Plate-I: PMC’s showing meiotic abnormalities in the treated population of chickpea.

Fig. 1. Metaphase-I with 8 bivalents (Control)
Fig. 2. Metaphase-I with $2^I+3^II+1^III+1^V$
Fig. 3. Metaphase-I showing stickiness
Fig. 4. Metaphase-I showing precocious separation of chromosomes
Fig. 5. Metaphase-I showing non-orientation of bivalents
Fig. 6. Anaphase-I (Control)
Fig. 7. Anaphase-I showing unequal separation of chromosomes
Fig. 8. Anaphase-I showing chromatin bridge and the laggard (Arrow points towards laggard)
Fig. 9. Anaphase-II (Control)
Fig. 10. Anaphase-II showing non-disjunction of chromosomes
Fig. 11. Telophase-I (Control)
Fig. 12. Telophase-I showing micronuclei formation
Fig. 13. Telophase-II (Control)
Fig. 14. Telophase-II showing disturbed polarity
Fig. 15. Telophase-I showing cytomixis
Plate-II:  Chlorophyll mutants.

Fig. 1.  Control seedling

Fig. 2.  Albina mutant (white leaves of seedling)

Fig. 3.  Chlorina mutant (light green colour)

Fig. 4.  Tigrina mutant (patches of green dots on leaflets)

Fig. 5.  Viridis mutant (viridine green colour)

Fig. 6.  Xantha mutant (bright yellow colour)
Plate-III: Morphological mutants (mutants with altered plant height and growth habit).

Fig. 1. Tall mutant
Fig. 2. Dwarf mutant
Fig. 3. Bushy mutant
Fig. 4. Prostrate mutant
Plate-IV: Morphological mutants (mutants with altered growth habit).

Fig. 1. Control

Fig. 2. Axillary branched mutant

Fig. 3. One sided branching mutant

Fig. 4. Spreading mutant
PLATE - IV
Plate-V: Morphological mutants (mutants with altered leaf morphology).

Fig. 1. Leaf of control plant

Fig. 2. Narrow leaf (small narrow leaflets with pointed tips)

Fig. 3. Giant leaf mutant (large and thick leaflets, larger size stipules)

Figs. 4 & 5. Altered leaf architecture mutants

Fig. 6. Rachis (Control)

Fig. 7. Elongated rachis mutant
PLATE - V

1

2

3

4

5

6

7
Plate-VI: Morphological mutants (mutants with altered flower characters).

Fig. 1. Pink colour flower (Pusa-256-Control)

Fig. 2. White flower mutant of Pusa-256

Fig. 3. A branch showing double flowers (Pusa-256)

Fig. 4. White colour flower (BG-1053-1053)

Fig. 5. Light blue flower mutant of BG-1053

Fig. 6. Open flower mutant of BG-1053 (Androecium open)

Fig. 7. Open flower mutant of Pusa-256 (Androecium and Gynoecium open)

Fig. 8. Non-flowering/ Vegetative mutant
Plate-VII: High yielding mutants.

Fig. 1. Control plant (Pusa-256)

Fig. 2. Control plant (BG-1053)

Fig. 3. High yielding mutant (Pusa-256-A) isolated from 300Gy gamma rays treatment

Fig. 4. High yielding mutant (Pusa-256-B) isolated from 0.2% EMS treatment
Plate-VIII: High yielding mutants.

Fig. 1. High yielding mutant (Pusa-256-C) isolated from 0.3% EMS treatment

Fig. 2. High yielding mutant (Pusa-256-D) isolated from 100Gy gamma rays + 0.2% EMS treatment

Fig. 3. High yielding mutant (BG-1053-A) isolated from 200Gy gamma rays treatment

Fig. 4. High yielding mutant (BG-1053-B) isolated from 0.3% EMS treatment
Plate-IX: Pods and seeds of the control and high yielding mutants.

**Fig. 1.** Pods of the var. Pusa-256 (Control; left) and the mutant Pusa-256-C (right). Increased girth and pod length of the mutant

**Fig. 2.** Seeds of the var. Pusa-256 (Control; left) and the mutant Pusa-256-C (right). Increased seed size of the mutant

**Fig. 3.** Pods of the var. BG-1053 (Control; left) and the mutant BG-1053-A (right). Increased girth and pod length of the mutant

**Fig. 4.** Seeds of the var. BG-1053 (Control; left) and the mutant BG-1053-A (right). Increased seed size of the mutant
Plate-X: SDS-PAGE, surface graph and densitogram of seed storage proteins of the control and high yielding mutants of the var. Pusa-256.

Fig. 1. SDS-PAGE gel

Fig. 2. Surface graph of whole gel

Fig. 3. Densitogram of Markers (M), Control (Cl) and the mutants viz., Pusa-256-A (A), Pusa-256-B (B), Pusa-256-C (C) and Pusa-256-D (D)
Plate-XI: SDS-PAGE, surface graph and densitogram of seed storage proteins of the control and high yielding mutants of the var. BG-1053.

Fig. 1. SDS-PAGE gel

Fig. 2. Surface graph of whole gel

Fig. 3. Densitogram of Marker (M), Control (C) and the mutants viz., BG-1053-A (A) and BG-1053-B (B)
Protein markers:
M1: Phosphorylase b (97.4 kDa); M2: Bovine serum albumin (66 kDa); M3: Ovalbumin (43 kDa); M4: Carbonic anhydrase (29 kDa); M5: Soyabean trypsin inhibitor (20.1 kDa); M6: Lysozyme (14.3 kDa)
Protein markers:
M1: Phosphorylase b (97.4 kDa); M2: Bovine serum albumin (66 kDa); M3: Ovalbumin (43 kDa); M4: Carbonic anhydrase (29 kDa); M5: Soyabean trypsin inhibitor (20.1 kDa); M6: Lysozyme (14.3 kDa)
APPENDICES
Appendix I: Reagents used for the estimation of NRA, chlorophyll and carotenoid contents and mineral elements.

(A) 0.1M phosphate buffer (7.4 pH)
27.2 g of KH$_2$PO$_4$ and 45.63 g of K$_2$HPO$_4$·7H$_2$O were dissolved separately in 1000 ml of DDW.
The above solution of KH$_2$PO$_4$ and K$_2$HPO$_4$·7H$_2$O were mixed in the ratio of 36:64, respectively.

(B) 0.2M potassium nitrate
20.2 g of KNO$_3$ was dissolved in sufficient DDW and final volume was made up to 1000 ml using DDW.

(C) Isopropanol (5%)
5 ml of isopropanol was pipette into sufficient DDW and final volume was made up to 100 ml, using DDW.

(D) Sulphanilamide (1%)
1 g of sulphamnilamide was dissolved in 100 ml of 3N HCL.
3N HCL was prepared by dissolving 25.86 ml of HCl in sufficient DDW and final volume was maintained to 100 ml, using DDW.

(E) N-1-ethyl-ethylenediamine dihydro chloride-HCl (NED-HCl) (0.02%)
20 mg of NED-HCl was dissolved in sufficient DDW and final volume was made up to 100 ml, using DDW.

(F) Acetone (80%)
80% acetone was prepared by mixing 80 ml of acetone with 20 ml of DDW.

(G) Acid mixture
The acid mixture was made by nitric, sulfuric, and perchloric acids in the ratio 10: 1: 4 by volume, respectively.
Appendix II: Reagents used for the estimation of seed protein.

Reagent A:
2\% of sodium carbonate in 0.1 N NaOH (1\:1) ratio

Reagent B:
0.5\% of CuSO\textsubscript{4} in 1\% of sodium tartarate (1\:1) ratio

Reagent C:
Alkaline CuSO\textsubscript{4} in solution obtained by mixing 50 ml of reagent A with 1 ml of reagent B

Reagent D:
Carbonate copper sulphate solution same as C except for omission of NaOH

Reagent E:
Folin’s phenol reagent; Folin phenol reagent was made after diluting it with DDW in the ratio of 1:2

Reagent F:
1N NaOH
Appendix III: Reagents and components used in SDS-PAGE.

(A) Re-suspension buffer:
- Tris (pH 6.8) – 50 mM
- DDT – 100 mM
- 2% SDS

(B) Resolving gel: (10% gel)
- Distilled H2O – 12.3 ml
- 1.5 M Tris HCl (pH 8.8) – 7.5 ml
- 20 % SDS – 0.15 ml
- 30% Acrylamide solution – 9.9 ml
- 10% ammonium persulphate (APS) – 0.15 ml
- TEMED – 0.015 ml

(C) Stacking gel: (4% gel)
- Distilled H2O – 3.075 ml
- 0.5 M Tris HCl (pH 6.8) – 1.25 ml
- 20 % SDS – 0.025 ml
- 30% Acrylamide solution – 0.67 ml
- 10% ammonium persulphate (APS) – 0.025 ml
- TEMED – 0.005 ml

*APS and TEMED were added just prior to pouring the gel.

(D) 5X Running buffer:
- Tris base – 15 g
- Glycine – 72 g
- SDS – 5 g
- Distilled H2O – make volume upto 1 litre
  (Diluted to 1X before use)

(E) Staining:
- Washing solution - 1 ml formaldehyde+40 ml methanol+60 ml distilled water
- Sodium thiosulphate - 200 mg in 1 litre water
- Silver nitrate solution – 0.1%
- Developer - sodium carbonate (3g) in 80 ml water+sodium thiosulphate solution (1ml) and formaldehyde (1ml) and make the volume 100 ml with water
- Stopper - acetic acid solution (5%)

*All the components have been added sequentially
Appendix IV: Estimates of mean (\( \bar{X} \)), coefficient of variation (C.V.\%) for various quantitative traits in M\(_1\) generation of chickpea (Cicer arietinum L.) var. Pusa-256.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days to flowering</th>
<th>Plant height (cm)</th>
<th>Days to maturity</th>
<th>Pods bearing branches/plant</th>
<th>Pods/plant</th>
<th>Seeds/pod</th>
<th>100 seed weight (g)</th>
<th>Total plant yield (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>93.87±0.35</td>
<td>54.43±0.18</td>
<td>140.93±0.27</td>
<td>9.73±0.17 (3.08)</td>
<td>80.27±0.51</td>
<td>1.49±0.004</td>
<td>22.23±0.20</td>
<td>23.13±0.13</td>
</tr>
<tr>
<td>100 Gy γ rays</td>
<td>93.93±0.10</td>
<td>53.31±1.06</td>
<td>140.47±0.52</td>
<td>9.93±0.37 (6.44)</td>
<td>81.87±1.43</td>
<td>1.55±0.006</td>
<td>23.34±0.30</td>
<td>24.07±0.57</td>
</tr>
<tr>
<td>200 Gy γ rays</td>
<td>94.00±1.01</td>
<td>53.10±1.08</td>
<td>140.00±1.56</td>
<td>10.40±0.30</td>
<td>82.13±1.16</td>
<td>1.66±0.007</td>
<td>23.22±0.29</td>
<td>24.04±0.67</td>
</tr>
<tr>
<td>300 Gy γ rays</td>
<td>93.07±1.38</td>
<td>52.14±1.11</td>
<td>139.47±1.14</td>
<td>10.87±0.54</td>
<td>81.20±1.42</td>
<td>1.53±0.007</td>
<td>22.10±0.53</td>
<td>24.14±0.42</td>
</tr>
<tr>
<td>400 Gy γ rays</td>
<td>92.47±1.01</td>
<td>50.18±1.14</td>
<td>138.93±0.90</td>
<td>10.13±0.66</td>
<td>79.93±1.69</td>
<td>1.47±0.008</td>
<td>21.39±0.85</td>
<td>23.73±0.41</td>
</tr>
<tr>
<td>C.D. (p=0.05)</td>
<td>2.05</td>
<td>3.21</td>
<td>3.40</td>
<td>1.56</td>
<td>4.38</td>
<td>0.18</td>
<td>1.21</td>
<td>1.39</td>
</tr>
<tr>
<td>0.1% EMS</td>
<td>93.53±0.94</td>
<td>54.31±0.19</td>
<td>141.07±0.66</td>
<td>10.13±0.33</td>
<td>82.73±1.31</td>
<td>1.42±0.017</td>
<td>22.13±0.26</td>
<td>23.00±0.50</td>
</tr>
<tr>
<td>0.2% EMS</td>
<td>92.93±0.98</td>
<td>53.96±1.15</td>
<td>141.47±0.22</td>
<td>10.26±0.37</td>
<td>82.67±1.90</td>
<td>1.60±0.016</td>
<td>23.24±0.55</td>
<td>24.19±0.42</td>
</tr>
<tr>
<td>0.3% EMS</td>
<td>93.06±1.16</td>
<td>52.97±1.28</td>
<td>139.93±0.87</td>
<td>9.93±0.59</td>
<td>81.40±1.60</td>
<td>1.59±0.015</td>
<td>20.90±0.96</td>
<td>24.78±0.50</td>
</tr>
<tr>
<td>0.4% EMS</td>
<td>92.80±1.20</td>
<td>50.63±1.37</td>
<td>138.87±0.87</td>
<td>9.67±0.74</td>
<td>80.13±2.71</td>
<td>1.53±0.019</td>
<td>22.42±1.35</td>
<td>23.94±0.41</td>
</tr>
<tr>
<td>C.D. (p=0.05)</td>
<td>2.64</td>
<td>3.38</td>
<td>2.68</td>
<td>1.24</td>
<td>5.34</td>
<td>0.41</td>
<td>2.56</td>
<td>1.50</td>
</tr>
<tr>
<td>100Gy γ rays+0.1%EMS</td>
<td>94.20±1.10</td>
<td>52.78±0.74</td>
<td>140.87±0.48</td>
<td>10.00±0.23</td>
<td>82.27±1.38</td>
<td>1.44±0.009</td>
<td>21.94±0.60</td>
<td>23.98±0.36</td>
</tr>
<tr>
<td>100Gy γ rays+0.2%EMS</td>
<td>93.40±1.36</td>
<td>52.10±1.25</td>
<td>139.20±0.53</td>
<td>10.40±0.30</td>
<td>81.40±1.40</td>
<td>1.60±0.012</td>
<td>22.43±0.30</td>
<td>24.14±0.43</td>
</tr>
<tr>
<td>200Gy γ rays+0.1%EMS</td>
<td>93.40±0.80</td>
<td>51.28±1.04</td>
<td>139.07±1.07</td>
<td>9.47±0.40 (7.45)</td>
<td>81.47±0.94</td>
<td>1.53±0.010</td>
<td>22.09±0.38</td>
<td>23.12±0.68</td>
</tr>
<tr>
<td>200Gy γ rays+0.2%EMS</td>
<td>91.93±1.07</td>
<td>49.84±1.36</td>
<td>138.87±2.15</td>
<td>9.20±0.42 (7.83)</td>
<td>80.20±2.27</td>
<td>1.33±0.009</td>
<td>21.44±0.85</td>
<td>22.98±0.56</td>
</tr>
<tr>
<td>C.D. (p=0.05)</td>
<td>2.03</td>
<td>3.59</td>
<td>3.72</td>
<td>1.13</td>
<td>5.48</td>
<td>0.34</td>
<td>1.14</td>
<td>1.71</td>
</tr>
</tbody>
</table>

± Standard error; Figures in parenthesis represent C.V. (%).
* Significant at p=0.05 level.
### Appendix V: Estimates of mean (\( \bar{X} \)), coefficient of variation (C.V.%) for various quantitative traits in M$_2$ generation of chickpea (*Cicer arietinum* L.) var. BG-1053.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days to flowering</th>
<th>Plant height (cm)</th>
<th>Days to maturity</th>
<th>Pods bearing branches/plant</th>
<th>Pods/plant</th>
<th>Seeds/pod</th>
<th>100 seed weight (g)</th>
<th>Total plant yield (g)</th>
<th>C.D. (p=0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>98.00±0.23</td>
<td>57.35±0.27</td>
<td>146.87±0.40</td>
<td>12.27±0.18</td>
<td>91.67±0.47</td>
<td>1.32±0.002</td>
<td>19.21±0.24</td>
<td>20.14±0.40</td>
<td>5.74</td>
</tr>
<tr>
<td>100 Gy y rays</td>
<td>97.87±2.48</td>
<td>57.34±0.57</td>
<td>146.40±1.59</td>
<td>13.33±0.98</td>
<td>92.00±1.10</td>
<td>1.53±0.017</td>
<td>19.83±1.29</td>
<td>20.42±0.61</td>
<td>3.30</td>
</tr>
<tr>
<td>200 Gy y rays</td>
<td>98.53±1.28</td>
<td>56.88±1.74</td>
<td>145.53±1.85</td>
<td>12.67±0.57</td>
<td>91.27±1.35</td>
<td>1.41±0.020</td>
<td>20.24±1.05</td>
<td>21.34±0.60</td>
<td>1.67</td>
</tr>
<tr>
<td>300 Gy y rays</td>
<td>99.40±1.36</td>
<td>56.89±1.78</td>
<td>145.40±1.96</td>
<td>12.00±0.64</td>
<td>91.73±1.39</td>
<td>1.39±0.014</td>
<td>19.14±0.50</td>
<td>20.12±0.51</td>
<td>1.96</td>
</tr>
<tr>
<td>400 Gy y rays</td>
<td>98.87±1.77</td>
<td>54.98±1.71</td>
<td>145.00±2.09</td>
<td>11.93±0.59</td>
<td>90.53±1.71</td>
<td>1.31±0.013</td>
<td>19.00±0.71</td>
<td>21.32±0.88</td>
<td>0.86</td>
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<tr>
<td>C.D. (p=0.05) C. D. (p=0.05)</td>
<td>5.74</td>
<td>3.37</td>
<td>2.67</td>
<td>1.13</td>
<td>4.30</td>
<td>0.22</td>
<td>1.39</td>
<td>1.44</td>
<td></td>
</tr>
</tbody>
</table>

± Standard error; Figures in parenthesis represent C.V. (%).
Appendix VI: Comparative effects of gamma rays, EMS and their combinations on mean and coefficient of variation of various quantitative traits in M<sub>1</sub> generation of chickpea (*Cicer arietinum* L.) var. Pusa-256.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Control</th>
<th>Gamma rays</th>
<th>EMS</th>
<th>Gamma rays + EMS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>C.V. (%)</td>
<td>Mean*</td>
<td>C.V. (%)**</td>
</tr>
<tr>
<td>Days to flowering</td>
<td>93.87</td>
<td>0.65</td>
<td>93.37</td>
<td>2.04</td>
</tr>
<tr>
<td>Plant height (cm)</td>
<td>54.43</td>
<td>0.58</td>
<td>52.18</td>
<td>3.61</td>
</tr>
<tr>
<td>Days to maturity</td>
<td>140.93</td>
<td>0.33</td>
<td>139.71</td>
<td>1.58</td>
</tr>
<tr>
<td>Pods bearing branches/plant</td>
<td>9.73</td>
<td>3.08</td>
<td>10.33</td>
<td>7.86</td>
</tr>
<tr>
<td>Pods/plant</td>
<td>80.27</td>
<td>1.23</td>
<td>81.28</td>
<td>3.04</td>
</tr>
<tr>
<td>Seeds/pod</td>
<td>1.49</td>
<td>0.27</td>
<td>1.55</td>
<td>0.77</td>
</tr>
<tr>
<td>100 seed weight (g)</td>
<td>22.23</td>
<td>1.53</td>
<td>22.51</td>
<td>3.86</td>
</tr>
<tr>
<td>Total plant yield (g)</td>
<td>23.13</td>
<td>0.99</td>
<td>23.99</td>
<td>3.73</td>
</tr>
</tbody>
</table>

* Each value is the average of mean of four treatments.

** Each value is the average of coefficient of variation of four treatments.
Appendix VII: Comparative effects of gamma rays, EMS and their combinations on mean and coefficient of variation of various quantitative traits in M$_1$ generation of chickpea (*Cicer arietinum* L.) var. BG-1053.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Control</th>
<th>Gamma rays</th>
<th>EMS</th>
<th>Gamma rays + EMS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>C.V. (%)</td>
<td>Mean*</td>
<td>C.V. (%)**</td>
</tr>
<tr>
<td>Days to flowering</td>
<td>98.00</td>
<td>0.41</td>
<td>98.67</td>
<td>3.03</td>
</tr>
<tr>
<td>Plant height (cm)</td>
<td>57.35</td>
<td>0.84</td>
<td>57.49</td>
<td>4.49</td>
</tr>
<tr>
<td>Days to maturity</td>
<td>146.87</td>
<td>0.48</td>
<td>145.58</td>
<td>2.23</td>
</tr>
<tr>
<td>Pods bearing branches/plant</td>
<td>12.27</td>
<td>2.44</td>
<td>12.48</td>
<td>9.61</td>
</tr>
<tr>
<td>Pods/plant</td>
<td>91.67</td>
<td>0.88</td>
<td>91.38</td>
<td>2.63</td>
</tr>
<tr>
<td>Seeds/pod</td>
<td>1.32</td>
<td>0.23</td>
<td>1.41</td>
<td>1.97</td>
</tr>
<tr>
<td>100 seed weight (g)</td>
<td>19.21</td>
<td>2.13</td>
<td>19.55</td>
<td>5.61</td>
</tr>
<tr>
<td>Total plant yield (g)</td>
<td>20.14</td>
<td>3.43</td>
<td>20.80</td>
<td>5.39</td>
</tr>
</tbody>
</table>

* Each value is the average of mean of four treatments.

** Each value is the average of coefficient of variation of four treatments.