

**Improvement of Black Gram [*Vigna mungo* (L.)
Hepper] Variety Barkha for Yield and Maturity
through Mutagenesis**

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MOHAN DADARWAL

Thesis

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1. INTRODUCTION

Urd, also referred to as the **urd bean**, **urid**, **black gram**, **black lentil** or **white lentil** [*Vigna mungo* (L.) Hepper] is a bean grown in southern Asia. It is largely used to make dal from the whole or split, dehusked seeds. It, along with the mung bean was placed in *Phaseolus* but has been transferred to *Vigna*. It was at one point considered to belong to the same species as mung bean. Black gram originated in India where it has been in cultivation from ancient times and is one of the most highly prized pulse of India. It has also been introduced to other tropical areas mainly by Indian immigrants. It is an erect, sub-erect or trailing, densely hairy annual herb. The tap root produces a branched root system with smooth, rounded nodules. The pods are narrow, cylindrical and up to 6 cm long. The bean is boiled and eaten whole or after splitting into dal; prepared like this it has an unusual mucilaginous texture. Ground into flour or paste, it is also extensively used in culinary preparation like dosa, Idli, vada and papad. It is very nutritious and is recommended for diabetics, as are other pulses. Though very beneficial in limited quantities but excessive intake causes flatulence, which some times can be prevented by adding a little asafoetida, pepper and ginger in the culinary preparations. The product sold as "black lentil" is usually the whole urad bean or urad dal. The product sold as "white lentil" is the same lentil with the black skin removed.

Black gram is the fourth important pulse crop in India which occupies about 12 per cent of the total pulse area and contributing about 8 per cent to the total pulse production. It is mostly grown in Madhya Pradesh, Maharashtra, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Orissa, Bihar and Rajasthan. Black gram has high nutritional value with 24 per cent protein, 60 per cent carbohydrate and 15 per cent fat, 64 units vitamin A, 140 units vitamin B and 0.2 per cent mineral matter. In spite of its high nutritional value its productivity is very low.

Black gram is still cultivated on marginal lands under rainfed conditions and faces terminal drought which affects its productivity to a great extent. Low and uneven rainfall pattern of the state since last five years have urged the need to develop

early maturing varieties of black gram to avoid yield losses due to long dry span during maturity. Barkha variety of black gram is well adapted to the climatic conditions of southern Rajasthan. It is liked by the farmers due to its bold, black shining grains but it is late in maturity and faces terminal drought. This strongly thrust the importance to induce earliness is that it can be well adopted.

Genetic improvement of a crop primarily depends upon extent of genetic variability present in the population. Experimentally, induced mutations provide an important source of variability. The practical utility of induced mutations for the improvement of quantitatively inherited characters in urd bean is well recognized. Chemical mutagens particularly alkylating agents play an important role in inducing mutations in crop plants. It has been reported by many workers that these are more effective and efficient than ionizing radiations (Tikko and Jain, 1974; Gautam *et al.*, 1992). Chemical mutagens generally lead to toxic side effect and ultimately cause lethality at the time of germination and seedling establishment. However, several chemicals particularly growth regulators such as Gibberellic acid, Indol acetic acid and thio compounds have been successfully used to modify the damaging effect of chemical mutagens. Internal phytohormonal balance is radically disturbed by treatment with growth regulators notably Gibberellic acid and Indol acetic acid. Kumar (1967), Dayal and Kaul (1969) reported a markedly modifying effect of Gibberellic acid in reducing chromosomal aberrations brought about by various mutagens. Significant reversal of radiation induced a seedling injury along with chromosomal aberrations brought about by Gibberellic acid in pea and barley has been demonstrated by Narsinghani and Kumar (1971).

Artificial induction of mutations using EMS and gamma rays in black gram has been attempted by few workers (Kundu and Singh, 1981; Singh and Raghuvanshi, 1991; Gautam and Mittal, 1998 and Singh *et al.*, 2000) induction of mutations using DMS has been attempted only by Barwa (1991), but no publish work regarding DMS treatment along with growth regulator on black gram is available. Therefore, present investigation is proposed to induce variability in black gram through mutation breeding by using chemicals mutagens like Ethylmethane sulphonate (EMS) and Dimethyl sulphonate (DMS) and their modifiers viz., Indol Acetic Acid (IAA) and

Gibberellic Acid (GA) to isolate early maturing and high yielding genotype with shining bold grains from M₂ generation of Barkha, so that, it can very well fit in the cropping pattern under rainfed conditions. The research work is proposed with the following objectives:

- (i) To estimate the variability induced in M₂ generation.
- (ii) To estimate efficiency and effectiveness of chemical mutagens, and
- (iii) To isolate high yielding and early maturing mutants from M₂ generation.

2. REVIEW OF LITERATURE

Breeding potential in a crop preliminary depends on the nature and extent of genetic variability present in the population. Lack of genetic variation available in existing germplasm restricts its further improvement. In order to induce variability, mutation breeding can be valuable supplement to the conventional breeding methods. The term mutation was introduced by Hugo-de-Vries in 1901 in connection with sudden heritable changes observed by him in *Oenothera* spp. However, systematic studies on mutation began in 1910 with the discovery of white eyed mutant of *Drosophila* by Morgan. It was in 1927 when Muller in *Drosophila* and Stadler (1928) in barley, reported that mutation can be induced by X-rays and used as promoting method to develop variations for breeding purposes. Subsequently mutagenic effect of mustard gas and other chemical compounds were discovered by Auerbach and Robson (1946). The probability of isolation of mutants of economic importance would be high in population with higher frequency and wider spectrum of mutations.

Gustaffson (1954) suggested that chemical mutagens were more efficient than radiations in causing mutations. Among the numerous chemical mutagens alkylating agents have been used extensively because of their great efficiency. Within alkylating group EMS and DMS have been found to be very effective mutagens. EMS possesses high potency of inducing mutations, Cuttarnach *et al.* (1969) and Kempanna *et al.* (1969). Tikko and Jain (1974) and Gautam *et al.* (1992) have suggested that EMS is an effective mutagen inducing higher frequency of chromosomal breaks.

A number of reports are now available which state the modifying effect of various chemicals, growth hormones and growth regulators. Various chemicals like sodium and potassium cyanide at non-toxic doses, cysteine glutathione, cysteamine chelating agents viz. EDTA, colchicine derivatives BAL, Sodium hydrosulphate 2-4 dinitrophenol and ATP applied before or after irradiations significantly modified the radiations damage and reduced the frequency of chromosomal aberration (Bacq *et al.*, 1951; Riley, 1955; Lucznik and Carapkin, 1959). Modifying effect of GA with mutagens observed by Kumar (1964), Dayal and Kaul (1969) in barley.

A survey of pertinent literature revealed that only a limited number of published reports are available in respect of the genetic studies aimed at improving the yield potential and maturing habit in black gram. The results of available reports indicate the status of genetic variability present in the black gram germplasm and amount of primary information with regard to its utility in plant breeding. The contribution of different workers on the aspects of induced mutation in black gram and related crops are summarized as under.

Dayal and Kaul (1969) reported that post treatment of GA with MMS in barley reduced mutagenic effect on germination significantly it also reduced frequency of chromosomal aberrations, plant height, ear length, Fertility of M_1 spikes and weight of 500 grains was not affected by GA treatment. Kryukova and Nazarova (1969) observed that gamma and X-rays irradiated bean seedlings when treated with GA reduced chromosomal aberrations to 30-40 per cent.

Narsinghani and Kumar (1971) reported that reduction in the height of pea seedling to 3.40 cm and 3.00 cm caused by EMS and MMS as compared to 5.16 cm in control. The mutagenic effect was neutralized by the GA treatment and increased the height to 6.80 cm and 5.00 cm, respectively. They further found improvement in the pollen fertility and mitotic and meiotic chromosomal aberrations with a post treatment of GA.

Zargar (1973) studied the effect of GA on cytomorphological damage caused by gamma rays in guar. Post irradiation treatment of GA revealed no significant modifying effects of radiation damage for all the seedlings and plant characters. However, it markedly decreased the frequency of chromosomal aberrations especially translocations, bridges and laggards.

Bhadra (1982) isolated mutant in T-9 and S-1 varieties of black gram treated with EMS and gamma rays. The mutant isolated were dwarf, erect, unbranched compact, sterile, narrow leaves, bold and shrunken black seeded, non-hairy pods with early and synchronous maturity.

Laxmi and Gupta (1983) in fenugreek identified two mutants with longer leaves and dark seeds resulting from 0.3 per cent EMS treatment. They also observed a compact mutant with longer leaves at 0.4 per cent EMS and early flowering type with small leaves and small pods with fewer seeds at 0.5 per cent EMS treatment.

Yadav and Singh (1983) studied genetic variability induced by gamma rays, EMS and combination of both in M₃ generation of green gram cultivar T-44. The data recorded on number of nodules per plant, nodule dry weight, seedling height etc. were analysed and found that EMS was more effective for inducing genetic variability followed by gamma rays and combination treatment.

Khan (1984) treated seeds of mung bean with hydrazine hydrate and EMS and reported that M₂ generation variances were higher for plant height, days to 75 per cent maturity, number of pods per plant, pod length, number of seeds per pod, 1000-seed weight and seed yield per plant.

Reddy and Smith (1984) computed mutagenic effectiveness and efficiency of hydrazine (HZ) and ethylmethane sulphonate (EMS) in local sorghum variety of Texas. On the basis of seedling injury, sterility in M₁ generation and chlorophyll and morphological mutations in M₂ generation, hydrazine was found to be highly efficient mutagen. Hydrazine induced a broader spectrum of chlorophyll and morphological mutations in M₂ generation compared to EMS. The 0.015 M concentration of hydrazine was the most efficient mutagenic treatment.

Khan and Khan (1984) reported higher variance in M₂ generation induced by gamma radiation in *Vigna radiata* for plant height, days to maturity, number and length of pods, number of seeds per pod, 100 seed weight and seed yield.

Khan *et al.* (1985) measured the variation for morphological characters in M₂ generation of three black gram varieties T-9, Pant U-19 and UPU-1 after treatment with NMV. It was observed that the lower doses of mutagen enhanced the above characters while higher doses showed reverse trend.

Singh and Raghuvanshi (1985) irradiated seeds of T-9 variety of *Vigna mungo* by 10, 20 and 30 kr of gamma rays followed by treatment of 0.25 per cent EMS. In M₂ generation two pentafoolate mutant were isolated at 20 kr. In M₃ generation this mutant proved stable. In 1991 they studied dry seeds of black gram (*Vigna mungo*) cultivar T-9 irradiated with gamma rays followed by EMS treatment. A bold seeded mutant was selected in M₂ and subsequently evaluated in M₃. It showed more vigorous growth and produced more leaves and pods, larger seeds and evaluation upto M₈ generation showed the mutant to be stable.

EI Sahhee *et al.* (1986) irradiated seeds of two cultivars, Calland and Hampton of soybean with eight doses of gamma rays ranging from 25 kr to 40 kr and treated the seed with eight concentrations of EMS ranging from 0.1 to 1.5 per cent and reported that in M₁ generation, germination percentage, plant survival, stem length, number of branches pods and seeds, seed weight and percentage of normal seed decreased with increasing doses of mutagens.

Ommen and Gopimany (1986) irradiated seeds of cowpea cultivar New Era with six doses of gamma rays ranging from 5-30 kr. Besides their seeds were also treated with seven concentrations of EMS ranging from 0.1-0.7 per cent. They reported reduction in plant survival, plant growth and fertility in M₁ generation, they also observed an increase in chlorophyll mutation frequency with increase in doses.

Khan *et al.* (1987) observed inhibitory effect of MMS in M₁ generation of black gram variety UPV-1. L.D. 50 dose observed at 0.065 per cent MMS. Significant decrease in plant height, number of pods, branches per plant was recorded. This effect was gradual and mostly dose dependent.

Ignacimuthu and Babu (1989) used the seed of *Vigna mungo*, *Vigna radiata* for the induction of mutation with EMS and gamma rays. The results suggest that the range of induced variation in the seed protein is narrow within species, but within each treatment line, the range was very broad.

Rokadia and Mathur (1989) treated seeds of fenugreek variety UM-75 and PEB with three doses of EMS (0.2, 0.4 and 0.6 per cent). A significant positive shift

in the mean value was observed for number of branches and number of grains per pod in variety UM-75, for plant height, number of pods per plant, pod length in variety PEB and for days to 50 per cent flowering and days to 75 per cent maturity and grain yield in both the varieties. Test weight in both the varieties showed significant negative shift in mean.

Sinha and Bharti (1990) irradiated seed of black gram variety T-9 with 15, 30, 45 and 60 kr doses of gamma rays, from M_3 generation 30 non-segregating families were selected to raise the M_4 generation mutants with lower plant height and branches per plant, higher pods per plant and larger pods were obtained Heritability ranged from 41.2 per cent (seeds per pod) to 79.4 per cent (plant height).

Tripathi (1990) studied induced variability in mung bean varieties Dhauli and Kurda Local treated with 0.2, 0.4 and 0.6 per cent EMS and in combination with gamma-radiation (5, 10, 20 and 30 kr). In the M_2 generation a total of 12 characters were recorded and found that 30 kr gamma radiations produced the highest frequency of micromutations. This was followed by 15 kr + 0.6 per cent EMS, 10 kr + 0.4 per cent EMS and gamma radiation were recommended for inducing mutation for yield components.

Fehr *et al.* (1991) developed two mutant soybean lines with palmitic acid content of >180 g/kg treatment of A1937 and Elgin seeds with N-nitroso-N-methyl urea (NMU) and EMS respectively resulting A 1937 NMV-85 and Elgin EMS-421 and were crossed to determine their genetic relationship for elevated palmitic acid content and obtained transgressive segregants with >250 g/kg palmitic acid the highest content know in soybean. When A 1937- NMV-85 was crossed to C 1727 controlled increased palmitic acid content indicating that alleles controlling high palmitic acid content are tightly linked.

Singh (1991) treated Krishana variety of black gram with varying concentrations of EMS for four hours at $27 \pm 2^\circ\text{C}$ after 4 hours presoaking in distilled water. He reported that in M_1 there was a significant reduction in seed germination, survival percentage and seedling height with increase in concentration of mutagens and also reduced pollen fertility, number of primary branches, number of clusters per

plant and number of grains per pod though days to flowering and protein content remained unaffected.

Badami and Bhalla (1992) studied mutagenic effectiveness and efficiency of gamma rays at 20, 40 and 30 kr, magnetic field (MR) at 3000, 4000 and 5000 G doses and sodium azide (SA) 1×10^{-3} , 2×10^{-3} and 3×10^{-3} M concentrations and combination treatments (as post-treatment of gamma irradiated seeds with sodium azide) in two cluster bean varieties Pusa Navbahar (PNB) and FS-227. It was observed that effectiveness and efficiency values varied with both the treatments and variety under consideration, showing mutagen specificity.

Charumathi *et al.* (1992) treated dry seeds of black gram of variety LBG-17 (Krishna) with gamma rays (10, 20, 30 and 40 kr) and observed greater variability for number of branches per plant, pods per plant, pod length, seeds per pod, seed yield per plant, 100-seed weight and protein percentage in M_3 as compared to M_2 generation.

Gautam *et al.* (1992) reported percentage of pollen fertility and ovule sterility after seed treatment of T-9 with gamma radiation (5, 10, 20, 30 and 40 kr) and EMS (10, 20, 30, 40 and 50 mM) applied as sole and combination treatments (20 mM EMS only). Values were calculated for mutation frequency, mutagenic effectiveness and efficiency. The synergistic effect of combination treatments was also assessed. Gamma rays were more effective than EMS, whereas, EMS treatment alone was 2-2.5 times more efficient in inducing mutations. A progressive increase in mutation frequency of chlorophyll and viable mutation was observed with increasing doses. Synergistic effect was also observed for increasing mutation frequency in M_2 generation.

Vandana and Dubey (1992) reported a range of variability, heritability, genetic advance and net genetic gain for yield and its components for eleven M_2 plants following seed treatment with varying concentrations of EMS and methylmethane sulphonate in fababean (*Vicia faba* L.). Heritability estimates were highest for seeds per pod which was followed by pods per plant, seed yield, plant height, days to flowering, number of branches per plant and 100-seed weight. Heritability for seeds

per pod was comparatively low. Genetic advance expressed as percentage of mean was highest for seed yield followed by seeds per plant, pods per plant, number of branches per plant and plant height. High value of genetic gain was obtained for seeds per plant, while genetic gain was moderately high for plant height and pods per plant.

Ahmed and Yaqoob (1993) exposed dry seeds of two mungbean varieties (MC562-1 and MC-1) to four doses of gamma radiation (10, 20, 30, 40 and 50 kr). The analysis of the results showed greater variability for plant height, number of pod cluster, pods per plant and grain yield. The highest magnitude of variability was observed for plant height (54.3 per cent increase over the respective control) and lowest variability were reported for pod length.

Solanki and Sharma (1994) treated the seeds of lentil cultivar Precoz Selection (large seeded) with three doses, each at gamma rays, EI (ethylene imine) and N-nitroso-N-ethylene urea (NEU). In general, mutagenic effectiveness and efficiency decreased with increase in the dose of mutagens, however, the highest dose of gamma rays and medium doses of the two chemicals were found to be most efficient for inducing mutations. Effectiveness of mutagens differed considerably. NEU was 1.2 and 240 times more effective than EI and gamma rays, respectively. The order of effectiveness of mutagens was NEU (168.1) > EI (138.6) > gamma rays (0.7). Mutagenic efficiency was not as variable as their effectiveness however; the trend among the mutagens was similar to that observed for mutagenic effectiveness. NEU showed the highest efficiency (0.38) followed by EI (0.33) and gamma rays. Thus, NEU was 1.2 and 1.1 times as much efficient as gamma rays and EI, respectively.

Ahmed Johans (1995) carried out a study to determine effectiveness and efficiency of gamma rays in relation to induction of chlorophyll mutations in M₂ generation in different genotypes of black gram. The chlorophyll mutation frequency increased up to 50 kr of gamma rays and the maximum increase was recorded in hybrid CoBG 301 x PDU1 followed by CoBG 301 and PDU1. The viridis type was found to be maximum. The efficiency of chlorophyll mutation was high in PDU1 on lethality basis and CoBG 301 on injury basis.

Gahukar *et al.* (1996) treated seeds of *Cajanus cajan* with (0.1 and 0.2 per cent for 12 hrs.) and gamma irradiation (10 and 20 kr). M₂ generation was evaluated for yield, plant height, number of branches per plant and pods per plant. Variation in these traits increased under both treatments and a desirable decrease in plant height was observed in all the progenies. Number of branches per plant, pods per plant and yield per plant increased more under chemical than physical treatments, indicating its potential to improve the traits in pigeonpea breeding.

Kumari (1996) treated dry and dormant seeds of faba bean varieties VH 82-1 and JV2 with gamma radiation (10, 20 and 30 kr), 0.1 and 0.4 per cent ethylmethane sulphonate (EMS) and combination of 3 doses of gamma-radiation with 0.1 per cent EMS. In M₁ generation decrease in seed germination and seedling emergence was observed in both varieties with combined and single mutagen treatment. Whereas plant survival decreased with increase in mutation. Induced pollen sterility was significant and dose dependent for both treatments. In both the varieties combine treatment had more adverse effect on pollen fertility.

Mohapatra *et al.* (1996) observed mutant lines derives from green gram (*Vigna radiata*) variety M15 by 13 different mutagenic treatments (Combination of EMS, sodium azide, N-methyl-N-nitrosourea and gamma radiation) and efficiency of mutagenic treatment was assessed. It was reported that 0.5 per cent EMS after 4 hours pre-soaking and 0.05 per cent SA at pH 5 were the most efficient treatment for improving yield components.

Singh (1996) isolated a bold seeded mutant from M₂ progeny of a 20 kr gamma rays irradiated plant population of *Vigna mungo* cultivar TG Mutant plant had large leaves, flowers similar to control but with upper part of the style and stigma curved with larger and healthy pods, higher seed yield per plant and were cytologically normal. The protein content of seeds was higher in the mutant, while amino acid content and tyrosin inhibitor activity were similar to the control.

Vanniarajan *et al.* (1996) treated the seeds of two cultivars of *Vigna mungo* ADT-3 and Vamban with gamma rays at 20, 30, 40, 50, 60, 70, 80, 90 and 100 kr doses soaked in 10, 20, 30, 40, 50, 60 and 10 mM EMS for 6 hrs. Data on six

quantitative traits were recorded in the M_2 and M_3 generations. The highest level of variability were observed for pod length by gamma radiation and in pods per plant after EMS treatments.

Gautam and Mittal (1998) observed ten different types of macro-mutants and four micro-mutants in black gram (*Vigna mungo*) cultivar T-9 treated with varying doses of gamma rays, EMS and their combinations and recorded mutation in M_2 generation where all viable mutants bred true in the M_3 generation and of which few mutants recorded significantly higher grain yield as compared to the normal wild type parent.

Kharkwal (1998a) studied a comparative mutagenic effectiveness and efficiency of two physical (gamma rays and fast neutrons) and two chemical mutagens (NMU and EMS) on two desi (G-130 and C-214), one Kabuli (C-104) and one green seeded (L-345) varieties of chickpea (*Cicer arietinum* L.). The treatments included three doses each of gamma rays (400, 500 and 600 GR and fast neutrons 5, 10 and 15 GY) and two concentrations with two different duration of two chemical mutagens, NMU (0.01 per cent 20 hrs. and 0.02 per cent 8 hrs.) and EMS (0.1 per cent 20 hrs. and 0.2 per cent 8 hrs.). Results indicated that chemical mutagens particularly NMU are not only more effective but also efficient than physical mutagens. Mutagenic effectiveness and efficiency showed differential behaviour depending upon mutagens and varietal type. Chemical mutagens were more efficient than physical in inducing chlorophyll as well as viable and total number of mutagens. Among the mutagens NMU was the most potent, while in the physical, gamma irradiations was more effective. Out of four mutagens NMU was the most effective and efficient in inducing a high frequency and wide spectrum of chlorophyll mutations in the M_2 followed by fast neutrons.

Kharkwal (1998b) studied on frequency and spectrum of chlorophyll mutation in chickpea induced by two physical (gamma rays and fast neutrons) and two chemical mutagens (NMU and EMS) in relation to the effect in M_1 plants and induction of mutations in M_2 generation. Chemical mutagens were found to be efficient in inducing chlorophyll mutations in chickpea. Highest frequency of

mutations was observed in green seeded variety L-345. Kabuli variety C-104 was least responsible for chlorophyll mutations.

Mohanti *et al.* (1998) reported two useful mutants induced from locally adopted gram (*Vigna radiata*) variety Kalamung by gamma radiation viz., small podded mutants with highest pods per plant (7.09 ± 6.8) and seed yield per plant (9.73 ± 1.37 g) and large podded mutant found superior to parents in seeds per pod (11.20 ± 0.87) having higher pod length (8.97 ± 0.13 cm) and 100-seed weight (3.62 ± 0.06 g) with potential yield (8.81 ± 1.8 g) per plant compared to yield of parent (5.97 ± 0.99 g) per plant.

Prema Manapure *et al.* (1998) observed a negative effect on the mean value of plant height, pods per plant and yield per plant and a positive effect on branches per plant in M₂ generation of gamma rays treated seeds of black gram cultivar TAU-1 with highest variability being observed for pods per plant.

Kumar and Mishra (1999) subjected seeds of *Vigna radiata* L. variety PDM-84-103 to treatment with various doses of gamma rays (10, 20 m 30 and 40 kr) and DES (0.25, 0.50, 0.75 and 1.00 per cent) separately. Reduction in germination, height of seedlings, number of leaves, pods per plant, seeds per pod and yield per plant was recorded in treated population in addition to increased days to flowering, and pollen sterility percentage. Highest dose of gamma rays and DES produced more severe effects for most of the parameters.

Mallick *et al.* (1999) investigated the effectiveness of EMS in inducing chlorophyll mutants in four varieties of green gram (B1, B105, LM23 and 851) and observed four types of chlorophyll mutations (albina, xantha, chlorina and viridis) with xantha types being most frequent in all varieties. EMS treatment exhibited different mutation frequencies with different varieties of green gram. Highest frequency of mutation was observed in K 851.

Sharma and Talukdar (1999) treated seeds of green gram (*V. radiata*) with variable doses of EMS, gamma rays and their combinations to induce mutations and found large amount of genetic variability in M₂ and M₃ generations. Gamma rays in

general induced higher mean performance and variance than EMS when treated singly and even more higher in combined treatments. A trifoliate macro mutant with higher yield performance in M₂ generation of AAV 34 treated with 0.1 per cent EMS +10 kr and 30 kr gamma rays respectively were obtained.

Singh *et al.* (1999) observed the mutagenic effects of gamma rays (10, 20, 30 and 40 kr) and EMS (0.01, 0.02, 0.03 and 0.04 mM) and their combinations (10 kr + 0.02 mM and 0.04 mM) and their combinations (10 kr + 0.02 mM, 20 kr + 0.02 mM, 30 kr + 0.02 mM) and 40 kr + 0.02 mM) on frequency and spectrum of chlorophyll and macro mutant in two cultivars namely PD4-1 and T-9 for urdbean. Conclusively, the combination treatments have yielded the higher frequency and wide spectrum of chlorophyll mutations, whereas, the various doses of mutagenic treatment have independent response towards macro mutation in both the cultivars.

Prakash and Shambhu (2000) treated the rice bean (*Vigna umbellate*) varieties L-1 and RBL-50 with variable doses of gamma rays and EMS and they found a gradual reduction in germination with increase in doses. The EMS treatment significantly reduced root length in L-1 with LD₅₀ value ranged between 0.38-0.72 per cent among the varieties. Whereas, in gamma rays treatments LD₅₀ value ranged irrespective of varieties.

Singh *et al.* (2000) suggested that the mutagenic treatments had wider value for range, mean and coefficient of variation than control for different characters in two cultivars (namely PD 4-1 and T-9) of urdbean. Positive and negative shift in mean value observed for all the quantitative traits. All the mutagenic treatments influence the mean range and CV values independently in both the varieties. However, the combination of various doses of gamma rays with EMS (0.02 mM) was found effective for causing induced genetic variability in urdbean cultivars.

Waghmare and Mehra (2000) in grass pea (*Lathyrus sativus* L.) observed a significant increase in variability for grain yield per plant followed by number of pods per plant, number of seeds per pod and plant height in M₂ and M₃ generations, while reduction in days to flowering, days to maturity, number of primary branches, pod length and number of seeds per pod in both the generations.

Khan and Qureshi (2001) studied the chickpea genotypes viz., Noor 91, Punjab 91 and C-141 irradiated with 40, 50 and 80 kr of gamma rays separately and simultaneously with gibberellic acid (GA₃). Decrease in mean value for all the characters viz., plant height, number of primary and secondary branches, pods per plant, seeds per pod, 100-seed weight, harvest index, grain and biological yield were recorded in gamma rays treated population except days to flowering and maturity in Punjab 91 and C-141. However, in Noor 91 increase over control was recorded for plant height, number of primary branches and days to flowering and maturity.

Majeed-Ur-Rahman *et al.* (2001) tested seeds of mungbean line K-851 with 10 different concentrations (0.01 per cent to 0.1 per cent) of hydrazine hydrate as well as sodium azide and were germinated at $25 \pm 1^{\circ}\text{C}$ reported a dose dependent reduction in germination and seedling growth for both chemicals with LD₅₀ 0.052 and 0.067 for HH and SA respectively.

Sujay Rakshit *et al.* (2001) treated 200 seeds of mung bean (*Vigna radiata*) cultivars, PDM 145, PDM 54, UPM 79-3-4 and urd bean (*V. mungo*) cutlivars PDUI, Pant U30 and T-9 for mutation studies using five doses of EMS (0.01, 0.02, 0.03, 0.04 and 0.05 M). Chlorophyll mutation chlorina was more common in urd bean and virdis in mung bean. EMS at 0.05 m induced highest proportion of chlorophyll mutations. Mung bean cultivars showed higher inter Varietal differences than the urd bean cultivars in terms of mutagenic sensitivity. Effectiveness and efficiency of 0.01 M EMS were higher in urd bean, while EMS above 0.03 M concentration showed higher effectiveness and efficiency in mung bean.

Waghmare *et al.* (2001) reported for the first time a fascinated mutant in grass pea (*Lathyrus sativus* L.) cultivar P-27 following 250 kr gamma rays treatment characterized by broadened stem small narrow leaves and pods. The flattened stem of the shoot apex appeared like a cluster of closely fused branches and mutant was fertile with less number of primary and secondary branches, finally resulting in low yield and delayed maturity.

Banu *et al.* (2002) studied induced mutation in cowpea cultivars Co-6 and VBN-1. The mutagens used were physical (gamma rays) and chemical (ethylmethane sulphonate and methylmethane sulphonate) mutagens at 0.05, 0.10, 0.15, 0.20 and 0.25 per cent. The induction was characterized by the occurrence of morphological deviants in the earlier days and aberrants in the later stages. The frequency of viable mutations was influenced by the general genetic architecture of the plant. The maximum mutability was observed in Co-6; however, the mutation spectrum induced was slightly broader in VBN-1 than in Co-6. Among the mutagens, gamma rays were more successful in inducing higher frequency as well as broader spectrum of viable mutations than EMS indicating the efficiency of physical mutagens.

Solanki and Sharma (2002) treated seeds of a macrosperma lentil (*Lens culinaris*) cultivar Precoz with three doses (0.005, 0.01 and 0.02 per cent) each of ethyleneimine (EI) and N-nitroso N-ethyl urea, N-ethyl-N-nitroso urea (NEU) and gamma rays (5, 10 and 20 kr). In M_2 based on desired shift in character mean and higher CV than the highest observed in control, followed by identification of M_3 families with higher mean than the highest in the control. Among the mutagens tested NEU induced the highest frequencies of mutated and promising progenies with multiple characters in both the M_2 and M_3 , followed by EI and gamma rays and different groups of mutagenic damage were observed to follow the pattern: HH > HL > LL in the M_2 and HH > LL in M_3 .

Atta *et al.* (2003) treated dry and healthy chickpea cultivated variety Pusa 329 seeds with gamma rays (250 and 300 Gy) and EMS (0.3 and 0.4 per cent). The morphological mutations for plant type, growth habit, branching, leaf type, pod size, flower colour, and chlorophyll content were observed in the M_2 generation.

Sharma *et al.* (2005) determined the mutagenic sensitivity, mutagenic efficiency and effectiveness of gamma rays and EMS in PDU-1 and T-9 variety of blackgram. They observed that the increasing doses of gamma rays and EMS decreased germination, plant survival and plant fertility. They also observed parallelism between radio-sensitivity and chemo mutability of urdbean [*Vigna mungo* (L.)Hepper] genotypes. The efficiency and the effectiveness of EMS were higher than the gamma rays and the lower doses of mutagens were more effective and efficient than the higher doses.

3. MATERIALS AND METHODS

The present investigation entitled “Improvement of Black Gram [*Vigna mungo* (L.) Hepper] Variety Barkha for Yield and Maturity through Mutagenesis” was carried out at the Experimental field of Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, Udaipur situated at an elevation of 528.17 meters above mean sea level at a latitude of 24° 35’N and longitude of 73° 42’ E, during *kharif*, 2005. The meteorological data recorded during crop period are presented in Appendix-I.

3.1 Experimental Material :

The seed material used in the present investigation consisted of Barkha variety of black gram. Barkha developed at Agriculture Research Station, Banswara, which is bold and bright seeded, high yielding, highly branched, late maturity and well adopted to climate of Rajasthan and liked by local farmers but due to late in maturity it faces terminal drought.

Seed of this variety was treated with chemical mutagens viz. Etylmethane sulphonate (EMS), Dimethyle sulphonate (DMS) and their combinations with different plant growth regulators viz. Indol Acitic Acid (IAA) and Gibberellic acid (GA). M₁ generation was raised by Dr. Shailesh Kumar Jain for his Ph. D. research work, *kharif*, 2001-02, under the guidance of Dr. V. L. Mathur Assoc. Prof. Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, Udaipur. Normal appearing competitive ten M₁ plants (progenies) from each selected treatment (families) as below were advanced to M₂ generation.

1. Control
2. EMS 0.4 per cent
3. EMS 0.6 per cent
4. DMS 0.04 per cent
5. DMS 0.06 per cent
6. EMS 0.4 + 3×10^{-3} M IAA
7. EMS 0.4 + 3×10^{-4} M IAA
8. EMS 0.6 + 3×10^{-3} M IAA

9. EMS $0.6 + 3 \times 10^{-4}$ M IAA
10. DMS $0.04 + 3 \times 10^{-3}$ M GA
11. DMS $0.04 + 3 \times 10^{-4}$ M GA

3.2 Experimental Methodology

Normal appearing plants from eleven treatments (M_1 generation) which exhibited relatively high fertility were selected to advance in M_2 generation. The M_2 generation was raised in compact family block design with three replications. Each treatment was taken as family and within treatment the individual plant progeny was taken as progenies. All the progenies within family were randomized, likewise the family blocks were also randomized. Progenies were sown in single row plot of three meter length and distance between plant to plant and row to row (30 x 10 cm) was maintained. All recommended agronomical practices were adopted to raise a healthy crop.

3.3 Characters Studied and Procedure of Observations:

(A) Macro mutations

(I) Chlorophyll mutations:

Among the M_2 progenies chlorophyll mutants were observed time to time field visit as classified by Gustafsson (1940) and Singh *et al.* (1999).

(II) Morphological Variants:

The treatments were screened several times during entire growth period to detect viable mutants affecting various morphological attributes.

(III) Mutation frequency:

(a) M_2 family basis (percentage of mutated M_2 progenies) :

The frequencies of chlorophyll and morphological mutants were calculated as given below (Kharakwal, 1998a):

$$\text{Mutation frequency (\%)} = \frac{\text{Number of mutant progenies}}{\text{Total number of } M_2 \text{ progenies}} \times 100$$

(b) Population basis (percentage of mutants):

$$\text{Mutation frequency (\%)} = \frac{\text{Number of mutated plants}}{\text{Total number of } M_2 \text{ plants}} \times 100$$

(IV) Mutagenic effectiveness and efficiency:

Mutagenic effectiveness given as estimate of the frequency of mutation induced by a unit dose of mutagen, while mutagenic efficiency indicates the yield of mutation in relation to the total biological damage measured in M_1 generation (Kharakwal, 1998a).

$$\text{Mutagenic effectiveness of chemical} = \frac{\text{Percentage of families segregating for mutation on } M_2 \text{ basis}}{\text{Duration of mutagenic treatment} \times \text{Conc. of Mutagen (\%)}}$$

$$\text{Mutagenic efficiency} = \frac{\text{Percentage of families segregating for mutation on } M_2 \text{ basis}}{\text{Biological damage in } M_1 \text{ generation}}$$

(B) Micro mutations

Observations were recorded on ten randomly selected plants in each progeny of all the families except days to 50 per cent flowering and days 75 per cent maturity, which were observed on whole plot basis.

(i) Days to 50 per cent flowering:

Duration in days from date of sowing to the date on which 50 per cent of plants completed the opening of first flower was considered as days to flowering.

(ii) Days to 75 per cent maturity:

Duration in days taken from sowing to the date on which 75 per cent plants were matured.

(iii) Plant height (cm):

Height of the plant was measured from ground level to the tip of main shoot of ten randomly selected plants and averaged.

(iv) Number of primary branches per plant:

Total number of branches originated from main stem was counted at the time of harvesting in each randomly selected plant.

(v) Number of pods per plant:

The number of pods per plant were recorded by counting the total number of pods in each of ten selected plants and averaged.

(vi) 100-seed weight (g):

A sample of hundred seed was taken from the produce of each plant and weighted in gram. The average was worked out.

(vii) Seed yield per plant (g):

Total seed obtained from each selected plant was weighted in gram separately and average was taken.

(viii) Biological yield per plant (g):

The ten randomly selected plants from each treatment were harvested separately. These plant were sun-dried and weighted (including pods), average value was workout to obtain biological yield per plant (g).

(ix) Harvest index (%):

Harvest index is the ratio of seed yield to biological yield, and was calculated using the formula:

$$\text{Harvest index (\%)} = \frac{\text{Seed yield per plant (g)}}{\text{Biological yield per plant (g)}} \times 100$$

(x) Seed Protein content (%):

Protein content of seed was estimated by the micro-Kjeldahl's method (Linder, 1944). Three seed samples per treatment per replication were analyzed for protein content and average was taken. The detail procedure used is given in Appendix-II.

3.4 Statistical methods:

The M_2 generation was raised in the compact family block design with three replications. Selected eleven treatments from M_1 generation were taken as families and within treatment the individual plant progeny was taken as progenies. Both families and progenies within families were randomized. The analysis of variance for each of the family was done separately according to Panse and Sukhatme (1978). The components of variance and their expectations are given as following.

Analysis of variance for differences between families and within families (between progenies)

Source	d.f.	S.S.	M.S.	EMS
Replication	$r - 1$	SSr	MSr	
Families	$n - 1$	SSn	MSn	$\sigma_e^2 + rp\sigma_F^2$
Progenies	$p - 1$	SSp	MSp	$\sigma_e^2 + r\sigma_P^2$
Error		SSe	MSe	σ_e^2
Total (T)		SS(T)		

Where,

r, n, p = replications, families, progenies in a family and error, respectively.

(i) Critical difference for difference between families :

$$CD = \sqrt{\frac{2 \text{ MSe}}{Pr}} \times t \text{ value at 5\% level of significance of error d.f.}$$

(ii) Critical difference for differences between progenies within family :

$$CD = \sqrt{\frac{2 \text{ MSe}}{r}} \times t \text{ value at 5\% level of significance of error d.f.}$$

(iii) Coefficient of variation

$$CV = \frac{\sqrt{\text{MSe}}}{\bar{X}} \times 100$$

Variability parameters:

Following genetic variability parameters calculated in all those families which revealed significant progeny differences.

(i) Genotypic Coefficient of Variation (GCV) :

The magnitude of genetic variation existing in a character was worked out by the formula given by Burton (1952).

$$GCV = \frac{\sqrt{V_g}}{\bar{X}} \times 100$$

Where,

$$V_g = \frac{\text{MSp} - \text{MSe}}{r}$$

Where,

V_g = Genotypic variance

$\bar{X}$ = Mean of the character under study

MSp = Mean square due to progenies

MSe = Error variance

r = Number of replications.

(ii) Phenotypic Coefficient of Variation (PCV) :

The magnitude of phenotypic variation existing in a character was estimated by using the formula suggested by Burton (1952).

$$PCV = \frac{\sqrt{V_{ph}}}{\bar{X}} \times 100$$

$$V_{ph} = V_g + MSe$$

Where,

V_{ph} = Phenotypic variance

$\bar{X}$ = Mean of the character under study

V_g = Genotypic variance

MSe = Error variance

(iii) Heritability :

Heritability in broad sense was estimated by using following formula proposed by Burton and Davane (1953), Jhonson *et al.* (1955) and Hanson *et al.* (1956).

$$H = \frac{V_g}{V_{ph}} \times 100$$

Where,

V_g = Genotypic variance

V_{ph} = Phenotypic variance

(iv) Genetic gain :

It is the genetic advance expressed as per cent of mean :

$$\text{Genetic gain} = \frac{GA \times 100}{\bar{X}}$$

Where genetic advance (GA) was estimated using the formula suggested by Robinson *et al.* (1949), Johnson *et al.* (1955).

$$GA = k [V_g/V_{ph}] \times \sqrt{V_{ph}}$$

Where,

V_g = Genotypic variance

V_{ph} = Phenotypic variance

$\bar{X}$ = Mean of the character under study

K = Selection differential (constant) at 5 % selection intensity (Allard, 1960) i.e. 2.06

4. RESULTS

The present investigation entitled “Improvement of Black Gram [*Vigna mungo* (L.) Hepper] Variety Barkha for Yield and Maturity through Mutagenesis” was conducted during *Kharif*, 2005 at the Experimental field of Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, Udaipur. Normal appearing competitive 10 M₁ plants (progenies) from each selected treatment (families) were advanced to M₂ generation. The M₂ generation was raised in compact family block design with three replications for evaluation of macro and micro mutational changes. The results obtained in M₂ generation are presented as under:

(A) Macro mutations:

The frequency and spectrum of macro mutations (i.e., chlorophyll and morphological) are presented in Table 1.

(i) Chlorophyll mutations:

Among the M₂ progenies three types of chlorophyll mutants (Table-1 & Fig. 1) as classified by Gustafsson (1940) and Singh *et al.* (1999) were observed viz., Xantha (a lethal mutation with entirely yellow leaves), chlorina (yellowish green coloured leaves with majority of them died after 45-60 days) and virscent (yellow green leaves with later transformed into green and survived).

The occurrence of xantha and chlorina types of mutants was more frequent than other types of chlorophyll mutants in all the mutagen treated population.

(ii) Morphological mutations:

The spectrum of morphological mutations (Table 1) is classified in five classes viz., bunchy, dwarf (reduced plant height), unbranched, elongated leaf type and indeterminate growth habit (Fig.2).

Plants of elongated leaf habit were common occurrence in all the families of both the mutagens except control.

(iii) Mutation frequency:

The mutation frequency was calculated on population as well as family basis (Table 1). The frequency of chlorophyll mutants varied with concentration of mutagens. The highest frequency of chlorophyll mutations was observed in family EMS 0.4 + 3×10^{-3} M IAA at population (0.93) and family basis (50). No chlorophyll mutants were observed in the untreated control.

(iv) Efficiency and effectiveness of mutagens:

The data presented in Table 2 revealed that efficiency and effectiveness of various mutagenic treatments. Pollen sterility estimated in M_1 generation in respect of treatment was used as criterion for assessing biological damage.

Effectiveness (Me/t.c.) of DMS was the highest at DMS 0.04 + 3×10^{-3} M GA (250) and which decreased with increase in the concentrations of DMS and was the lowest at 0.06 percent DMS (83.33). Likewise the effectiveness (Me/t.c.) of EMS was the highest at EMS 0.4 + 3×10^{-3} M IAA (31.25) and which decreased with increase in the concentrations of EMS and was the lowest at EMS 0.6 per cent (8.33).

DMS 0.04 per cent treatment along with both the doses of GA was approximately nine times more effective than EMS 0.4 per cent treatment whereas, EMS 0.4 per cent was highly efficient with both the doses of IAA as compared to other treatments. EMS 0.4 + 3×10^{-3} M IAA treatment was most efficient treatment (1.889) whereas, DMS 0.06 per cent recorded as the least efficient treatment (0.472).

(B) MICRO-MUTATIONS :

Analysis of variance revealed that highly significant differences existed between the families for all the traits (Table-3).

(i) Days to 50 per cent flowering:

Progenies differences were significant in all the families except control and EMS 0.6 per cent (Table 3). On the basis of mean family EMS 0.4 + 3×10^{-4} M IAA (37.77) was significantly earlier in flowering than control (38.53). Maximum range for days to 50 per cent flowering was recorded in family EMS 0.4 + 3×10^{-3} M IAA (35.67-41.00) against the control (38.33-39.00) (Table 4). Maximum coefficient of

variation was observed in family EMS 0.4 + 3 x 10⁻³ M IAA (7.70) than control (1.26). From all families only six progenies exhibited significant early flowering than control (Appendix-III). Maximum GCV, PCV and heritability was observed in family EMS 0.6 + 3 x 10⁻³ M IAA (GCV = 3.94, PCV = 4.30, Heritability = 84.01, Genetic gain = 7.44) (Table 5).

(ii) Days to 75 per cent maturity:

Progeny differences were significant in all the families except control (Table 3). Family EMS 0.4 + 3 x 10⁻³ M IAA (78.83) and Family EMS 0.4 + 3 x 10⁻⁴ M IAA (78.90) were significantly earlier in maturity than control (79.77). Highest range for days to 75 per cent maturity was observed in family EMS 0.6 + 3 X 10⁻³ M IAA (76.00 – 82.33) against control (79.00–80.33). Coefficient of variation in control was 0.97 per cent which increased to 4.95 in family EMS 0.4 + 3 X 10⁻³ M IAA (Table 4). Eighteen progenies exhibited early maturity than control (Appendix-III and table 6). The variability parameters recorded for all the families were low in magnitude except EMS 0.4 + 3 X 10⁻³ M IAA (GCV = 2.69, PCV = 2.74, Heritability = 96.59, Genetic gain = 5.45) (Table 5).

(iii) Plant height (cm):

Progeny differences were significant in all the families except control (Table 3). Maximum plant height was observed in family EMS 0.4 +3 x 10⁻³ (28.60) Than control (27.40). Wide range was observed in family DMS 0.06 per cent (20.14-32.12) than control (26.93-27.86). Coefficient of variation in control was 2.29 per cent which increased in all the families. Highest coefficient of variation was observed in family EMS 0.4 + 3 x 10⁻⁴ M IAA (18.91) (Table 4). Thirty four progenies exhibited significant increase in plant height than control in all the mutagenic families (Appendix-III). Maximum GCV, PCV, Heritability and Genetic advance was observed in family EMS 0.4 + 3 x 10⁻⁴ M IAA (GCV = 10.23, PCV = 10.61, Heritability = 92.94 and Genetic gain = 20.32) followed by DMS 0.06 (GCV = 9.82, PCV = 10.47, Heritability = 87.90 and Genetic gain = 18.96) (Table 5).

(iv) Number of primary branches per plant:

Progeny differences were significant in all the families except control (Table 3). Maximum number of primary branches per plant was observed in family EMS 0.4

+ 3×10^{-3} M IAA (2.80) than control (2.56). Highest range for this trait was observed in family DMS 0.04 + 3×10^{-3} MGA (1.87-3.14) as compared to (2.36 - 2.69) control (Table 4). Coefficient of variation was maximum in family DMS 0.04 + 3×10^{-4} M GA (37.08). Higher number of primary branches per plant was observed in twenty seven progenies over all the families (Appendix-III). Family DMS 0.04 + 3×10^{-4} M GA showed highest magnitude for GCV (19.78) and PCV (21.34) whereas Heritability (93.75) and Genetic gain (31.44) was higher in family DMS 0.04 + 3×10^{-3} M GA (Table 5).

(v) Number of pods per plant:

Statistically significant differences between progeny were recorded in all the families except control, EMS 0.6 per cent, DMS 0.04 per cent and DMS 0.06 per cent (Table 3). None of the families exhibited positive shift in number of pods per plant as compared to control (15.86). Wide range for number of pods per plant was observed in family DMS 0.04 + 3×10^{-3} M GA (13.60 - 18.23) against control (15.67 - 16.03). Coefficient of variation was 1.20 percent in control. It was increased at all the mutagenic treatments and highest in family EMS 0.4 per cent (19.40) (Table 4). Among all the families six progenies exhibited higher number of pods per plant than control (Appendix-III). PCV (10.90) and GCV (9.07) was maximum in family EMS 0.4 + 3×10^{-3} M IAA whereas maximum value of Heritability (90.96) and Genetic gain (16.33) was observed in family DMS 0.04 + 3×10^{-3} M GA (Table 5).

(vi) 100-seed weight (g):

No significant differences between progenies were observed for 100-seed yield than control (4.37). Coefficient of variation was 1.82 per cent in control and it was increased in all the families. Range for seed yield per plant was observed narrow in all the families than control (Table 4). None of the progeny was found superior than control for 100-seed weight (Appendix-III). The variability parameters were low in magnitude in all the families (Table 5).

(vii) Seed yield per plant (g):

Progeny differences were found significant in all the families except control, EMS 0.6 per cent and DMS 0.06 per cent (Table 3). Grain yield was higher in two families viz., EMS 0.4 per cent (3.78) and family EMS 0.4 + 3×10^{-3} M IAA (3.70)

than control (3.60). Coefficient of variation was 1.96 per cent in control which increased in all the mutagenic treatment and it ranged from 1.96 per cent (control) to 12.64 per cent (EMS 0.4 + 3×10^{-4} M IAA). Wide range for seed yield per plant was observed in all the families than control (3.53 - 3.65) (Table 4). In all the families only eight progenies were statistically superior for grains yield per plant than control (Appendix-III and table 6). Maximum value of variability parameters was observed in family EMS 0.4 + 3×10^{-3} M IAA (GCV = 6.86, PCV = 7.06, Heritability = 94.46 and Genetic gain = 13.73) followed by family DMS 0.04 + 3×10^{-3} M GA (GCV=5.44, PCV = 5.63, Heritability = 93.39 and Genetic gain = 10.83) (Table 5).

(viii) Biological yield per plant (g):

For biological yield per plant progenies differences were significant in all the families except control (Table 3). Biological yield was significantly higher in all the families than control (16.39). Highest biological yield was observed in family DMS 0.06 per cent (21.53). Increase in range was observed in all the families than control (16.08-17.17). Higher coefficient of variation was observed in all the treatments than control (4.53). Maximum coefficient of variation (22.69) was observed in DMS 0.04 per cent (Table 4). Among all the families thirty five progenies were superior for biological yield per plant over control (Appendix-III). Maximum GCV (12.37), PCV (12.55), Heritability (97.17) and Genetic gain (25.11) were observed in family DMS 0.04 per cent followed by EMS 0.4 + 3×10^{-3} M IAA viz., GCV (11.12), PCV (11.20), Heritability (98.46) and Genetic gain (22.72) (Table 5).

(ix) Harvest index (%):

For harvest index progeny differences were significant in all the families except control (Table 3). None of the family exhibited significant increase in harvest index than control (18.03), though increased in range was exhibited by all the families. Highest coefficient of variation was observed in DMS 0.04 + 3×10^{-3} M GA (22.26) than control (4.35) (Table 4). One progeny among all the families was found superior than control (Appendix-III). Maximum GCV (12.14), PCV (12.30), Heritability (97.46) and Genetic gain (24.69) were observed in family DMS 0.04 + 3×10^{-3} M GA followed by EMS 0.4 + 3×10^{-4} M IAA viz., GCV (11.53), PCV (11.71), Heritability (97.00) and Genetic gain (23.40) (Table 5).

(x) Seed Protein content (%):

Significant progeny differences were observed in all the families except control and DMS $0.04 + 3 \times 10^{-3}$ M GA (Table 3). Seed Protein content was significantly higher in family EMS 0.4 per cent (24.67), EMS $0.6 + 3 \times 10^{-3}$ M IAA (24.94) and EMS $0.6 + 3 \times 10^{-4}$ M IAA (24.78) than control (24.45). Narrow range for protein content was observed in all the families. Coefficient of variation was highest in EMS $0.4 + 3 \times 10^{-3}$ M IAA (7.10) than control (2.72) (Table 4). Ten progenies among all the families were significantly superior to control for protein content (Appendix-III). Maximum GCV (3.47), PCV (3.50), Heritability (98.51) and Genetic gain (7.11) were observed in family EMS $0.6 + 3 \times 10^{-3}$ M IAA (Table 5).

5. DISCUSSION

Black Gram [*Vigna mungo* (L.) Hepper] is one of the important pulse crop of India. It is largely grown during *Kharif* season in marginal and sub-marginal areas. However, its productivity is relatively low and needs genetical amelioration.

Breeding potential in a crop preliminary depends on the nature and extent of genetic variability present in the population. Lack of genetic variation available in existing germplasm restricts its further improvement. Mutation is the fundamental basis of new genetic changes or creates variability in the heritable material. Hugo de Vries (1901) described the term 'mutation' as a relatively large heritable change resulting in discontinuous variation.

Ever since Muller (1927) and Stadler (1928) demonstrated the artificial induction of mutation using X-rays in *Drosophila* and Barley. Work on chemical mutagenesis was started by Scacharov (1936) using iodine on *Drosophilla*. Auerbach and Robson (1946) using mustard gas gave a theory of chemical mutagenesis. In case of chemical mutagens a wide range of chemicals like EMS, DMS, MMS, EI and DES etc. have been tried and their efficiency was evaluated. Alkylating agents react directly with DNA by alkylating phosphate group and react with –COOH, –SH and –NH group of bases results in point mutations.

The mutagenic effectiveness and efficiency of mutagens and their doses are pre-requisite for induction and utilization of mutations. Effectiveness means the rate of mutations as related to dose, while efficiency usually refers to the mutation rate in relation to damage (Sharma *et al.*, 2005). In order to increase the efficiency and effectiveness of chemicals the studies were also directed to identify chemicals which may possess protective properties against chemical mutagens. Different growth regulators were reported which reduced the cytomorphological damage caused by mutagens and increase the efficiency of chemical mutagens viz., GA (Dayal and Kaul, 1969 in barley and Zargar, 1973 in black gram). Mutation breeding has been successfully used to induce variability and for improvement of one or two characters

in black gram by number of scientist's viz., Khan *et al.* (1985), Gautam *et al.* (1992), Hipziba and Subramaniam (1994), Prema *et al.* (1998) and Singh *et al.* (2000).

Therefore, present investigation was undertaken to induce mutations leading to macro mutational and micro mutational changes in respect of yield and yield attributes in black gram variety Barkha which is well adopted to climatic conditions of Rajasthan but late in maturity and faced terminal drought, so the main objective of the investigation are to estimate variability induced in M_2 generation, to estimate efficiency and effectiveness of chemical mutagens and to isolate high yielding and early maturing mutants from M_2 generation.

Before discussing the results obtained in M_2 generation, let us have a brief mention of those factors which may cause a variation of the kind observed in this study and the assumption which can be made keeping in view their significance. Apart of the variation among individuals in treated populations may be described to interactions of new genotypes with the environment. From the present study, it is impossible to estimate the $G \times E$ interaction, but keeping in view that mutation is a random process, it is reasonable to assume that a similar magnitude of $G \times E$ interaction existed in the control and treated population. Out crossing, as possible some of bias in these parameters of variability may be considered negligible because black gram is highly self-pollinated crop. Sterility did not seem to account for any major part of the variation, because there was no evidence of it in the material studies.

In M_2 generation, macro and micro mutational changes in respect to yield and yield related traits were studied. Under macro-mutational changes morphological and chlorophyll mutants was studied. Micro mutations were studied with two set of analysis. In one the mean, range and coefficient of variation was estimated. In the other, the estimate of genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance were computed in all those treatments, which revealed significant progeny differences.

Macro-mutational changes are easily detected on account of their easily discernible phenotype. In the present study few changes both in plant type and chlorophyll mutations were observed. In general five type of morphological mutant

viz., bunchy, dwarf, unbranched, elongated leaf type and indeterminate growth habit and three chlorophyll mutants viz., xantha, chlorina and virscent were observed. The occurrence of bushy habit plant and virscent and xantha type chlorophyll mutants was more frequent than other type of mutants in all the mutagenic families. Maximum mutation frequency was observed with family EMS 0.4 + 3×10^{-3} M IAA. The highest frequency of xantha mutants suggesting that genes for xanthophylls development are readily available for mutagenic action. Similar observation was also observed by Mallick *et al.* (1999).

Mutagenic efficiency was higher at lower doses of mutagens viz., EMS and DMS, further their respective modifiers increased the efficiency of mutagens. In the present study, EMS was found to be generally more efficient mutagen than DMS. Higher mutagenic efficiency at the lower doses of mutagens was also reported in mungbean (Mehraj-ud-din, 1999) and black gram (Sharma *et al.*, 2005).

The mutagenic effectiveness was higher at lower concentrations of mutagens and DMS was six time effective mutagen than EMS. In the present study DMS 0.04 per cent along with GA treatment was most effective mutagenic treatment. The effectiveness was decreased with increasing the doses of mutagens. The effectiveness of these mutagenic treatments is more or less comparable with those reported by Kharakwal (1998b) and Sharma *et al.* (2005) for gamma rays and EMS, and by Nagabhuhnam *et al.* (1992) for sodium azide treatment. It is known that genetic system has profound influence on the outcome of mutagenic effectiveness (Roy, 2000).

Analysis of variance of M₂ generation revealed significant inter-family differences for all the traits. This included that different loci/genes have been affected in the progenies in respect of all traits (Mahala *et al.*, 1999). Progeny differences were significant in all most all the families for all the traits except 100-seed weight.

The mean values of different characters shifted either to positive or negative direction from the control due to mutagenic treatments. EMS 0.4 + 3×10^{-3} M IAA treatment exhibited early maturity with higher number of primary branches per plant, plant height and seed yield. EMS 0.4 per cent was also efficient treatment for seed

yield and seed protein content. High estimate of coefficient of variation with increased range for most of the traits indicate induction of polygenic mutants. Similar observations were recorded by Prema Manapure *et al.* (1998) and Solanki and Joshi (2000).

In all there were eight progenies identified which was high yielder with most of the yield contributing traits and eighteen progenies were earlier in maturity than control and there were another variants which had higher estimates for some traits but low for other traits.

The coefficient of variation and range were higher in all the families as compared to their respective control for all the traits. These results are in broad conformity with those of earlier researchers (Khan, 1984; Khan and Khan, 1984 and Solanki and Sharma, 2005).

A perusal of the data for quantitative characters indicates significant differences in the mean values of treated population. The mean of different characters shift either to positive or negative direction from control. Decrease in mean values of various characters is in agreement with the hypothesis that, due to mutagenic treatment, mean is shifted to a direction opposite to selection (Bhatia and Swaminathan, 1962). The occurrence of mutants with equal frequencies towards positive and negative direction may be considered as an important reason to justify the tendency of positive and negative shift in the mean values away from the control in the treated populations (Gregory, 1967).

Wider range in M_2 families for most of the traits indicates induction of variations in polygenic traits both in negative and positive direction. Apart from the comparable mean of progenies of various treatments the coefficient of variation was distinctly high for certain characters than others, it further confirm that induction of polygenic mutations exhibiting that these traits are governed by more number of genes than those show less coefficient of variations.

Further it was noticed that plant growth regulators showed consistent performance in M_2 generation. They showed protective properties against toxic

effects of mutagens for almost all the traits in M₂ families. IAA along with various concentrations of EMS was more efficient as compared to GA with DMS treatments. Modifiers increased the mean, coefficient of variation and range for most of the traits in both the varieties as compared to individual mutagenic treatment.

Variability parameters like genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance were calculated for all the families. The genotypic and phenotypic coefficient of variation and gave an idea about the relative magnitude of variability present in general values of phenotypic coefficient of variation in all the families were slightly higher than their corresponding genotypic coefficient of variation. Gap between genotypic coefficient of variation and phenotypic coefficient of variation was narrow which reflected lesser degree of environmental influence on the genotypic variability. Similar trend were also observed by Ahmed and Yaqoob (1993) in mungbean and Hipziba and Subramaniam (1994) in black gram.

In the present investigation variability generated through mutagens and their modifiers did not showed any specific trend in terms of characters or families while EMS 0.4 per cent with IAA induced high genotypic and phenotypic coefficient of variations for most of the yield traits. Maximum value for GCV was recorded for number branches per plant followed by biological yield.

The efficiency with which genotypic variability can be exploited for improvement through selection depends on its heritability (Burton 1952). A character possessing higher GCV with high heritability can be easily improved by selection. In present investigation high heritability was recorded for seed protein content, biological yield and harvest index in almost all the families. These results were in accordance with the findings of Vandna and Dubey (1992) in black gram.

Shift in gene frequency towards desirable side under some selection pressure is termed as genetic advance, which is also expressed as percentage of mean (genetic gains). Johnson *et al.* (1955) emphasized the significance of genetic advance as an estimate for predicting the expected gain by selection. In present study high value of genetic gain was observed in all most all the families for biological yield per plant and

harvest index. Variability coupled with high heritability and greater expected genetic gain is an induction of greater role of additive gene effects in genetic control of the given character. Character with greater contribution and additive gene effect can be easily improved through selection (Panse, 1978). Higher genotypic variability along with high heritability and greater genetic gain was recorded in family EMS 0.4 + 3×10^{-3} M IAA and EMS 0.4 + 3×10^{-4} M IAA for grains yield and most of the traits. These results are in agreement with those reported by Hipziba and Subramaniam (1994).

If we assess the families on the basis of highest values of GCV, PCV, heritability and genetic gain, it could be concluded that EMS 0.4 + 3×10^{-3} M IAA and EMS 0.4 + 3×10^{-4} M IAA generated high magnitude of variability for grain yield and other yield contributing traits.

On the basis of above discussion it was observed that the mean values of most of the traits shifted either in positive or negative direction in all the families. Family EMS 0.4 + 3×10^{-3} M IAA was early in maturity and it also having high mean for yield and most of the yield traits. Range and coefficient of variation were also higher in these families. If we assess the families on the basis of highest value of GCV PCV, Heritability and Genetic advance it could be recorded that EMS 0.4 per cent and EMS 0.4 per cent with their respective modifiers generated highest magnitude of variability for grain yield and other yield contributing traits.

Based on the above discussion it is suggested that to isolate desirable mutants viz., higher yielding and early maturing type superior progenies of EMS treatments along with modifiers should carry forward in subsequent generations.

6. SUMMARY

The present investigation entitled “Improvement of Black Gram [*Vigna mungo* (L.) Hepper] Variety Barkha for Yield and Maturity through Mutagenesis” was undertaken with the specific objectives, to estimate variability induced in M₂ generation, to estimate efficiency and effectiveness of chemical mutagens and isolate high yielding and early maturing mutants from M₂ generation.

The experiment was conducted at Experimental field of Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, Udaipur during *Kharif* 2005. The black gram cultivar Barkha was treated with three concentrations of mutagens each of EMS (0.2, 0.4 and 0.6 per cent) and DMS (0.02, 0.04 and 0.06 per cent) along with modifiers like IAA and GA (3×10^{-3} M and 3×10^{-4} M) and M₁ generation raised by Dr. Shailesh Kumar Jain for his Ph. D. research work. To raise M₂ generation eleven treatments were selected from M₁ and each treatment was considered as a family and each plant as progeny for evaluation of micro mutational (morphological and chlorophyll mutations) and macro mutational changes.

Among macro mutation five morphotypes were detected viz., bunchy, dwarf (reduced plant height), unbranched, elongated leaf type and indeterminate growth habit, Further three types of chlorophyll mutants were identified in the entire population viz., xantha, chlorina and virscent. Among the chlorophyll mutants xantha and virscent were frequent than the rest.

In general it was observed that EMS 0.4 per cent treatment along with both the doses of modifier (IAA) was the most efficient and DMS 0.04 per cent with modifier (GA) was most effective mutagenic treatment.

For assessment of induced variation in M₂ generation in respect of various quantitative and qualitative characters observations on ten randomly selected plants were recorded and subjected to statistical analysis. The analysis of variance revealed that mean square between families were highly significant for all the traits studied.

Mean squares due to progenies were significant in all most all the families except control for all the characters except 100-seed weight.

The mean values of different characters shifted either to positive or negative direction from the control due to mutagenic treatments. EMS 0.4 + 3×10^{-3} M IAA treatment exhibited early maturity with higher number of primary branches per plant, plant height and seed yield. EMS 0.4 per cent was also efficient treatment for seed yield and seed protein content. High estimate of coefficient of variation with increased range for most of the traits indicate induction of polygenic mutants.

In all there were eight progenies identified which was higher yielder with most of the yield contributing traits and eighteen progenies were early in maturity than control and there were another variants which had higher estimates for some traits but low for others.

Variability parameters were computed in all those treatments which showed significant progeny differences. Treatment exhibiting higher genetic variation usually had higher values of heritability and genetic advance barring few exceptions. EMS with modifiers proved to be the most efficient mutagen as it affected all the direct components of yield. It exhibited high value for variability parameters for yield and its contributing traits.

Therefore, it is concluded that EMS 0.4 per cent treatment along with modifier was found to be the most efficient treatment, it induced early maturity along with high mean for yield and yield contributing traits. Range and variance was also increased for most of traits. It also exhibited high values of variability parameters indicating polygenic mutants. Therefore, these treatments and progenies should be carried further in M₃ generation to isolate early maturing, high yielding lines.

SALIENT FINDINGS:

1. The variety Barkha was mutagen sensitive in respect of the parameters used in field studies.
2. In M_2 generation macro mutational changes like morphological (bunchy, dwarf, unbranched, elongated leaf type and indeterminate growth habit) and chlorophyll (xantha, chlorina and virscent) mutants were observed.
3. EMS 0.4 per cent along with IAA was most efficient and DMS 0.04 per cent with GA were more effective mutagenic treatments.
4. The analysis of variance revealed that mean square due to families were highly significant for all the traits. A significant progeny difference was recorded in all most all the families except control for all the characters except 100- seed weight.
5. In M_2 generation mean of different characters shifted either to positive or negative direction from the control with increase in range and coefficient of variation.
6. In all there were eight progenies identified which was higher yielder with most of the yield contributing traits and eighteen progenies were earlier in maturity than control.
7. Family EMS 0.4 + 3×10^{-3} M IAA and DMS 0.04 + 3×10^{-3} M GA exhibited higher values for variability parameters for most of the traits studied.
8. Therefore, it is concluded that EMS 0.4 treatment along with modifier was found to be the most efficient treatment, it induced early maturity along with high mean for yield and yield contributing traits. Range and variance was also increased for most of traits. It also exhibited high values of variability parameters indicating polygenic mutants. In all there were eight progenies identified which was higher yielder with most of the yield contributing traits and eighteen progenies were early in maturity than control. Therefore, these treatments and progenies should be carried further in M_3 generation to isolate early maturing, high yielding lines.

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Table 1 : Frequency of morphological and chlorophyll mutants in Barkha variety of black gram in M₂ generation

Treatments	Total plant observed	Total number of progenies observed	Morphological mutant					Chlorophyll mutant			Total No. of mutant	Total No. of progeny represent mutation	Mutation freq. (population basis)	Mutation freq. (family basis)
			Bunchy	Dwarf	Unbranched	Elongated leaf	Indeterminate growth habit	Xantha	Chlorina	Virscnt				
Control	750	10	-	-	-	-	-	-	-	-	-	-	-	-
EMS 0.4 per cent	750	10	1	-	1	1	-	1	1	-	5	3	0.67	30
EMS 0.6 per cent	750	10	-	-	-	1	1	1	-	-	3	2	0.40	20
DMS 0.04 per cent	750	10	-	1	1	-	-	1	1	-	4	2	0.53	20
DMS 0.06 per cent	750	10	1	-	-	1	1	-	-	-	3	2	0.40	20
EMS 0.4 + 3 x 10 ⁻³ M IAA	750	10	-	1	1	2	-	1	1	1	7	5	0.93	50
EMS 0.4 + 3 x 10 ⁻⁴ M IAA	750	10	1	-	-	1	1	-	1	1	5	4	0.67	40
EMS 0.6 + 3 x 10 ⁻³ M IAA	750	10	1	1	-	1	-	1	1	-	5	3	0.67	30
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	750	10	1	-	1	1	-	1	-	-	4	3	0.53	30
DMS 0.04 + 3 x 10 ⁻³ M GA	750	10	1	1	-	1	-	1	-	1	5	4	0.67	40
DMS 0.04 + 3 x 10 ⁻⁴ M GA	750	10	-	1	-	1	1	1	-	-	4	3	0.53	30

Table 2 : Effectiveness and efficiency of different mutagens in Barkha variety of black gram in M₂ generation

Treatments	% of M₂ families segregating for mutation (Me)	Pollen sterility % in M₁ (S)	Mutagenic effectiveness (Me/t.c.)	Mutagenic efficiency (Me/S)
Control	-	-	-	-
EMS 0.4 per cent	30	30.36	18.75	0.988
EMS 0.6 per cent	20	37.37	8.33	0.535
DMS 0.04 per cent	20	36.43	125	0.549
DMS 0.06 per cent	20	42.37	83.33	0.472
EMS 0.4 + 3 x 10 ⁻³ M IAA	50	26.47	31.25	1.889
EMS 0.4 + 3 x 10 ⁻⁴ M IAA	40	27.57	25.00	1.451
EMS 0.6 + 3 x 10 ⁻³ M IAA	30	34.42	12.5	0.872
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	30	36.31	12.5	0.826
DMS 0.04 + 3 x 10 ⁻³ M GA	40	34.63	250	1.16
DMS 0.04 + 3 x 10 ⁻⁴ M GA	30	34.11	187.5	0.879

t=Duration of mutagenic treatment (4 hours), c=Concentration of Mutagen

Table 3 : Mean squares for different characters in Barkha variety of black gram in M₂ generation

Sources	Days to 50 per cent flowering	Days to 75 per cent maturity	Plant height	Number of branches per plant	Number of pods per plant	100 seed weight	Seed yield per plant	Biological yield	Harvest index	Seed Protein content
Replication	0.91	0.371	1.97 *	0.08**	0.65	0.010	0.02	0.27**	0.39 *	0.19
Between Family	4.60**	2.39**	68.14**	1.92**	17.11**	0.19**	0.98**	66.90**	65.27**	8.27**
Within Family										
Control	0.24	0.60	0.39	0.05	0.04	0.01	0.01	0.15	0.12	0.14
EMS 0.4 per cent	3.65**	6.85**	12.07**	0.46**	9.30**	0.05	0.22**	7.42**	6.22**	2.44**
EMS 0.6 per cent	0.83	2.52**	18.11**	0.16**	0.87	0.02	0.02	17.06**	5.37**	1.05**
DMS 0.04 per cent	1.87 *	6.37**	10.64**	0.13**	0.72	0.05	0.07**	18.32**	4.68**	2.12**
DMS 0.06 per cent	2.74**	8.85**	19.60**	0.17**	0.83	0.03	0.02	9.16**	3.07**	2.18**
EMS 0.4 + 3 x 10 ⁻³ M IAA	8.67**	15.20**	12.22**	0.09**	7.90**	0.02	0.10**	12.95**	10.17**	2.95**
EMS 0.4 + 3 x 10 ⁻⁴ M IAA	6.89**	11.93**	27.90**	0.21**	3.99**	0.03	0.20**	11.04**	10.11**	0.91**
EMS 0.6 + 3 x 10 ⁻³ M IAA	8.21**	9.66**	17.01**	0.33**	2.13**	0.02	0.10**	11.99**	4.16**	2.52**
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	5.70**	10.16**	17.48**	0.52**	1.54**	0.04	0.03**	15.20**	7.43**	3.04**
DMS 0.04 + 3 x 10 ⁻³ M GA	2.37**	8.13**	15.22**	0.48**	5.19**	0.06	0.12**	15.62**	10.18**	0.26
DMS 0.04 + 3 x 10 ⁻⁴ M GA	2.00 *	2.90**	9.79**	0.67**	2.52**	0.03	0.12**	13.99**	6.01**	0.80**
Error	0.86	0.51	1.15	0.03	0.55	0.03	0.01	0.12	0.24	0.17

*, ** Significant at 5% and 1% level of significance, respectively

Table 4 : Mean, range and coefficient of variation for different characters in Barkha variety of black gram in M₂ generation.

Families		Days to 50 pre cent flowering	Days to 75 per cent maturity	Plant height (cm)	Number of primary branches per plant	Number of pods per plant	100 seed weight (g)	Seed yield per plant (g)	Biological yield per plant (g)	Harvest index (%)	Seed Protein content (%)
Control	M	38.53	79.77	27.40	2.56	15.86	4.37	3.60	16.39	18.03	24.45
	R	38.33-39.00	79.0-80.33	26.93-27.86	2.36-2.69	15.67-16.03	4.29-4.46	3.53-3.65	16.08-17.17	17.10-18.49	24.07-24.88
	CV	1.26	0.97	2.29	8.38	1.20	1.82	1.96	4.53	4.35	2.72
EMS 0.4 per cent	M	38.50	79.70	27.53	2.59	15.72	4.30	3.78	18.38	17.13	24.67
	R	35.67-39.33	76.33-81.67	22.67-29.68	1.94-3.08	14.10-19.17	4.09-4.46	3.52-4.34	16.30-21.20	15.48-19.33	23.14-26.07
	CV	4.96	3.28	12.62	26.25	19.40	5.31	12.50	14.82	14.55	6.34
EMS 0.6 per cent	M	39.20	80.67	24.39	2.12	14.21	4.21	3.26	21.40	13.34	23.88
	R	38.33-40.00	79.33-82.00	20.76-28.04	1.83-2.54	13.07-15.00	4.03-4.36	3.14-3.39	17.97-24.20	11.67-15.15	23.07-25.10
	CV	2.32	1.97	17.45	18.68	6.56	3.73	4.48	19.30	17.37	4.29
DMS 0.04 per cent	M	38.80	80.43	25.46	2.26	14.81	4.24	3.36	18.87	15.22	24.30
	R	37.33-40.00	77.67-82.67	22.25-28.09	1.94-2.58	13.77-15.53	4.00-4.37	3.20-3.65	16.83-20.97	13.00-16.85	23.15-26.03
	CV	3.52	3.14	12.81	15.84	5.74	5.47	8.12	22.69	14.21	5.99
DMS 0.06 per cent	M	39.00	80.70	24.15	1.90	13.70	4.18	3.27	21.53	13.24	24.24
	R	38.00-40.67	78.33-83.33	20.14-32.12	1.59-2.31	12.79-14.33	4.05-4.39	3.16-3.44	18.83-24.83	11.99-14.63	23.35-26.28
	CV	4.24	3.69	18.33	21.80	6.64	4.01	4.51	14.06	13.24	6.08
EMS 0. 4 + 3 x 10 ⁻³ M IAA	M	38.23	78.83	28.60	2.80	15.84	4.37	3.70	20.54	15.42	24.19
	R	35.67-41.00	76.00-82.00	25.56-32.29	2.54-3.09	14.10-18.73	4.25-4.45	3.53-4.07	17.80-24.23	13.25-18.60	23.11-26.22
	CV	7.70	4.95	12.22	10.65	17.74	2.92	8.50	20.35	20.68	7.10

Cont.....

Families		Days to 50 pre cent flowering	Days to 75 per cent maturity	Plant height	Number of primary branches per plant	Number of pods per plant	100 seed weight	Seed yield per plant	Biological yield per plant	Harvest index	Seed Protein content
				(cm)			(g)	(g)	(g)	(%)	(%)
EMS 0. 4 + 3 x 10 ⁻⁴ M IAA	M	37.77	78.90	27.93	2.58	15.97	4.28	3.51	20.03	15.02	23.62
	R	35.33-39.67	75.67-81.00	23.64-32.74	2.22-2.30	14.90-18.13	4.14-4.42	3.32-3.94	17.67-23.23	12.49-18.23	23.00-24.22
	CV	6.95	4.38	18.91	17.78	12.51	3.86	12.64	16.59	21.16	4.03
EMS 0.6 + 3 x 10 ⁻³ M IAA	M	38.60	79.70	27.91	2.37	14.56	4.23	3.35	20.71	13.99	24.94
	R	35.00-40.67	76.00-82.33	23.90-31.12	1.89-2.84	13.53-16.47	4.03-4.33	3.21-3.71	17.90-23.50	12.21-15.55	23.14-26.11
	CV	7.42	3.90	14.78	24.11	10.03	3.55	9.46	16.72	14.58	6.36
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	M	38.67	79.47	27.87	2.43	14.59	4.39	3.27	19.75	14.35	24.78
	R	37.00-41.00	76.67-82.33	23.80-30.19	1.74-2.85	13.37-15.60	4.11-4.46	3.15-3.54	17.47-24.23	11.62-16.69	23.24-26.51
	CV	6.18	4.01	15.00	29.58	8.51	4.35	5.63	19.75	18.99	7.04
DMS 0.04 + 3 x 10 ⁻³ M GA	M	38.43	79.27	27.38	2.38	14.76	4.16	3.42	20.67	14.33	23.34
	R	36.33-39.67	76.00-81.67	23.88-29.95	1.87-3.14	13.60-18.23	3.95-4.41	3.21-3.93	17.90-23.67	12.05-17.53	23.11-24.00
	CV	4.01	3.60	14.25	29.09	15.42	5.78	10.05	19.13	22.26	2.20
DMS 0.04 + 3 x 10 ⁻⁴ M GA	M	38.23	79.53	26.77	2.20	14.80	4.26	3.39	19.67	14.81	23.57
	R	37.33-39.67	77.67-81.00	23.52-29.48	1.75-2.89	13.80-16.90	4.08-4.40	3.23-3.91	17.07-23.83	12.38-16.34	23.00-24.11
	CV	3.70	2.14	11.69	37.08	10.72	3.75	10.25	19.02	16.56	3.80
X		38.54	79.72	26.85	2.38	14.98	4.27	3.45	19.81	14.99	24.18
Se		0.169	0.131	0.196	0.031	0.135	0.032	0.021	0.062	0.089	0.076
CD 5%		0.471	0.364	0.546	0.086	0.376	0.088	0.059	0.174	0.248	0.212
CD 1%		0.621	0.480	0.720	0.113	0.496	0.117	0.078	0.229	0.327	0.279
CV		2.399	0.897	3.995	7.088	4.928	4.068	3.351	1.723	3.252	1.718

Table 5 : Estimates of variability parameters in Barkha variety of black gram in M₂ generation

Characters/ families	GV (%)	PV (%)	GCV (%)	PCV (%)	H (in broad sense) (%)	GG (%)
Days to 50 per cent flowering						
Control	0.03	0.27	0.00	0.00	0.00	0.00
EMS 0.4 per cent	0.84	1.61	2.38	3.29	52.09	3.53
EMS 0.6 per cent	0.05	0.84	0.00	0.00	0.00	0.00
DMS 0.04 per cent	0.11	1.46	0.86	3.11	7.68	0.49
DMS 0.06 per cent	0.53	1.40	1.87	3.03	38.25	2.39
EMS 0. 4 + 3 x 10 ⁻³ M IAA	2.28	3.24	3.95	4.71	70.40	6.83
EMS 0. 4 + 3 x 10 ⁻⁴ M IAA	1.75	2.71	3.50	4.36	64.57	5.79
EMS 0.6 + 3 x 10 ⁻³ M IAA	2.32	2.76	3.94	4.30	84.01	7.44
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	1.47	2.20	3.13	3.84	66.54	5.26
DMS 0.04 + 3 x 10 ⁻³ M GA	0.37	1.41	1.57	3.09	25.98	1.65
DMS 0.04 + 3 x 10 ⁻⁴ M GA	0.23	1.34	1.25	3.03	17.07	1.07
Days to 75 per cent maturity						
Control	0.11	0.32	0.42	0.71	34.60	0.50
EMS 0.4 per cent	1.52	3.12	1.55	2.22	48.66	2.22
EMS 0.6 per cent	0.55	1.17	0.92	1.34	47.04	1.30
DMS 0.04 per cent	1.77	2.19	1.66	1.84	80.90	3.07
DMS 0.06 per cent	2.57	2.82	1.99	2.08	91.20	3.91
EMS 0. 4 + 3 x 10 ⁻³ M IAA	4.51	4.67	2.69	2.74	96.59	5.45
EMS 0. 4 + 3 x 10 ⁻⁴ M IAA	3.45	3.83	2.36	2.48	90.23	4.61
EMS 0.6 + 3 x 10 ⁻³ M IAA	2.76	3.17	2.09	2.23	87.15	4.01
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	2.84	3.48	2.12	2.35	81.57	3.94
DMS 0.04 + 3 x 10 ⁻³ M GA	2.29	2.74	1.91	2.09	83.40	3.59
DMS 0.04 + 3 x 10 ⁻⁴ M GA	0.71	1.20	1.06	1.38	58.93	1.67

Cont.....

Characters/ families	GV (%)	PV (%)	GCV (%)	PCV (%)	H (in broad sense) (%)	GG (%)
Plant height						
Control	0.05	0.26	0.78	1.87	17.54	0.67
EMS 0.4 per cent	3.12	4.63	6.41	7.82	67.26	10.83
EMS 0.6 per cent	4.88	6.55	9.06	10.49	74.48	16.10
DMS 0.04 per cent	2.53	4.50	6.25	8.33	56.28	9.66
DMS 0.06 per cent	5.62	6.39	9.82	10.47	87.90	18.96
EMS 0. 4 + 3 x 10 ⁻³ M IAA	3.20	4.61	6.25	7.51	69.29	10.72
EMS 0. 4 + 3 x 10 ⁻⁴ M IAA	8.16	8.78	10.23	10.61	92.94	20.32
EMS 0.6 + 3 x 10 ⁻³ M IAA	4.55	6.20	7.64	8.92	73.37	13.49
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	5.02	5.70	8.04	8.56	88.09	15.54
DMS 0.04 + 3 x 10 ⁻³ M GA	4.13	5.44	7.42	8.52	75.91	13.32
DMS 0.04 + 3 x 10 ⁻⁴ M GA	2.66	3.49	6.09	6.98	76.11	10.95
Number of branches per plant						
Control	0.01	0.02	4.35	5.03	74.67	7.74
EMS 0.4 per cent	0.13	0.14	14.20	14.72	93.13	28.23
EMS 0.6 per cent	0.03	0.07	8.80	12.62	48.61	12.64
DMS 0.04 per cent	0.02	0.07	6.41	11.98	28.64	7.07
DMS 0.06 per cent	0.04	0.08	10.12	14.93	46.01	14.15
EMS 0. 4 + 3 x 10 ⁻³ M IAA	0.02	0.04	5.23	6.89	57.64	8.17
EMS 0. 4 + 3 x 10 ⁻⁴ M IAA	0.05	0.09	8.63	11.64	55.06	13.20
EMS 0.6 + 3 x 10 ⁻³ M IAA	0.09	0.12	12.56	14.41	75.90	22.54
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	0.14	0.18	15.46	17.59	77.24	27.99
DMS 0.04 + 3 x 10 ⁻³ M GA	0.14	0.15	15.76	16.28	93.75	31.44
DMS 0.04 + 3 x 10 ⁻⁴ M GA	0.19	0.22	19.78	21.34	85.87	37.75

Cont.....

Characters/ families	GV (%)	PV (%)	GCV (%)	PCV (%)	H (in broad sense) (%)	GG (%)
Number of pods per plant						
Control	0.01	0.05	0.00	0.00	0.00	0.00
EMS 0.4 per cent	2.47	3.43	9.99	11.79	71.88	17.45
EMS 0.6 per cent	0.14	0.50	2.64	4.97	28.34	2.90
DMS 0.04 per cent	0.02	0.62	0.85	5.31	2.58	0.28
DMS 0.06 per cent	0.10	0.95	0.00	0.00	0.00	0.00
EMS 0. 4 + 3 x 10 ⁻³ M IAA	2.07	2.98	9.07	10.90	69.32	15.56
EMS 0. 4 + 3 x 10 ⁻⁴ M IAA	1.16	1.27	6.75	7.06	91.47	13.30
EMS 0.6 + 3 x 10 ⁻³ M IAA	0.55	0.82	5.10	6.21	67.42	8.62
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	0.06	1.26	1.70	7.70	4.87	0.77
DMS 0.04 + 3 x 10 ⁻³ M GA	1.51	1.66	8.31	8.72	90.96	16.33
DMS 0.04 + 3 x 10 ⁻⁴ M GA	0.65	0.97	5.44	6.66	66.54	9.13
100 seed weight						
Control	0.00	0.01	0.00	0.00	0.00	0.00
EMS 0.4 per cent	0.01	0.02	2.46	3.63	45.89	3.44
EMS 0.6 per cent	0.00	0.02	0.00	0.00	0.00	0.00
DMS 0.04 per cent	0.00	0.04	1.33	4.84	7.52	0.75
DMS 0.06 per cent	0.00	0.03	0.00	0.00	0.00	0.00
EMS 0. 4 + 3 x 10 ⁻³ M IAA	0.00	0.01	0.84	2.50	11.26	0.58
EMS 0. 4 + 3 x 10 ⁻⁴ M IAA	0.00	0.02	1.57	2.91	29.32	1.76
EMS 0.6 + 3 x 10 ⁻³ M IAA	0.00	0.02	0.53	3.29	2.56	0.17
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	0.00	0.02	1.58	3.47	20.77	1.49
DMS 0.04 + 3 x 10 ⁻³ M GA	0.01	0.07	0.00	0.00	0.00	0.00
DMS 0.04 + 3 x 10 ⁻⁴ M GA	0.02	0.06	0.00	0.00	0.00	0.00

Cont.....

Characters/ families	GV (%)	PV (%)	GCV (%)	PCV (%)	H (in broad sense) (%)	GG (%)
Seed yield per plant						
Control	0.00	0.01	0.00	0.00	0.00	0.00
EMS 0.4 per cent	0.06	0.08	6.47	7.55	73.47	11.43
EMS 0.6 per cent	0.00	0.01	1.63	3.57	20.98	1.54
DMS 0.04 per cent	0.02	0.03	4.28	4.77	80.66	7.92
DMS 0.06 per cent	0.01	0.03	0.00	0.00	0.00	0.00
EMS 0. 4 + 3 x 10 ⁻³ M IAA	0.03	0.04	4.41	5.11	74.48	7.84
EMS 0. 4 + 3 x 10 ⁻⁴ M IAA	0.06	0.06	6.86	7.06	94.46	13.73
EMS 0.6 + 3 x 10 ⁻³ M IAA	0.03	0.04	4.87	5.76	71.45	8.47
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	0.00	0.03	0.00	0.00	0.00	0.00
DMS 0.04 + 3 x 10 ⁻³ M GA	0.03	0.04	5.44	5.63	93.39	10.83
DMS 0.04 + 3 x 10 ⁻⁴ M GA	0.03	0.04	5.46	5.90	85.78	10.42
Biological yield						
Control	0.15	0.20	2.34	2.74	73.00	4.12
EMS 0.4 per cent	2.21	2.26	8.08	8.19	97.46	16.44
EMS 0.6 per cent	5.08	5.19	10.54	10.65	97.96	21.48
DMS 0.04 per cent	5.44	5.60	12.37	12.55	97.17	25.11
DMS 0.06 per cent	2.69	2.86	7.62	7.86	94.07	15.23
EMS 0. 4 + 3 x 10 ⁻³ M IAA	5.21	5.30	11.12	11.20	98.46	22.72
EMS 0. 4 + 3 x 10 ⁻⁴ M IAA	3.27	3.40	9.02	9.20	96.13	18.23
EMS 0.6 + 3 x 10 ⁻³ M IAA	3.56	3.68	9.10	9.26	96.59	18.43
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	4.50	4.68	10.75	10.95	96.33	21.73
DMS 0.04 + 3 x 10 ⁻³ M GA	4.65	4.76	10.44	10.55	97.80	21.26
DMS 0.04 + 3 x 10 ⁻⁴ M GA	4.16	4.28	10.37	10.52	97.18	21.05

Cont.....

Characters/ families	GV (%)	PV (%)	GCV (%)	PCV (%)	H (in broad sense) (%)	GG (%)
Harvest index						
Control	0.14	0.27	2.11	2.86	54.45	3.20
EMS 0.4 per cent	1.72	2.16	7.65	8.58	79.39	14.04
EMS 0.6 per cent	1.55	1.73	9.33	9.88	89.27	18.16
DMS 0.04 per cent	1.36	1.49	7.66	8.02	91.10	15.06
DMS 0.06 per cent	0.75	1.25	6.56	8.46	60.11	10.48
EMS 0.4 + 3 x 10 ⁻³ M IAA	3.02	3.12	11.26	11.45	96.71	22.82
EMS 0.4 + 3 x 10 ⁻⁴ M IAA	3.00	3.10	11.53	11.71	97.00	23.40
EMS 0.6 + 3 x 10 ⁻³ M IAA	1.20	1.34	7.84	8.27	89.96	15.32
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	2.00	2.68	9.85	11.42	74.47	17.51
DMS 0.04 + 3 x 10 ⁻³ M GA	3.03	3.11	12.14	12.30	97.46	24.69
DMS 0.04 + 3x10 ⁻⁴ M GA	1.76	1.89	8.96	9.29	92.95	17.79
Seed Protein content						
Control	0.13	0.13	1.48	1.50	98.42	3.03
EMS 0.4 per cent	0.73	0.74	3.46	3.49	98.16	7.06
EMS 0.6 per cent	0.31	0.33	2.32	2.42	91.71	4.57
DMS 0.04 per cent	0.63	0.66	3.25	3.33	95.31	6.54
DMS 0.06 per cent	0.65	0.66	3.32	3.36	97.54	6.75
EMS 0.4 + 3 x 10 ⁻³ M IAA	0.47	1.71	2.85	5.40	27.83	3.10
EMS 0.4 + 3 x 10 ⁻⁴ M IAA	0.27	0.28	2.20	2.22	98.02	4.49
EMS 0.6 + 3 x 10 ⁻³ M IAA	0.75	0.76	3.47	3.50	98.51	7.11
EMS 0.6 + 3 x 10 ⁻⁴ M IAA	0.74	1.25	3.48	4.51	59.72	5.55
DMS 0.04 + 3 x 10 ⁻³ M GA	0.06	0.11	1.07	1.44	55.44	1.64
DMS 0.04 + 3 x 10 ⁻⁴ M GA	0.24	0.24	2.07	2.10	97.07	4.20

Table 6 : Magnitude of various yield attributes of 22 progenies showing significant higher seed yield and early maturity in M₂ generation

Progenies	Days to 50 per cent flowering	Days to 75 per cent maturity	Plant height (cm)	Number of branches per plant	Number of pods per plant	100 seed weight (g)	Seed yield per plant (g)	Biological yield (g)	Harvest index (%)	Seed Protein content (%)
F2 P4	35.67	76.33	29.46	2.62	15.90	4.14	3.80	16.30	18.91	23.53
F2 P7	38.33	79.33	28.04	2.93	18.70	4.20	4.34	18.10	19.33	25.07
F 4 P1	39.00	77.67	26.66	2.29	15.27	4.33	3.65	24.44	13.00	24.13
F6 P2	36.33	76.00	30.64	3.07	18.73	4.39	4.07	17.80	18.60	23.29
F 6P5	35.67	75.33	29.51	2.69	15.77	4.44	3.57	22.47	13.72	23.11
F6P6	36.67	77.67	26.46	2.85	15.23	4.26	3.58	24.23	12.86	23.21
F6 P8	38.33	77.67	28.90	2.65	14.57	4.36	3.71	18.23	16.90	24.04
F7 P2	35.33	75.67	23.77	2.81	14.93	4.34	3.33	18.33	15.39	23.00
F7 P3	36.67	77.67	29.05	2.30	16.03	4.22	3.40	19.23	15.01	23.18
F7 P5	37.33	78.00	32.74	3.04	17.90	4.23	3.94	17.67	18.23	23.08
F7 P8	35.67	76.00	30.37	2.40	15.23	4.23	3.32	23.23	12.49	23.11
F7 P10	38.67	80.67	24.63	2.39	18.13	4.14	3.93	18.23	17.73	24.17
F8 P4	35.00	76.00	29.53	1.89	14.53	4.25	3.24	18.40	14.98	26.11
F9 P1	37.67	76.67	28.73	2.54	14.23	4.44	3.23	22.50	12.54	25.19
F9 P3	37.00	77.00	28.62	2.85	14.97	4.45	3.19	24.23	11.62	23.24
F9 P8	37.33	78.00	30.19	1.82	14.17	4.43	3.25	19.13	14.52	25.00
F10 P1	39.00	78.33	29.75	3.14	18.23	4.09	3.93	18.50	17.53	24.00
F10 P3	36.33	76.00	26.44	2.63	14.23	4.10	3.35	23.67	12.40	23.14
F10 P5	38.00	78.00	28.81	1.93	15.10	4.28	3.49	19.33	15.31	23.34
F11 P2	37.33	77.67	27.91	2.83	15.00	4.08	3.37	23.83	12.38	23.04
F11 P3	39.67	80.00	24.52	2.61	15.67	4.30	3.28	22.67	12.63	24.08
F11 P4	37.67	79.33	25.61	2.89	16.90	4.27	3.91	20.33	16.14	23.96

APPENDIX-III

Mean of M₂ progenies for different characters in Barkha variety of black gram.

Treatments	Days to 50 per cent flowering	Days to 75 per cent maturity	Plant height (cm)	Number of branches per plant	Number of pods per plant	100 seed weight (g)	Seed yield per plant (g)	Biological yield (g)	Harvest Index (%)	Seed Protein content (%)
Control										
P1	38.33	80.00	26.96	2.68	16.03	4.29	3.61	16.22	18.21	24.79
P2	38.33	79.67	27.14	2.38	15.80	4.36	3.58	16.10	18.19	24.10
P3	39.00	80.00	27.68	2.74	15.77	4.36	3.64	16.18	18.35	24.88
P4	38.33	79.00	27.84	2.69	15.97	4.35	3.65	16.08	18.49	24.81
P5	38.67	80.33	27.23	2.55	15.97	4.36	3.63	16.45	18.08	24.07
P6	38.33	79.33	27.86	2.36	15.87	4.39	3.60	15.92	18.47	24.06
P7	38.33	80.33	27.61	2.55	15.83	4.36	3.60	16.17	18.23	24.78
P8	38.33	79.67	27.10	2.54	15.90	4.46	3.64	17.11	17.44	24.81
P9	39.00	79.33	26.93	2.57	15.80	4.43	3.53	16.47	17.66	24.11
P10	38.67	80.00	27.60	2.54	15.67	4.39	3.54	17.17	17.10	24.10
EMS 0.4 per cent										
P1	38.00	80.67	26.82	2.37	14.87	4.40	3.52	17.53	16.72	24.07
P2	39.33	80.67	29.68	2.59	15.03	4.34	3.79	16.63	18.56	25.03
P3	39.00	80.00	27.07	2.17	14.50	4.19	3.69	18.23	16.83	24.53
P4	35.67	76.33	29.46	2.62	15.90	4.14	3.80	16.30	18.91	23.53
P5	38.67	79.00	22.67	1.94	14.10	4.46	3.71	17.13	17.81	25.58
P6	39.33	79.67	26.91	2.25	14.97	4.31	3.57	19.20	15.68	26.07
P7	38.33	79.33	28.04	2.93	18.70	4.20	4.34	18.10	19.33	25.07
P8	39.33	81.00	28.85	2.91	14.77	4.38	3.54	19.33	15.48	25.12
P9	38.33	81.67	27.27	2.99	15.17	4.09	3.69	20.10	15.50	24.58
P10	39.00	78.67	28.56	3.08	19.17	4.44	4.19	21.20	16.51	23.14

Cont.....

Treatments	Days to 50 per cent flowering	Days to 75 per cent maturity	Plant height (cm)	Number of branches per plant	Number of pods per plant	100 seed weight (g)	Seed yield per plant (g)	Biological yield (g)	Harvest Index (%)	Seed Protein content (%)
EMS 0.06 per cent										
P1	39.33	81.33	22.49	1.83	13.07	4.20	3.14	18.31	14.64	24.24
P2	39.33	81.33	27.17	1.88	14.27	4.26	3.39	19.13	15.06	25.10
P3	38.67	80.33	20.76	1.97	14.13	4.26	3.32	22.10	13.05	23.14
P4	38.67	80.00	25.16	2.27	15.00	4.15	3.18	23.14	12.08	23.43
P5	39.00	81.00	24.81	1.86	14.57	4.03	3.29	20.24	13.98	23.07
P6	38.33	79.33	21.94	2.19	13.60	4.29	3.19	24.15	11.67	24.07
P7	40.00	82.00	22.76	2.54	14.50	4.21	3.22	23.50	12.04	23.84
P8	39.67	81.67	23.76	2.25	14.40	4.23	3.33	24.20	12.10	24.07
P9	39.67	79.67	28.04	2.22	14.40	4.17	3.34	21.23	13.59	23.77
P10	39.33	80.00	26.98	2.19	14.13	4.36	3.20	17.97	15.15	24.08
DMS 0.04 per cent										
P1	39.00	77.67	26.66	2.29	15.27	4.33	3.65	24.44	13.0	24.13
P2	38.67	80.67	28.09	2.56	15.53	4.18	3.59	20.41	14.98	23.15
P3	38.67	81.00	24.73	2.58	14.83	4.33	3.27	20.97	13.50	24.49
P4	39.33	81.33	27.49	2.00	13.77	4.12	3.20	17.77	15.27	24.14
P5	39.33	79.67	26.02	2.29	14.80	4.00	3.21	16.83	16.03	24.11
P6	40.00	82.67	23.01	2.17	14.57	4.33	3.25	17.30	15.82	26.03
P7	37.67	82.00	22.25	1.94	14.70	4.09	3.32	16.40	16.85	25.18
P8	39.00	80.00	24.41	2.25	15.30	4.35	3.45	17.23	16.69	24.29
P9	39.00	80.33	25.43	2.17	14.63	4.37	3.30	18.17	15.37	23.24
P10	37.33	79.00	26.55	2.31	14.73	4.35	3.31	19.17	14.71	24.27

Treatments	Days to 50 per cent flowering	Days to 75 per cent maturity	Plant height (cm)	Number of branches per plant	Number of pods per plant	100 seed weight (g)	Seed yield per plant (g)	Biological yield (g)	Harvest Index (%)	Seed Protein content (%)
DMS 0.06 per cent										Cont.....
P1	38.00	81.00	20.14	1.59	14.13	4.14	3.21	24.83	11.45	24.04
P2	38.67	81.67	23.72	1.95	12.93	4.21	3.32	22.30	12.96	24.00
P3	38.67	80.00	25.73	2.03	14.33	4.09	3.44	21.00	14.05	24.21
P4	39.33	81.00	29.12	2.03	13.57	4.19	3.23	19.83	14.0	23.35
P5	38.33	78.33	24.19	1.70	12.79	4.14	3.23	18.83	14.63	25.07
P6	40.67	83.00	21.02	1.56	14.23	4.05	3.29	20.00	14.13	26.28
P7	40.33	83.33	22.78	1.81	14.03	4.29	3.36	21.83	13.34	24.11
P8	38.00	78.67	24.12	2.31	13.53	4.39	3.25	21.33	13.22	24.07
P9	39.67	79.00	24.77	2.12	13.87	4.14	3.20	22.17	12.62	23.77
P10	38.33	81.00	25.96	1.91	13.60	4.16	3.16	23.17	11.99	23.53
EMS 0.4 + 3 x 10⁻³ M IAA										
P1	41.00	82.00	29.63	2.82	15.80	4.42	3.71	22.13	14.34	24.11
P2	36.33	76.00	30.64	3.07	18.73	4.39	4.07	17.80	18.60	23.29
P3	38.33	78.33	32.29	3.09	18.67	4.25	3.99	21.03	15.93	26.22
P4	40.33	81.33	27.83	2.74	15.97	4.44	3.68	18.23	16.78	24.14
P5	35.67	75.33	29.51	2.69	15.77	4.44	3.57	22.47	13.72	23.11
P6	36.67	77.67	26.46	2.85	15.23	4.26	3.58	24.23	12.86	23.21
P7	38.00	79.00	28.12	2.79	14.10	4.45	3.59	23.47	13.25	24.21
P8	38.33	77.67	28.90	2.65	14.57	4.36	3.71	18.23	16.90	24.04
P9	38.33	80.00	25.56	2.54	14.53	4.30	3.62	18.53	16.33	25.51
P10	39.33	81.00	27.10	2.75	15.07	4.35	3.53	19.30	15.46	24.07

Treatments	Days to 50 per cent flowering	Days to 75 per cent maturity	Plant height (cm)	Number of branches per plant	Number of pods per plant	100 seed weight (g)	Seed yield per plant (g)	Biological yield (g)	Harvest Index (%)	Seed Protein content (%)
EMS 0.4 + 3 x 10⁻⁴ M IAA										Cont.....
P1	39.67	81.00	27.82	2.46	15.47	4.29	3.57	21.00	14.52	
P2	35.33	75.67	23.77	2.81	14.93	4.34	3.33	18.33	15.39	23.00
P3	36.67	77.67	29.05	2.30	16.03	4.22	3.40	19.23	15.01	23.18
P4	39.67	80.33	30.36	2.76	16.17	4.35	3.70	21.27	14.81	23.14
P5	37.33	78.00	32.74	3.04	17.90	4.23	3.94	17.67	18.23	23.08
P6	38.00	79.00	23.64	2.68	15.40	4.42	3.32	18.23	15.41	24.04
P7	38.00	79.67	28.90	2.76	15.53	4.39	3.33	21.87	13.21	24.22
P8	35.67	76.00	30.37	2.40	15.23	4.23	3.32	23.23	12.49	23.11
P9	38.67	81.00	27.99	2.22	14.90	4.16	3.30	21.23	13.45	24.07
P10	38.67	80.67	24.63	2.39	18.13	4.14	3.93	18.23	17.73	24.17
EMS 0.6 + 3 x 10⁻³ M IAA										
P1	40.33	81.00	24.79	2.26	13.80	4.26	3.29	23.03	12.49	24.11
P2	37.67	80.00	28.95	2.59	14.63	4.29	3.27	23.50	12.21	23.14
P3	38.67	80.00	28.95	1.97	13.53	4.24	3.30	17.90	15.55	25.22
P4	35.00	76.00	29.53	1.89	14.53	4.25	3.24	18.40	14.98	26.11
P5	38.00	78.67	28.48	2.07	14.40	4.30	3.17	18.47	14.66	25.37
P6	38.33	79.67	23.90	2.68	13.80	4.24	3.21	21.80	12.82	25.11
P7	38.67	79.00	31.12	2.71	15.27	4.33	3.71	20.50	15.31	26.07
P8	40.33	82.33	25.40	2.84	16.47	4.25	3.66	22.50	13.98	24.14
P9	40.67	81.67	29.73	2.32	14.70	4.15	3.33	20.50	13.98	25.11
P10	38.33	78.67	28.25	2.40	14.50	4.03	3.30	20.50	13.88	25.07

Treatments	Days to 50 per cent flowering	Days to 75 per cent maturity	Plant height (cm)	Number of branches per plant	Number of pods per plant	100 seed weight (g)	Seed yield per plant (g)	Biological yield (g)	Harvest Index (%)	Seed Protein content (%)
EMS 0.6 + 3 x 10⁻⁴ M IAA										Cont.....
P1	37.67	76.67	28.73	2.54	14.23	4.44	3.23	22.50	12.54	
P2	40.00	81.33	24.15	2.51	14.43	4.43	3.32	18.67	15.12	24.21
P3	37.00	77.00	28.62	2.85	14.97	4.45	3.19	24.23	11.62	23.24
P4	40.33	80.67	23.80	2.84	14.10	4.46	3.15	19.67	13.81	24.11
P5	38.00	79.33	26.01	2.85	15.27	4.42	3.24	21.07	13.34	26.51
P6	38.67	80.00	30.14	2.60	15.60	4.11	3.54	17.67	16.69	24.07
P7	41.00	82.33	27.68	1.74	15.50	4.30	3.26	19.57	14.29	24.14
P8	37.33	78.00	30.19	1.82	14.17	4.43	3.25	19.13	14.52	25.00
P9	37.67	79.00	29.81	2.50	13.37	4.45	3.25	17.47	15.71	26.07
P10	39.00	80.33	29.57	2.06	14.27	4.46	3.30	17.50	15.87	25.22
DMS 0.04 + 3 x 10⁻³ M GA										
P1	39.00	78.33	29.75	3.14	18.23	4.09	3.93	18.50	17.53	24.00
P2	39.00	79.33	27.77	2.52	13.93	4.12	3.39	19.67	14.69	23.18
P3	36.33	76.00	26.44	2.63	14.23	4.10	3.35	23.67	12.40	23.14
P4	38.67	81.67	23.88	2.40	15.00	4.11	3.43	19.00	15.30	23.14
P5	38.00	78.00	28.81	1.93	15.10	4.28	3.49	19.33	15.31	23.34
P6	38.00	78.67	27.04	1.87	14.87	4.25	3.42	19.33	15.03	23.18
P7	38.67	80.67	29.95	2.13	13.93	3.95	3.30	23.33	12.38	23.11
P8	38.33	80.33	29.95	2.42	13.60	4.28	3.21	23.47	12.05	23.70
P9	39.67	79.00	25.88	2.02	14.43	4.41	3.27	22.47	12.71	23.18
P10	38.67	80.67	24.36	2.73	14.30	4.03	3.38	17.90	15.89	23.46

Treatments	Days to 50 per cent flowering	Days to 75 per cent maturity	Plant height (cm)	Number of branches per plant	Number of pods per plant	100 seed weight (g)	Seed yield per plant (g)	Biological yield (g)	Harvest Index (%)	Seed Protein content (%)
DMS 0.04 + 3 x 10⁻⁴ M GA										
P1	37.67	78.33	27.11	2.14	14.03	4.28	3.33	17.07	16.34	Cont.....
P2	37.33	77.67	27.91	2.83	15.00	4.08	3.37	23.83	12.38	23.04
P3	39.67	80.00	24.52	2.61	15.67	4.30	3.28	22.67	12.63	24.08
P4	37.67	79.33	25.61	2.89	16.90	4.27	3.91	20.33	16.14	23.96
P5	38.00	79.00	23.52	1.68	13.80	4.26	3.45	19.83	14.80	23.11
P6	38.33	79.67	26.92	2.24	14.00	4.40	3.48	17.83	16.32	24.14
P7	37.67	80.00	29.48	1.58	14.60	4.29	3.34	18.80	15.10	23.11
P8	38.00	80.33	28.01	1.93	14.67	4.26	3.26	17.67	15.57	24.11
P9	38.33	80.00	26.41	2.35	14.83	4.12	3.23	19.17	14.42	23.97
P10	39.67	81.00	28.19	1.75	14.53	4.29	3.27	19.50	14.37	23.00
$\overline{X}$	38.54	79.72	26.85	2.38	14.98	4.27	3.45	19.81	14.99	24.18
Se	0.53	0.41	0.62	0.10	0.43	0.10	0.07	0.20	0.28	0.24
CD 5%	1.49	1.15	1.73	0.27	1.19	0.28	0.19	0.55	0.78	0.67
CD 1%	1.96	1.52	2.28	0.36	1.57	0.37	0.25	0.72	1.04	0.88

APPENDIX- I

Mean weekly meteorological parameters during crop growth period (*Kharif* 2005)

Standard week No.	Period	Temperature (°C)		Relative humidity (%)		Sun-shine hrs. per day	Evapo-ration (mm per day)	Total rainfall (mm)	Wind velocity (kg hr ⁻¹)
		Max.	Min.	Max.	Min.				
27	2-8 July	31.9	24.2	83	63	5.7	6.2	0.0	6.6
28	9-15 July	32.1	25.5	84	66	5.5	6.2	0.0	7.4
29	16-22 July	33.0	25.8	83	67	5.0	6.8	0.0	7.6
30	23-29 July	33.0	24.5	85	69	4.6	6.3	158.2	6.2
31	30 July-5 Aug.	28.7	23.7	96	88	2.2	3.0	145.4	2.2
32	6-12 Aug.	28.5	23.3	95	81	2.4	3.5	0.0	5.4
33	13-29 Aug.	30.9	23.5	90	65	3.9	3.9	0.0	2.7
34	20-26 Aug.	30.3	22.5	80	57	7.7	5.4	0.0	3.6
35	27 Aug.-2 Sept.	32.5	22.3	80	46	9.3	5.6	0.0	1.8
36	3-9 Sept.	35.3	23.2	77	50	6.6	5.9	61.6	2.1

Source : Agro Meteorological Observatory, Rajasthan College of Agriculture, Udaipur.

ABSTRACT

Improvement of Black Gram [*Vigna mungo* (L.) Hepper] Variety Barkha for Yield and Maturity through Mutagenesis

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The present study entitled “Improvement of Black Gram [*Vigna mungo* (L.) Hepper] Variety Barkha for Yield and Maturity through Mutagenesis” was carried out with the effect of EMS, DMS and their post treatment with respective modifiers IAA and GA on different traits in black gram variety Barkha. The experiment was carried out in compact family block design during *Kharif*, 2005 at Experimental field of Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, Udaipur.

Observations were recorded on various quantitative and qualitative traits in M_2 generation. Ten normal appearing plants with high fertility were selected from eleven efficient M_1 treatments to raise the M_2 generation for evaluation of both micro and macro mutational changes. In the present study five type of morphological mutant and three chlorophyll mutants were observed. EMS 0.4 per cent and DMS 0.04 per cent with modifiers were observed most efficient treatments.

Analysis of variance revealed significant differences among all the families for all the traits. Whereas, progenies differences were significant in all most all the families except control for all the traits except 100-seed weight.

The mean values of different characters shifted either to positive or negative direction from the control due to mutagenic treatments. EMS $0.4 + 3 \times 10^{-3}$ M IAA induced early maturity with higher yield and yield contributing traits. High coefficient of variation and range was observed for all the treatments. On the basis of yield parameters there were eight progenies identified which were high yielder with most of the yield contributing traits and eighteen progenies were earlier in maturity than control.

Variability parameters viz., GCV, PCV, Heritability and Genetic advance were calculated for all the families. Family EMS 0.4 per cent and DMS 0.04 per cent with modifiers exhibited high values for variability parameters for yield and yield contributing traits. Therefore, progenies from the above treatments should be carried forward to M_3 generation for isolating early maturing high yielding lines.

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vu{k*i*.k

mMn [foXuk ex*k* $\frac{1}{4}$,y- $\frac{1}{2}$ glij] dh cj[kk fdLe e mRifjortuu }kjk mit ,o ifjiDork e l/kk*j*

ekgu nknjoky *
LukRdkUkj 'kk/kdrk

Mk- $\frac{1}{4}$ Jher*h* $\frac{1}{2}$ oh-,y-ekFk*j* **
e[; l*y*kgdk*j*

oreku vUo"*k*.k ^mmMn [foXuk ex*k* $\frac{1}{4}$,y- $\frac{1}{2}$ glij] dh cj[kk fdLe e mRifjortuu }kjk mit ,o ifjiDork e l/kk*j*^m uked 'kh"*k*d d vUrxr mMn dh cj[kk fdLe e b-,e-,l-] Mh-,e-,l- ,o mud Øfed :ikU*rj* vkb-,
-, ,o th-, d l*k*Fk i'p mipk*j* d iHkk*o* }kjk mit ,o ifjiDork e l/kk*j*
fd;k x;kA ;g i;kx vfojy dy [k.Md vfHkdYiuk d vUrxr [kjhQ&2005
e ikni ituu ,o vkuokf"*k*dh foHkkx] jk tLFkku df"*k* egkfo|ky;] mn;ij d
ik;kf*xr* [kr ij yxk;k x;kA

,e&2 ih<h e fofHkUu ek=kRed ,o x.kkRed y{k.kk dk voykdu fd;k
x;kA ,e&1 ih<h l ,e&2 ih<h mxku d fy, ,o mle l{e ,o nh?*k*
mRifjoruk dk eY;kdu dju d fy, X;kjg n{k mipk*j* e iR;d l n l
l*ke*U; fn[ku oky ik/kk dk p;u fd;k x;kA oreku vUo"*k*.k e ikp idk*j* d
vkdjkRed ,o rhu idk*j* d i.kgfjr jfgr :ikU*rj* ik; x;kA mRifjoru
{kerk ,o mRifjoru iHkkfor Øe'*k* b-,e-,l- 0-4 ifr'*kr* ,o Mh-,e-,l- 0-04
ifr'*kr* ,o mud :ikU*rj* d i'p mipk*j* e vf/kd ikb xbA i l*j*.k fo'y"*k*.k
l Kkr gvk fd lHkh dyk d lHkh x.kk e l*k*Fkd vrj FkkA tcf*d* lUrfr;k e
l*k*Fkd vU*rj* 100&nkuk d Hkk*j* dk NkMd*j* yxHkx lHkh dyk e ik;k x;kA

mRifjortuu d iHkkok d dk*j*.k lHkh y{k.kk e mrk*j* p<ko ik;k x;kA
vf/kd mit 'kh?*k* idko dk y{k.k b-,e-,l- $0.4 + 3 \times 10^{-3}$,e- vkb- ,
mipk*j* l ifjr ik;k x;kA i*j*l ,o fofHkUurk x.kkd lHkh mipk*j* e vf/kd

* LukRdkUkj 'kk/kdrk] ikni ituu ,o vkuokf"*k*dh foHkkx] jk tLFkku df"*k* egkfo|ky;] mn;ijA

** l*g*&vkp*k*;] ikni ituu ,o vkuokf"*k*dh foHkkx] jk tLFkku df"*k* egkfo|ky;] mn;ijA

ik;k x;kA vkB lUrfr vf/kd mit okyh ,o vBkjg lUrfr tYnh idu okyh
ik;h xbA

lHkh dyk e fofHkUu ikpyu Øe'k% vkuokf'kd fofHkUurk x.kkd] y{k.k
i: ih fofHkUurk x.kkd fi=xE;rk ,o tufur vfHkykHk dk v/;;u fd;k x;kA

b-,e-,l- 0-4 ifr'kr ,dy ,o b-,e-,l- 0-4 ifr'kr ,o Mh-,e-,l-
0-04 ifr'kr o bud : ikUrjk e mit ,o mit lcf/kr x.kk d fy, fofHkUurk
ikpyu vf/kd ik;k x;kA vr% vf/kd mit nu okyh o tYnh idu okyh
lUrfr dk iklr dju d fy, bu dyk dk ,e&3 ih<h e y tkuk pkfg,A

APPENDIX-II

Procedure of seed protein content estimation through micro kjeldahl's method (Lindner, 1944)

Digestion:

1. Grind the seed material weigh 0.1 gm of sample and put it in a dried Kjeldhal's flask.
2. Add 2ml of concentrated sulphuric acid (Analar) and digest on heater for 1.30 hours.
3. To this, add 0.5 ml of hydrogen peroxide (H_2O_2) with alternate heating and cooling till the colour disappears. Heat till hydrogen peroxide fumes escape.
4. Transfer the content of Kjeldhal flask in 100 ml volumetric flask and make volume.
5. Colour development:
6. Take 5ml of aliquot in 50 ml volumetric flask add 2 ml and 1 ml of 10% solution of sodium hydroxide and sodium silicate, respectively. Add Nessler's reagent and finally make volume with distilled water.
7. Run a control with distilled water.
8. Adjust colorimeter using control and take readings at 540 nm filter.

Standard Curve:

Dissolve 0.1179 grams of ammonium sulphate in distilled water and make the volume to one litre (25 ppm solution), pipette out and 0.5, 1.0, 1.5, 2.0, 2.5, 5.0, 7.5 ppm and 10 ppm of this solution in 50 ml volumetric flask. Colour is developed by procedure given above and take reading at 540 nm filter. Draw a graph of ppm nitrogen v/s optical density.

The protein content was calculated by multiplying the nitrogen content with a constant factor 6.25.