A. Characterization of germplasms

Morphological traits namely, stem (nature, color), leaf (shape, serration, venation, color), buds (shape, color), sepals (number, shape, color, bracts), petals (number, shape, color), stamens (number, anther shape, color, nature of filament), ovary (shape, color, nature of style, stigma), fruit (color, shape) and seed (color, shape, size, texture) are ascertained from identically mature plants of germplasm I and II. From the morphological point of view, both germplams vary from each other on the basis of stem color (I: purple green to light purple green, more purplish at nodal region; II: slight purple to reddish, purple shade near nodes), ovary shape (I: obconical to dome shaped; II: obpyriform), stigma nature (I: 5, spathulate, swollen; II: 5, clavate to rounded), fruit shape (I: oblong conical; II: ovoid spindle) and seed characteristics (I: rounded with verrucose interrupted lines; II: reniform, longitudinal verrucose lines).

SEM analysis of seed surfaces suggest variations in seed shape (I: round to globose; II: reniform), size (I: 3.90 mm ± 0.13 × 3.88 mm ± 0.15; II: 3.27 mm ± 0.10 × 4.02 mm ± 0.14) and surface ornamentation (I: testal surface with 20 verrucose lines, no honey-comb like structure, cellular appearance clear, hilum depressed with paraphysis, head of the paraphysis is not capitate; II: testal surface with 12 verrucose lines, honey-comb-shaped alveolate structure in testal surface, cellular appearance not clear, hilum depressed with paraphysis, paraphysis with capitate head) between germplasm I and II.

Anatomical studies (stem and root) performed between germplasm I and II show distinctiveness between them. Cuticle (I: thin, single layered; II: medianly thick, single layered), hypodermis (I: one layered; II: usually 2 cell layered thick), cortex (I: outer cortex 8 - 10, inner cortex 6 - 8 cell layered; II: outer cortex 4 - 5, inner cortex 3 - 4 cell layered), endodermis (I: indistinct; II: distinct), cambium (I: 2 - 3 cell layered thick; II: 1 - 2 cell layered thick), ray cells (I: 1 - 2 seriate; II: uniseriate) and pith (I: parenchymatous with mucilaginous cavity; II: parenchymatous with mucilaginous cavity) are found to differ between the germplasms. Root anatomical features in germplasm I- cork 8 cell layered, secondary growth prominent, vascular tissue mostly with xylem, phloem fibre patches in rings, usually 6; germplasm II- nearly identical to germplasm I excepting irregular patches of phloem fibre, 8 - 12 cells.
Although chromosome number \((2n = 72)\) germplasm I: 35.81 II + 0.38 I; germplasm II: 35.80 II + 0.40 I), pollen fertility (I: 33.81%; II: 30.86%) and pollen viability (I: aniline blue- 36.36%, lugol’s iodine- 42.09%; II: aniline blue- 34.48%, lugol’s iodine- 38.79%) were nearly identical in both germplasms, pollen size differ significantly (I: 153.70 \(\mu\)m \(\pm\) 2.95 \(\times\) 147.60 \(\mu\)m \(\pm\) 2.06; II: 129.20 \(\mu\)m \(\pm\) 1.99 \(\times\) 121.90 \(\mu\)m \(\pm\) 1.94).

Biochemical attributes namely, seed protein (mg/g), total soluble sugar (mg/g) and essential oil (% yield) contents did not vary significantly between the germplasms as evidence from \(\chi^2\)- test of heterogeneity. Stomata in both the germplasms are amphistomatic, paraectic (rare often anomocytic), isodiametric, polygonal and elongated in nature. Guard cells and subsidiary cells of the stomata are with randomly distributed chloroplast and the surfaces with wavy continuous striations.

Seed protein profile following SDS-PAGE suggests distinctive variations between both germplasms in relation to number of polypeptide bands (I: 21; II: 30), number of high molecular weight bands in kDa (I: 3; II: 5) and number of low molecular weight bands in kDa (I: 12; II: 17). Ten base 30 RAPD molecular markers have been used to characterize the germplasms and it has been found that the number of fragments amplified is 84 in germplasm I and 99 in germplasm II.

Masters (1874) reported 2 varieties (multiformis and betulifolius; based on leaf shape primarily) in A. moschatus and subsequently Hochreutiner (1900) added 2 more varieties in the species (genuinus and rugosus). Borssum-Waalkes (1966) recognize 3 subspecies in A. moschatus, viz. subsp. moschatus, subsp. biakensis (Hochr.) Bross. and subsp. tuberosus (span.) Bross., of which only subsp. moschatus was reported from India and was corroborated by Sivaranjan and Pradeep (1996) from their taxonomical studies on Malvaceae. Hamon and van Sloten (1989) suggested that the genus Abelmoschus appears as a regular series of polyploids with \(x = 12\), chromosome number varying from 14 to 97. A. moschatus had \(n = 36\). Thus, it is apparent that the germplasms studied are A. moschatus var. moschatus and the 2 germplasms (the traits were uniform and the plants bred true) are found to vary widely between themselves in relation to most of the parameters studied. Therefore, it would be logical to recommend germplasm I as cultivar I- tall branched and germplasm II as cultivar II- dwarf unbranched.
B. F\textsubscript{1} hybrid analysis

Germplasm II (dwarf, unbranched as female) crossed with germplasm I (tall, branched as male) yielded good filled seeds which produced F\textsubscript{1} hybrid plants; however, reciprocal crosses formes only small sized fruits with dusty seeds which possibly indicates disturbances in pre- and post fertilization events during the course of seed formation. Upon considering that crossings are performed between germplasms of a same species and that one way cross is successful, therefore genomic instability between parents may not be the possible cause for failure of reciprocal crossings and seed setting. Microspores and megaspores are morphologically alike in both germplasms. Akhond et al. (2000) reported pre- and post zygotic barriers for successful crossings between \textit{A. esculentus} and \textit{A. moschatus}; although, the species are reported to be cross compatible. For successful seed development in crossing experiments ratio of 2:3:2 of maternal tissue: endosperm: embryo (Katsiotis et al. 1995), 2:1 ratio of maternal: paternal genomes in the endosperm, integrated genetic control of rapidly changing metabolism in the endosperm (Lester and Kang 1998) among others have been proposed. Thus, further studies are required to unravel the possible cause for failure of reciprocal crossings between 2 germplasms of \textit{A. moschatus} aiding to developmental biology.

The F\textsubscript{1} hybrid plants looked phenotypically alike and resemble female parents for most qualitative traits. For quantitative traits, the hybrid is either lower or intermediate to parents. As compared to either of the parent, first flowering flash in hybrid plant has been delayed. Although complete pairing of bivalents (36 II formations) in hybrid plants is much lower than either of the parents, pollen fertility and pollen viability in the plant types are nearly comparable. Seed set per fruit in hybrid has been intermediate to parents.

The RAPD profiles show 82.10% polymorphism across the plant types and it may be attributed to the differences in the binding sites throughout genome of parents and hybrid. Average number of fragments generated over the primers is found to vary between the parents and polymorphism percentage has been noted to be 74.83%, thereby suggesting distinct genetic variations between them. The hybrid shows band similarities with male, female and both the parents and also possesses few specific bands, thereby indicating trueness of the raised plant type. Dendrogram constructed by UPGMA also suggest parent and hybrid relationship. RAPD markers have been utilized...
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for hybrid identification and authentication in different plant species (Smith et al. 1996; Haiyuan et al. 1998; Mehetre et al. 2004; Iva et al. 2005; Ali et al. 2008; Farzaneh et al. 2010). Upon considering the number and frequency of scorable fragments, polymorphism percentage and different efficiency parameters, taken together, it seems that OPA 01, OPA 02, OPA 10, OPB 02, OPB 04, OPB 05, OPB 08, OPC 03, OPC 05 and OPC 10 are efficient and effective markers which can be significant RAPD marker for screening A. moschatus germplasms including hybrid(s). Nair et al. (2013) reported five RAPD primers namely, OPX 18, UBC 210, 292 and OPAE 03, 15 suitable for characterizing the species of A. moschatus. Thus, present investigation authenticates the trueness of the raised F₁ hybrid as well as its stability. The F₁ hybrid is significant as it has enhanced genetic diversity among the existing germplasm(s) of the species. Further, the germplasms are characterized genetically using RAPD markers.

C. Study on induced mutagenesis

Induced mutagenesis has great relevance in modern plant breeding for the development of improved plant types (Kharkwal 2000); however, most of the mutations are lethal, semi-lethal and have very low productivity and do not have practical value (Waghmare and Mehra 2001) possibly due to doses administered or due to mutagen(s) employed. Thus, it is of utmost importance in any crop plant to have basic information regarding mutagenic sensitivity and mutagenic efficiency and effectiveness to monitor successful mutagenesis experiments and to raise viable macromutants of interest.

In the present investigation, germplasm I and II are treated with EMS and NH₂OH at different concentration and durations for raising ‘plant type’ mutation. Parameters like seed germination and seedling growth under Petri plate condition(s) and field germination, survivability, pollen fertility and viability, sterilities (flower and capsule) and seed yield are assessed in M₁ generation in relation to controls for estimation of mutagenic sensitivity of both germplasms of A. moschatus. Frequency of seed germination under Petri plate condition in germplasm I and II is found to be reduced in treatments in comparison to controls. In both germplasms, reduction in germination frequency seems to be more pronounced in higher doses of treatments. In relation to germination frequency it is found that germplasm I is relatively more sensitive than germplasm II and EMS is more effective than NH₂OH. Reduction in percentage of germination under similar conditions in Petri plates accentuates the assumption that treatments had positively affected the physiological phenomenon and
may be regarded as inhibitory action of the mutagens. Lethal dose- 50 (LD$_{50}$) gives an idea about the appropriate dose of mutagens in an experiment on induced mutagenesis. LD$_{50}$ seems to lie beyond 0.50%, 6h EMS treatment in both germplasms. However with NH$_2$OH treatments, LD$_{50}$ could not be ascertained due to variable response in germination frequency in relation to different doses of treatment. It seems that the doses of EMS as well as NH$_2$OH administered are mostly sub- lethal in nature and nearly appropriate for conducting experiments on induced mutagenesis.

In both germplasms as well as in EMS and NH$_2$OH treatment, seedling growth (assessed on the 8th day of the treatment) show either reduction or enhancement in comparison to respective controls. Seedling growth has been found to enhance significantly in germplasm I (EMS: 0.25%, 6h and 0.50%, 6h; NH$_2$OH: 0.25%, 3h and 0.25%, 6h) and reduce in germplasm II (EMS: 0.50%, 6h; NH$_2$OH: 0.50%, 6h) in few treatments in relation to controls. Enhancement and reduction in seedling growth in relation to respective controls suggest significant effect of mutagenic treatments. Reductions in germination frequency and seedling growth have been attributed to the nature and extent of chromosome aberration occurring in the cells (Sax 1942, Lea 1947, Read 1959, Evans and Sparrow 1961, Mukherjee and Basu 1979, Datta and Biswas 1983, Datta et al. 1986, Ghosh et al. 2012) and to structural changes (Gray and Read 1950). Evans (1965) considered blockage of cells into mitosis as the most important cellular event after mutagenic treatments, which results in cessation of growth. Reduction in growth in higher doses of the mutagens may be primarily due to the destruction of auxin of meristematic cells and physiological and biochemical disturbances (Gunckel and Sparrow 1954, Raj et al. 1972, Singh 1974).

Biological damages namely, lethality, injury and seed sterilities are assessed in M$_1$ generation in both germplasms to ascertain mutagenic sensitivity. In germplasm I lethality is 16.67% to 83.33% in EMS and 33.33% to 83.33% in NH$_2$OH treatments; while, injury varies from 10.33% to 79.95% in both EMS and NH$_2$OH. Lethality and injury are of higher magnitude in germplasm II (lethality: EMS- 6.25% to 56.25%; NH$_2$OH- 6.25% to 37.50%; injury: EMS- 65.13% to 95.81%, NH$_2$OH- 65.89% to 95.29%).

In both germplasms, flower, capsule and seed sterilities are found to increase as well as decrease in relation to respective controls. Sterilities are noted not to be dose dependent. Seed yield has been studied to be 10.82 g and 14.43 g in control plants of
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germlasm I and II respectively and it varies among treatments (germplasm I: EMS- 0.83 g to 13.60 g, NH$_2$OH- 5.08 g to 13.36 g; germplasm II: EMS- 5.65 g to 17.60 g, NH$_2$OH- 9.04 g to 20.98 g). Reduction in the mean number of seeds/plant has also been reported in different plant species following mutagen treatments (Balient et al. 1968, Srinivasachar and Malik 1969; Singh and Roy 1971, Wanjari 1976, Kumar et al. 1978, Premsekar and Appadurail 1981, Kumar and Nijam 1983, Rang 2000, Sengupta 2003, Paul 2005, Mukherjee 2006, Ghosh 2013). Number of seeds/plant is an important yield attributing trait, which is the result of cumulative effects of many important processes like sporogenesis, pollination, fertilization and embryogeny. Physiological disturbances may adversely affect any or all of the sequential processes of seed development. Bansal and Natarajan (1965) were of opinion that sterility induced by chemical mutagens, more particularly alkylating agents, was not found to be associated with chromosomal abnormalities.

From the assessment of $M_1$ parameters in relation to mutagenic sensitivity it is logical to ascertain that the doses monitored in EMS and NH$_2$OH treatments are sub-lethal (although none of the employed doses in NH$_2$OH showed 50% reduction in germination) and it may provide adequate genetic variations at $M_2$ for screening of desirable macromutants.

The mutagenic action of EMS results from its reaction with DNA by alkylating the phosphate groups (Alexander and Stacey 1958, Stacey et al. 1958). Heslot (1965) suggested that the triesters formed due to alkylation of the phosphate groups by EMS are unstable and tend to loose the alkyl group but it is not known if these alkyl groups are liable to interfere with DNA replication; alkylation of a phosphate can cause breakage of the linkage between deoxyribose and phosphate. The exact consequences of such an event are, however, unknown. EMS shows more specificity to guanine and cytosine (Freese 1963) and specifically N-7 position guanine is highly susceptible to alkylation by the mutagen (Bautz and Freese 1960, Brookes and Lowley 1960). Occasional pairing error may results due to base substitution by another purine, likewise a pyrimidine by a different pyrimidine through the incorporation of the alkyl group into a base and thus resulting error in base pairing (Lawley and Brookes 1961) or loss of a base due to alkylation may result in the formation of a gap in the DNA template (Krieg 1963, Lawley 1966) and during replication, this is either ignored (deletion) or a base selected at random is inserted into the new strand opposite the
deletion (Sen 1976). Such substitution may lead to mutation. Chromosomal aberration might well be excepted following EMS treatments, as alkylating agents are known to break DNA strand by an indirect mechanism, that is, by facilitating depurinization and depyrimidation which possesses the effect of labializing the sugar phosphate backbone (Fishbein et al. 1970). Revall (1958) suggested that biological effects may be results of chemical reaction between alkylating agents and molecular constituents of the cells, which in turn cause direct metabolic disturbances such as stickiness and clumping and chromosome break. Wolff (1966) was of opinion that any change in the cellular metabolism and the production of ATP can influence the repair of chromosomal damage since many enzymes are involved in the process. Mutation induced by hydroxylamine was due to hydroxylation of the amino group of cytosine and uracil (Freese et al. 1961, Tessman et al. 1964).

In the present investigation 5 and 3 viable macromutant types (germplasm I: ‘lax branching’, ‘pigmented stem’, ‘long petiole’, ‘large flower’ and ‘early flowering’; germplasm II: ‘funnel’, ‘thick stem’ and ‘late flowering’) are screened in germplasm I and II respectively following different mutagenic treatments at M$_2$ from seedling to maturity. Mutation frequency is not dose dependent. Mutation frequency has been reported to be variable following EMS treatments in barley (Heslot et al. 1959, Gaul 1962, Nilan 1964), sesame (Sengupta 2003), basil (Mukherjee 2006), jute (Maity 2009), varieties of ashwagandha (Das et al. 2010), kalmegh (Ghosh 2013) among others; however, direct relationship between mutation frequency and mutagen doses are reported in different plant species (Ehrenberg and Gustafsson 1957, Ehrenberg 1960, Nilan 1964, Konzak et al. 1965, Wagner et al. 1968, Sree Ramulu 1970, Dnyansagar and Gaikwad 1979). Frequency of mutations, induced by various mutagenic treatments in M$_2$ generation, appears to have a direct relationship with various mutagen sensitivity parameters studied in M$_1$ generation (Dixit 1985, Tripathi 1995). There have also been reports that temperature, pre- soaking, pH, washing in water after treatments and handling of treated seeds influence M$_1$ parameters as well as mutation frequency in M$_2$ generation (Gaul and Mittelstenscheid 1960, Nilan et al. 1964, Wales 1967, Mikaelsen et al. 1968).

The macromutants have affected branching pattern (‘lax branching’ and ‘funnel’), stem coloration (‘pigmented stem’), stem characteristics (‘thick stem’) and floral traits (‘long petiole’, ‘large flower’, ‘early flowering’ and ‘late flowering’).
Mutation frequency has been found to be higher in germplasm I than II and EMS seems to induce higher frequency of mutation than NH$_2$OH. Mutation frequency is found not to be dose dependent. Over the mutagen treated population different macromutants have arisen in the following order: germplasm I- ‘pigmented stem’ > ‘long petiole’ > ‘lax branching’ > ‘large flower’ = ‘early flowering’; germplasm II- ‘late flowering’ > ‘funnel’ > ‘thick stem’. Maximum frequency of mutation has been recorded in 0.25%, 6h EMS (6.29%) and 0.50%, 3h NH$_2$OH (4.35%) in germplasm I and 0.25%, 6h EMS (3.66%) and 0.50%, 3h NH$_2$OH (2.51%) in germplasm II. Spectrum of mutation has been 1 to 2 in germplasm I and 1 to 3 in germplasm II.

The mutagenic effectiveness relates dose to mutational events, while, mutagenic efficiency is defined as the relation of number of mutational events to undesirable effects such as lethality, injury and sterility (Nilan et al. 1965). In the present investigation, mutagenic effectiveness is higher in both germplasm in threshold concentrations and duration of treatments. It seems that EMS is more effective than NH$_2$OH. The degree of mutagenic efficiency has been found to vary depending on the criteria selected for estimation of mutagenic efficiency. Based on sterility, efficiency has been relatively low compared to that of lethality and injury in most of the treatments of the mutagens. This may be due to the fact that induced sterility is higher for the mutagens than the amount of seedling injury and inhibition of germination frequency. Significance of mutagenesis rests largely on increasing the efficiency and effectiveness of mutation production. According to Konzak et al. (1965) the effectiveness of a chemical as a mutagenic agent depends on the nature and characteristics of the organism concerned as a whole as well as on specific properties of the tissue treated in addition to the chemical properties of the agent. Further, they were of opinion that various physical and chemical properties, including temperature, the presence or absence of catalytic agents, hydrogen ion concentration etc. markedly affect mutagenic efficiency. The author also suggested that EMS possesses many properties favourable to high mutagenic effectiveness as well as high mutagenic efficiency. Efficiency and effectiveness of EMS and other alkylating agents in induced mutagenesis have been well demonstrated in different crop plants (Blixt 1964, Heringa 1964, Wellensiek 1965a, Monti 1968, Nerkar 1977, Sengupta 2003, Mukherjee 2006, Das et al. 2010, Ghosh 2013).
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In the present study, mutagenic efficiency and mutagenic effectiveness are calculated from viable mutation frequency as was suggested by Walther (1969) rather than from chlorophyll mutation frequency (Konzak et al. 1965). Jagtap and Das (1976) evaluated mutagenic efficiency on the basis of the proportion of mutants of practical values, i.e. only viable mutations were taken into account in ascertaining the efficiency and effectiveness of the mutagens.


The ‘early flowering’ mutant noted in the present investigation is always a breeder’s choice. The mutant type is only recovered in germplasm I from 0.25%, 3h NH$_2$OH treatment. Galston and Siegel (1954) have attributed physiological mechanism for ‘early flowering’. Brock (1967) was of opinion that flowering type has been conditioned by two separate genetic systems, one controlling flowering process such as flower initiation and the other influencing the rate of development from initiation to flower emergence i.e. growth rate. Induced ‘early flowering’ mutants following mutagen treatments have been reported in different plant species (Martens and Burdick 1956, Wellensiek 1965b, Brock 1966, Lawrence 1968, Hossain 1970, Nayer 1979, Ghosh and Chatterjee 1981, Datta 1982, Datta and Biswas 1985, Rang 2000, Sengupta 2003, Paul 2005, Mukherjee 2006, Ghosh 2013). ‘Late flowering’ mutant plants are identified in germplasm I and II of ambrette in different treatments of EMS and NH$_2$OH. Sengupta and Datta (2004a) reported an induced protein rich ‘late flowering’ mutant in sesame. Induction of ‘lax branching’ plant type in germplasm II is significant, although ‘lax branching’ trait may not be promising for increasing
plantation per unit area but high yield ability of the mutant is rather compensating. ‘Pigmented stem’, ‘thick stem’, ‘funnel’, ‘large flower’ and ‘long petiole’ mutant plant types are important in the species as they have enriched genetic diversity. ‘Pigmented stem’ and ‘thick stem’ mutants were also reported in Corchorus olitorius (Maity and Datta 2009).

The ‘long petiole’ mutant is found to be concomitantly associated with larger and broader leaves. This trait has been found to be associated with long petiole trait in all plants studied at M2, M3 and M4, thereby suggesting possible pleiotropic action of the mutant gene(s). Kreft (1985) suggested that high lysine genes in barley and genes for the determinant growth in buck wheat (Fagopyrum esculentum) are suitable examples to show that the effect of single mutation could be complex or ‘pleiotropic’. Pleiotropic gene action has been found to influence stem, petiole, bract tip, pigmentation of sunflower (Deveraja and Goud 2005). Gene ‘bic’ with pleiotropic effects for bicolor flowers and dark olive brown seed coat has been reported in Phaseolus coccineus (Bassett and Miklas 2007). Stearns (2010) suggested that pleiotropic gene action plays an important influence on the fields of physiological and medical genetics as well as on evolutionary biology.

Inheritance of mutant trait(s) is assessed only from selfed seeds of M2 mutants in M3 generation. Most of the mutant traits (excepting ‘funnel’) segregated at M3 to a close fit of 3:1 ratio, thereby possibly suggesting monogenic recessive inheritance of the mutants. The ‘funnel’ trait segregates to a close fit of 15:1 indicating digenic mode of inheritance. Most of the mutants in angiosperm have been reported to be controlled by a single pair of recessive gene, but instances of digenic inheritance has also been reported (Nilan 1967, Brock 1971, Gustafsson 1975, Johns et al. 1981, Datta and Biswas 1985, Gaur and Gour 1999, Rang and Datta 2001, Datta and Rang 2001, Datta and Saha 2001, Sengupta and Datta 2004b).

The chromosome number in control and mutant plant types has been suggested to be $2n = 72$ always. Meiotic analyses performed in true breeding macromutants at M4 (germplasm I: 35.81 II + 0.39 I per cell; germplasm II: 35.80 II + 0.34 I per cell) reveal that the mean chromosome association at MI vary from 35.26 II + 1.48 I (‘large flower’) to 36.00 II (‘pigmented stem’) in germplasm I and 35.45 II + 1.11 I (‘thick stem’) to 36.00 II (‘funnel’) in germplasm II. Pollen fertility in germplasm I has been recorded to be 33.81% and it is 30.86% in germplasm II. The pollen fertility of mutant
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Plant types in germplasm I ranges from 31.68% (‘early flowering’) to 40.41% (‘pigmented stem’) and that in germplasm II varies from 34.66% (‘late flowering’) to 38.36% (‘thick stem’). Meiotic analysis of the mutants suggests that they are the outcome of genic changes rather than cytological.

Pollen viability is also assessed in the plant types following 2 stain test namely lugol’s iodine and aniline blue. On comparative basis it has been noted that viable pollen grains are more in lugol’s iodine than in aniline blue. Pollen viability is found to be 42.09% and 36.36% in germplasm I and 38.68% and 34.48% in germplasm II following lugol’s iodine and aniline blue staining respectively. Most of the mutants in both the germplasms show relatively higher percentage of pollen viability than control.

The germination frequency assessed at M₄ has been 8.33% in germplasm I and 62.22% in germplasm II. Germination frequency vary from 6.67% (‘pigmented stem’) to 13.89% (‘large flower’) and 46.67% (‘late flowering’) to 68.33% (‘funnel’) among the mutant plant types of germplasm I and II respectively.

Pure lines of control (germplasm I and II) and true breeding M₄ mutant plant types in relation to respective controls have been statistically analyzed considering 7 (germplasm I) and 6 (germplasm II) different quantitative parameters under uniform agroclimatic condition(s) to assess variations between/among the plant types for a specific trait. Result indicates that most of the mutants exhibited superiority for different traits over their respective control. As compared to control germplasm I, ‘lax branching’, ‘large flower’ and ‘early flowering’ mutants are with enhanced number of capsules/plant and seed yield/plant. Seed yield/plant also increase significantly in ‘early flowering’ mutant. ‘Lax branching’ and ‘long petiole’ mutants also possesses longer capsules than control. Number of primary branches/plant has been found to increase significantly in ‘pigmented stem’. ‘Long petiole’, ‘large flower’ and ‘early flowering’ plant types are taller plants than control. In comparison to control germplasm II, ‘funnel’ and ‘thick stem’ mutant plant types are taller with significantly enhance number of capsule/plant, seed/capsule and seed yield/plant. ‘Thick stem’ mutant also possesses broader capsules than control. Seed sizes in the mutant plant types do not vary significantly with their respective controls. The present study, therefore, opens up the possibility of direct selection of the desire plant types; however, germination frequency in germplasm I plant types seems to be a hindrance for their exploration.
ANOVA test performed for 7 and 6 parameters for germplasm I and II plant types respectively reveal significant variations for all the studied traits excepting for capsule breadth and number of seeds/capsule in germplasm I and II respectively. Estimates of genetic parameters reveal that the magnitude of heritability is high to very high (75.00% to 99.86% in germplasm I; 80.00% to 99.36% in germplasm II) excepting for capsule breadth (0.00%) in germplasm I and number of seeds/capsule (42.19%) in germplasm II. Plant height and number of capsules/plant in both germplasms can be the important selection criteria in the plant species as high heritability has been coupled with relatively high genetic gain.

Seed protein (mg/g), total soluble sugar (mg/g) and essential oil (% yield) content are noted to be 19.167, 0.363 and 0.208 in germplasm I and 14.235, 0.648 and 0.204 in germplasm II respectively. The quantitative traits in mutant plant types of both germplasms do not vary significantly in relation to control.

Seed viability has been 80.0% and 88.0% in germplasm I and II respectively and it varies from 60.0% (‘long petiole’) to 96.0% (‘early flowering’) in mutants of germplasm I and 60.0% (‘late flowering’) to 88.0% (‘funnel’) in mutants of germplasm II.

Although ambrette [A. moschatus (L.) Medik] is economically important crop, there have been no attempts made for its genetic improvement. Therefore, present investigation was designed primarily to create genetic variations using the tools of induced mutagenesis and to raise desirable plant type mutants (high yielding) of interest. The plant types evolved seems to be in the direction of the objective underlined and correspond closely with the idiotype been looked for in the crop. The yield ability in the macromutants may even be better with improved agronomic managements. Further, intermating among the macromutants followed by rigorous selection may give rise to better plant types of interest. Raised macromutants showed significant variations for different economic traits which may be utilized for efficient plant breeding. Thus, variations released through mutations have enriched genetic diversity in the species which did not exist in natural population earlier.