.00 | 71.07 |
|                   | 30 KR+0.3% EMS | 75.63    | 57.80     | 74.17 | 59.80 |
| Untreated         | Control | 93.30       | 74.60     | 93.33 | 90.70 |
| Mean              |         | 88.72         | 67.35     | 82.71 | 80.54 |
| CV                |       | 5.16          | 8.41      | 7.16  | 7.05  |
| CD 5%             |       | 7.83          | 9.66      | 10.10 | 9.68  |
| S. Em+            |       | 2.64          | 3.27      | 3.42  | 3.28  |
| F. cal            |       | 4.19          | 3.52      | 5.93  | 11.00 |

* Mean of three replications

Table 5: Effect of mutagenic treatments on number of seeds per plant in M1 generation

| Treatment         | Doses | Variety*       |
|-------------------|-------|----------------|
|                   | JG 62 | BDNG 798       | JAKI 9218 | VIJAY |
| Gamma             | 20 KR | 16.33          | 62.60     | 85.67 | 86.13 |
| rays (KR)         | 30 KR | 90.63          | 61.10     | 86.07 | 88.37 |
|                   | 40 KR | 88.33          | 67.17     | 80.83 | 85.93 |
| Ethyl             | 0.2% EMS | 88.00      | 63.53     | 85.03 | 78.50 |
| methane           | 0.3% EMS | 85.00        | 70.33     | 78.73 | 79.00 |
| Sulphonate (%)    | 0.4% EMS | 86.50        | 73.20     | 74.83 | 65.67 |
| Gamma rays        | 20 KR+0.2% EMS | 84.00      | 69.13     | 77.50 | 76.27 |
| +Ethyl methane    | 30 KR+0.2% EMS | 86.50    | 66.43     | 68.70 | 65.30 |
| sulphonate        | 20 KR+0.3% EMS | 78.90    | 54.33     | 65.33 | 67.40 |
|                   | 30 KR+0.3% EMS | 72.33    | 54.60     | 70.20 | 55.13 |
| Untreated         | Control | 90.20         | 73.30     | 90.20 | 88.00 |
| Mean              |         | 85.25         | 65.07     | 78.46 | 75.97 |
| CV                |       | 5.93          | 8.85      | 8.02  | 7.96  |
| CD 5%             |       | 8.62          | 9.82      | 10.73 | 10.32 |
| S. Em+            |       | 2.92          | 3.32      | 3.63  | 3.49  |
| F. cal            |       | 3.37          | 3.92      | 4.90  | 10.20 |

* Mean of three replications
100 seed weight (gm)

The mean 100 seed weight (gm) in JG 62 was reported to be 16.58 gm at 30 KR followed by 14.88 gm at 20 KR and 14.72 gm at 20 KR. Similarly in chemical mutagenic treatments the highest mean 100 seed weight (gm) was 16.93 gm at 0.3%EMS, whereas in combination treatments (20 KR+0.3% EMS) the highest mean of 100 seed weight (gm) was noted to be 18.08 gm respectively as compared to control. The results showed that the mean 100 seed weight (gm) in genotype BDNG 798 was found to be 24.80 at 30 KR followed by 24.06 gm at 40 KR, 23.36 gm at 20 KR and 23.32 gm at 0.3%EMS followed by 22.36 gm at 0.4%EMS and 21.24 gm at 0.2%EMS, respectively. In combination treatments the mean 100 seed weight (gm) was noted to be 26.64 gm at 30KR+0.2%EMS followed by 26.38 gm at 20KR+0.3%EMS, 26.17 gm at 30KR+0.3%EMS and 25.70 gm at 20KR+0.2%EMS as compared to control.

In genotype JAKI 9218 the 100 seed weight (gm) was reported to be 19.32 gm at 40 KR followed by 17.27 gm at 30 KR and 16.03 gm at 20 KR respectively. Whereas highest chemical mutagenic treatments it was recorded to be 20.32 gm at 0.2% EMS also in combination treatments the maximum mean 100 seed weight was noted to be 21.62 gm at 20KR+0.2% EMS, EMS respectively, as compared to control. The mean 100 seed weight (gm) in Vijay was reported to be highest 16.46 gm at 40 KR. Similarly in chemical mutagenic treatments the highest mean 100 seed weight (gm) was 20.02 gm at 0.3%EMS, whereas in combination treatments (20 KR+0.2% EMS) the highest mean of 100 seed weight (gm) was noted to be 20.00 gm respectively as compared to control.

| Treatment  | Doses  | Variety* |
|------------|--------|----------|
|            |        | JG 62    | BDNG 798 | JAKI 9218 | VIJAY  |
| Gamma      | 20 KR  | 12.99    | 14.60    | 13.73     | 14.06   |
| rays (KR)  | 30 KR  | 15.02    | 15.15    | 14.86     | 13.98   |
|            | 40 KR  | 13.00    | 16.15    | 15.61     | 14.14   |
| Ethyl      | 0.2% EMS | 14.88    | 13.49    | 17.27     | 14.74   |
| methane    | 0.3% EMS | 14.39    | 16.40    | 13.38     | 15.81   |
| sulphonate(%) | 0.4% EMS | 13.01    | 16.36    | 11.75     | 12.28   |
| Gamma rays | 20 KR+0.2% EMS | 15.10    | 17.76    | 16.75     | 15.25   |
| +Ethyl methane | 30 KR+0.2% EMS | 15.18    | 17.69    | 13.67     | 11.21   |
| sulphonate | 20 KR+0.3% EMS | 14.26    | 14.33    | 13.50     | 12.44   |
|            | 30 KR+0.3% EMS | 11.28    | 14.28    | 13.49     | 10.61   |
| Untreated  | Control | 13.72    | 17.36    | 16.22     | 15.57   |
| Mean       |        | 13.89    | 15.78    | 14.57     | 13.64   |
| CV         |        | 5.99     | 8.94     | 8.19      | 8.05    |
| CD 5%      |        | 1.42     | 2.40     | 2.03      | 1.87    |
| S.Em+      |        | 0.48     | 0.81     | 0.69      | 0.63    |
| F. cal     |        | 6.48     | 3.37     | 8.76      | 7.76    |

* Mean of three replications

| Variety* |
|----------|
| JG 62    |
| BDNG 798 |
| JAKI 9218|
| VIJAY    |

| Doses  | Variety* |
|--------|----------|
| Gamma  | 20 KR    |
| rays (KR) | 30 KR    |
|        | 40 KR    |
| Ethyl  | 0.2% EMS |
| methane| 0.3% EMS |
| sulphonate(%) | 0.4% EMS |
| Gamma rays | 20 KR+0.2% EMS |
| +Ethyl methane | 30 KR+0.2% EMS |
| sulphonate | 20 KR+0.3% EMS |
|            | 30 KR+0.3% EMS |
| Untreated  | Control   |
| Mean       |            |
| CV         | 6.11      |
| CD 5%      | 1.70      |
| S.Em+      | 0.58      |
| F. cal     | 4.87      |

* Mean of three replications

Lethality

The highest lethality percentage in M1 generation of genotype JG 62 was recorded in chemical mutagenic treatments, which was 47.33% at 0.4% EMS followed by 46.0% at 0.3% EMS, whereas in physical mutagenic treatment the maximum lethality was recorded to be 24.0% at 20 KR followed by 22.0% at 40 KR doses of Gamma rays treatments. Similarly, in combination treatments the maximum lethality percentage was recorded to be 30.0% at 30 KR+0.3% EMS followed by 29.33% at 20 KR+0.3% EMS as compared to control (23.33%) and in genotype BDNG 798 the highest lethality percentage was noted in combination treatments, which was 41.33% at 30 KR+0.3% EMS, whereas in physical mutagenic treatment the maximum lethality was recorded to be 26.0% in 20 KR and in chemical mutagenic treatments the maximum lethality percentage was recorded to be 38.67% at 0.3% EMS treatment respectively, as compared to control (12.0%). As well as in genotype JAKI 9218 showed the highest lethality...
percentage was noted in chemical mutagens treatments, which was 58.67% at 0.4% EMS, whereas in combination treatment the maximum lethality was recorded to be 49.33% in 30 KR+0.2% EMS followed by 28.67% at 20 KR+0.3% EMS treatments and in physical mutagenic treatments the maximum lethality percentage was recorded to be 16.67% at 40 KR dose of Gamma rays treatments as compared to control (19.33%).

The highest lethality percentage of genotype Vijay was recorded in chemical mutagenic treatments, which was 34.0% at 0.4% EMS followed by 31.33% at 0.3% EMS treatments respectively, whereas in physical mutagenic treatment the maximum lethality was recorded to be 24.0% at 30 KR followed by 20.0% at 40 KR doses of Gamma rays treatments. Similarly, in combination treatments the maximum lethality percentage was recorded to be 32.0% at 30 KR+0.3% EMS followed by 26.7% at 20 KR+0.2% EMS as compared to control (17.33%)

| Table 8: Effect of mutagenic treatments on lethality (%) in M₁ generation |
|-----------------|---------|---------|---------|---------|
| Treatment       | Doses   | Variety |          |
|-----------------|---------|---------|---------|
| Gamma rays (KR) | 20 KR   | 24.00   | 11.33   | 14.00   |
|                 | 30 KR   | 16.00   | 14.67   | 14.67   | 24.00   |
|                 | 40 KR   | 22.00   | 26.00   | 16.67   | 20.00   |
| Ethyl methane   | 0.2% EMS| 22.00   | 20.67   | 28.67   | 24.67   |
| Sulphonate(%)   | 0.3% EMS| 46.00   | 38.67   | 32.00   | 31.33   |
| Gamma rays      | 20 KR+0.2% EMS| 24.67 | 14.00   | 23.33   | 26.67   |
| + Ethyl methane | 30 KR+0.2% EMS| 28.67 | 26.67   | 49.33   | 23.33   |
| Sulphonate      | 20 KR+0.3% EMS| 29.33 | 22.00   | 28.67   | 20.00   |
| Un-treated      | Control | 23.33   | 12.00   | 19.33   | 17.33   |
| Mean            |         | 28.48   | 22.48   | 27.82   | 24.24   |
| CV              |         | 11.61   | 15.09   | 16.78   | 17.30   |
| CD 5%           |         | 5.64    | 5.79    | 7.96    | 7.15    |
| S.Em+           |         | 1.91    | 1.96    | 2.69    | 2.42    |
| F. cal          |         | 26.49   | 26.68   | 28.44   | 7.08    |

* Mean of three replications

The impact of the mutagenic treatments on seed germination and on some morphological traits

From the present investigation on impact of the mutagenic treatments on seed germination and on some morphological traits it was revealed that the mutagenic treatments viz., 20 KR, 30 KR, 0.2% EMS, 0.3% EMS, 20 KR+0.2% EMS and 30 KR+0.2% EMS among 11 treatments have shown some prominent effect on individuals of selected chickpea varieties viz., JG 62, BDNG 798, JAKI 9218 and Vijay as compared to other treatments. Reduction in germination in mutagenic treatment has been due to delay or inhibition of physiological and biological processes necessary for germination. It was also evident from the present study that the effectiveness of EMS treatments initially increased with an increase in concentration but decreased at higher concentration.

The present findings are conformity with the findings of Khan et al. (2005) [2] observed decrease in plant height, number of primary and secondary branches, pods per plant, seeds per pod and grain yield were significantly affected due to genotypes, treatments and also by their interaction.

The trend of the overall effectiveness of mutagenic treatments on experimental genotypes, JG 62, BDNG 798 and Vijay showed changes in their varetial characteristics which are in agreement with the findings of Shah et al. (2008) [9] in case of Pb-2000 and C-44 with mutagenic treatments. Wani (2009) [8] observed in case of Gamma rays, the lethality increased with an increase in dose from 150 to 400 Gy in var. Pusa-212 and Pusa-372, whereas it decreased beyond the dose of 300 Gy in the var. Pusa-212. It was further confirmed by comparing with similar results were earlier reported by Wani and Anis (2014) [10], Pawar et al. (2018) [4], Ungandhar et al. (2018) [3].

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