**STUDIES ON HETEROSIS AND INBREEDING DEPRESSION FOR YIELD AND IT’S CONTRIBUTING TRAITS IN GREENGRAM [*Vigna radiata* (L.) Wilczek]**

**Abstract**

The current investigation was carried out at Student Instruction Farm of Chandra Shekhar Azad university of Agriculture and Technology Kanpur, U.P. of nineteen diverse genotypes of greengram consisting of 16 lines and 3 testers. The genotypes were crossed in line x tester mating design during *kharif* 2021 to obtain the 48 F1 hybrids to test the standard heterosis against the commercial check KM2241. For getting the F2 seeds, half seeds of each F1 were sown in *zaid* 2022. The final trial comprising 48 F1s, 48 F2s and the check KM2241 were sown in randomized block design during *kharif* 2022. The best crosses that showed highly significant standars heterosis in positive direction for seed yield per plant as compared to the check were KM2401 X PDM139 followed by IPM302 X PDM139, KM2404 X PDM139, KM2426 X K851 and IP-7 X PDM139. The maximum negative and highly significant inbreeding depression against the check for seed yield per plant was estimated for KM2414 X PDM139 followed by KM2290 X KM2241, KM2290 X PDM139, KM2408 X PDM139 and KM2408 X K851. The crosses that showed maximum positive heterosis and maximum negative inbreeding depression for the seed yield per plant can be commercially exploited as hybrids for the improvement of greengram.

**Keywords:** Greengram, Heterosis, Inbreeding Depression

**Introduction**

The improvement of greengram is mainly dependent on the selection of crosses between several parents with limited genetic variability **(****Dhurai *et al.* 2016)**. The basic task of the breeder in self-pollinated species such as greengram is the aggregation of superior alleles into a single pure line or cultivar **(Elizabeth *et al.* 2016)**. Due to the evolutionary history of the cultivar, it is becoming increasingly apparent that what could be described as economic importance is not present even in the best cultivar. Incorporation of a highly useful allele would substantially improve the net genetic worth of the best populations available to breeders **(Suresh *et al.* 2018).** In this process, the operational problem is to identify a procedure that would yield genetic information about cultivar potential and to sequence a high proportion, if not all, of the favourable alleles that exist in one or other of several source populations in one or more base populations **(****Chavan *et al.* 2019)**. In India, the presence of many improved varieties that have increased production indicates that there is still scope for increasing the yield potential of cultivars through genetic improvement in the parent stock. To increase the yield potential of hybrids, it is necessary to rearrange genes by crossing and study heterotic effects in F1 and its maintenance in F2 generations **(Kakde *et al.* 2019)**. The study of heterosis and inbreeding depression will have a direct application of breeding methodology for genetic improvement of greengram **(Mohan *et al.* 2019)**.

**Materials and Methods**

19 diverse greengram genotypes out of which 16 lines namely KM2399, KM2401, KM2403, KM2404, KM2408, KM2409, KM2414, KM2417, SML664, SML681, IP-7, IPM302, HUM12, KM2290, KM2426, KM2427 and 3 testers K851, PDM139 and KM2241 were crossed in line x tester mating design to obtain 48 F1 hybrids during *kharif,* 2021. For obtaining the F2 seeds for the estimation of inbreeding depression half seeds of each F1 were grown during *zaid,* 2022. The final trial comprising half of each 48 F1s, 48 F2s and the check KM2241 were grown in the randomized block design during *kharif* 2022 at Student Instruction Farm, C. S. Azad University of Agriculture and Technology, Kanpur. Each treatment is grown in a plot of size 4m x 1.8m with the row length of 4m with spacing 30cm x 10cm. all the recommended agronomic practices were adopted for raising the good crop. The observations were recorded on randomly selected five plants from each treatment namely Days to 50% flowering, Days to maturity, Plant height (cm), Number of primary branches per plant, Number of clusters per plant, Number of pods per plant, Pod length (cm), Number of seeds per pod, 100-seed weight (g), Biological yield (g), Harvest index (%), Seed yield per plant (g) and Protein content (%).

**Results and Discussion**

Heterosis calculated as per cent increase over economic parent (KM2241) for thirteen characters have been given in table 1 and described as follows. The negative and significant values of heterosis was considered desirable for days to 50% flowering, days to maturity and plant height. However, for rest of the traits, positive and significant values were considered desirable.

Significant standard heterosis over KM2241 in the desirable direction was exhibited by different crosses in all the characters *viz*, IPM302 X K851, IPM302 X KM2241 and KM2403 X PDM139 for days to 50% flowering; KM2403 X K851, KM2403 X PDM139 and KM2403 X KM2241 for days to maturity; KM2408 X KM2241, KM2404 X K851 and KM2414 X K851 for plant height; KM2399 X PDM139, KM2404 X KM2241, KM2399 X KM2241 for number of clusters per plant; KM2404 X KM2241, KM2404 X PDM139andKM2404 X K851 for number of pods per plant; KM2414 X PDM139, KM2403 X K851 and KM2408 X KM2241 for pod length; KM2399 X PDM139, KM2414 X PDM139 and KM2399 X K851 for number of pods per plant; KM2399 X PDM13, IPM302 X PDM139 and SML664 X KM2241 for 100 seed weight; IPM302 X KM2241, HUM12 X K851 and IP-7 X KM2241 for biological yield; KM2408 X KM2241, HUM12 X KM2241 and KM2290 X K851 for harvest index; SML681 X PDM139, SML681 X K851 and KM2403 X K851 for protein content; KM2401 X PDM139, IPM302 X PDM139 and KM2404 X PDM139 for seed yield per plant. The findings are in conformity with the results of **Latha *et al.* (2019), Singh *et al.* (2021), Reddy *et al.* (2011), Dhurai *et al.* (2015)** and **Sandhiya and Saravanan (2018).**

The estimation of inbreeding depression has been presented in Table 2. The significant and positive estimates of inbreeding depression were desirable for days to 50% flowering, days to maturity and plant height. However, for rest of the traits, significant and negative values were considered desirable. The results obtained are described character wise under following heads.

The maximum positive inbreeding depression was recorded in KM2404 X PDM139, KM2404 X K851 and KM2408 X K851 for days to 50% flowering; KM2399 X KM2241, SML681 X K851 and KM2409 X K851 for das to maturity; KM2426 X K851, KM2426 X PDM139 and KM2290 X KM2241 for plant height. The maximum negative inbreeding depression was recorded in IP-7 X KM2241, KM2290 X PDM139 and KM2399 X K851for number of branches per plant; SML681 X K851, KM2414 X KM2241 and KM2403 X PDM139 for number of clusters per plant; KM2408 X KM2241, KM2414 X KM2241 and KM2401 X K851for number of pods per plant; KM2290 X KM2241, IP-7 X PDM139 and KM2404 X K851 for pod length; SML681 X KM2241, KM2290 X K851 and IPM302 X K851for number of seeds per pod; KM2290 X PDM139, KM2290 X KM2241 and HUM12 X PDM139 for 100 seed weight; SML681 X K851, KM2417 X KM2241 and KM2403 X K851 for biological yield; for KM2290 X KM2241, KM2414 X PDM139 and KM2408 X PDM139 for harvest index; KM2404 X KM2241, IP-7 X PDM139 and KM2290 X KM2241 for protein content; KM2414 X PDM139, KM2290 X KM2241 and KM2290 X PDM139 for seed yield per plant. Similar findings were also reported by **Khattak *et al.* (2007), Lenka *et al*. (2021), Singh *et al*. (2015), Srivastava *et al.* (2013)** and **Shalini *et al*. (2019).**

**Conclusion**

Significant standard heterosis over KM2241 in the positive direction for seed yield per plant were observed by KM2401 X PDM139, IPM302 X PDM139 and KM2404 X PDM139. The maximum negative inbreeding depression for seed yield per plant were observed by KM2414 X PDM139, KM2290 X KM2241 and KM2290 X PDM139. The crosses in which significant heterosis was followed by higher inbreeding depression, indicated the presence of non-additive gene action and can be used for commercial exploitation of heterosis.

**Table 1. Heterosis (%) over economic parent KM2241 for thirteen characters in greengram.**

\*Significant at 5%, \*\*Significant at 1%.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Crosses** | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Number of branches per plant** | **Number of clusters per plant** | **Number of pods per plant** | **Pod length (cm)** | **Number of seeds per pod** | **100-seed weight (g)** | **Biological yield (g)** | **Harvest index (%)** | **Protein content (%)** | **Seed yield per plant (g)** |
| KM2399 X K851 | -17.32\*\* | -8.61 \*\* | -10.00\*\* | -25.00 | 84.62 \*\* | 37.04 \*\* | -22.42 \*\* | 47.62 \*\* | 13.88 \* | 33.39 \*\* | 39.13 \*\* | 9.74 \*\* | 85.59 \*\* |
| KM2399 X PDM139 | -17.32 \*\* | -7.66 \*\* | -8.33 \* | -12.50 | 92.31 \*\* | 40.74 \*\* | -19.39 \*\* | 61.90 \*\* | 94.62 \*\* | -3.06 | 77.73 \*\* | 0.61 | 79.55 \*\* |
| KM2399 X KM2241 | -16.54 \*\* | -10.05 \*\* | -9.17 \* | -12.50 | 84.62 \*\* | 35.19 \*\* | -10.3 | 33.33 | 19.38 \*\* | 4.24 | 28.61 \*\* | 4.48 | 34.09 \*\* |
| KM2401 X K851 | -11.81 \*\* | -6.22 \*\* | -10.83 \*\* | -12.50 | 61.54 \*\* | 25.93 \*\* | -19.39 \*\* | 23.81 | 7.18 | -6.52 \* | 79.18 \*\* | 11.02 \*\* | 69.20 \*\* |
| KM2401 X PDM139 | -13.39 \*\* | -6.70 \*\* | -11.67 \*\* | -12.50 | 76.92 \*\* | 31.48 \*\* | -4.85 | 47.62 \*\* | 7.00 | 8.68 \*\* | 76.60 \*\* | 12.60 \*\* | 95.92 \*\* |
| KM2401 X KM2241 | -14.17 \*\* | -7.66 \*\* | -9.17 \* | 12.50 | 69.23 \*\* | 24.07 \*\* | -20.00 \*\* | 42.86 \* | -8.83 | 22.23 \*\* | 16.56 \*\* | 6.36 \* | 51.53 \*\* |
| KM2403 X K851 | -14.96 \*\* | -13.88 \*\* | -8.33 \* | -25.00 | 23.08 | 46.30 \*\* | -14.55 \* | 19.05 | -3.95 | -29.75 \*\* | 42.36 \*\* | 14.51 \*\* | -2.04 |
| KM2403 X PDM139 | -18.11 \*\* | -13.40 \*\* | -10.00 \*\* | 0.00 | 30.77 | 51.85 \*\* | -12.12 | 23.81 | 0.80 | -14.53 \*\* | 26.14 \*\* | 9.30 \*\* | 14.73 \*\* |
| KM2403 X KM2241 | -14.17 \*\* | -13.40 \*\* | -10.83 \*\* | -25.00 | 38.46 \* | 48.15 \*\* | -26.67 \*\* | 33.33 | 5.31 | 23.23 \*\* | 44.92 \*\* | 8.39 \*\* | 68.18 \*\* |
| KM2404 X K851 | -13.39 \*\* | -6.70 \*\* | -27.50 \*\* | -25.00 | 76.92 \*\* | 53.70 \*\* | -27.27 \*\* | 0.00 | 8.11 | 32.62 \*\* | 36.85 \*\* | 3.83 | 85.23 \*\* |
| KM2404 X PDM139 | -11.81 \*\* | -4.78 \* | -25.83 \*\* | -12.50 | 76.92 \*\* | 57.41 \*\* | -13.33 | 23.81 | 16.32 \* | -28.36 \*\* | 16.66 | 1.85 | 93.18 \*\* |
| KM2404 X KM2241 | -16.54 \*\* | -7.18 \*\* | -26.67 \*\* | -25.00 | 92.31 \*\* | 61.11 \*\* | -8.48 | 0.00 | -20.58 \*\* | 0.00 | 30.03 \*\* | 5.45 | 32.72 \*\* |
| KM2408 X K851 | -8.66 \*\* | -4.78 \* | -26.67 \*\* | -12.50 | 61.54 \*\* | 33.33 \*\* | -23.03 \*\* | 14.29 | -14.91 \* | 9.78 \*\* | 18.84 \*\* | 2.32 | 29.13 \*\* |
| KM2408 X PDM139 | -14.17 \*\* | -5.26 \*\* | -25.83 \*\* | -12.50 | 46.15 \*\* | 29.63 \*\* | -12.73 | 19.05 | -7.83 | 14.20 \*\* | 7.47 | 7.10 \* | 21.47 \*\* |
| KM2408 X KM2241 | -11.81 \*\* | -6.70 \*\* | -28.33 \*\* | 0.00 | 53.85 \*\* | 27.78 \*\* | -14.55 \* | 42.86 \* | 3.54 | -18.26 \*\* | 95.42 \*\* | 5.39 | 64.75 \*\* |
| **Table 1. Continued….**  **Crosses** | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Number of branches per plant** | **Number of clusters per plant** | **Number of pods per plant** | **Pod length (cm)** | **Number of seeds per pod** | **100-seed weight (g)** | **Biological yield (g)** | **Harvest index (%)** | **Protein content (%)** | **Seed yield per plant (g)** |
| KM2409 X K851 | -15.75 \*\* | -6.70 \*\* | -25.00 \*\* | -25.00 | 69.23 \*\* | 27.78 \*\* | -7.27 | 0 | 15.98 \* | -18.75 \*\* | 107.65 \*\* | 6.94 \* | 65.24 \*\* |
| KM2409 X PDM139 | -18.11 \*\* | -5.74 \*\* | -25.83 \*\* | -12.50 | 84.62 \*\* | 24.07 \*\* | -15.76 \* | 33.33 | 5.76 | -3.39 | 78.24 \*\* | 5.47 | 73.93 \*\* |
| KM2409 X KM2241 | -15.75 \*\* | -6.22 \*\* | -26.67 \*\* | -12.50 | 53.85 \*\* | 24.07 \*\* | -22.42 \*\* | 14.29 | 19.43 \*\* | 36.97 \*\* | 6.5 | 9.26 \*\* | 56.82 \*\* |
| KM2414 X K851 | -7.87 \*\* | -6.70 \*\* | -27.50 \*\* | -12.50 | 38.46 \* | 20.37 \*\* | -13.33 | 23.81 | 4.70 | 36.68 \*\* | -14.36 \*\* | 10.37 \*\* | 14.73 \*\* |
| KM2414 X PDM139 | -10.24 \*\* | -3.35 | -26.67 \*\* | 0.00 | 53.85 \*\* | 20.37 \*\* | -13.94 \* | 52.38 \*\* | -8.33 | 20.79 \*\* | 1.37 | 9.52 \*\* | 23.72 \*\* |
| KM2414 X KM2241 | -11.02 \*\* | -3.83 \* | -26.67 \*\* | -25.00 | 46.15 \*\* | 20.37 \*\* | -10.30 | 33.33 | -19.25 \*\* | 13.05 \*\* | -4.63 | 5.69 \* | 5.68 |
| KM2417 X K851 | -6.30 \* | -5.26 \*\* | -5.00 | -25.00 | 69.23 \*\* | 37.04 \*\* | -22.42 \*\* | 9.52 | -14.63 \* | 18.00 \*\* | 5.01 | 12.24 \*\* | 33.16 \*\* |
| KM2417 X PDM139 | -9.45 \*\* | -10.05 \*\* | -4.17 | -12.50 | 76.92 \*\* | 40.74 \*\* | -26.06 \*\* | 14.29 | -2.98 | -7.48 \* | 56.98 \*\* | 8.16 \*\* | 54.55 \*\* |
| KM2417 X KM2241 | -11.02 \*\* | -9.57 \*\* | -2.5 | 0.00 | 69.23 \*\* | 35.19 \*\* | -20.00 \*\* | -14.29 | 3.14 | -27.60 \*\* | 119.17 \*\* | 12.91 \*\* | 63.64 \*\* |
| SML664 X K851 | -17.32 \*\* | -7.66 \*\* | -15.00 \*\* | -25.00 | 76.92 \*\* | 38.89 \*\* | -27.27 \*\* | 19.05 | 0.80 | -31.17 \*\* | 136.97 \*\* | 13.43 \*\* | 71.61 \*\* |
| SML664 X PDM139 | -15.75 \*\* | -7.66 \*\* | -17.50 \*\* | 0.00 | 69.23 \*\* | 42.59 \*\* | -23.03 \*\* | 19.05 | 13.16 \* | -13.62 \*\* | 111.70 \*\* | 13.43 \*\* | 86.71 \*\* |
| SML664 X KM2241 | -17.32 \*\* | -8.13 \*\* | -18.33 \*\* | 0.00 | 46.15 \*\* | 40.74 \*\* | -15.15 \* | 23.81 | 23.60 \*\* | -5.35 | 81.15 \*\* | 12.73 \*\* | 71.43 \*\* |
| SML681 X K851 | -6.30 \* | -7.18 \*\* | 3.33 | -12.50 | 30.77 | 29.63 \*\* | -12.12 | -9.52 | 15.63 \* | -24.72 \*\* | 62.26 \*\* | 15.74 \*\* | 24.68 \*\* |
| SML681 X PDM139 | -6.30 \* | -7.18 \*\* | -0.83 | -12.50 | 38.46 \* | 37.04 \*\* | -12.12 | -4.76 | 17.11 \*\* | 10.74 \*\* | 27.37 \*\* | 16.42 \*\* | 41.00 \*\* |
| SML681 X KM2241  \*Significant at 5%, \*\*Significant at 1%. | -4.72 | -10.05 \*\* | -3.33 | 0.00 | 53.85 \*\* | 38.89 \*\* | -14.55 \* | -14.29 | 9.98  Continued…. | 33.48 \*\* | 28.48 \*\* | 10.66 \*\* | 61.41 \*\* |
| **Table 1. Continued….**  **Crosses** | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Number of branches per plant** | **Number of clusters per plant** | **Number of pods per plant** | **Pod length (cm)** | **Number of seeds per pod** | **100-seed weight (g)** | **Biological yield (g)** | **Harvest index (%)** | **Protein content (%)** | **Seed yield per plant (g)** |
| IP-7 X K851 | -16.54 \*\* | -6.22 \*\* | -10.00 \*\* | 0.00 | 61.54 \*\* | 40.74 \*\* | -20.61 \*\* | 33.33 | 19.90 \*\* | 14.20 \*\* | 54.01 \*\* | 2.37 | 83.21 \*\* |
| IP-7 X PDM139 | -14.17 \*\* | -9.09 \*\* | -8.33 \* | -25.00 | 76.92 \*\* | 44.44 \*\* | -22.42 \*\* | 28.57 | 8.11 | 42.73 \*\* | 30.24 \*\* | 7.23 \* | 87.84 \*\* |
| IP-7 X KM2241 | -17.32 \*\* | -8.13 \*\* | -11.67 \*\* | -25.00 | 69.23 \*\* | 38.89 \*\* | -18.18 \*\* | 14.29 | 5.19 | 48.04 \*\* | 14.70 \*\* | 4.80 | 76.99 \*\* |
| IPM302 X K851 | -18.90 \*\* | -12.44 \*\* | -12.50 \*\* | -12.50 | 46.15 \*\* | 42.59 \*\* | -10.91 | -19.05 | 9.67 | -8.17 \* | 75.99 \*\* | 6.36 \* | 55.22 \*\* |
| IPM302 X PDM139 | -16.54 \*\* | -11.96 \*\* | -12.50 \*\* | -12.50 | 61.54 \*\* | 44.44 \*\* | -21.82 \*\* | -9.52 | 24.02 \*\* | -26.27 \*\* | 155.48 \*\* | 6.81 \* | 94.32 \*\* |
| IPM302 X KM2241 | -18.90 \*\* | -11.48 \*\* | -14.17 \*\* | -12.50 | 53.85 \*\* | 46.30 \*\* | -16.36 \* | -9.52 | 8.55 | 70.36 \*\* | -1 | 11.11 \*\* | 66.98 \*\* |
| HUM12 X K851 | -7.87 \*\* | -4.78 \* | -20.00 \*\* | -12.50 | 69.23 \*\* | 35.19 \*\* | -18.79 \*\* | 19.05 | -3.35 | 54.34 \*\* | -10.55 \* | 3.93 | 43.78 \*\* |
| HUM12 X PDM139 | -12.60 \*\* | -5.26 \*\* | -17.50 \*\* | 0.00 | 76.92 \*\* | 38.89 \*\* | -19.39 \*\* | 9.52 | -6.92 | 20.95 \*\* | 37.75 \*\* | 1.27 | 73.65 \*\* |
| HUM12 X KM2241 | -14.17 \*\* | -6.70 \*\* | -20.83 \*\* | -12.50 | 61.54 \*\* | 40.74 \*\* | -21.21 \*\* | 9.52 | -5.89 | -12.71 \*\* | 94.93 \*\* | 1.39 | 80.89 \*\* |
| KM2290 X K851 | -16.54 \*\* | -6.22 \*\* | -12.50 \*\* | -25.00 | 76.92 \*\* | 25.93 \*\* | -15.15 \* | -9.52 | -8.83 | -17.42 \*\* | 85.25 \*\* | 3.83 | 52.97 \*\* |
| KM2290 X PDM139 | -18.11 \*\* | -6.22 \*\* | -11.67 \*\* | -12.50 | 76.92 \*\* | 29.63 \*\* | -21.82 \*\* | 33.33 | -15.79 \* | -27.60 \*\* | 84.88 \*\* | 1.59 | 39.47 \*\* |
| KM2290 X KM2241 | -18.11 \*\* | -5.74 \*\* | -12.50 \*\* | 0.00 | 69.23 \*\* | 24.07 \*\* | -45.94 \*\* | 42.86 \* | -16.38 \* | 36.14 \*\* | -2.51 | 5.70 \* | 29.99 \*\* |
| KM2426 X K851 | -3.15 | -7.66 \*\* | -10.83 \*\* | -12.50 | 76.92 \*\* | 31.48 \*\* | -21.82 \*\* | 23.81 | 4.63 | 34.88 \*\* | 27.23 \*\* | 6.63 \* | 88.06 \*\* |
| KM2426 X PDM139 | -6.30 \* | -7.66 \*\* | -12.50 \*\* | -25.00 | 76.92 \*\* | 33.33 \*\* | -24.85 \*\* | 9.52 | 6.28 | 19.24 \*\* | 30.79 \*\* | 3.22 | 64.22 \*\* |
| KM2426 X KM2241  \*Significant at 5%, \*\*Significant at 1%. | -7.09 \*\* | -8.13 \*\* | -10.83 \*\* | -12.50 | 76.92 \*\* | 31.48 \*\* | -30.91 \*\* | 4.76 | 5.90  Continued…. | -11.29 \*\* | 82.35 \*\* | 4.48 | 70.45 \*\* |
| **Crosses** | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Number of branches per plant** | **Number of clusters per plant** | **Number of pods per plant** | **Pod length (cm)** | **Number of seeds per pod** | **100-seed weight (g)** | **Biological yield (g)** | **Harvest index (%)** | **Protein content (%)** | **Seed yield per plant (g)** |
| KM2427 X K851 | -7.87 \*\* | -9.57 \*\* | -20.00 \*\* | -12.50 | 53.85 \*\* | 46.30 \*\* | -24.24 \*\* | 9.52 | -17.07 \*\* | -6.32 | 44.37 \*\* | 8.33 \*\* | 39.47 \*\* |
| KM2427 X PDM139 | -10.24 \*\* | -11.00 \*\* | -20.00 \*\* | -12.50 | 76.92 \*\* | 40.74 \*\* | -21.21 \*\* | -4.76 | 11.42 | 0.00 | 83.65 \*\* | 6.31 \* | 79.96 \*\* |
| KM2427 X KM2241 | -9.45 \*\* | -11.00 \*\* | -22.50 \*\* | -12.50 | 69.23 \*\* | 35.19 \*\* | -19.39 \*\* | 9.52 | 11.84 | 8.68 \*\* | 57.78 \*\* | 7.48 \*\* | 78.57 \*\* |

**Table 1. Continued….**

\*Significant at 5%, \*\*Significant at 1%.

**Table 2. Estimation of inbreeding depression in F2 generation for thirteen characters in greengram.**

\*Significant at 5%, \*\*Significant at 1%.

Continued….

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Crosses** | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Number of branches per plant** | **Number of clusters per plant** | **Number of pods per plant** | **Pod length (cm)** | **Number of seeds per pod** | **100-seed weight (g)** | **Biological yield (g)** | **Harvest index (%)** | **Protein content (%)** | **Seed yield per plant (g)** |
| **KM2399 X K851** | 1.90 | -1.05 | -1.85 | -16.67\*\* | 8.33\*\* | 4.05\*\* | 4.69\*\* | 22.58\*\* | 14.29\*\* | 30.64\*\* | -15.34\*\* | -0.43 | 20.00\*\* |
| **KM2399 X PDM139** | 4.76\*\* | -1.55 | -2.73\*\* | 14.29\*\* | -4.00\*\* | 3.95\*\* | -1.50 | 32.35\*\* | 90.49\*\* | -2.15\*\* | 10.78\*\* | 0.44 | 8.86\*\* |
| **KM2399 X KM2241** | 1.89 | 2.66\*\* | -4.59\*\* | 0.00 | 4.17\*\* | -2.74\*\* | 4.05\*\* | 10.71\*\* | 9.29\*\* | -4.28\*\* | -36.53\*\* | -0.88 | -42.37\*\* |
| **KM2401 X K851** | 0.00 | 0.00 | 0.93 | 0.00 | -9.52\*\* | -4.41\*\* | -6.77\*\* | 23.08\*\* | 2.38\*\* | -20.94\*\* | 41.25\*\* | -0.85 | 28.95\*\* |
| **KM2401 X PDM139** | 0.00 | 0.51 | -5.66\*\* | -14.29\*\* | 13.04\*\* | 8.45\*\* | 12.74\*\* | 16.13\*\* | 6.02\*\* | -24.01\*\* | 37.69\*\* | 0.42 | 22.73\*\* |
| **KM2401 X KM2241** | 4.59\*\* | -1.55 | -6.42\*\* | 22.22\*\* | 18.18\*\* | 4.48\*\* | 1.52 | 13.33\*\* | -14.29\*\* | -10.35\*\* | 8.00\*\* | -0.84 | -1.52 |
| **KM2403 X K851** | 5.56\*\* | -0.56 | -5.45\*\* | 0.00 | -6.25\*\* | 0.00 | 7.09\*\* | 4.00\*\* | 1.37 | -56.29\*\* | 36.01\*\* | -0.83 | 0.00 |
| **KM2403 X PDM139** | 2.88\*\* | 1.66 | 3.7\*\* | 12.5\*\* | -11.76\*\* | -1.22 | 4.83\*\* | 30.77\*\* | -6.33\*\* | -12.23\*\* | -8.33\*\* | 0.41 | -21.57\*\* |
| **KM2403 X KM2241** | 5.5\*\* | -8.29\*\* | -2.8\*\* | -16.67\*\* | 5.56\*\* | 5.00\*\* | -11.57\*\* | 10.71\*\* | 3.76\*\* | 32.73\*\* | -20.54\*\* | 0.84 | 18.92\*\* |
| **KM2404 X K851** | 6.36\*\* | 2.05\*\* | -5.75\*\* | -16.67\*\* | 4.35\*\* | 1.20 | -20.83\*\* | 4.76\*\* | 6.02\*\* | 18.05\*\* | 7.17\*\* | 0.00 | 23.93\*\* |
| **KM2404 X PDM139** | 8.04\*\* | -1.01 | -6.74\*\* | -14.29\*\* | 8.7\*\* | 4.71\*\* | 6.29\*\* | 19.23\*\* | 18.55\*\* | -52.96\*\* | 40.01\*\* | -0.45 | 8.24\*\* |
| **KM2404 X KM2241** | 4.72\*\* | -1.55 | -7.95\*\* | -16.67\*\* | 12.00\*\* | 4.60\*\* | 0.66 | -19.05\*\* | -23.38\*\* | -26.09\*\* | -2.16\*\* | -2.71\*\* | -28.81\*\* |
| **KM2408 X K851** | 6.03\*\*\* | -1.01 | -5.68\*\* | -14.29\*\* | 4.76\*\* | -2.78\*\* | -4.72\*\* | 25.00\*\* | -18.18\*\* | -12.00\*\*\* | -21.61\*\* | 1.32 | -36.21\*\* |
| **KM2408 X PDM139** | 4.59\*\* | 1.52 | -4.49\*\* | 14.29\*\* | -15.79\*\* | -4.29\*\* | 4.17\*\* | -16.00\*\* | -20.55\*\* | 23.08\*\* | -80.57\*\* | -0.87 | -38.89\*\* |
| **Table 2. Continued…**  **Crosses** | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Number of branches per plant** | **Number of clusters per plant** | **Number of pods per plant** | **Pod length (cm)** | **Number of seeds per pod** | **100-seed weight (g)** | **Biological yield (g)** | **Harvest index (%)** | **Protein content (%)** | **Seed yield per plant (g)** |
| **KM2408 X KM2241** | 1.79 | -1.03 | -3.49\*\* | 25\*\* | -10\*\* | -7.25\*\* | -8.51\*\* | -6.67\*\* | -9.76\*\* | 2.61\*\* | -8.23\*\* | -0.87 | -5.41\*\* |
| **KM2409 X K851** | -0.93 | 2.05\*\* | -6.67\*\* | -16.67\*\* | 13.64\*\* | 5.8\*\* | 5.88\*\* | -23.81\*\* | -11.11\*\* | -2.68\*\* | 16.89\*\* | 0.87 | 14.67\*\* |
| **KM2409 X PDM139** | 1.92 | -0.51 | -3.37\*\* | 0.00 | 4.17\*\* | 1.49 | 10.79\*\* | 25.00\*\* | -20.69\*\* | -13.64\*\* | 23.74\*\* | 0.43 | 13.33\*\* |
| **KM2409 X KM2241** | -1.87 | -1.53 | -5.68\*\* | 0.00 | 10\*\* | -1.49 | 1.56 | -4.17\*\* | 1.71 | 1.52 | -17.74\*\* | -1.27 | -15.94\*\* |
| **KM2414 X K851** | 4.27\*\* | -2.05\*\* | -1.15 | 0.00 | -11.11\*\* | -3.08\*\* | 5.59\*\* | 7.69\*\* | 0.00 | 32.81\*\* | -10.36\*\* | -0.85 | -35.29\*\* |
| **KM2414 X PDM139** | -1.75 | 1.98 | -4.55\*\* | 12.5\*\* | -5.00\*\* | 4.62\*\* | 6.34\*\* | 6.25\*\* | 3.58\*\* | 20.02\*\* | -90.96\*\* | -0.42 | -52.73\*\* |
| **KM2414 X KM2241** | -2.65\* | 1.00 | -7.95\*\* | -16.67\*\* | -15.79\*\* | -4.62\*\* | 6.08\*\* | 10.71\*\* | -9.68\*\* | 11.54\*\* | -43.44\*\* | 1.26 | -26.88\*\* |
| **KM2417 X K851** | 3.36\*\* | -1.01 | 0.88 | -16.67\*\* | 13.64\*\* | 6.76\*\* | 2.34\*\* | -8.7\*\* | -13.21\*\* | 5.36\*\* | -16.59\*\* | 1.25 | -10.34\*\* |
| **KM2417 X PDM139** | -0.87 | 0.00 | -4.35\*\* | 0.00 | 8.70\*\* | 10.53\*\* | -0.82 | -8.33\*\* | -6.85\*\* | -27.91\*\* | 29.87\*\* | -0.41 | 10.29\*\* |
| **KM2417 X KM2241** | -1.77 | -2.12\* | -3.42\*\* | 0.00 | 4.55\*\* | 1.37 | -11.36\*\* | -16.67\*\* | -2.50\*\* | -73.52\*\* | 48.77\*\* | -1.67 | 11.11\*\* |
| **SML664 X K851** | -1.9 | -1.55 | -3.92\*\* | -16.67\*\* | 4.35\*\* | 0.00 | -1.67 | 4.00\*\* | -13.92\*\* | -34.43\*\* | 33.65\*\* | 1.63 | 10.81\*\* |
| **SML664 X PDM139** | -1.87 | -1.55 | -8.08\*\* | 12.50\*\* | 9.09\*\* | 9.09\*\* | 6.30\*\* | -4.00\*\* | 2.33\*\* | 14.64\*\* | 1.20 | 1.22 | 15.66\*\* |
| **SML664 X KM2241** | 4.76\*\* | -3.65\*\* | -3.06\*\* | 12.50\*\* | 0.00 | 2.63\*\* | 10.71\*\* | 11.54\*\* | 5.38\*\* | -31.86\*\* | 30.07\*\* | 0.81 | 7.79\*\* |
| **SML681 X K851** | 2.52\*\* | 2.06\*\* | 4.84\*\* | 14.29\*\* | -17.65\*\* | 0.00 | 9.66\*\* | -10.53\*\* | -3.45\*\* | -85.76\*\* | 27.90\*\* | -0.82 | -33.93\*\* |
| **SML681 X PDM139** | -1.68 | -1.55  \*Significant at 5%, \*\*Significant at 1%. | -5.04\*\* | 0.00 | -11.11\*\* | -1.35 | 7.59\*\* | -35.00\*\* | 3.37\*\* | -17.31\*\*  Continued…. | -1.23 | -1.64 | -18.75\*\* |
| **Table 2. Continued…**  **Crosses** | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Number of branches per plant** | **Number of clusters per plant** | **Number of pods per plant** | **Pod length (cm)** | **Number of seeds per pod** | **100-seed weight (g)** | **Biological yield (g)** | **Harvest index (%)** | **Protein content (%)** | **Seed yield per plant (g)** |
| **SML681 X KM2241** | -0.83 | -2.13\*\* | -6.9\*\* | 25\*\* | 0.00 | 1.33 | 9.22\*\* | -55.56\*\* | -2.09\*\* | 5.09\*\* | -7.54\*\* | 1.64 | -2.07\*\* |
| **IP-7 X K851** | -4.72\*\* | -2.04\*\* | 3.70\*\* | 25\*\* | -4.76\*\* | 1.32 | -2.29\*\* | 7.14\*\* | 13.98\*\* | 11.54\*\* | -14.48\*\* | -1.29 | -1.27 |
| **IP-7 X PDM139** | 0.00 | -1.58 | 4.55\*\* | -16.67\*\* | 8.70\*\* | 5.13\*\* | -21.88\*\* | -3.70\*\* | 6.02\*\* | 36.93\*\* | -23.43\*\* | 1.71\*\* | 22.16\*\* |
| **IP-7 X KM2241** | 3.81\*\* | 0.52 | -3.77\*\* | -33.33\*\* | 9.09\*\* | 2.67\*\* | 9.63\*\* | -16.67\*\* | 14.49\*\* | 46.49\*\* | -50.45\*\* | 0.00 | 19.5\*\* |
| **IPM302 X K851** | -3.88\*\* | -2.73\*\* | -9.52\*\* | -14.29\*\* | -5.26\*\* | 9.09\*\* | -1.36 | -41.18\*\* | 12.11\*\* | 0.00 | -4.35\*\* | -0.84 | -4.35\*\* |
| **IPM302 X PDM139** | -3.77\*\* | -2.17\*\* | -9.52\*\* | 0.00 | 4.76\*\* | 7.69\*\* | -16.28\*\* | -21.05\*\* | 18.92\*\* | -5.75\*\* | 17.05\*\* | 0.00 | 12.28\*\* |
| **IPM302 X KM2241** | -2.91\*\* | -2.16\*\* | -5.83\*\* | -14.29\*\* | 5\*\* | 6.33\*\* | 9.42\*\* | -36.84\*\* | 4.99\*\* | 38.75\*\* | -71.96\*\* | 0.00 | -5.33\*\* |
| **HUM12 X K851** | -1.71 | -2.51\*\* | -7.29\*\* | 0.00 | 13.64\*\* | 1.37 | 8.21\*\* | -8.00\*\* | -13.89\*\* | 30.98\*\* | -77.60\*\* | -0.45 | -22.58\*\* |
| **HUM12 X PDM139** | 4.50\*\* | -2.02\*\* | 7.07\*\* | 12.5\*\* | 13.04\*\* | 4.00\*\* | 0.75 | -13.04\*\* | -35.73\*\* | 8.64\*\* | -8.05\*\* | -1.36 | 1.28 |
| **HUM12 X KM2241** | 3.67\*\* | -2.56\*\* | -5.26\*\* | 0.00 | 14.29\*\* | 6.58\*\* | -8.46\*\* | -26.09\*\* | -31.51\*\* | -26.87\*\* | 28.25\*\* | -0.46 | 8.97\*\* |
| **KM2290 X K851** | 4.72\*\* | -2.55\*\* | 6.67\*\* | 0.00 | 8.70\*\* | -1.47 | -4.29\*\* | -52.63\*\* | -34.29\*\* | -47.39\*\* | 30.16\*\* | -0.90 | -2.94\*\* |
| **KM2290 X PDM139** | 4.81\*\* | -2.04\*\* | -2.83\*\* | -28.57\*\* | 8.70\*\* | 7.14\*\* | -7.75\*\* | -7.14\*\* | -48.48\*\* | -26.48\*\* | -7.12\*\* | -0.89 | -35.48\*\* |
| **KM2290 X KM2241** | -2.88\*\* | -2.54\*\* | 7.62\*\* | 12.50\*\* | 9.09\*\* | 1.49 | -44.62\*\* | 23.33\*\* | -37.07\*\* | 29.04\*\* | -95.87\*\* | 1.77\*\* | -38.98\*\* |
| **KM2426 X K851** | 0.00 | -3.11\*\* | 12.15\*\* | 0.00 | 13.04\*\* | 4.23\*\* | 1.55 | 11.54\*\* | -2.44\*\* | 28.13\*\* | -12.01\*\* | -0.88 | 19.5\*\* |
| **KM2426 X PDM139**  \*Significant at 5%, \*\*Significant at 1%. | 5.88\*\* | -2.59\*\* | 11.43\*\* | 0.00 | 8.70\*\* | 4.17\*\* | -17.74\*\* | 0.00 | 4.41\*\* | 21.44\*\*  Continued…. | -15.08\*\* | 1.30 | 9.59\*\* |
| **Crosses** | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Number of branches per plant** | **Number of clusters per plant** | **Number of pods per plant** | **Pod length (cm)** | **Number of seeds per pod** | **100-seed weight (g)** | **Biological yield (g)** | **Harvest index (%)** | **Protein content (%)** | **Seed yield per plant (g)** |
| **KM2426 X KM2241** | -1.69 | -2.6\*\* | -6.54\*\* | 0.00 | 13.04\*\* | 0.00 | -13.16\*\* | -18.18\* | 10.84\*\* | 0.00 | 8.00\*\* | -0.44 | 8\*\* |
| **KM2427 X K851** | 0.85 | -6.88\*\* | -8.33\*\* | 0.00 | 10.00\*\* | 1.27 | -2.40\*\* | -8.70\*\* | -15.38\*\* | 6.82\*\* | -10.78\*\* | 2.14\*\* | -3.23\*\* |
| **KM2427 X PDM139** | -4.39\*\* | -5.91\*\* | -5.21\*\* | 0.00 | 13.04\*\* | 6.58\*\* | -10.00\*\* | -5.00\*\* | 1.20 | 10.89\*\* | 13.03\*\* | 0.86 | 22.5\*\* |
| **KM2427 X KM2241** | -2.61\*\* | -1.61 | -5.38\*\* | 14.29\*\* | 13.64\*\* | 10.96\*\* | -7.52\*\* | -4.35\*\* | -3.53\*\* | 13.99\*\* | -11.73\*\* | 1.27 | 3.9\*\* |

**Table 2. Continued…**

\*Significant at 5%, \*\*Significant at 1%.

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