GAMMA RAYS INDUCED MUTAGENESIS IN DAHLIA (*Dahlia variabilis* L.) AND PROPAGATION OF MUTANTS OBTAINED THROUGH STEM CUTTINGS

Ph.D. (Hort.) Thesis

By

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INDIRA GANDHI KRISHI VISHWAVIDYALAYA

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BHARTI SAO

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FOR THE DEGREE OF

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In

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CERTIFICATE – I

This is to certify that the thesis entitled **"Gamma rays induced mutagenesis in Dahlia (*Dahlia variabilis* L.) and propagation of mutants obtained through stem cuttings"** submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Horticulture** in the Department of **Floriculture and Landscape Architecture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Bharti Sao** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by her.

Date: 21/09/2021

Chairman

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman	**(Dr. L. S. Verma)**	.....
Member	**(Dr. T. Tirkey)**	.....
Member	**(Dr. G. L. Sharma)**	.....
Member	**(Dr. R. R. Saxena)**	.....

CERTIFICATE-II

This is to certify that the thesis entitled entitled **"Gamma rays induced mutagenesis in Dahlia (*Dahlia variabilis* L.) and propagation of mutants obtained through stem cuttings"** submitted by **Bharti Sao** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Horticulture** in the Department of **Floriculture and Landscape Architecture** has been approved by the external examiner and Student's Advisory Committee after oral examination.

Ruman

Signature of External Examiner

(Name ...Dr. Raj Kumar...)

Date: 21/09/2021

Major Advisor _____

Head of the Department _____ 7/X/21

Faculty Dean _____ 7/X/21

Approved/ Not Approved

Director of Instructions _____

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"Education plays vital role in personal and social development and teacher plays a fundamental role in imparting education. Teachers have crucial role in shaping young people not only to face the further with confidence but also to build up it with aim and responsibility. There is no substitute for teacher pupil relationship."

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Raipur
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(Bharti Sao)

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LIST OF ABBREVIATIONS

Abbreviations	Description
%	Percent
@	At the rate
^{O}C	Degree Celsius
ANOVA	Analysis of variance
at par	At equality
CD	Critical difference
cm	Centimeter
cv.	Cultivar
Co	Cobalt
CV	Coefficient of variance
d.f.	Degree of Freedom
et al.	And others
Fig.	Figure
FCRD	Factorial Completely Randomized Design
g	Gram
GA_3	Gibberellic acid
Gy	Gray
ha	Hectare
IBA	Indole-3-butaric acid
i.e.	Id est (that is)
kR	kilorad
m	Meter
NAA	Alpha-Naphthalene acetic acid
No.	Number
NS	Non-significant
ppm	Parts per million
RH	Relative humidity
RHS	Royal Horticultural Society
Sig.	Significant
SEm±	Standard error of mean
spp.	Species
vM_1	Vegetative Mutant generation 1
vM_2	Vegetative Mutant generation 2
Var.	Variety
via.	Through
viz.	Namely

THESIS ABSTRACT

Title of the Thesis	:	"Gamma rays induced mutagenesis in Dahlia (*Dahlia variabilis* L.) and propagation of mutants obtained through stem cuttings."
Full Name of the Student	:	Bharti Sao
Major Subject	:	Floriculture and Landscape Architecture
Name and Address of Major Advisor	:	Dr. L. S. Verma Associate Professor, Department of Floriculture and Landscape Architecture, Collage of Agriculture, IGKV, Raipur (C.G.)
Degree to be Awarded	:	Doctor of Philosophy in Horticulture (Floriculture and Landscape Architecture)

Signature of the Student

Signature of Major Advisor

Date... 21/09/2021

Signature of Head of Department

ABSTRACT

The present investigation entitled "Gamma rays induced mutagenesis in Dahlia (*Dahlia variabilis* L.) and propagation of mutants obtained through stem cuttings." was undertaken in the Department of Floriculture and Landscape Architecture, IGKV, Raipur (C.G.) in two experiments. The Experiment- I entitled "Gamma ray induced mutagenesis in dahlia" was conducted during winter season of 2018-19 in Factorial Completely Randomized Design (FCRD) with four replications using three dahlia cultivars (Kenya Blue, Kenya Yellow and Kenya Original) and three doses of gamma rays with control (0, 10, 15 and 20 Gy). Whereas, Experiment-II entitled "Effect of rooting hormones in the propagation of dahlia mutants through stem cuttings" was conducted during winter season of 2019-20 in Factorial

Completely Randomized Design (FCRD) with three replications using mutants of two dahlia cultivars (Kenya Blue and Kenya Yellow) in which desirable mutants for trait (colour) obtained after screening of vM_1 population and ten different combinations of rooting hormones with three doses each IBA, NAA and their combinations. The main objective of the investigation is induction of dahlia flower mutants through gamma radiation and its propagation by using rooting hormones.

The result of experiment indicated that the mortality percentage and abnormal plant percentage increased with increase in dose of gamma rays whereas, percentage of survival was decreased. Kenya Yellow had maximum mortality as well as abnormal plant percentage. However, significantly higher survival percentage was noted in Kenya Original. The probit analysis indicated the extrapolated LD_{50} dose was found beyond 20 Gy for survival of cultivars, Kenya yellow had low LD_{50} but high mutation frequency as compared to other cultivars of dahlia. Gamma radiation at lower doses (10 Gy) had stimulatory effect on some of the flowering traits like days taken for first bud appearance and number of days taken for flower opening, whereas rest of the other floral, vegetative, tuber and physiological characters were reduced and retarded with increased doses. These decreases were inversely proportional to the dose employed. Mutants for flower colour trait were isolated from vM_1 generation in 10 Gy gamma ray irradiated plant in the form of chimera. 24 mutants isolated from three cultivars of dahlia (6 in Kenya Blue, 15 in Kenya Yellow and 3 in Kenya Original) for flower colour which were exhibited variation in quantitative characters from their respective parents.

The effect of rooting hormones and mutants of cultivars were significant on majority of rooting characters. IBA @ 250 ppm + NAA @ 500 ppm recorded minimum days for rooting. However, IBA @ 1000 ppm gave best result in rooting percentage, number of root cutting^{-1} and root length whereas, highest survival percentage was observed in NAA @ 500 ppm. Among the mutants of cultivar, Kenya Blue performed better in rooting characters, number of leaves plant^{-1}, total number of branches plant^{-1} and plant spread, wherein the mutants of Kenya Yellow recorded maximum plant height. Plants treated with IBA @ 500 ppm perform great in plant height, number of leaves plant^{-1}, plant spread, days taken for first bud

appearance, number of days taken to full bloom, flower diameter, number of ray floret flower^{-1}, longevity of flower, duration of flowering and tuber characters whereas, IBA @ 1000 gave better result in total number of branches plant^{-1}, flower stalk diameter, number of flower plant^{-1} and flower weight. However, the number of days taken for flower opening and flower stalk length was best in IBA @ 250 ppm + NAA @ 250 ppm. Mutants of cultivar Kenya Blue gave superior result in most of the flowering character like days taken to first bud appearance, flower diameter, number of ray floret, longevity of flower and flower weight whereas, mutants of Kenya Yellow perform best in other floral and tuber characters. The highest leaf chlorophyll content was recorded in IBA @ 250 ppm and mutants of Kenya Blue. In vM_2 generation, total 26 mutants (8 in Kenya Blue and 18 in Kenya Yellow) were screened out for ornamental traits from mutants of vM_1 generation of dahlia cultivars.

शोध ग्रंथ सारांश

(अ) शोध ग्रंथ का शीर्षक	:	डहेलिया (डहेलिया वैरियाविलिस) में गामा विकिरणों द्वारा अनुवांषिक विभिन्नताओं को प्रेरित करना एवं तथा प्राप्त उत्परिर्तियों का तना कटिंग के माध्यम से प्रसार
(ब) छात्र का पूर्ण नाम	:	भारती साव
(स) प्रमुख विषय	:	पुष्प विज्ञान एवं भुदृश्य वास्तुकला
(द) प्रमुख सलाहकर	:	डॉ. एल.एस. वर्मा, सह– प्राध्यापक, पुष्प विज्ञान एवं भुदृश्य वास्तुकला विभाग, कृषि महाविद्यालय, इंदिरा गांधी कृषि विश्वविघालय, रायपुर (छ.ग.)
(इ) उपाधि	:	पी. एच.डी. (उद्यानिकी), पुष्प विज्ञान एवं भुदृश्य वास्तुकला

प्रमुख सलाहकार के हस्ताक्षर

छात्र/छात्रा के हस्ताक्षर

दिनांक : 21/09/2021

विभागाध्यक्ष के हस्ताक्षर

सारांश

प्रस्तुत, शोध शीर्षक "डहेलिया (डहलिया वैरियाविलिस) में गामा विकिरणों द्वारा आनुवांषिक विभिन्नताओं को प्रेरित करना एवं प्राप्त उत्परिवर्तियों का तना कटिंग के माध्यम के माध्यम से प्रसार" का कार्य बागवानी अनुसंधान सह अनुदेषात्मक फॉर्म, पुष्प विज्ञान एवं भुदृष्य वास्तुकला विभाग, कृषि महाविद्यालय, इंदिरा गांधी कृषि विष्वविद्यालय, रायपुर (छ.ग.) पर दो प्रयोग के माध्यम से किया गया। प्रथम प्रयोग जिसका शीर्षक" गामा विकिरणों द्वारा आनुवांषिक विभिन्नताओं को वर्ष 2018–19 के दौरान शरद ऋतु में किया गया जिसमें डहेलिया की 03 प्रजाति केनिया ब्लू, केनिया येला एवं केनिया ओरिजीनल को गामा विकिरणों के 0.00Gy, 10Gy, 15Gy एवं 20Gy के द्वारा उपचार कर, चार पुनरावृत्तियों के साथ क्रमगुणित पुर्णतः यादृच्छिक रूपरेखा में लगाया गया। द्वितीय प्रयोग जिसमे "डहेलिया उत्परिवर्तियों के प्रसार में रूटिंग हार्मोन का प्रभाव है। इसे वर्ष 2019–20 के दौरान शरद ऋतु में किया गया। इस शोध कार्य में डहेलिया की उन दो प्रजातियों केनिया ब्लू तथा केनिया यलो के उत्परिवर्तियों को लिया गया, जिसमें वांछिनीय उत्परिवर्तन देखा गया था, इन प्रजातियों को इंडोल ब्यूटारिक एसिड (आइ.बी.ए.) तथा दोनो मिश्रण के 10 उपचार सम्मिश्रित से उपचारित कर तीन पुनरावृत्तियों के साथ क्रमगुणित पूर्णतः यादृच्छिक रूपरेखा में लगाया गया । शोध का मुख्य उदेश्य गामा विकिरण द्वारा डहेलिया उत्परिवर्तियों को प्रेरित करना तथा रूटिंग हार्मोन का उपयोग कर इनका प्रसार करना है।

प्रयोग दर्शाता है कि गामा विकिरणों की मात्रा में विद्वि के साथ – साथ नश्वरता प्रतिशत एवं आसमान्य पौध प्रतिषत में भी वृद्वि हुई जबकि उत्तरजीविता प्रतिशत में कमी आई। केनिया येलों प्रजाति में सबसें अधिक नश्वरता एवं असामान्य पौधें प्राप्त हुए, जबकि प्रजाति केनिया ओरीजिनल में अधिकतम उत्तरजीविता प्राप्त हुई। प्रोबिट विश्लेषण दर्शाता है कि सभी प्रजातियों के लियें बहिर्वेशन नश्वरता आधारित LD50 की मात्रा 20Gy से अधिक है। अन्य प्रजातियों की तुलना में केनिया येलों की LD50 सबसे कम पायी गई है। परंतु इस प्रजाति में ही सबसे अधिक उत्परिवर्ती आवृत्ति पायी गयी। कुछ पुष्प लक्षणों जैसे – प्रथम कलिका के बनने का दिन तथा कलिकाओं से पुष्प बनने के दिन पर न्यूनतम गामा विकिरणों (10Gy) का उत्तेजक प्रभाव देखा गया, जबकि अन्य पुष्पीय, वनस्पतिक, कंदीय व कार्यकीय लक्षणों में गामा विकिरणों की मात्रा बढ़ने के साथ –साथ प्रबल गिरावट पाई गयी । प्रथम संतती में न्यूनतम गामा विकिरण (10Gy) द्वारा 24 पूर्ण पुनित पौधे (06 केनिया ब्लू में, 15 केनिया येलो में तथा 03 केनिया ओरिजनल) पाये गए। ये सभी उत्परिवर्ती विभिन्न मात्रात्मक लक्षणों में अपने संबधित जनक से भिन्न थे।

दूसरे शोध में बहुताय जड़ीय लक्षणों पर डहेलिया प्रजातियों के उत्परिवर्तियों और रूटिंग हार्मोन का प्रभाव सार्थक पाया गया। विभिन्न रूटिंग हार्मोन के संयोजन में आई.बी.ए.250 पी.पी.एम.+एन.ए.ए.250 पी.पी.एम के उपचार से जड़ निकले में लगने वाले समय में कमी पायी गई। इसी प्रकार आई.बी.ए. 1000 पी.पी.एम. का उपचार जड़ प्रतिषत, प्रति कटिंग जड़ संख्या तथा जड़ो की लम्बाई में अधिक प्रभावी पाया गया, जबकि अधिकतम उत्तरजीविता प्रतिषत एन.ए.ए.500 पी.पी.एम. के उपचार में देखा गया। दोनो उत्परिवर्ती प्रजातियों की तुलना में केनिया ब्लू विभिन्न जड़ीय लक्षणों, प्रति पौधा पत्तियों की संख्या, प्रति पौधा शाखाओं की संख्या एवं पौध का फैलाव में अधिक बेहतर पाई गयी, जबकि केनिया येलो में पौध की बढ़वार अधिक प्राप्त हुई। आई.बी.ए.500 पी.पी.एम. का प्रभाव पौध लंबाई प्रति पौधा, प्रति पौधा पत्तियों की संख्या, पौध फैलाव, पहली कली निकलने का समय, पूर्णतः फूल खिलने का समय, प्रति पुष्प अर पुष्पक की संख्या पुष्प की आयु, पुष्प अवधि तथा कंदीय लक्षणों में श्रेष्ठ पाया गया, जबकि आई.बी.ए. 1000 पी.पी.एम. का उपचार प्रति पौधा शाखाओं की संख्या, पुष्प डण्ठल का व्यास, प्रति पौधा पुष्प संख्या तथा पुष्प भार में बेहतर देखा गया। इसी प्रकार पुष्प के खिलने में लगने वाला समय तथा पुष्प डण्ठल की लम्बाई आई.बी.ए. 250 पी.पी.एम. + एन.ए.ए. 250 पी.पी.एम. के उपचार में श्रेष्ठ पायी गयी। केनिया ब्लू के उत्परिवर्तियों द्वारा अधिकतम पुष्पीय लक्षणों जैसे–पहली कली के निकलने का समय, पुष्प ब्यास, अर पुष्पक की संख्या, पुष्प आयु और पुष्प भार में बेहतरीन परिणाम देखा गया । जबकि अन्य पुष्पीय व कंदीय लक्षणों के श्रेष्ठ परिणाम केनिया येलो के उत्परिवर्तीयों में देखें गयें। प्रथम संतति से द्वितीय संतति में कुल 26 उत्परिवर्ती (केनिया ब्लू में 08 और केनिया येलो में 18) प्राप्त किये गयें जो अपने संबध जनक सें मात्रात्क गुणों में विभिन्नता प्रदर्षित करते है।

CHAPTER-I
INTRODUCTION

Floriculture is derived from the Latin dialect which means “to cultivate flowers”. Although flowers have been an integral part of the Indian culture and are cultivated for numerous functions starting from artistic to social and religious functions, the commercial floriculture industry has come into entity only recently. A major increase in the demand for cut and loose flowers has led to floriculture being significant for industrial trades in Indian agriculture. These industries are dynamic, global and fast growing, characterized by important change in the distribution network (Rikken, 2010). The production of floriculture products has grown quite steadily over the last 20 years with an average annual growth of 6-9% (Abrol and Baweja, 2019). India is endowed with diverse agro-climatic conditions, offers contrasting climatic zones which leads to cultivation of various crops at different times in diverse areas. Karnataka, Andhra Pradesh, Haryana, Tamil Nadu, Rajasthan and West Bengal are few of the distinctive states where Floriculture has significantly prospered. About 313 thousand hectares of area was under floriculture producing with 2059 thousand MT of loose flowers and 807 lakh numbers of cut flowers in India in 2018-19. Chhattisgarh, situated in central eastern part of India, with its pleasant climate provides a surreal prospect to promote cultivation of different floriculture crops like Marigold, Rose, Chrysanthemum, Gladiolus, Tuberose, Orchids, Gerbera, Anthurium. In Chhattisgarh floriculture has taken up about 13.2 thousand ha with a production of 47.5 thousand MT (mainly loose flowers) (Anonymous, 2019). This contributes to about 1.3 percent of the National floriculture (loose flowers) production.

Dahlia, a valuable flowering plant used for garden display, exhibition, cut flower production, flower arrangement for borders, beds or mixed borders, growing in containers and making garlands. (Giannasi, 1998). The flower belongs to the family Asteraceae and its two main species are *Dahlia pinnata* and *Dahlia coccinea*. Among the 27 species comprising the genus, the best known are *Dahlia*

coccinea, *Dahlia merckii*, *Dahlia pinnata*, *Dahlia imperialis* and *Dahlia variabilis* (Marina, 2015). It has certain medicinal and nutritional uses as well. Tubers of dahlia are rich in starch-insulin which can be converted into fructose, a sweetening substance used by diabetic patients (Ioana *et al.,* 2017). The extract of flower petals helps to increase the appetite, gastric secretion and tone the cell wall. Both the tuberous root and flowers are used in culinary art as an appreciated spice for its peculiar taste and flavour. The tuberous roots can be cooked like vegetables and the colourful flower petals are used in salads. As natural repellents or insecticides for stored insect products, the essential oils of *Dahlia pinnata* have been shown to have potential for growth (Fierascu *et al.,* 2019). The major tuberous rooted dahlia growing countries are Netherlands, Japan, France, South Africa, UK, Italy, Germany and the USA. In India, commercial cultivation of dahlia is limited to the hills and plains of eastern India including Jammu and Kashmir.

The specific name adopted, *Dahlia variabilis* indicates its characteristic of spontaneously creating new forms, as well as its capacity to interbreed and hybridize, which have led to a number of types, forms and hybrids that contributed to their botanical classification. There are currently about 20,000 varieties recognized by the International Registration of Dahlias (Marina, 2015). This flower exhibits different colors, sizes and flower shapes. In particular, dahlias exhibit a wide range of colors of ray florets, such as ivory, red, yellow, pink and purple. The pigments accumulated in ray florets are flavonoids, butein, mainly anthocyanin's and flavones and their derivatives that produce yellow, red and ivory colours (Yamaguchi *et al.,* 1999).

Dahlia plants reproduce sexually by seed and vegetatively through tuberous roots. The most commonly used methods for its propagation are via cuttings or tuberous root division. The main advantages of propagation by cuttings are the relative simplicity of the operations, low unit cost of production and the ease with which the plants re-establish themselves, which makes this method of propagation highly practical and economically viable. (Wei, 1958). The ability of rooting varies with genotypes and also depends on the age of the plant used as source of cuttings. There have been significant efforts have been taken to enhance adventitious

rooting by checking the combined impact of various plant growth regulators (Da Silva, 2006). Indole Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA) are still the most commonly used auxins for rooting stem cuttings and micro cuttings rootings produced by tissue-culture (Zimmerman and Wilcoxon, 1935). The significance of hormones in the rooting of cuttings was clearly identified in 1935 when indole acetic acid in lanolin paste was first used successfully to stimulate the rooting of lemon, Lantana and Acalypha cuttings by Cooper. Indole acetic acid (IAA) is the naturally occurring auxin found in plants. The most commonly used auxin IBA (synthetic) is proven to be the most effective hormone promoting in production of adventitious roots compared to IAA (natural) (Pop *et al.,* 2011). A number of dahlias are available in the market but their novelty in commercial characteristics such as earliness, longer duration of flowering, local adaptive flower colour, shape, size, growth habit, post-harvest life etc. is more valued and generally favored by consumers, which makes the scope for breeding new dahlia varieties visible.

Dahlia spp. has a high occurrence of polyploidy and thus, exhibit variations in colour, size and flower shape. By using hybridization many new cultivars have been developed already. In general, crosses may be restricted by incompatibility or variations in ploidy level and a high degree of heterozygosity, resulting in a complex genetic factor inheritance. In conventional breeding, this causes some significant problems. Here, mutation breeding gives an advantage as a large variation can be realized for the improvement of one or few characters of outstanding cultivar, without altering the remaining genotype within a short span of time. Mutation can be defined as the sudden heritable change in the number or sequence of nucleotides. It occurs in cells by alteration in nuclear DNA, which is also known as point mutation and causes addition, deletion, transition and transversion in nucleolus of cell or certain changes in cytoplasmic DNA (i.e., male sterility) referred to as cytoplasmic mutation (Patil, 2009). While there are certain limitations to mutations, most of the mutations are detrimental and inadmissible. As useful mutations are produced at a very low frequency (0.1 %), it is important to scrutinize a large plant population to recognize and isolate desirable mutants (Lawrence, 2010). Mutation breeding is now commonly accepted for the

enhancement of modern-day dahlia cultivars as well as other ornamental crops such as chrysanthemum and gladiolus as a valuable complementary method. In vegetatively propagated plants, the key benefit of induced mutation includes the ability to change one or a few characters of an excellent cultivar without altering the remaining genotype. In addition, without further breeding, any induced color sports may be used directly for propagation as a cutting. Another explanation is that there are many heterozygous cultivars that can allow for prolonged variation through mutations and hybridizations. In general, it is not difficult to select mutants with directly perceptible characteristics, including flower shape or size or colour. The technique of induced mutation is now considered to be an effective method for improving many vegetatively propagated crops, providing an opportunity to increase the variability of an economically valuable cultivar and is also useful in the absence of the desired recombinants from established germplasm. Hence, for the introduction of potential mutants, there is a wide scope for involving mutagenic breeding strategies in extremely heterozygous organisms such as dahlias.

In Dahlia, freshly harvested tubers were more suitable for irradiation. As the elevated polyploidy and the large number of flower color genes draw attention to this species, *Dahlia variabilis* must be regarded as a promising species for mutation breeding. Due to the high degree of heterozygosity and vegetative proliferation, flower colour and other distinguishable mutations varying from dominant to recessive may be found in the content.

In addition, the genetic makeup of a given variety is not substantially altered. Cross breeding of a certain variety of dahlia would never result in a genotype that is similar, apart from one recently added as a lower color change. For this reason, the mutation breeding is an essential way of developing certain varieties. Due to the complex genetics and uncertain genetic background of current cultivars, material selection is extremely strenuous, making it almost impossible to choose cultivars. Thus mutation breeding is also more prospective than hybridization breeding (Broertjes and Ballego, 1967, 1968, 1976). In order to give a mutated cell, the best chance of participating in the formation of the shoot, it is important to irradiate the buds at the earliest possible stage of growth. Irradiation

should be carried out immediately after harvest when no visible eyes on these so-called dormant tubers can be detected.

Dahlia growing in India and particularly Chhattisgarh is carried out by amateur garden lovers, nurserymen and a few institutions, mostly for the purpose of dahlia shows and exhibitions. The commercial cultivation of the crop, especially among the farmers has not gained popularity as that gained by other floricultural crops. On the other hand, the effects of gamma rays on dahlia have been studied by several workers in abroad and different states of India but very few varieties have been developed through gamma radiations. In Chhattisgarh the work on above aspect has not yet been taken. Hence, looking to the present need towards development of new dahlia varieties through mutation breeding and its successfully propagation by using best combination of rooting hormones, are need to be carried out for Chhattisgarh.

Keeping in view the above aspects, the present investigation entitled **"Gamma rays induced mutagenesis in Dahlia (*Dahlia variabilis* L.) and propagation of mutants obtained through stem cuttings"** was carried out during the winter season of 2018-19 and 2019-20 at the Horticultural Research cum Instructional Farm, Department of Floriculture and Landscape Architecture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) with following objectives:

1. To find out the doses of gamma rays for inducing variability in Dahlia cultivars
2. To assess the vegetative and floral characteristics of gamma irradiated Dahlia cultivars
3. To screen gamma irradiation induced mutants in Dahlia cultivars
4. To find out the effect of rooting hormones and their doses on propagation of Dahlia mutants through stem cuttings

CHAPTER-II
REVIEW OF LITERATURE

The role on induction of mutation through physical mutagen, especially gamma irradiation and the effects of rooting hormones on the propagation through the cutting of ornamental flower crops has been carried out in abroad and India by several researchers. It will be useful to review their works in dahlia as well as related ornamental flower crops and supplement the view to strength the concept development from present experiment **"Gamma rays induced mutagenesis in Dahlia (*Dahlia variabilis* L.) and propagation of mutants obtained through stem cuttings"** has been completed under following heads:

2.1 Effect of various mutagens on dahlia

2.2 Effect of various mutagens on other ornamental crops

2.3 Effect of rooting hormones on the propagation of dahlia

2.4 Effect of rooting hormones on the propagation of other ornamental crops

2.1 Effect of various mutagens on dahlia

Broertjes and Ballego (1967) irradiated the tubers of several dahlia cultivars with different dosages of X-rays. The optimal dose ranged from 2 to 3 Krad, taking into account the development of rooted cuttings, days taken for rooting, subsequent development of the young plants and mutation frequency. They observed a number of mutations in flower color and shapes in the irradiated varieties like 'Salmon Rays', 'Arthur Godfrey' and 'Eldorado'.

Das *et al.* (1978) worked on fourteen cultivars of dahlia cultivars with gamma radiations at doses up to 8 Krad and was able to discover 19 mutations mostly for flower color. The optimal dosage for mutation induction was measured to be 2-3 Krad.

Dube *et al.* (1980) studied the tubers of fourteen leading varieties of dahlia with gamma radiations at doses ranging from 1 to 8 Krad. The findings showed that there was a proportional decrease in tuber growth with the rise in doses from 2 Krad, while a sharp decrease was observed at 4 Krad, whereas 6 and 8 Krad doses were found to be lethal. Whereas, LD_{50} was found to be between 3-4 Krad, 2-3 Krad was found to be the optimum dose for mutation induction. The frequency of mutations differed with both the dosage & variety and the highest number of mutants was observed at the 2 Krad dose.

Misra (1990) treated the 9 dahlia cultivars (tuber) with ^{60}Co gamma radiation doses were within the range of (0-4.5 Krad) and reported that the 4 dahlia cultivars namely Eggleston, Powder Puff, African Queen and Garden Glory showed increased plant height and an increase in floral parts after 0.5 Krad treatment. Certain abnormalities in vegetative and floral character were also observed. One pure white variant was recorded under 1.5 Krad treatment in vM_1 which was reversed in vM_2 generation.

Vaclavik (2000) produced a yellow-coloured mutant in dahlia (*Dahlia pinnata*) by irradiating it with gamma rays of radioisotope ^{60}Co. When tested for the tomato spotted wilt virus by DAS-ELISA, the irradiated materials had a high proportion of plants with increased values of absorbance.

Hamatani *et al.* (2001) treated (1 cm long) shoots of dahlia (*Dahlia pinnata* cav.) with an N-heavy ion beam (10 Gy) and observed robust growth of shoots in both *in vitro* and *in vivo* and showed the highest mutation frequencies like diameter of flower (3-12 cm), variations in flower colour such as darker or light colored petals or white tipped petals. Frequency of flowering was decreased with an increase in heavy-ion beam exposure and the same phenomena were also noticed with gamma radiation treatment.

Dwivedi and Banerji (2008) isolated mutant which appeared in the form of chlorophyll variegation in foliage and the flower head in the form of white sectors in ray florets in M_1 generation after irradiation of dahlia cultivar Pinki. The

observation concluded that there was a decline in survival percentage, plant height, numbers of leaves and peduncle size and length. Morphological abnormalities had elevated with increased exposure to gamma rays. LD_{50} on a survival basis was determined in between 1000 and 1500 rads and these doses are recommended for the induction of somatic mutation in dahlia.

Pal (2015) irradiated tubers of six dahlia cultivars viz. Jyotsana, Agni, Tanaya, Glory of India, Donald and Masterpiece with different doses (0.0, 1.0 1.5, 2.0, 2.5 and 3.0 Kr) of gamma radiations and found that 1.0 Krad was better for enhancement of a few vegetative, floral and mutational characters, whereas doses of 1.5 Krad was more suited for induction of flower color mutation.

Manu (2017) investigated the effect of gamma radiations on different dahlia cultivars and it was found that vegetative growth was significantly reduced at higher doses of gamma rays compared to lower doses, whereas the dose of radiation increased, the days to flowering increased as well. Number of flowers/plant and flower diameter were inversely proportional to mutagen dose. However, the number of flowers, ray florets and number of petals got significantly reduced with increasing rate of gamma irradiation and the delay in flowering resulted in a reduced longevity period both in intact and cut flower condition.

2.2 Effect of various mutagens on other ornamental crops

Datta *et al.* (2006) induced mutagenesis and mutant induction by adding physical and chemical mutagens despite the implementation of new technologies for novel variety production. This is deemed to be a significant aspect of the breeding of ornamental and floricultural plants. In both *in-vivo* and *in-vitro* systems, via a reasonably easy-to-apply technology. However, the new characters in plant form, leaf and flower color and shape can be induced without a negative residual effect on human health (in the case of consumables).

Velmurugan *et al.* (2010) found that 2 Krad gamma rays and 750 mM EMS were the LD_{50} value for shoot tip explants in *in-vitro* mutation. Similarly, for callus culture, the LD_{50} value was 1.0 Krad gamma rays and 200 mM EMS. The *in vitro*

mutants derived from callus exerted a negative genotypic correlation and forskolin content was expressed in phenotypic correlation.

Kazi (2015) reported 198 commercial mutant varieties of chrysanthemum from different countries. The mutant character includes the flower colour, shape and size. Most mutants are created through x-rays or gamma radiation. He discovered that in any plant breeding program, genetic variation is important for crop improvement and induced mutations are highly effective in improving natural genetic resources.

Chrysanthemum

Lamseejan *et al.* (2000) cultured the ray florets of chrysanthemum (*Chrysanthemum morifolium*) on the MS medium containing 10 mg liter^{-1} BA. Multiple shoots produced were irradiated with various doses of gamma radiation (0, 10, 30, 50, 70, 90 and 110 Gy). From M_1V_1 to M_1V_4, sub-culturing is carried out three times, after which M_1V_4 shoots were rooted and transplanted to the greenhouse. Result revealed that within 25–30 days, M_1V_4 shoots irradiated at 50 Gy and above were destroyed. 14 Gy dose was the LD_{50} for this purple clone of chrysanthemum. Only the untreated and treated plants with 10 Gy were able to prosper and full grown plants were developed.

Banerji and Datta (2002) irradiated the rooted cuttings of chrysanthemum with gamma rays of 0, 15, 20 and 25 Gy. They reported a reduction in survival percentage, growth, plant height, number of branches and number of leaves plant^{-1}. Likewise, an increase in morphological chromosomal abnormalities was also reported in following radiation doses. After irradiation, substantial decreases were reported in plant height and guard cell width. No change in the number of chromosomes in the mutant was registered.

Dilta *et al.* (2003) studied the effect of gamma radiations on vegetative characters of chrysanthemum by treated the rooted cuttings with gamma radiation at 0 and 20 Gy and cultivated subsequently under field conditions. He concluded a decrease in survival percentage, plant height, growth, number of branches, leaf number, leaf size and plant spread with increased dose. Although, plants treated

with 20 Gy recorded an increase in the magnitude of plant abnormalities (of leaves).

Mishra *et al.* (2003) obtained two yellow-colored mutants by irradiating *Chrysanthemum morifolium* Ramat cv. “Lalima” under 0.5 Gy gamma radiation. In which, one of the mutants had a flat-spoon-shaped ray florets similar to their parent, while the other had tubular florets.

Banerji and Datta (2005) treated the rooted cuttings of *Chrysanthemum morifilium* Ramat cv. “Khumaini” with different doses (150, 200 and 250 Gy) of gamma rays. They observed a reduction in survival percentage, plant height, growth, number of branches plant^{-1}, number of leaves plant^{-1}, number of flowers and flower diameter. Whereas, increase abnormalities in foliage and flower, chromosomal aberrations and delay in flowering were noted with increased dose. Somatic mutation in floret color was also detected in vM_1 as a sectorial chimera. The percentage of mutation also increased with an increase in exposure to gamma irradiation. A total of 3 mutations were induced in flower color and isolated in pure form.

Datta *et al.* (2005) irradiated the ray florets of *Chrysanthemum morifolium* Ramat. cvs. (Flirt, Puja, Maghi and Sunil) with gamma radiation dose of 500 and 1000 rad and cultured on MS medium supplemented with various growth regulators concentrations and combinations. The frequency of direct shoot regeneration of gamma rays treated florets has decreased. The radiation effect was observed on plant regeneration from floret explants treated with gamma rays, as well as on plant height, leaf and flower size. Five solid flower color/floret form mutants with minor changes in ray floret morphology have been described and created.

Boersen *et al.* (2006) studied the effect of various rates of gamma rays on the frequency of mutation in inflorescence colour and type of chimerism in chrysanthemum cv. “Cherry Dark”. They observed a linear decrease in plant height and a quadric pattern in survival percent with increases in mutagen doses.

Mishra *et al.* (2009) studied the effect of gamma irradiation on chrysanthemum cultivar 'Pooja' with references to somatic mutation in flower color and shape. They treated rooted cuttings of 'Pooja' with different doses of gamma radiation (10, 15, 20 and 25 Gy) and concluded that the gamma irradiation treatment substantially delayed the development of flower bud, color and full bloom.

Nagatomi and Degi (2009) clarified the effect of chronic and acute radiation in *in-vitro* culture on mutation induction of flower color in chrysanthemum. The combination of both the radiation produced a 10 times higher mutation rate than the traditional chromic approach and also produced non-chimeric mutants. Somaclonal variation in plants regenerated from callus has often been observed, but no major variations have occured in callus regenerants from non-irradiated plants. The chronic culture method clearly created the widest color range in chrysanthemum, while the acute culture method resulted in a relatively low rate of mutation and a narrow flower color spectrum. In this study, 10 flower color mutants were created that were derived from chronic irradiation and only one from acute irradiation.

Lee *et al.* (2010) studied the induction of mutations for stem quality in chrysanthemum (*D. grandiflora*) by using gamma irradiation. They found that individuals survived regardless of the irradiation dose but with an increase in the dose of radiation, growth was reduced proportionally. Particularly, at 40 and 50 Gy, the plant height and length of the internodes were significantly reduced from two to four times. The morphological features of the leaves, the length of the leaves and the width of the leaves were gradually reduced and the length of the petioles increased as the dosage increased. This contributed to the fact that gamma-ray treatment can be a successful means of causing exclusive mutations in *D. grandiflora*.

Mahure *et al.* (2010) irradiated the un-rooted cuttings of chrysanthemum cultivar "Red Gold" by different doses (10, 20 and 30 Gy) of gamma radiations to induce positive variance. They found that lower gamma irradiation doses induced

encouraging novelties while a high degree of abnormalities and consequent mortality were often induced by higher doses.

Mohin *et al.* (2010) worked under the net house for vM_3 generation on radiation-induced variability in chrysanthemum and found that the survival of plants of all mutants over control was substantially reduced. Compared to the control, the reduction in plant height, plant spread, number of branches plant^{-1}, number of leaves plant^{-1}, length of leaves, width of leaves, petiole length, leaf area and chlorophyll content was recorded in vM_3 generation. As a bud sport, a yellow flower with a modified head-shape mutant of the chrysanthemum cultivar A-22 was developed.

Kaul *et al.* (2011) cultured nodal segments of *Dendranthema grandiflora* Tzelev cv. "Snow Ball" in MS medium supplemented with 0.5 mg l^{-1} BA, 0.1 mg l^{-1} IAA and 1 mg l^{-1} GA_3, after that produced 2-3 cm long *in-vitro* raised shoots were treated with different doses (5, 10, 20 and 30 Gy) of gamma rays and multiplied on the same medium. *In vitro* flower color mutation was detected in one branch of the same plant with irradiation of 10 Gy. The original floral color of cultivar Snow Ball is white with flat and incurving florets while the mutant floret colour was yellow with flat and incurving florets.

Kumari *et al.* (2013) treated the rooted cuttings of chrysanthemum variety "Otome Pink" with various doses (10, 15 and 20 Gy) of gamma rays included control and different morphological, palynological, and anatomical characters were evaluated. They noticed that the plant survival percentage, plant height, flower head count, number of stems plant^{-1}, stem girth and number of leaves plant^{-1} decreased after gamma irradiation whereas, at the 20 Gy gamma irradiation dose, delayed flowering and planting in the vegetative stage were observed. However, as the dose increased, there was a reduction in pollen fertility, the amount of chloroplasts guarding cell-1, flower head size and fresh weight were observed, while with an increased dose of gamma irradiation, flower head fasciation and asymmetrical growth of flower heads increased. Two variants were obtained, one with yellow color at 10 Gy and the other with quilled petals at 15 Gy and vegetatively multiplied further.

Kapadiya *et al.* (2014) made a comparative study to exploit variability and evaluated its heritable effects on various parameters viz. survival rate, morphological and flowering in chrysanthemum variety 'Maghi' induced by treatment of three concentrations EMS and DES each with (0.02, 0.03 and 0.04 %) and five doses (0.5, 1.0, 1.5, 2.0 and 2.5 Krad) of gamma rays. Result revealed that all the mutagenic treatments delayed flowering up to 6 to 7 days whereas flowering duration was significantly reduced, whereas flower head diameter, number of ray and disc florets were significantly increased with treatment of 0.5 and 1.0 Krad gamma rays, respectively. However, weight of flower, number of flowers and flower yield plant^{-1} were highest at the lowest dose (0.5 Gy) of gamma rays. Compared to EMS and DES, total abnormalities in floral and foliage characters were higher in gamma rays. Two foliage mutants with 0.03 percent EMS and 1.0 Krad gamma rays were exhibited by Variety Maghi and these mutants lost their flowering potential.

Sadhukhan *et al.* (2015) exposed the three varieties of chrysanthemum viz. BC-8-05, Winter Queen and Bidhan Shova to various doses (0, 10, 15, 20, 25 and 30 Gy) of gamma irradiation for study the rooting potential. Result revealed that compared to control, the roots numbers as well as root length increased significantly in some instances under 10 Gy but there was a decrease in root length with a further increase in dosage and also a poor morphological appearance. However, the delayed root initiation time and survival percentage have resulted from a rise in radiation doses. In the 50 unrooted cuttings of the Winter Queen, the highest LD (20.1 Gy) was reported, whereas it was found to be the lowest in the 50 rooted cuttings of Bidhan Shova (10.2 Gy).

Singh and Bala (2015) irradiated the terminal rooted cuttings of chrysanthemum cv. Bindiya with different doses (0, 10, 20 and 30 Gy) of gamma radiation. They observed the highest plant survival percentage, number of branches, minimum days to bud initiation and early bud opening under 10 Gy treatment, whereas morphological abnormalities like fused leaves with lower chlorophyll level were observed under higher dose (30 Gy) treatment. The original flower colour of cultivar Bindiya is red but the flower color mutants isolated from

plants treated with 10 Gy and 20 Gy gamma rays treatment were of nearest shades of red group 44 C, 46 C and red group 46 B as shown in the RHS Colour Chart.

Patil *et al.* (2017) irradiated the chrysanthemum cv. “Local Golden” with different doses (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 krad) of gamma radiation and observed reduction plant survival percentage, plant height, number of branches plant^{-1}, number of suckers plant^{-1} with an increase in the gamma rays dose. However, the LD_{50} is found in the range of 2.5 and 3.0 krad and after treatment with 1.5 krad, a chimera in the ray florets of the flower was found in one plant.

Singh *et al.* (2019) estimated the efficacy of various doses (0, 10, 20 or 30 Gy) of gamma rays to induce novel mutations in chrysanthemum cv. “Gul-e-Sahir” by using terminal rooted cuttings. They observed marked variations in colour of leaf, shape of leaf, flower diameter, shape and colour between the mutated and control populations, whereas four new flower colour variants with altered or novel flower colours were isolated that were distinctive and distict from the original colour of flower. The ray florets were normal in control while spoon-shaped, narrow, broad, flat and tubular in shape in mutated population.

Gerbera

Laneri *et al.* (1990) irradiated the shoots of *in vitro*-raised plantlets of gerbera pink cv. ‘Rebecca’ with treatment of 20 Gy gamma radiation and then micro propagated for 2 cycles. It was revealed that the irradiated treatment induced a 25% reduction in the propagation rate in each cycle.

Jerzy and Lubomski (1992) treated the leaf explants of sixteen cultivars of *Gerbera jamesonii* with different doses (5-25 Gy) of gamma radiations and cultured on MS medium. The formation of shoots (frequency and intensity) was based on the irradiation dose and on the cultivar. The 20 and 25 Gy doses significantly reduced the regeneration potential of leaf explants, but even the 25 Gy doses did not fully reduce the development of adventitious shoots.

Jain *et al.* (1998) reported that the treatment of two gerbera cultivars with gamma irradiation (10 and 20 Gy doses) produced mutants with showing flower colour, flower morphology and plant morphology traits with an average of 8.6%.

Gladiolus

Dobanda (2004) reported that the length of gladiolus phenological phases increased, which was directly proportional to the radiation doses applied. When exposed to excess radiation dose of 50 Gy, gladiolus regenerates and showed degradation of characters such as plant height, length of flower-bearing stem, total number of flower bud, number of flowers opened simultaneously, diameter of perianth, number, weight and viability of corms. Exposure of plants to gamma radiation causes major modifications in the plant genome that tend to regenerate a high polymorphism of the DNA fragment for fragment size, density, presence or absence.

Srivastava *et al.* (2007) confirmed that the gamma irradiation treatments adversely affected all the morphological characters of gladiolus cvs. (Sylvia and Eurovision). The result revealed that plants treated with 20 Gy recorded significantly maximum plant height, number of leaves, leaf length and breadth, length of spike, rachis length, number of florets spike^{-1} and floret diameter whereas, days for corm sprout and days for flowering was significantly reduced over the control. However, all the characteristics were adversely affected as the doses increased and the dose 80 Gy proved lethal and cultivar Eurovision was more resistant to irradiation treatment and reacted positively to mutagenic treatments at lower doses than cv. Sylvia.

Patil (2009) irradiated the corms of different gladiolus cvs. (American Beauty, Nova Lux and Eurovision) with 7 doses of gamma rays (0, 1, 2, 3, 4, 5, 6 and 7 Krad) and observed that the lower doses (up to 3 Krad) were comparatively better than higher doses (4 Krad and 7 Krad) and both sprouting and survival were decreased. With an increase in doses, the average time taken for sprouting has improved. For both sprouting and survival, the LD_{50} dose was found to be

approximately greater than 7 Krad. In certain cases, the floral characteristics were diminished and retarded at and above 4 Krad treatments.

Karki and Srivastava (2010) studied the impact of gamma irradiation on various growth and flowering attributes on 20 varieties of gladiolus. They found that lower doses (0.5 and 1.5 Krad) were successful in improving some essential vegetative and floral parameters. From this experiment four mutants were obtained.

Tiwari *et al.* (2010) treated the corms of different gladiolus cvs. Nova lux, Peter Pears, Advance Red and White Prosperity with 5, 10 and 15 Krad of gamma radiations. They noted a result of significant increase in plant height and length of spikes at 5 Krad treatment whereas, stunted growth of the plant and spike length reduction was observed under 10 Krad dose of gamma rays. However, the number of spikes plant^{-1} and number of florets spike^{-1} increased at 5 Krad while it showed a negative effect at higher doses.

Singh and Kumar (2013) conducted an experiment by treating different gladiolus varieties (Hermajesty, Gunjan, Gulal, Jessica, J.V. Gold, Jyotsana, Picotee, Rose Supreme, Shabnam and Urmil) with different doses of gamma radiations. They recorded earliest sprouting of 50 percent corms in cultivar Jyotsana treated with 2 Krad gamma rays whereas, the interaction of variety Jyotsana with 1 Krad gamma rays recorded best results. However, late sprouting and maximum plant height were recorded at Gunjan treated with 7 Krad gamma rays and a maximum number of leaves were observed in interaction of J.V.Gold and 2 Krad.

Shukla *et al.* (2018) investigated the effect of gamma radiations on flowering and vase attributes associated with mutation and purification of novel types in gladiolus. They treated corms with different doses of (15, 30, 45 and 60 Gy) gamma rays and revealed that the low doses of gamma irradiation resulted in hormesis and induced promoting vase life and novelties in flowering, whereas the higher doses induced a higher degree of abnormalities which led to mortality and blindness. Six variants were also obtained exhibiting variation in spike length in

Candyman treated with 15 Gy, spike duoblness in Candyman treated with 45 Gy and change in floret colour in American Beauty and Her Majesty treated with 30, 45, 60 Gy, respectively.

Devi *et al.* (2019) studied the effect of different two doses of gamma rays (1.5 Krad and 3 Krad) in gladiolus cultivars for inducing phenotypical changes. They observed changes of colour in Praha cultivar from red to light orange at 1.5 Krad and different chimera was found at 1.5 Krad and 3 Krad in Tiger Flame cultivar. Corm sprouted early and numbers of sprouting corm^{-1} increased. Floral characters such as spike emergence, floret spike^{-1}, floret diameter, length of spikes and rachis length were also better in 1.5 Krad and 3 Krad.

Marigold

Singh *et al.* (2009) irradiated the seeds of African marigold cv. 'Pusa Narangi Gainda' with different doses (0, 100, 200, 300 and 400 Gy) of gamma rays to induce mutation. They found a decrease in plant survival percentage, plant height, number of branches plant^{-1}, number of leaves plant^{-1}, leaf size, plant spread, stem girth, increased vegetative and floral abnormalities with the increase in the dose of gamma rays whereas, abnormal leaves and plants percentage was recorded maximum as increased dose of gamma rays. Meanwhile, the days of bud initiation, color appearance and days of full bloom were all significantly delayed while the other flowering characters like flower diameter, height and weight of the flower, number of ray florets and size decreased with increasing doses. As the dose of gamma irradiation increased, floral abnormalities and plants with abnormal flower-heads increased proportionally.

Majumder *et al.* (2018) conducted an experiment to develop mutant populations through gamma irradiation *in vivo* grown seedlings and in vitro raised proliferated cultures of marigold cultivar 'Pusa Narangi Gainda'. The result revealed that v4 exhibited maximum average flower diameter with equivalence to parent. The maximum petal width among the mutants of M_1 was observed in vitro raised mutant v8. Based on the dendrogram generated, Putative mutant 3 exhibits

the highest dissimilarity than the parent, whereas Putative mutants 5 and 6 were found to be similar to each other but were distinct from the parent.

Sarhan *et al.* (2019) studied the impact of different doses of gamma radiations (5, 10 and 15 Krad.) on the vegetative growth and chemical constituents of *Tagetes erecta*. They found that all the gamma irradiation treatment reduced the plant height, seed germination percentage and number of leaves. Length and number of the shoot were decreased by plants treated by 5 Krad. All treatments of gamma irradiation significantly increased earlier flower bud initiation. Plants treated with 5 Krad decreased the number of days required for flower opening. Treated plants with 5 and 10 Krad exhibited increased diameter of flower, number of flower plant^{-1}, fresh and dry mass plant, leaf area, contents of chlorophylls a and b and carotenoids (mg g^{-1} F.W) in the leaves and total carbohydrates (D. W%).

Bougainvillea

Sharma *et al.* (2002) isolated bract color mutant 'Palekar' from bougainvillea plants by gamma radiation, which is the first known mutant for this trait.

Swaroop *et al.* (2015) irradiated the bougainvillea cultivar Mahatma Gandhi with different doses (0, 500, 1000, 1500 and 2000 rads) of gamma radiations. The results indicated a reduction of percentage of sprouting with an increased dose of gamma rays and minimum survival percentage was observed at 2000 rads. However, the other growth characters such as number of branches plant^{-1}, length of sub-branch, number of leaves branch^{-1}, length of leaves, width of leaves, length of petiole, length of internodes, length of flower tube, length of bract, length of thorn and number of thorns branch^{-1} were found statistically significant as compared to control. It was also observed the treatment of 2000 rads of gamma rays produce small plants and has taken more days for sprouting.

Rose

Datta and Chakrabarty (2005) studied the impact of both chemical and physical mutagens in rose and reported that the mutations were mainly in flower

colour and form. More than 30 rose mutant varieties have been produced and commercialized mainly for changed flower colour, higher oil content and better oil quality.

Koh *et al.* (2010) irradiated the rooted cuttings of two roses viz. Spidella and Cabernet with different doses of (30, 50, 70, 90, 110, 130, 150 and 170 Gy) gamma radiation. They observed LD_{50} dose was found beyond 110 Gy for Spidella and 150 Gy for Cabernet respectively, whereas a 50 percent decrease in shoot length was observed under 70-90 Gy dose for Spidella and 110 Gy dose for Cabernet. However, 30-170 Gy irradiated plants of Spindella and Cabernet induced various colours of solid, chimeric and mosaic petal mutants. The mutants obtained from Spidella had white, ivory, pink ivory, light pink and deep pink petal colours, whereas mutants of Cabernet had pink, deep pink, magenta, orange-red and purple petal colours.

Tuberose

Krasaechai (1992) irradiated the bulbs of *Polianthes tuberosa* with various doses (0, 5, 10, 15, 20, 25 and 30 Gy) of gamma rays and obtained that the doses of 10 Gy or above reduced growth rate and bulb survival percentage was effectively zero after 15-20 weeks after treatment with 25 or 30 Gy treatment. All irradiated plants had leaf chimeras but no flower colour mutations were found.

Ali (2002) investigated the impact of gamma irradiation on vegetative characters of tuberose and concluded that, lower doses of gamma rays gave a better result in growth characteristics such as percentage of sprouting, plant height and number of leaves $plant^{-1}$ as compared to higher radiation doses.

Anu *et al.* (2003) reported that plants of tuberose cultivars (Single, Double, Shringar and Suvasini) irradiated with 5.0 Gy gave a stimulatory effect on bulb characters, while combination effect was evident in all the bulb characters.

Mubarok *et al.* (2011) investigated the effect of different doses (0, 25, 50, 75 and 100 Gy) of gamma irradiation on vegetative growth characters of tuberose. The result revealed that the doses of gamma-irradiation more than 25 Gy caused

morphological damage, reduced the plant height to more than 40% and reduced bulb growth to less than 30% than the untreated plants.

Kaintura *et al.* (2016) treated the different cultivars (Kalyani Single, Kalyani Double, Suvasini, and Prajwal) of tuberose (*Polianthes tuberosa* Linn.) with different doses each of gamma rays (5, 15 Gy), X-rays (6, 12 Gy) and EMS (0.1, 0.2%) along with control and evaluated for numerous vegetative and floral characters. The result depicted that the treatment of the mutagens at lower doses had a significant stimulating effect on vegetative characters, percentage of sprouting and days require for sprouting, whereas the parameter pertaining to rate of survival, length of leaf, number of spikes plant^{-1}, florets spike^{-1}, duration of flowering and vase life were observed with a decreasing trend. Higher doses of all mutagens had detrimental effects on the vegetative and floral characters.

2.3 Effect of rooting hormones on the propagation of dahlia

Khan *et al.* (2003) reported that growth parameters viz. plant height and leaf area were significantly maximum in the highest level of gibberellic acid (90 ppm) on dahlia.

Pudelska *et al.* (2015) investigated the effectiveness of propagation of dahlia by using different types of stem cuttings. On an average 52–66 cuttings 'with heel' were excised from a single crown. Apart from this type of cuttings, the apical cuttings and leaf-bud two-nodes cuttings were also used, which allowed increasing the number of cuttings by an average of 40%, in comparison to the ones with a heel. Apical cuttings and two-node ones formed roots just as well (80–98%, depending on the cultivar) as those 'with heel' (96–99%). They were characterized with a lower fresh weight and smaller rooting system in comparison to heel cuttings but never the less they made a good quality plant material for further cultivation.

Hetman *et al.* (2017) studied the different types of cutting of *Dahlia pinnata* cvs. (Berliner Kleene, Gea, Orange and Orietta). Different types of cuttings were used and all of them were rooted very well. The results revealed that the types of cuttings were non-significant on rooting percentage. However, the

intensity of taking the roots depended on the cutting method. The growth started at the earliest in the case heel and tip cuttings. Plants formed from these types of cuttings are also characterized by the highest weight of the underground part.

Khuriwal *et al.* (2018) studied the effect of different plant growth regulators on plant growth, flower yield and quality of dahlia cultivar. They revealed that combination of different hormone sources of plant growth regulators significantly affected the growth parameters of dahlia such as plant height, plant spread, number of leaves plant^{-1}, days of first bud initiation, flower diameter, number of flower plant^{-1}, flower weight, flower yield ha^{-1}, average tuber weight, average yield of tuber. The flower yield attributes of dahlia were also influenced significantly by a combination of different plant growth regulators. The maximum value of the yield and yield attributes parameters viz. maximum number of flower plant^{-1}, flower yield ha^{-1}, number of flower plant^{-1} were found to be higher under the treatment T6 (GA_3 @ 200 ppm).

2.4 Effect of rooting hormones on the propagation of other ornamental crops

Kumar *et al.* (2019) reported that the application of auxin-based, commercially available rooting hormones contributes a significant role in the process of regeneration of roots from cuttings and their survival. Plant growth regulators like auxins play an important role in the improvement of rooting of cuttings.

Bougainvillea

Shepherd and Winston (2000) tested different concentrations of IBA (0, 125, 250, 500 and 1000 ppm) on three types of cuttings (softwood, semi-hardwood and hardwood) of bougainvillea cv. Thimma. They found that cuttings treated with IBA @ 125 ppm gave maximum rooting percentage, highest number of roots cutting^{-1}, longest roots, highest number of leaves and maximum survival percentage followed by treatment of 250 ppm and 500 ppm concentrations. Among the different types of cuttings, the softwood cutting treated with 125 ppm recorded highest number of roots, longest roots and highest number of leaves cutting^{-1}.

Singh (2012) investigated the impact of different concentrations of IBA (0, 1000, 1500 and 2000 ppm) on rooting potential in hardwood cuttings of bougainvillea cvs. (Louise Wathen, Thimma, Mrs. Butt and Shubhra). Results indicated that the IBA concentration and variety both had a significant effect on sprouting, rooting, callusing and establishment of cuttings, whereas cuttings of Louise Wathen's treated with IBA @1000 ppm gave superior response with 85.39% sprouting, 75.46% rooting, 80.78% callusing and 100% establishment.

Okunlola *et al*. (2016) worked on the stimulation of rooting of six *Bougainvillea species* using three different rooting hormones. The results showed that the root initiation in Bougainvillea cuttings could be enhanced when it is soaked with the IBA or coconut water for 5-10 minutes and the growth is also enhanced by propagation with the hardwood cutting.

Carnation

Bharathy *et al.* (2004) studied the effects of types of cutting, growth regulators and season on carnation cuttings. The results revealed that cuttings treated with NAA @ 500 ppm gave superior result in most of the rooting parameters such as earliness in rooting, rooting percentage, number of roots, root length and weight followed by treatment of IAA + IBA + NAA @ 500 ppm each and IAA 500 ppm alone.

Khewale *et al.* (2005) studied the influence of various concentrations of IBA (125 and 150 ppm) and growing media (sand and cocopeat) on root parameters in the propagation of carnation cv. Gaudina. The treatment of cocopeat + IBA @ 125 ppm was found to be the best combination. The application of IBA @ 125 ppm produced profound rooting and enhanced the root parameters like early rooting, rooting percentage, root length, total number of roots, number of secondary roots and tertiary roots and root volume.

Singh *et al.* (2006) reported that the treatment of carnation cultivar 'White Candy' with NAA @ 500 ppm + IBA @ 250 ppm produced the best results in days taken for rooting (32), root length (4.25 cm) and rooting percentage (72%).

Kothakapu and Sekhar (2014) studied the effect of plant growth regulators (NAA and IBA) at different concentrations and combinations on rooting of carnation (*Dianthus caryophyllus* L.) cuttings, done under polyhouse conditions. Among the plant growth regulator treatment with IBA @ 200 ppm recorded less number of days for formation of root initiation, highest rooting percentage, maximum number of roots, cumulative length of roots cutting^{-1} and highest establishment percentage of rooted cuttings followed by the treatment IBA @ 100 ppm + NAA @ 50 ppm. IBA treatments recorded superior rooting parameters over NAA treatments at that concentration and with an increase in the concentration of IBA and NAA recorded an increase in the rooting parameters.

Kumar *et al.* (2014) investigated the effect of various auxins (IBA, IAA and NAA) on different types of cuttings of carnation (*Dianthus caryophyllus* L.) to determine the efficacy of auxins in promoting rooting. The result revealed that the treatment of NAA encourage the early rooting, induce profuse rooting, root number, fresh and dry weight of roots and longer roots. Among the auxins used, NAA @ 500 ppm gave earliest rooting, highest rooting percentage, number of roots, root length and highest fresh and dry weight of roots. As respect to the interactions, tip cuttings treated with NAA @ 500 ppm recorded highest rooting percentage, number of roots, longest roots and highest fresh and dry weight of roots.

Renuka *et al.* (2015) studied the effect of different levels of IBA, NAA and their combinations on different cultivars of carnation. Among the plant growth regulators studied IBA @ 200 ppm recorded minimum number of days for root initiation, maximum number of roots cutting^{-1}, higher root length and maximum fresh weight of roots. Among the NAA treatments NAA @ 200 ppm recorded maximum root length and maximum fresh weight of roots. Among the combination treatments IBA @ 100 ppm + NAA @ 50 ppm recorded maximum rooting percentage. Among the cultivars studied Baltico recorded the maximum percentage of rooting and fresh weight of roots. Baltico treated with IBA @ 200 ppm recorded significantly superior rooting parameters.

Gowda *et al.* (2017) conducted an experiment to see the effect of IBA on twelve genotypes of carnation (*Dianthus caryophyllus* L.). Results revealed that genotype Dark Dona had highest rooting percentage, whereas, genotype Dark Dona took the minimum days for root initiation. However, the highest number of roots cutting^{-1}, highest fresh and dry weight of roots were recorded in the genotype Bizet.

Prince *et al.* (2017) noted that the cuttings of carnation (*Dianthus caryophyllus* L.) genotype Guadina treated with IBA @ 500 ppm gave the highest rooting percentage (91.33 %) and a similar tendency of superiority was observed for days for root initiation, number of roots cutting^{-1} and length of roots.

Malik *et al.* (2018) investigated the effect of different plant growth regulators (IAA, IBA and NAA) on various types of cuttings of carnation (*Dianthus caryophyllus* L.) to promoting rooting. The results revealed that the cuttings treated with NAA @ 500 mg lit^{-1} recorded earliest rooting, maximum number of roots, higher root length and highest fresh and dry weight of roots whereas, treatment of IAA @ 500 mg lit^{-1} gave highest rooting percentage. Interaction effect of auxin and the cutting type was also found to be significant and maximum number of roots, longest roots and highest fresh and dry weight of roots were observed in interaction of terminal cuttings and NAA @ 500 mg lit^{-1} but rooting percentage was found maximum under in terminal cuttings treated with IAA @ 500 mg lit^{-1}.

Nogueira *et al*. (2018) reported that carnation treated with IBA @ 3000 mg kg^{-1} provided 90% of rooting in the winter and 100% in the summer. However, treatment of IBA @ 2000 mg kg^{-1} gave a better quality of root system in the summer but in winter treatment with 2000 and 3000 mg kg^{-1} provided best result. Whereas, cuttings treated with IBA diluted in 50% alcohol and oven-dried at 30˚C exhibited a higher number of roots, root lengths and vigor.

Chrysanthemum

Grewal *et al.* (2005) indicated that cuttings of *D. grandiflora* (*Chrysanthemum morifolium*) 'Snowball' treated with IBA @ 400 ppm performed well with respect to the percentage of rooting.

Gautam *et al.* (2006) observed the effect of plant growth regulators viz., GA3 (50, 100, 150 and 200 ppm), NAA (50, 100, 150 and 200 ppm), B-nine (1000, 1500, 2000 and 2500 ppm) and Ethrel (50, 1000, 1250 and 1500 ppm) on the growth and development of chrysanthemum cv. 'Nilima'. The results indicated that all concentrations of GA3 and NAA @ 100 ppm increased the plant height, internal length and basal diameter. However, the number of branches and basal diameter were positively influenced by all treatments, whereas concentrations of both GA3 and NAA influenced plant spread.

Ganjure *et al.* (2012) observed that the treatment application of IBA @ 1000 ppm in chrysanthemum cv. 'Piwali Rewadi' gave best result in days require for rooting, fresh weight of roots, dry weight of roots, days for sprouting, fresh weight of shoots and dry weight of shoots.

Ranpise *et al.* (2012) reported that the treatment of tip cuttings of chrysanthemum in IBA @ 2000 ppm by quick dip method along with two sprays of IBA @ 10 ppm after 30 and 60 days of planting of cuttings in the main field found significantly superior over the control and other IBA treatments by recording a higher number of primary roots, maximum survival percentage after 30 days of planting, maximum primary and secondary branching, early buttoning, early flowering, days to buttoning to flowering, diameter of flower, weight of flowers and highest marketable flower yield.

Mehrabani *et al.* (2016) revealed that the highest rooting percentage, survival rate, numbers of roots and roots weight for *Chrysanthemum morifolium* (in August and September) was attained with 3000 mg lit^{-1} NAA. The concentration of auxin had a significant impact on number of roots, fresh weight of roots and survival rate of rosemary. Both IBA and NAA 3000 mg lit^{-1} gave positive effects on root fresh weight and survival rate.

Marigold

Bhatt and Chauhan (2012) studied the effect of auxin on rooting of African marigold (*Tegetes erecta* L.) treated with NAA (50, 100, 150 and 200 mg lit^{-1}) and IBA (50, 100, 150 and 200 mg lit^{-1}). Result revealed that the maximum average number of roots $cutting^{-1}$ after 20 and 30 days was 40.53 and 58.79, respectively under the treatments at IBA + NAA 150 mg lit^{-1} whereas, the average length of stem $cutting^{-1}$ was maximum (6.1 and 15.33 cm) under IBA + NAA 150 mg lit^{-1} after 20 and 30 days, respectively. However, the average length of root $cutting^{-1}$ was noted maximum (4.6 cm) under NAA 200 mg lit^{-1} after 20 days and (5.51 cm) under IBA + NAA 150 mg lit^{-1} after 30 days.

Ullah *et al.* (2013) conducted an experiment to optimize the IBA and NAA needed for the regeneration of Marigold. The result revealed that maximum branches $plant^{-1}$, maximum effect on roots $plant^{-1}$ were observed at IBA @ 400 ppm, whereas treatment with IBA @ 100 ppm recorded maximum flower size, maximum leaves $plant^{-1}$, maximum plant height and maximum value while increasing the IBA concentration decreases the root size. However, maximum leaf size showed in plants treated with IBA @ 200 and 400 ppm IBA. Maximum branches $plant^{-1}$ was recorded at NAA @ 400 ppm. Increased leaves $plant^{-1}$ was noted with an increase in NAA concentration. Maximum plant height was recorded at NAA @ 100 and 200 ppm. Dipping the seedling in a higher concentration of NAA showed the maximum roots $plant^{-1}$ and root size.

Watane *et al.* (2018) studied the effect of IBA and rooting media on rooting of cutting in African marigold cv. 'African Double Orange'. Results revealed that IBA @ 100 ppm recorded significantly early sprouting of cuttings, maximum number of leaves, fresh and dry weight of shoot, final success percentage of rooted cuttings, length of roots and number of roots.

Rose

Akhtar *et al.* (2002) studied the effect of two growth hormones NAA and IBA (500 ppm and 1000 ppm) on cuttings of two rose species i.e. *Rosa centifolia*

and *Rosa damascena* by quick dip method. The results showed substantial dominance of 1000 ppm over the rest of the treatments in both growth hormones. As compared to *Rosa damascena*, *Rosa centifolia* developed more roots and IBA gives significantly better roots compared to NAA.

Kazankaya *et. al* (2005) investigated the rooting capacity of some genotypes of *Rosa canina* L. by rooting in perlite medium using IBA (0, 1000, 2500, 5000 or 10000 ppm). The cuttings treated with IBA @ 2500 ppm recorded highest rooting (65-70%), whereas, IBA @ 1000 ppm showed lowest rooting percentage (2.5%). The internal IBA levels of November-cuttings treated with IBA @ 2500 ppm were determined by high-performance liquid chromatography (HPLC) after rooting, reaching a maximum of 1.525 µg g^{-1} at 30 days after rooting.

Haider *et al.* (2006) assessed the effect of growth hormones, Indole butyric acid (IBA) and Seradix-A on rooting of rose varieties, *Rosa damascena* and *R. centifolia*. It was found that both varieties behaved differently in different seasons. *Rosa centifolia* produced maximum shoot length and number of roots in spring, whereas *R. damascena* produced maximum shoot length in autumn and a maximum number of roots in spring when treated with Seradix-A. These results envisaged that the autumn season is the best for planting *R. damascena* and spring for *R. centifolia*. Seradix-A produced better results as compared to IBA.

Susaj *et al.* (2012) reported that the treatment of rose cuttings with 500 and 1000 ppm of NAA and IBA provided significantly higher values of recorded characteristics. IBA @ 500 ppm recorded maximal survival percentage, strongest roots and healthier seedlings whereas, maximum number of roots and longest roots were recorded under IBA @ 1000 ppm. The use of rooting hormones had positively affected sprout length. The longest sprouts were developed at IBA @ 500 ppm. The increase in the concentration of NAA and IBA from 500 ppm up to 1000 ppm resulted shorter shoots. The treatment of IBA @ 500 ppm seems to be the most feasible approach in terms of the production of seedlings and natural preservation.

Dawa *et al*. (2017) evaluated the effects of two growth regulators IBA and NAA on the rooting of three rootstocks of rose (*Rosa indica*, *Rosa banksiae* and *Rosa bourboniana*). They recorded that the treatment of IBA @ 1000 ppm gave early root initiation, maximum rooting, higher root length and more field survival. As respect to genotypes, *Rosa indica* performed better with recording maximum rooting, primary root number, root length, new leaf growth on cuttings and field survival, whereas NAA produced superior results in *Rosa indica*. However, IBA gave promising results in *Rosa banksiae* and *Rosa bourboniana*.

Tawfik *et al.* (2018) conducted an experiment on the conventional propagation of *Rosa hybrida* cv. 'Eiffel Tower' with the application of different concentrations of IBA (0, 500, 1000 and 1500 ppm) for two successive years. Results of investigation showed that the application of IBA significantly improved percentage of rooting, number of roots and root length of the treated cuttings comparing to the untreated ones.

CHAPTER- III
MATERIALS AND METHODS

The present investigation entitled **"Gamma rays induced mutagenesis in Dahlia (*Dahlia variabilis* L.) and propagation of mutants obtained through stem cuttings."** was carried out during the winter season of 2018-19 and 2019-20 at the Horticultural Research cum Instructional Farm, Department of Floriculture and Landscape Architecture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The materials used and the methods adopted to record the observations during this investigation are detailed in this chapter.

3.1 Experimental site

The experiment was conducted at the Horticultural Research cum Instructional Farm, Department of Floriculture and Landscape Architecture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during the winter season of 2018-19 and 2019-20.

3.2 Geographical situation and weather conditions of experimental site

Indira Gandhi Krishi Vishwa Vidyalaya, Raipur, is situated in the central part of Chhattisgarh at $21^0$16' North latitude and $81^0$36' East longitude at an altitude of 289.56 m above mean sea level. The region has a dry, sub-humid climate, coming under the seventh agro-climatic zone of the country, *i.e.* eastern plateau and hills. The average maximum and minimum temperatures are 42.8^0C and 10.1^0C in May and December, respectively. The summer is hot and dry, winters are cool and the rainy season receives average rainfall is 1200-1400 mm, out of which about 85 percent is received from the third week of June to the middle of September and scanty rain fall during October to February. Atmospheric humidity varied between 70 to 90 percent from mid-June to March and it drops up to 3 to 4 percent during summer season. Wind velocity is high from May to August

with its peak in June- July months. The weekly average of various weather parameters that prevailed during the investigation was recorded at Meteorological Observatory, IGKV, Raipur are presented in Appendix I and II for the year 2018-19 and 2019-20.

3.3 Experimental details

EXPERIMENT I - Gamma rays induced mutagenesis in dahlia

a) Layout of the experiment

Crop	:	Dahlia (*Dahlia variabilis* L.)
Place of experiment	:	Horticultural Research cum Instructional Farm, IGKV, Raipur
Growing condition	:	Open field
Planting material	:	Rooted cutting
Number of cultivars	:	03
Irradiation doses	:	04
Number of replications	:	04
Treatment combinations	:	12
Number of plants per treatment combination	:	10
Number of generations	:	1 (vM_1)
Mutagen used	:	Gamma rays

Table 3.1: Treatment details of experiment- I

S. No.	Factor: A (Cultivar)	S. No.	Factor: B (Radiation dose)
1.	C_1 - Kenya Blue	1.	I_0 - Control
2.	C_2 - Kenya Yellow	2.	I_1 - 10 Gy
3.	C_3 - Kenya Original	3.	I_2 - 15 Gy
		4.	I_3 -20 Gy

Kenya Blue

Kenya Yellow

Kenya Original

Plate 3.1: Dahlia cultivars used for the experiment

Table 3.2: Treatment combinations (experiment-1)

Treatment	Name of Cultivars	Dose of gamma irradiation
T_1 (C_1I_0)	Kenya Blue	0 Gy (Control)
T_2 (C_1I_1)	Kenya Blue	10 Gy
T_3 (C_1I_2)	Kenya Blue	15 Gy
T_4 (C_1I_3)	Kenya Blue	20 Gy
T_5 (C_2I_0)	Kenya Yellow	0 Gy (Control)
T_6 (C_2I_1)	Kenya Yellow	10 Gy
T_7 (C_2I_2)	Kenya Yellow	15 Gy
T_8 (C_2I_3)	Kenya Yellow	20 Gy
T_9 (C_3I_0)	Kenya Original	0 Gy (Control)
T_{10} (C_3I_1)	Kenya Original	10 Gy
T_{11} (C_3I_2)	Kenya Original	15 Gy
T_{12} (C_3I_3)	Kenya Original	20 Gy

b) Design

The experiment was carried out in a Factorial Complete Randomized Design (FCRD) with four replications under open field conditions.

c) Planting Materials

Rooted cuttings of three cultivars viz. Kenya Blue, Kenya Yellow and Kenya Original were taken as planting materials for the present investigation. These cultivars have different colours and genetic makeup, commonly dahlia is propagated by its tuberous root. The healthy rooted cuttings of 8-10 cm size of cultivars were selected for mutagenic treatment under present investigation.

d) Source of planting material

Rooted cuttings of dahlia cultivars viz. Kenya Blue, Kenya yellow, and Kenya original were procured from Horticultural Farm Nursery, Bidhan Chandra

Plate 3.2: A general view of experimental site during 2018-19

Krishi Vishwavidyalaya (BCKV) Mohanpur, Kalyani, Nadia (WB), for this investigation and experiment.

Table 3.3: Details of dahlia cultivars used as planting material in the experiment

S. No.	Notation	Name of cultivar	Colour	R.H.S. Colour Chart Reading
1.	C_1	Kenya Blue	Strong purplish pink	Red Purple Group 68B
2.	C_2	Kenya Yellow	Brilliant greenish yellow	Yellow Group 3A
3.	C_3	Kenya Original	Light yellowish pink	Red Group 36B

e) Treatment with gamma rays

The rooted cuttings of dahlia were irradiated with Gamma Cell 200 (Cobalt-60 source emitting 3600 rads per minute) at the Regional Nuclear Agriculture Research Center under the BARC's Nuclear Intervened Agriculture project, Bidhan Chandra Krishi Vishwavidyalaya (BCKV) Mohanpur, Nadia (WB) on 3rd December 2018. 40 rooted cuttings of equal plant heights of each of the varieties in each treatment were irradiated with 0, 10, 15, and 20 Gy doses.

Table 3.4: Details of gamma rays treatment doses and treatment time

S. No.	Notation	Dose of gamma rays (Gy)	Duration of exposure (min.)
1.	I_0	0.00	0.00
2.	I_1	10.0	1.26
3.	I_2	15.0	2.09
4.	I_3	20.0	2.52

f) Preparation of potting media

The media for raising dahlia seedlings were prepared one and half months before filling of pots. Media was prepared by mixing of following components:

a) Sandy loam soil - 50%
b) FYM - 45%
c) Vermiculite - 3%
d) Neem cake - 2%

g) Filling of pots and transplanting of seedlings

The eight-inch earthen pots used for raising dahlia seedlings were filled in the usual manner by potting mixture. The pots were watered for allowing the soil mix to settle before transplanting. The treated as well as untreated (control) rooted cuttings were planted in the pots on 4th December 2018 for the comparison in vM_1 generation.

EXPERIMENT II – Effect of rooting hormones on the propagation of dahlia mutants through stem cuttings

a) Layout of experiment

Planting material	:	Terminal shoot cuttings from mutants
Number of cultivars	:	Cultivars in which desirable mutants screened*
Treatment dose	:	10
Number of replications	:	3
Design of experiment	:	Factorial Completely randomized design (FCRD)

* Desirable mutants

b) Source of cutting and their preparation

Tubers from vM_1 generation were planted in mother block and after sprouting of these tubers were used for test crop which are propagated through stem cuttings. The apical portion of the cutting with a length of 8 cm and 3-4 leaves were used.

Table 3.5: Treatment details of experiment-II

Factor-I	**Cultivars**	
	Cultivars in which desirable mutants obtained after screening that is 1. C_1: Kenya Blue 2. C_2: Kenya Yellow	
Factor –II	**Concentration of rooting hormones (ppm)**	**Notation**
	IBA @ 250	H1
	IBA @ 500	H2
	IBA @ 1000	H3
	NAA @ 250	H4
	NAA @ 500	H5
	NAA @ 1000	H6
	IBA @ 125 ppm + NAA @ 125 ppm	H7
	IBA @ 250 ppm + NAA @ 250 ppm	H8
	IBA @ 500 ppm + NAA @ 500 ppm	H9
	Control (No Hormones)	H0

Table 3.6: Treatment combinations (experiment-II)

Treatments	**Treatment Combinations**
T_1 (C_1H_0)	Kenya Blue × No Hormone
T_2 (C_1H_1)	Kenya Blue × IBA @ 250 ppm
T_3 (C_1H_2)	Kenya Blue × IBA @ 500 ppm
T_4 (C_1H_3)	Kenya Blue × IBA @ 1000 ppm
T_5 (C_1H_4)	Kenya Blue × NAA @ 250 ppm
T_6 (C_1H_5)	Kenya Blue × NAA @ 500 ppm
T_7 (C_1H_6)	Kenya Blue × NAA @ 1000 ppm
T_8 (C_1H_7)	Kenya Blue × IBA @ 125 ppm + NAA @ 125 ppm
T_9 (C_1H_8)	Kenya Blue × IBA @ 250 ppm + NAA @ 250 ppm
T_{10} (C_1H_9)	Kenya Blue × IBA @ 500 ppm + NAA @ 500 ppm
T_{11} (C_2H_0)	Kenya Yellow × No Hormone
T_{12} (C_2H_1)	Kenya Yellow × IBA @ 250 ppm
T_{13} (C_2H_2)	Kenya Yellow × IBA @ 500 ppm
T_{14} (C_2H_3)	Kenya Yellow × IBA @ 1000 ppm
T_{15} (C_2H_4)	Kenya Yellow × NAA @ 250 ppm
T_{16} (C_2H_5)	Kenya Yellow × NAA @ 500 ppm
T_{17} (C_2H_6)	Kenya Yellow × NAA @ 1000 ppm
T_{18} (C_2H_7)	Kenya Yellow × IBA @ 125 ppm + NAA @ 125 ppm
T_{19} (C_2H_8)	Kenya Yellow × IBA @ 250 ppm + NAA @ 250 ppm
T_{20} (C_2H_9)	Kenya Yellow × IBA @ 500 ppm + NAA @ 500 ppm

c) Preparation of stock solution

The stock solution of NAA and IBA was prepared for 500 ppm in 1 liter of distilled water. 500 mg of NAA and IBA were dissolved in 0.1 N NaOH solution and volume makeup was up to 1 liter. The solution of required concentration and combination as per treatment was later made by diluting the stock solution with distilled water. The makeup volume was maintained to 200 ml. The stock solution used to prepare different concentrations of NAA and IBA is given in the table 3.7.

Table 3.7: Amount of stock solution taken to prepare the solution of required concentration

Concentration of auxin required	**Amount of stock solution taken and made up to 200 ml volume**
IBA 250 ppm	50 mg IBA
IBA 500 ppm	100 mg IBA
IBA 1000 ppm	200 mg IBA
NAA 250 ppm	50 mg NAA
NAA 500 ppm	100 mg NAA
NAA 1000 ppm	200 mg NAA
IBA 125 ppm + NAA 125 ppm	25 mg IBA + 25 mg NAA
IBA 250 ppm + NAA 250 ppm	50 mg IBA + 50 mg NAA
IBA 500 ppm + NAA 500 ppm	100 mg IBA + 100 mg NAA

d) Treatment of cuttings and planting in portrays

Basal ends of cuttings are immersed approximately one inch into a solution for a few seconds and planted in portrays having 9×11 cells. Cells of portray were filled well with an equal amount of cocopeat, sand, and vermiculite. Single cutting was planted in a single cell of portray. Portrays were kept under the poly-house for better rooting.

e) After care

Planted cutting was sprayed with Bavistin 0.2% to prevent the occurrence of fungal diseases. Regular irrigation was given to the cuttings with the help of

hazara (rose can) at the interval of 2-3 days. The rooted cuttings were transplanted 25 days after the planting of cuttings in grow bags (16×14 cm) in the open field.

3.4 Cultural operations

a) Irrigation and weeding

Standard cultural practices like weeding, hoeing, and irrigation were followed regularly. Irrigation was stopped twenty days before lifting the tubers.

b) Fertilizer application

Water-soluble fertilizers (nitrogen 4.5 g l^{-1}, P_2O_5 6 g l^{-1} and K_2O 1.5 g l^{-1}) were applied manually at fortnightly intervals starting from one month after transplanting.

c) Staking

Staking was done with bamboo sticks and tied with rope to avoid lodging of plants at bud stage.

d) Plant protection measures

Regular plant protection operation was carried out to keep the plants free from pest and disease. Botrytis blight, thrips and red spider mite were noticed during growing period. Thrips and spider mites were controlled by spraying Chlorpyrifos @ 0.5 ml per liter of water and imidaclopride @ 1.2 ml per liter of water. To protect the crop from botrytis blight saff @ 2.5 g per liter of water were sprayed.

e) Harvesting of flowers

Dahlia were harvested in full bloom stage.

f) Harvesting and cleaning of tubers

Tubers of dahlia were raised after flowering when the plants are almost dried and the colour of the stem turns yellow, at this stage the plants were cut

Plate 3.3: A view of seedling preparation

Plate 3.4: A view of experimental site during 2019-20

leaving only 15 cm stem from the ground. The tuberous roots were taken out with a forked hoe and is allowed to dry for 3 to 4 days in a shady place. Tubers roots are collected in plastic trays after removing the adhering soil and kept in a cool and dry place.

g) Storage of tubers

Tubers of each treatment were packed in plastic trays separately and labeled properly to avoid mixing. These tubers were stored in a cold store for three months (May-August). Before the storage of tubers in the cold store, they were treated with 0.2% carbendazim to avoid the chance of fusarium. These tubers were planted in mother block and subsequent of these tubers used for the preparation of next season cuttings were again planted in the next year (2019-20) as a second experiment.

3.5 Observations recorded

Observations on rooting, vegetative, floral, tuber, physiological and mutational characters were recorded based on five randomly selected plants per replication in each treatment. The observations which were recorded in percent or frequency were calculated based on the total number of plants scored. Experiment wise observations were recorded is as follow.

3.5.1 Experiment – I: List of observations

Table 3.8: Observation on mutational, vegetative, floral, tuber and physiological character with the screening of mutant population (vM_1) understudy in Experiment-I

(I)	**Mutational Characters**
	a) Mortality percentage
	b) Survival percentage
	c) Abnormal plant percentage
	d) LD_{50} dosage
	e) Mutations spectrum ,colour and frequency in vM_1 generation

(II)	**Vegetative characters** a) Plant height (30, 60, and 90 DAT) b) Number of leaves plant^{-1} (60 and 90 DAT) c) Total number of branches plant^{-1} d) Plant spread (cm)
(III)	**Floral characters** a) Days taken for first bud appearance b) Number of days taken for flower opening c) Number of days taken for full bloom d) Flower diameter (cm) e) Number of ray florets flower^{-1} f) Flower stalk length (cm) g) Flower stalk diameter (cm) h) Longevity of flower (days) i) Number of flowers plant^{-1} j) Flower weight plant^{-1} (g) k) Duration of flowerings (days)
(IV)	**Tuber characters** a) Number of tubers plant^{-1} b) Weight of tubers plant^{-1} (g) c) Diameter of tuber (cm)
(V)	**Physiological characters** Leaf chlorophyll content (mg g^{-1})
(VI)	**Screening of the mutant population and their characterization**

3.5.2 Experiment – II: List of observations

Table 3.9: Observations on rooting, vegetative, floral, tuber and physiological character with the screening of mutant population of vM_2 generation in Experiment-II

(I)	**Rooting characters** a) Days required for root initiation b) Rooting percentage (%) c) Survival percentage (%) d) Number of roots cutting^{-1} e) Root length (cm)
(II)	**Vegetative characters** a) Plant height (30, 60, and 90 DAT) b) Number of leaves plant^{-1} (60 and 90 DAT) c) Total number of branches plant^{-1} d) Plant spread (cm)
(III)	**Floral characters** a) Days taken for first bud appearance b) Number of days taken for flower opening c) Number of days taken for full bloom d) Flower diameter (cm) e) Number of ray florets flower^{-1} f) Flower stalk length (cm) g) Flower stalk diameter (cm) h) Longevity of flower (days) i) Number of flowers plant^{-1} j) Flower weight plant^{-1} (g) k) Duration of flowerings (days)
(IV)	**Tuber characters** a) Number of tubers plant^{-1}

	b) Weight of tubers plant^{-1} (g) c) Diameter of tuber (cm)
(V)	**Physiological characters** Leaf chlorophyll content (mg g^{-1})
(VI)	**Screening of the mutant population and their characterization**

3.5.3 Details of observations

3.5.3.1 Mutational characters

a) Mortality percentage

The number of rooted cuttings in each treatment in vM_1 was counted after 15 days of planting in open field conditions and expressed in percentage.

b) Survival percentage

The number of plants that survived out of the total number of rooted cuttings was counted after 30 days of planting.

c) Abnormal plant percentage

The number of abnormal plants in each treatment was counted at the flowering stage and it was expressed as a percentage of the total number of rooted cuttings planted.

d) LD_{50} dosage

The LD_{50} dose of irradiation was calculated by probit analysis method using observations on mortality percentage as described by Sharma (1998).

e) Mutations spectrum, colour and frequency

The spectrum of floral and morphological mutations was recorded in a generation. Floral mutants were classified as by visual observations under natural light with the help of R.H.S. Colour Chart. Morphological mutants were classified

as dwarfs, mutants with twisted leaves, split leaves, joint leaves, and crinkled leaves.

Frequency of floral and morphological mutations was estimated by the following formula:

$$\text{Mutation frequency (\%)} = \frac{\text{Number of mutants}}{\text{Total number of plants scored}} \text{x } 100$$

3.5.3.2 Rooting characters

a) Days required for root initiation

Rooting of cuttings was recorded at 10 days intervals up to thirty days, as under normal conditions rooting completed after this period. Then the average was calculated.

b) Rooting percentage

This parameter was calculated by the following formula

$$\text{Rooting percentage} = \frac{\text{Number of rooted cuttings}}{\text{Total number of cuttings planted}} \text{x } 100$$

c) Survival percentage

The survival percentages for each treatment were arrived at by counting the number of survived plants after 30 days of planting and values were expressed as a percentage.

$$\text{Survival percentage} = \frac{\text{Number of survived plants}}{\text{Total number of cuttings planted}} \text{x } 100$$

d) Number of roots cutting^{-1}

The number of roots was counted for each treatment from randomly selected five rooted cuttings and the mean was worked out.

Plate 3.4: A view of measurement of plant height (cm) by measuring scale

Plate 3.5: A view of experimental site (at flowering stage) during 2019-20

e) Root length (cm)

Length of roots were measured by meter scale for five randomly selected cuttings of each treatment and the average calculated by dividing the summations by five.

3.5.3.3 Vegetative characters

a) Plant height (cm)

The height of the plants was measured from the soil level in the pots to the base of the apical leaf (height) at 30, 60, and 90 days after planting (DAT) with the help of a meter scale.

b) Number of leaves plant^{-1}

The total number of compound leaves plant^{-1} were counted at 60 and 90 DAT. The mean value of leaves plant^{-1} was taken by adding the total number of leaves and dividing by the number of plants and subjected to statistical analysis.

c) Total number of branches plant^{-1}

The total number of branches plant^{-1} was counted at maturity and recorded.

d) Plant spread (cm)

The plant spread was measured by adding the North-South and East-West directions of tagged plants and the mean of plant spread was worked out at maturity (90 DAP).

3.5.3.4 Floral characters

a) Days taken for first bud appearance

This was recorded by counting the number of days from the date of planting to the stage at which the first flower bud was initiated in each cultivar. This was recorded from the tagged plants and the average was worked out.

b) Number of days taken for flower opening

The number of days taken for floral bud opening from the date of transplanting was recorded.

c) Number of days taken for full bloom

The number of days taken for the complete opening of inflorescence from the date of transplanting was recorded.

d) Flower diameter (cm)

The diameter of the three flowers was measured at the point of maximum breadth at the full bloom stage. This was measured by using Vernier caliper and the average flower diameter was expressed in centimeters.

e) Number of ray florets flower^{-1}

The number of ray florets flower^{-1} head was counted in each plant. The number of ray florets of three fully opened flowers from each cultivar was counted and the average was worked out to get average number of ray florets flower^{-1}.

f) Flower stalk length

The length of the stalk of the flower was taken from the origin of that stalk from the main stem to the neck of the flower and expressed in centimeters.

g) Flower stalk diameter

The diameter of the five flower stalk was measured in the full bloom stage in centimeters with the help of Vernier calipers and the average was worked out.

h) Longevity of flowers (days)

The durability of inflorescence from the day of the opening of flower to fading in the plant was recorded and expressed in days.

i) Number of flowers plant^{-1}

The number of flowers produced in the tagged plants was recorded and the average number of flowers produced plant^{-1} was worked out.

j) Flower weight plant^{-1} (g)

Fresh weight of 3 flowers plant^{-1} (5 plants/treatment) were recorded in grams in the experimental plot with digital balance and then averaged.

k) Duration of flowerings (days)

The number of days taken from the first flowering to the last flowering in a plant was recorded as the total duration of flowering.

3.5.3.5 Tuber characters

a) Number of tubers plant^{-1}

The number of tubers plant^{-1} was manually counted and the average was worked out.

b) Weight of tubers plant^{-1} (g)

The weight of tubers per treatment was found by a digital balance and the average was worked out.

c) Diameter of tuber (cm)

The diameter of tubers per treatment was measured in the time of lifting in centimeters with the help of Vernier calipers and the average was worked out.

3.5.3.6 Physiological characters

Leaf chlorophyll content (mg g^{-1})

Total chlorophyll content of the leaves was determined after 90 days of planting by using SPAD-502 meter and the average was worked out.

3.5.3.7 Screening of the mutant population and their characterization

Screening of mutants has been carried out in vM_1 (2018-19) and vM_2 (2019-20), as it is recorded in the literature (Broertjes and Van Harten, 1988) that possibility of getting solid mutants is more when selection is done in second or further generations.

3.6 Statistical Analysis

The data were statistically analyzed by using Complete Randomized Design (CRD) with two factors following the procedure outlined by **Gomez and Gomez (1984)**. The significance of the difference among treatment means was tested by F-test. Wherever the F-test was found to be significant, the critical difference (C.D.) at 5 percent level of significance was calculated. The results are presented in the form of graphs, tables and photographs at the appropriate places for interpretations of results.

Table 3.10: ANOVA TABLE

Source of Variation	**Degree of**	**Sum of square**	**Mean sum of Square**	**'F' Calculated**	**'F' Tabulated**
A (or main effect of A)	(a-1)	ASS	AMSS = ASS/(a-1)	AMSS/ErMSS	
B (or main effect of B)	(b-1)	BSS	BMSS = BSS/(b-1)	BMSS/ErMSS	
AB (or 2-way interaction)	(a-1)(b-1)	ABSS	ABMSS = ABSS/(a-1)(b-1)	ABMSS/ErMSS	
Error	ab(n-1)	ErSS	ErMSS = ErSS/ab(n-1)		
Total	abn-1	TSS	TMSS = TSS/abn-1		

Where,

ASS = Sum of square for factor A

BSS = Sum of square for factor B

ABSS = Sum of square for interaction of factor A and B

ErSS = Error sum of square

TSS = Total sumo of square

AMSS = Mean sum of square for factor A

BMSS = Mean sum of square for factor B

ABMSS = Mean sum of square for interaction of factor A and B

ErMSS = Mean sum of square for error

In order to compare the mean value of treatment, standard error and critical values were calculated as follows.

a. Standard Error of mean

$$\text{S Em} \pm = \frac{\sqrt{EMS}}{\text{r}}$$

Where,

S Em = Standard error of mean

EMS = Error Mean of square

r = Number of replications

b. Critical Difference

CD = SEd x t Value at 5% at error degree of freedom

$$\text{S Em} \pm = \frac{\sqrt{2EMS}}{\text{r}}$$

Where,

S Ed = Standard error of difference between two treatment means

EMS = Error Mean of square

r = Number of replications

CHAPTER-IV
RESULTS AND DISCUSSION

The results obtained from the present investigation entitled **"Gamma rays induced mutagenesis in Dahlia (*Dahlia variabilis* L.) and propagation of mutants obtained through stem cuttings"** conducted during winter season of 2018-19 and 2019-20 at the Horticultural Research cum Instructional Farm, Department of Floriculture and Landscape Architecture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) are described in this chapter. The Experiment- I entitled **"Gamma rays induced mutagenesis in dahlia"** was conducted during winter season of 2018-19, whereas, Experiment-II entitled **"Effect of rooting hormones in the propagation of dahlia mutants through stem cuttings"** was conducted during winter season of 2019-20. The data recorded on different parameters for both experiments were statistically analyzed and significance of the results was verified. The mutants screened in vM_1 was planted in second experiment (vM_2) through stem cutting with different combinations of rooting hormones. The experimental results obtained in the present investigation have been presented in this chapter, under following heads.

4.1 EXPERIMENT I – Gamma rays induced mutagenesis in dahlia

4.1.1 Effect of gamma radiations on mutational characters

4.1.2 Effect of gamma radiations on vegetative characters

4.1.3 Effect of gamma radiations on floral characters

4.1.4 Effect of gamma radiations on tuber characters

4.1.5 Effect of gamma radiations on physiological characters

4.1.6 Screening of mutants in vM1 population and their characterization

4.1.1 Effect of gamma radiations on mutational characters

Effect of different doses of gamma radiations was studied on mutational characters in three dahlia cultivars and results have been presented in ensuing pages.

4.1.1.1 Mortality percentage

There was a significant difference in the mortality percentage of plant in different cultivars as well as in different gamma radiation doses (Table 4.1 and Fig. 4.1). It is clear from the data that mortality percentage increased as the dose of gamma rays increased, as respect to different gamma radiation doses, significantly higher mortality percentage (38.81%) was recorded at 20 Gy as compared to rest of the treatments, among the cultivars of dahlia, cultivar Kenya Yellow recorded significantly higher mortality percentage (30.80%), whereas, minimum mortality percentage (16.44%) was observed in cultivar Kenya Original.

The interaction effect of gamma rays and cultivars was also found significant on mortality percentage. Interaction between cultivar Kenya Yellow and 20 Gy gamma radiation recorded significantly higher mortality percentage (47.82%) as compared to rest of the interactions.

The percentage of mortality increased in all the cultivars as the dose of gamma rays increased. Pal (2015) observed the maximum mortality percentage in highest dose of gamma radiation and minimum in lowest dose of gamma radiation when he treated the different dahlia cultivars with different doses of gamma rays. The results are in agreement with the work of Tiwari and Kumar (2011), who recorded maximum mortality at higher gamma radiation doses. The death of plants is attributed to the interaction of molecules with other molecules in the cell which produce free radicals of H and OH. The free radicals could combine to form toxic substances such as hydrogen peroxide which contribute to destruction of cells. These results corroborate with the findings of Lamseejan *et al.* (2000) in chrysanthemum and Devi *et al.* (2019) in gladiolus.

Table 4.1: Effect of gamma radiations on mortality percentage in dahlia cultivars

Radiation dose / Cultivar	Mortality percentage				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	0.00	15.34	22.28	38.86	19.12
Kenya Yellow	0.00	31.62	43.75	47.82	30.80
Kenya Original	0.00	11.70	24.30	29.75	16.44
Mean	0.00	19.55	30.11	38.81	
	CD at 5%			**S.Em±**	
Radiation Dose	0.53			0.18	
Cultivar	0.46			0.16	
R×C	0.93			0.32	

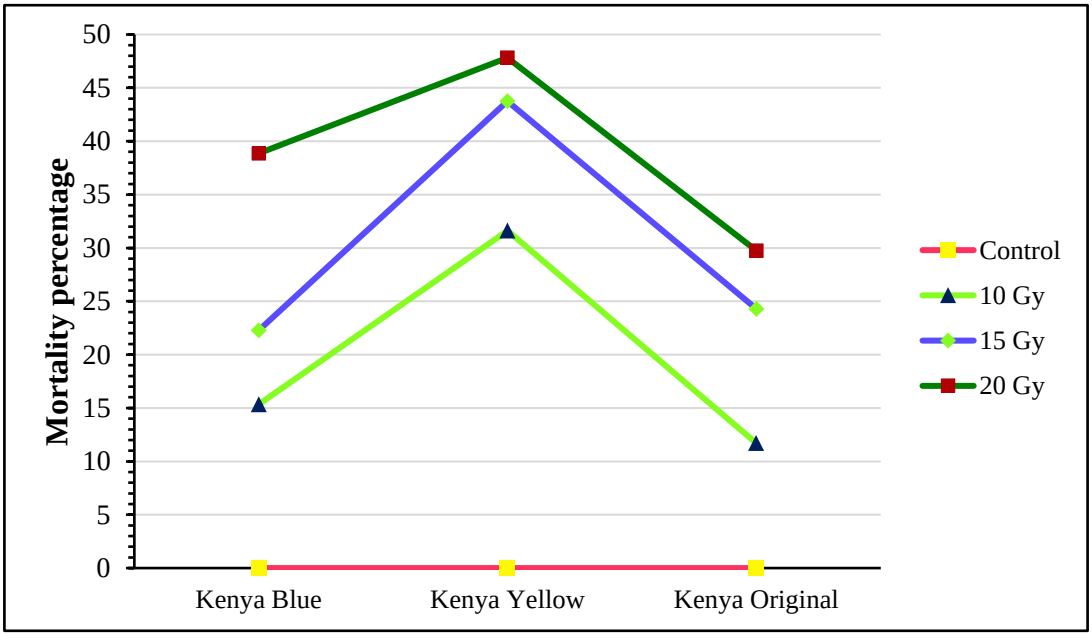

Fig. 4.1: Effect of gamma radiations on mortality percentage in dahlia cultivars

4.1.1.2 Survival percentage

The data pertaining to survival of plants after gamma radiations have been presented in Table 4.2 and Fig. 4.2. It is evident from the data that survival percentage decreased significantly at increased dose of gamma radiations and hundred percent survival was recorded in untreated plants, among gamma radiation doses, control plants showed significantly maximum survival percentage (100 %) followed by gamma radiation dose 10 Gy (80.39%), 15 Gy (69.89 %) and 20 Gy (60.67%). Cultivar differences for survival percentage were also highly significant. As respect to different cultivars, Kenya Yellow was significantly found to be more sensitive to higher exposure (69.16% survival), whereas, Kenya Blue (80.82%) and Kenya Original (83.30%) cultivars were significantly more tolerant to gamma radiations than Kenya Yellow.

The interaction of gamma radiation and cultivars also reveals significant differences. The interaction of cultivar Kenya Yellow and 20 Gy gamma rays resulted significantly minimum survival (52.18%) followed by interaction of Kenya Yellow with 15 Gy gamma rays (56.25%).

Survival of irradiated material is considered as one of the important criteria to estimate the dose levels of particular mutagen. Kaicker (1992) also stated the reduction in survival may be due to the toxic effect at higher concentration of gamma rays. Differences for radiation sensitivity among cultivar were also reported by Broertjes and Harten (1988). Survival percent was found to be decreasing with the increasing dose of gamma radiations. Tiwari *et al.* (2010) stated that reduction in survival rate at higher doses may be due to genetic loss which occurred because of chromosomal aberrations and gene mutation. Significant reduction in survival after exposure to gamma rays was also observed by Kumari *et al*. (2013) and Banerji and Datta (2005) in chrysanthemum.

Table 4.2: Effect of gamma radiations on survival percentage in dahlia cultivars

Radiation dose / Cultivar	Survival percentage				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	100	84.66	77.48	61.15	80.82
Kenya Yellow	100	68.20	56.25	52.18	69.16
Kenya Original	100	88.30	75.95	68.96	83.30
Mean	100	80.39	69.89	60.76	
	CD at 5%			**S.Em±**	
Radiation Dose	0.87			0.30	
Cultivar	0.75			0.26	
R×C	1.51			0.53	

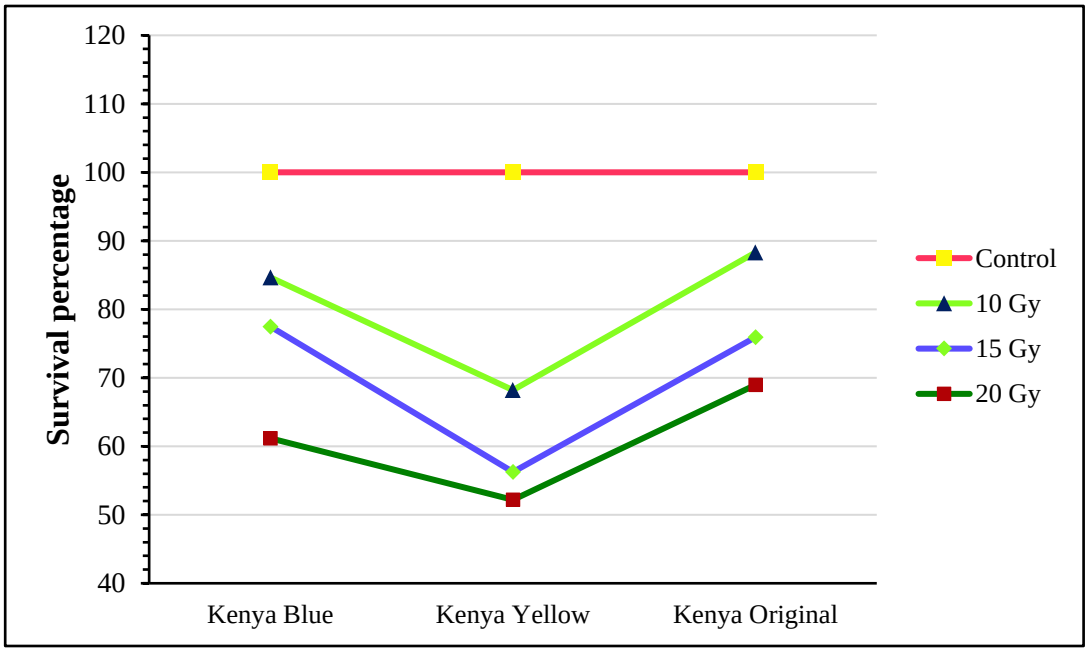

Fig. 4.2: Effect of gamma radiations on survival percentage in dahlia cultivars

4.1.1.3 Abnormal plants percentage

The effect of gamma radiations, different cultivars and their interactions on abnormal plant percentage were observed significant and shown in Table 4.3 and Fig. 4.3. It is evident that barring effect of cultivars and gamma radiation doses had significant effect on this character. Further, it is also clear from the data that percent abnormal plants increased with the increase in dose of gamma radiations, among the gamma radiation doses, treatment of 20 Gy recorded significantly higher percentage of abnormal plants (15.88%) as compared to the rest of the treatments. Cultivars also differed for this character and cultivar Kenya Blue exhibited significantly maximum percentage of abnormal plants (10.06%), whereas, minimum abnormal plants percentage (8.01%) was recorded in cultivar Kenya Original.

The interaction between cultivar Kenya Yellow and 20 Gy gamma rays treatment recorded significantly higher abnormal plants percentage (18.32%) as compared to rest of the interactions. However, minimum abnormal plant percentage (0%) was noted in untreated plants.

Plant abnormalities increased after irradiation and among the gamma rays treatment doses, maximum abnormal plants recorded with 20 Gy gamma rays treatment whereas, minimum with 0 Gy. These results are in accordance with earlier findings of Misra (1990) and Dwivedi and Banerji (2008), who recorded morphological abnormalities elevated with increased exposure to gamma rays. The abnormalities in irradiated plants may be due to chromosomal aberrations, disturbance in the production and distribution of growth substances, breakdown of phosphate metabolism and accumulation of free amino acids (Gunckel and Sparrow, 1961).

Table 4.3: Effect of gamma radiations on abnormal plants percentage in dahlia cultivar

Radiation dose / Cultivar	Abnormal plants percentage				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	0.00	6.14	12.15	15.34	8.41
Kenya Yellow	0.00	7.92	14.00	18.32	10.06
Kenya Original	0.00	4.88	13.16	14.00	8.01
Mean	0.00	6.31	13.10	15.88	
	CD at 5%			**S.Em±**	
Radiation Dose	0.32			0.11	
Cultivar	0.27			0.09	
R×C	0.55			0.19	

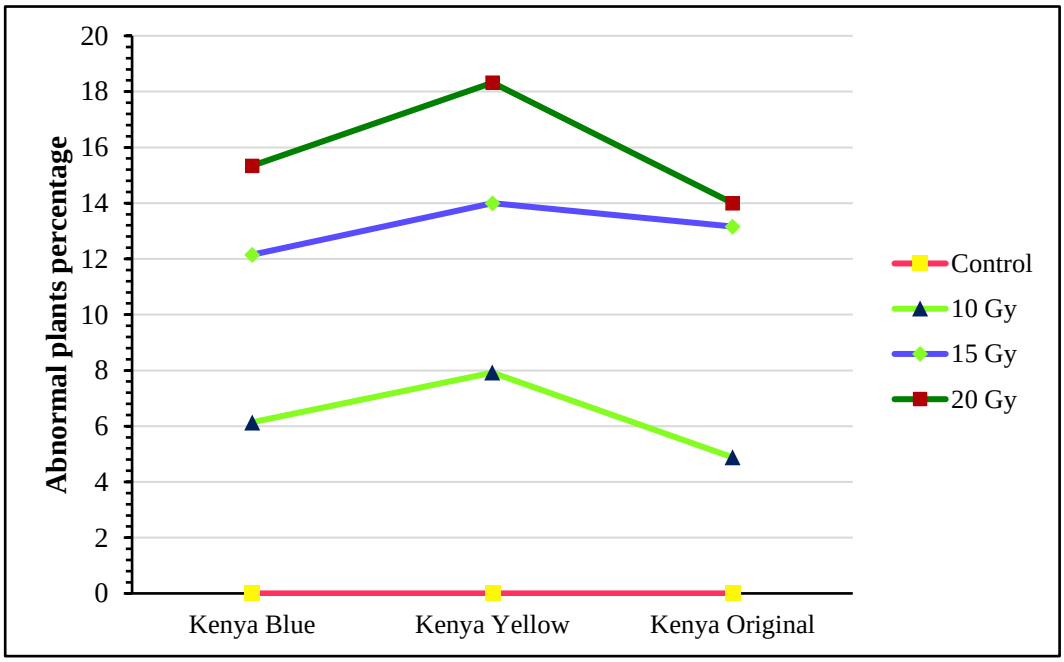

Fig. 4.3: Effect of gamma radiations on abnormal plants percentage (%) in dahlia cultivar

4.1.1.4 LD_{50} dosage

The probit analysis of LD_{50} dose for individual cultivars was carried out separately and presented in Table 4.4 and illustrated through Fig. 4.4, 4.5 and 4.6. The probit analysis indicated the extrapolated LD_{50} value based on mortality percent for dahlia cultivar of Kenya Blue (27.54 Gy), Kenya Yellow (20.89 Gy) and for Kenya Original (33.11 Gy). This indicated the significantly higher sensitivity of cultivar Kenya Yellow thus LD_{50} could be beyond this dose.

Table 4.4: Probit analysis for extrapolated LD_{50} of gamma rays in different cultivars of dahlia for mortality percentage

Cultivar	Radiation dose (Gy)	No. of rooted cuttings treated	Observed mortality (%)	Log_{10} of dose (x)	Working probit units (y)	LD_{50} dose (Gy)
Kenya Blue	10	40	15.34	1.00	3.96	27.54
	15	40	22.28	1.17	4.23	
	20	40	38.86	1.30	4.72	
Kenya Yellow	10	40	31.62	1.00	4.53	20.89
	15	40	43.75	1.17	4.85	
	20	40	47.82	1.30	4.95	
Kenya Original	10	40	11.70	1.00	3.82	33.11
	15	40	24.30	1.17	4.25	
	20	40	29.75	1.30	4.48	

The rooted cuttings irradiated with gamma rays saw an increase mortality percent with increase in dosage irrespective of cultivars used. Determination of radio sensitivity and LD_{50} dose of gamma rays are prerequisites for a mutation breeding programme (Khan *et al.*, 2015). The LD_{50} value was estimated on the basis of percent plant survival. In the present investigation, the radio sensitivity was estimated to be 20 Gy (LD_{50}) based on the percentage of survival of irradiated rooted cuttings. Broertjes and Van Harten (1988) reported varietal differences for radiation sensitivity LD_{50} for different vegetatively propagated crops such as gladiolus, chrysanthemum and others varied from 0.5-15 kR. Similar observation on mortality of treated material and radiation sensitivity among cultivars of crop were reported by Dwivedi and Banerji (2008) in dahlia and Koh *et al.* (2010) in rose.

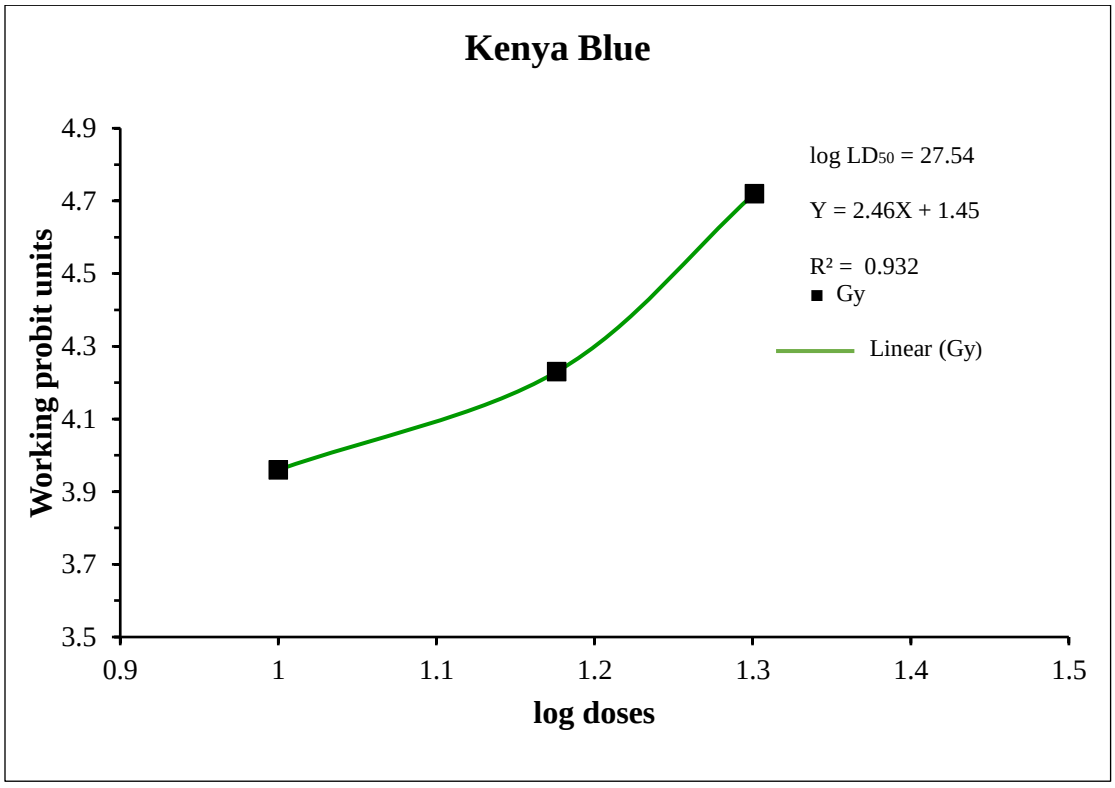

Fig. 4.4: Probit analysis for extrapolated LD_{50} of gamma radiations in cultivar Kenya Blue for mortality percentage

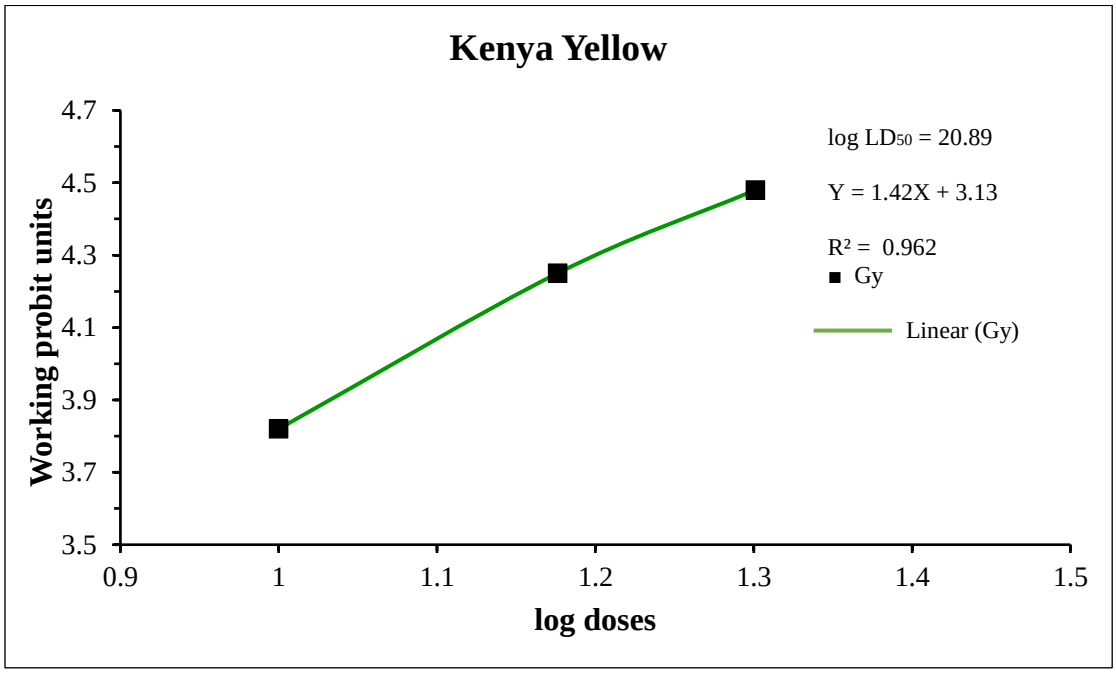

Fig. 4.5: Probit analysis for extrapolated LD_{50} of gamma radiations in cultivar Kenya Yellow for mortality percentage

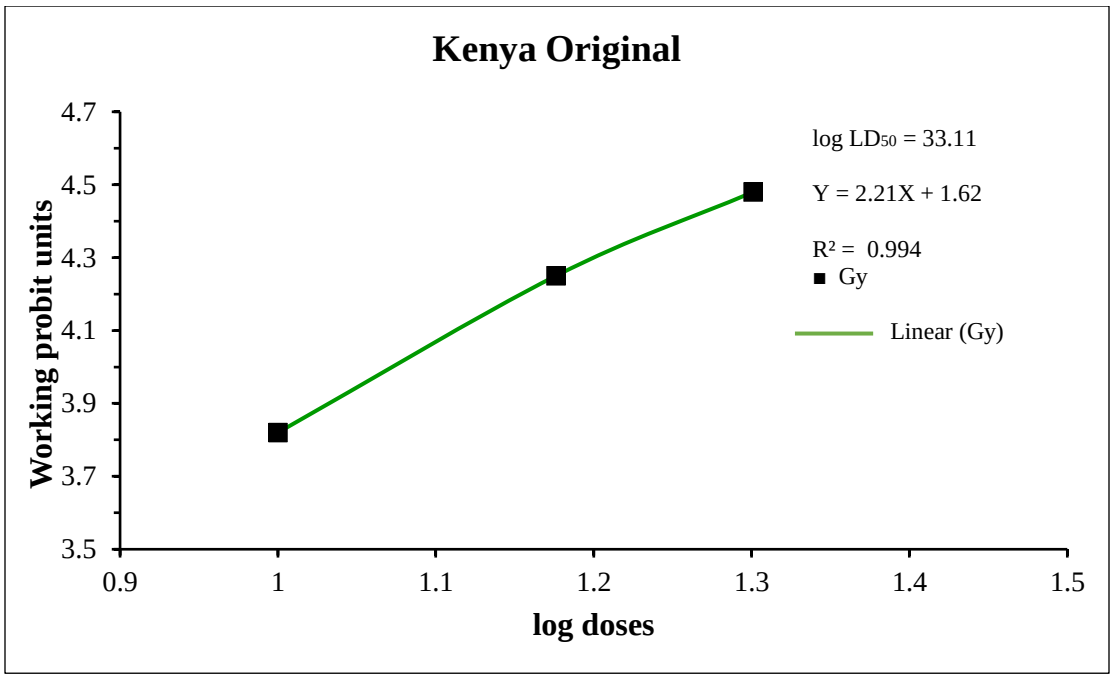

Fig. 4.6: Probit analysis for extrapolated LD_{50} of gamma radiations in cultivar Kenya Original for mortality percentage

4.1.1.5 Mutations spectrum, colour and frequency in vM_1 generation.

Data related to flower colour and mutation frequency are presented in Table 4.5 and 4.6 for vM_1 generation (experiment-1) of dahlia. It is evident that flower colour mutation frequency is genotypic and dose dependent phenomenon as different cultivars had different mutation frequencies at different doses. All of the colour mutation in vM_1 generation were in the form of chimeras (Plate 4.1, 4.2, 4.2a and 4.3). In general, all the flower colour mutations were found in only 10 Gy gamma ray dose in all the cultivars.

In vM_1 generation, 6 flower colour mutations in cultivar Kenya Blue, 15 flower colour mutations in cultivar Kenya Yellow and 3 flower colour mutations in cultivar Kenya Original were recorded at same 10 Gy gamma rays dose. Interactions of cultivar Kenya Yellow and 10 Gy gamma radiation dose recorded significantly higher mutation frequency (62.50 %) as compared to rest of the interactions.

It is evident from the tabular data that flower colour mutation frequency in all the cultivars were increased at higher dose of gamma rays (Stadler, 1929, Iba *et al*., 1965 and Hubbard, 1966). Rather *et al.* (2002) also reported increase in mutation frequency at higher doses of gamma radiations in Dutch Iris. Nagatomi *et al.* (1995), Lamseejan *et al.* (2003) and Misra *et al.* (2003) also obtained highest number of vegetative and floral mutation with increase in the dose of the mutagen up to a certain dose in chrysanthemum.

In vM_1 generation, most of the mutations were in the form of chimeras and the size of mutated sector varied from cultivar to cultivar from narrow streak on petal to entire petal, a single ray floret on flower to more than one ray floret to whole flower. These results are in parallel line with the findings of Broertjes and Ballego (1967), who observed a number of mutations for flower colour and shapes in irradiated varieties like “Salmon Ray”, “Arthur Godfrey” and “Eldorado”. The induction of flower colour mutations with gamma ray irradiation are in agreement with the results reported earlier (Datta *et al*., 2001, Misra and Datta, 2007 and Nencheva 2010) in chrysanthemum.

Table 4.5: Effect of gamma radiations on mutation spectrum, colour and frequency in vM$_1$ generation of dahlia cultivars

Cultivar	Gamma rays dose	No. of plants evaluated	Flower colour mutant	Mutation frequency (%)
Kenya Blue	10 Gy	24	**6**	25.00
	15 Gy	24	-	0.00
	20 Gy	24	-	0.00
Kenya Yellow	10 Gy	24	**15**	62.50
	15 Gy	24	-	0.00
	20 Gy	24	-	0.00
Kenya Original	10 Gy	24	**3**	12.50
	15 Gy	24	-	0.00
	20 Gy	24	-	0.00
Total			**24**	

Table 4.6: Mutation spectrum and colour of mutants isolated in vM_1 generation

S. No.	Mutant	Gamma rays dose	Colour in vM_1 as per RHS Colour Chart
1.	KBM_1	10 Gy	Red Purple Group 68 A + Yellow Group 4 C
2.	KBM_2	10 Gy	Red Purple Group N74 B + Red Purple Group 63 D
3.	KBM_3	10 Gy	Red Purple Group N74 B + Red Purple Group 69 D
4.	KBM_4	10 Gy	Red Purple Group N57 B
5.	KBM_5	10 Gy	Red Purple Group 73 A + Yellow Group 11 D
6.	KBM_6	10 Gy	Yellow Group 9 D + Red Purple Group 74 D
7.	KYM_1	10 Gy	White Group NN155 D + Yellow Group 3 C
8.	KYM_2	10 Gy	Yellow Group 9 D
9.	KYM_3	10 Gy	Yellow Group 7 A
10.	KYM_4	10 Gy	Orange Red Group N34 B + Yellow Group 1 B
11.	KYM_5	10 Gy	Yellow Group B 5 + Yellow Orange Group 22 B
12.	KYM_6	10 Gy	Yellow Group 5 C + Red Group 48 D
13.	KYM_7	10 Gy	Red Group 51 A + Green Yellow Group 1 A
14.	KYM_8	10 Gy	Red Purple Group 72 C + Yellow Group 5 B
15.	KYM_9	10 Gy	White Group NN155 D + Purple Group 77 D
16.	KYM_{10}	10 Gy	Yellow Group 2 D + Pink Group NN74 D
17.	KYM_{11}	10 Gy	Yellow Group 154 B + Orange Red Group 34 D
18.	KYM_{12}	10 Gy	Green Yellow Group 1 B + Yellow Group 12 C
19.	KYM_{13}	10 Gy	Orange Group 24 C
20.	KYM_{14}	10 Gy	White Group NN155 A + Purple Group 77 B
21.	KYM_{15}	10 Gy	White Group NN155 C
22.	KOM_1	10 Gy	Red Group 36 D
23.	KOM_2	10 Gy	Red Group 39 D
24.	KOM_3	10 Gy	Red Purple Group 58 D + White Group N155 B

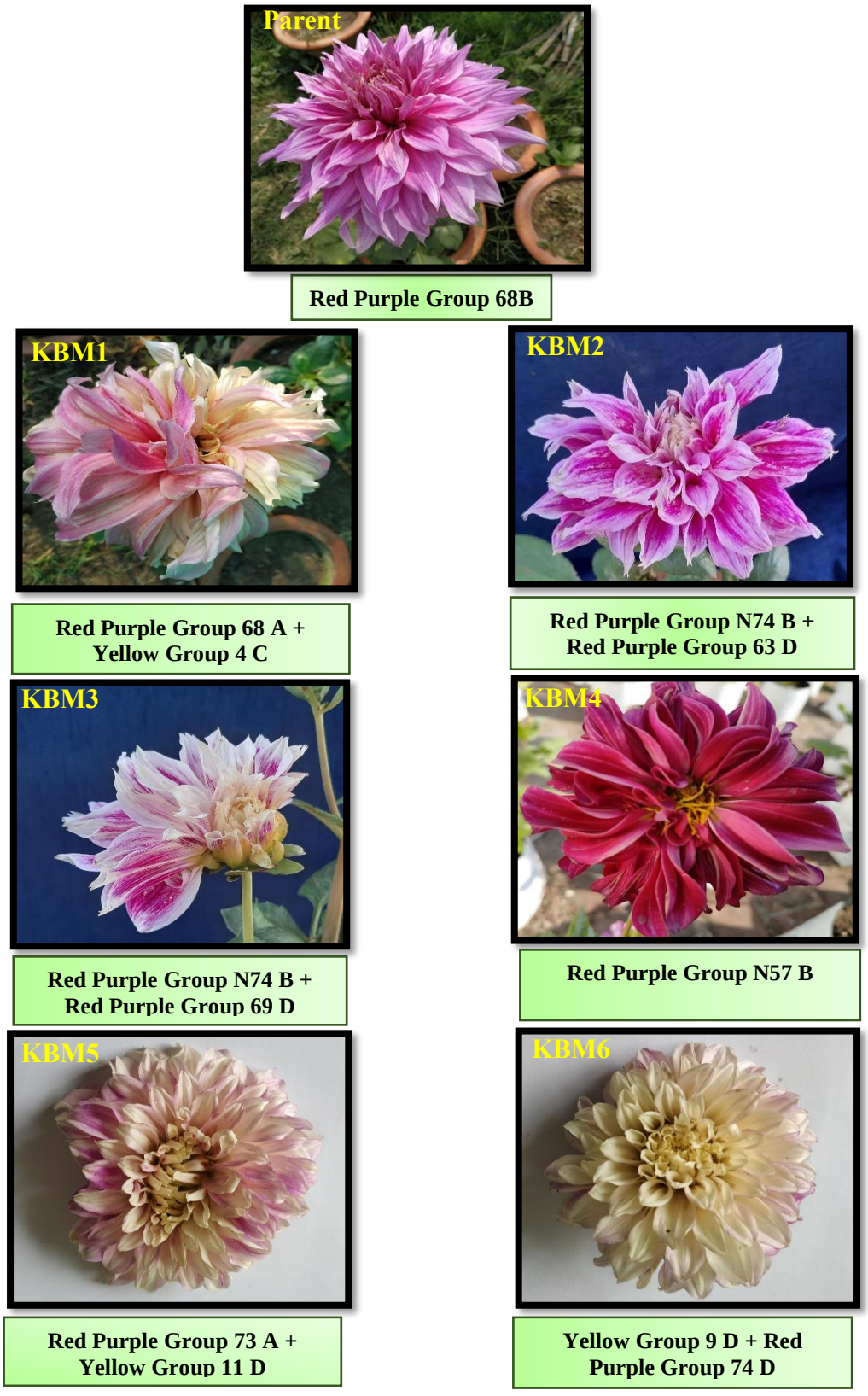

Plate 4.1: Mutation spectrum and colour mutants isolated from cultivar Kenya Blue in vM_1 generation

Yellow Group 3 A

White Group NN155 D + Yellow Group 3 C

Yellow Group 9 D

Yellow Group 7 A

Orange Red Group N34 B + Yellow Group 1 B

Yellow Group N34 B + Yellow Orange Group 22 B

Yellow Group 5 C + Red Group 48 D

Red Group 51 A + Green Yellow Group 1 A

Plate 4.2: Mutation spectrum and colour mutants isolated from cultivar Kenya Yellow in vM_1 generation

Red Purple Group 72 C + Yellow Group 5 B

White Group NN155 D + Purple Group 77 D

Yellow Group 2 D + Pink Group NN74 D

Yellow Group 154 B + Orange Red Group 34 D

Green Yellow Group 1 B + Yellow Group 12 C

Orange Group 24 C

White Group NN155 A + Purple Group 77 B

White Group NN155 C

Plate 4.2 a: Mutation spectrum and colour mutants isolated from cultivar Kenya Yellow in vM_1 generation

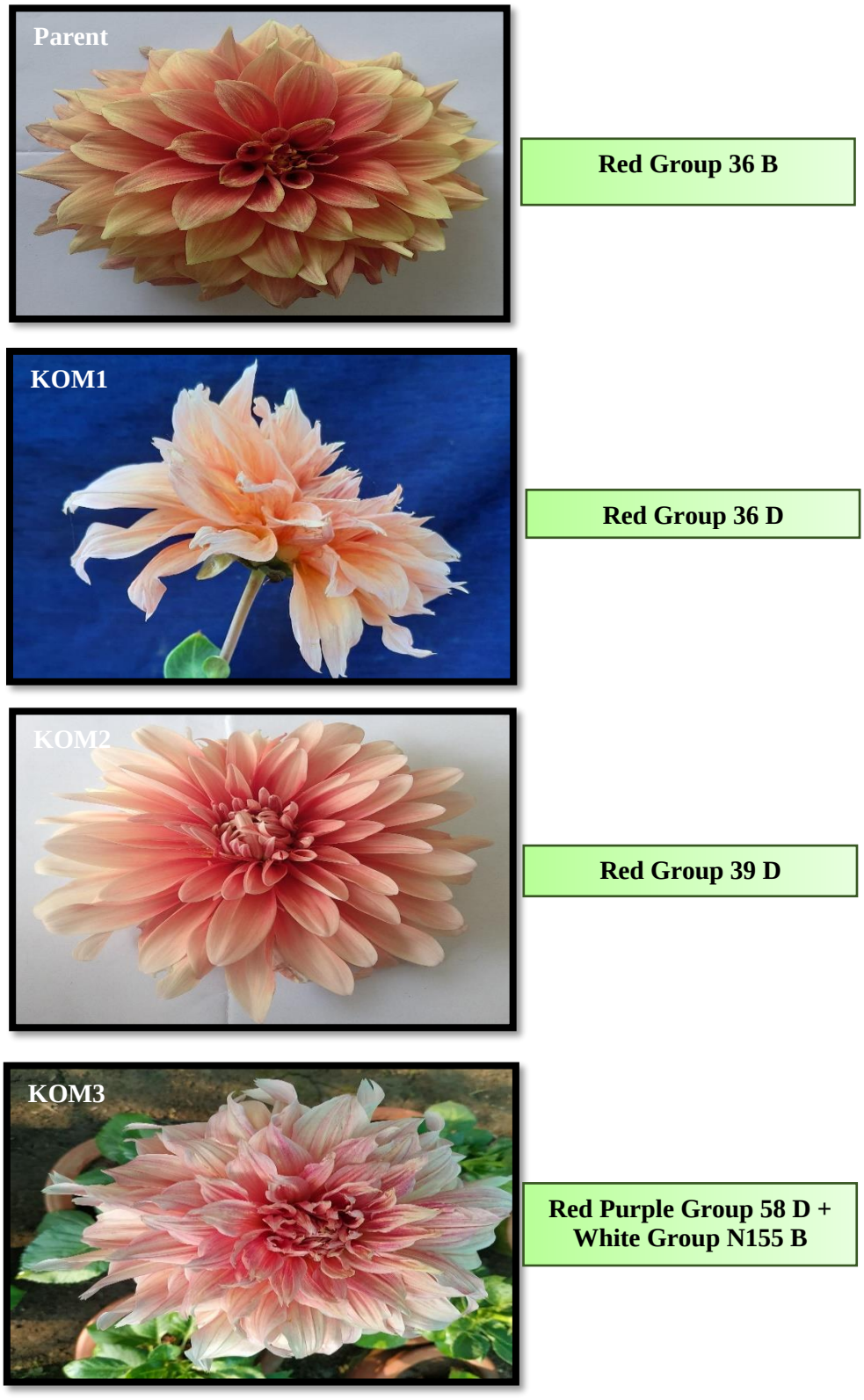

Plate 4.3: Mutation spectrum and colour mutants isolated from cultivar Kenya Original in vM_1 generation

4.1.2 Effect of gamma radiations on vegetative characters

Effect of different doses of gamma radiations was studied on vegetative characters in three dahlia cultivars.

4.1.2.1 Plant height

Results pertaining to effect of gamma radiations on plant height of cultivars and their interaction after 30, 60 and 90 DAT are presented in Table 4.7, 4.8, 4.9 and Fig. 4.7, 4.8 and 4.9.

4.1.2.1.1 Plant height at 30 DAT

A gradual decrease in plant height at 30 DAT was recorded with increase in gamma rays dose. Untreated plants were significantly taller (12.62 cm) than the plants treated with different doses of gamma radiations whereas, plants treated with 20 Gy gamma rays recorded minimum plant height (8.71 cm) at 30 DAT. Mean plant height recorded was 11.53 and 9.22 cm at 10 Gy and 15 Gy gamma rays treatments, respectively. The difference between plant height in untreated plants with 10 Gy was less as compared to higher doses. As evident from the tabulated data (Table 4.7), the effect of different cultivars was significant. Culivar Kenya Blue exhibited significantly maximum plant height (10.93 cm) at 30 DAT, which was higher than the rest of the cultivars whereas, minimum plant height (10.26 cm) recorded in Kenya original, which was *at par* with Kenya yellow (10.37 cm).

The interaction effect of gamma radiations and cultivars on plant height were significant. Plant height (14.23 cm) at 30 DAT was significantly maximum in interaction between cultivar Kenya Blue and control and minimum plant height (8.46 cm) was observed in 20 Gy gamma rays treated plants of cultivar Kenya Original, which was *at par* with cultivar Kenya Blue and Kenya Yellow (8.71 and 8.97cm, respectively) at same radiation dose and Kenya Original (8.96 cm) with 15 Gy.

Table 4.7: Effect of gamma radiations on plant height at 30 DAT in dahlia cultivars

Radiation dose / Cultivar	Plant height at 30 DAT (cm)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	14.23	11.15	9.62	8.71	10.93
Kenya Yellow	11.77	11.67	9.08	8.97	10.37
Kenya Original	11.86	11.78	8.96	8.46	10.26
Mean	12.62	11.53	9.22	8.71	
	CD at 5%			**S.Em±**	
Radiation Dose	0.33			0.11	
Cultivar	0.26			0.10	
R×C	0.58			0.20	

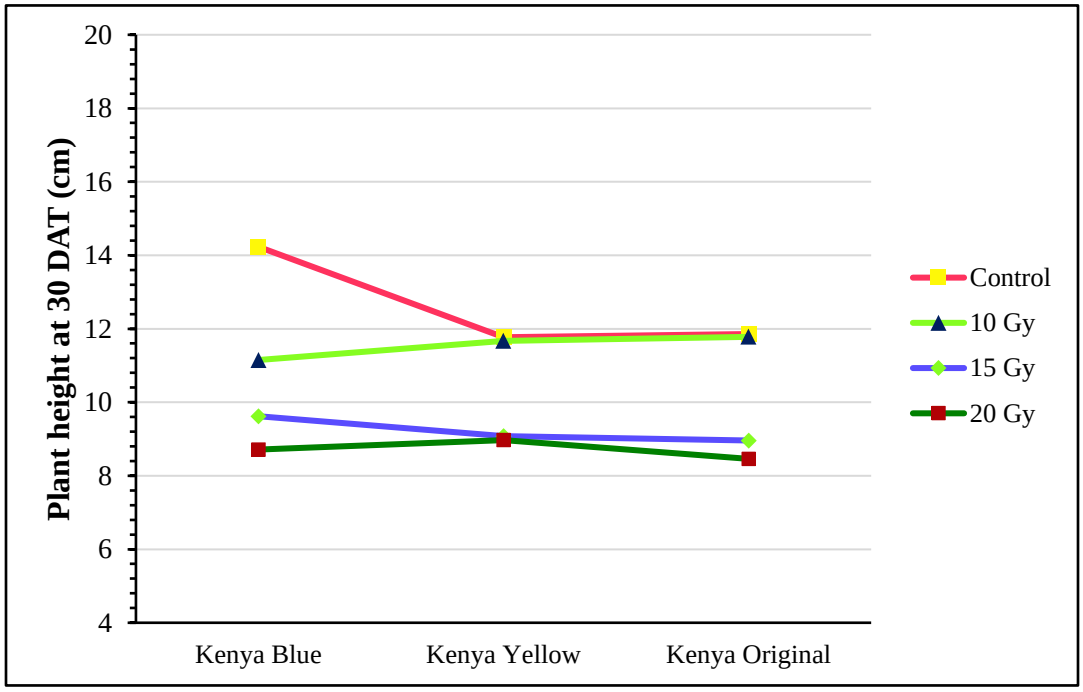

Fig. 4.7: Effect of gamma radiations on plant height at 30 DAT in dahlia cultivars

The plant height was significantly affected by gamma rays. In initial stages of planting plant height was reduced drastically due to the exposure of higher doses of gamma rays. These results are in conformity with the results of Dwivedi and Banerji (2008), who reported decrease in plant height in dahlia cultivar "Pinki" after irradiation with higher doses of gamma rays. There are few reports of increase in plant height at lower doses of gamma radiation, which was also found in the present study. Sensitivity of varieties to radiations also affected the plant height. This is similar to result of Mishra (1990) in dahlia, Banerji and Datta (2002) in chrysanthemum, Srivastava *et al.* (2007) in gladiolus and Sarhan *et al.* (2019) in marigold.

4.1.2.1.2 Plant height at 60 DAT

It is evident from the data (Table 4.8) that plant height gradually decreased with increase in gamma rays dose. It reflects that plants which were given 20 Gy gamma rays treatment recorded significantly minimum plant height (13.82 cm), while maximum plant height was observed in untreated plants (23.85 cm). The cultivars differences were also significant on plant height at 60 DAT, significantly maximum plant height (20.64 cm) recorded in cultivar Kenya Blue. However, the minimum plant height (18.15 cm) was observed in cultivar Kenya Original, which was *at par* with cultivar Kenya Yellow (18.30 cm).

The interaction effect of various gamma radiation doses and different cultivars of dahlia were found non-significant on plant height at 60 DAT.

The treatment of higher dose of gamma rays noted the decreasing plant height at 60 DAT in all the cultivars of dahlia (Manu, 2017). Das *et al.* (1978) stated that the plant height was highly influenced by the treatment of gamma radiation in all the varieties of dahlia. Reduction in plant height after 2 kR gamma rays exposure of chrysanthemum varieties was also observed by Dilta *et al.* (2003). Similar results on plant height have been reported by Pal (2015) in dahlia, Mishra *et al.* (2003) in chrysanthemum and Koh *et al.* (2010) in rose.

Table 4.8: Effect of gamma radiations on plant height at 60 DAT in dahlia cultivars

Radiation dose / Cultivar	Plant height at 60 DAT (cm)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	26.81	24.86	16.62	14.27	20.64
Kenya Yellow	22.38	22.03	15.43	13.36	18.30
Kenya Original	22.38	21.97	14.42	13.83	18.15
Mean	23.85	22.95	15.49	13.82	
	CD at 5%			**S.Em±**	
Radiation Dose	0.36			1.05	
Cultivar	0.91			0.32	
R×C	NS			0.63	

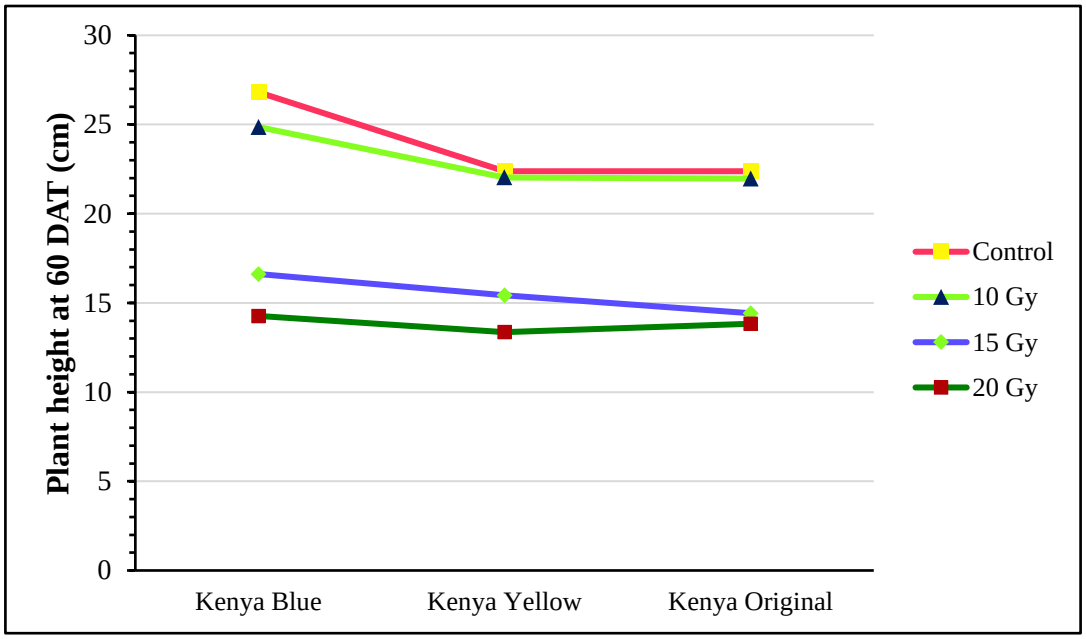

Fig. 4.8: Effect of gamma radiations on plant height after 60 DAT in dahlia cultivars

4.1.2.1.3 Plant height at 90 DAT

It is evident from the data (Table 4.9) that the plant height was gradually decreased with increase in gamma rays dose. Dose effect shows that, untreated plants recorded significantly maximum plant height (42.31 cm) at 90 DAT, while minimum plant height (25.97 cm) was recorded in 20 Gy. The cultivar differences were also significant, cultivar Kenya Blue noted significantly higher plant height (36.65 cm) at 90 DAT as compared to other cultivars dahlia.

The interaction effects of various gamma radiation doses and different cultivars of dahlia were found non-significant on plant height at 90 DAT.

The plant height at the time of maturity (90 DAT) decreased significantly with increasing doses of gamma rays, there was reduction in plant height after gamma radiations and reductions were more at higher doses. Significantly longer plant height in Kenya Blue at maturity might be due to the reason that it was slightly early cultivar and growth was faster as compared to other cultivars. These results are also in accordance with the findings of Hamatani *et al.* (2001) in dahlia and Banerji and Datta (2005) in chrysanthemum.

Table 4.9: Effect of gamma radiations on plant height at 90 DAT

Radiation dose / Cultivar	Plant height at 90 DAT (cm)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	44.3	43.09	30.68	27.98	36.65
Kenya Yellow	43.83	42.13	29.04	26.12	35.28
Kenya Original	38.29	36.72	25.24	23.80	30.01
Mean	42.31	40.65	28.32	25.97	
	CD at 5%			**S.Em±**	
Radiation Dose	1.05			0.36	
Cultivar	0.91			0.31	
R×C	NS			0.36	

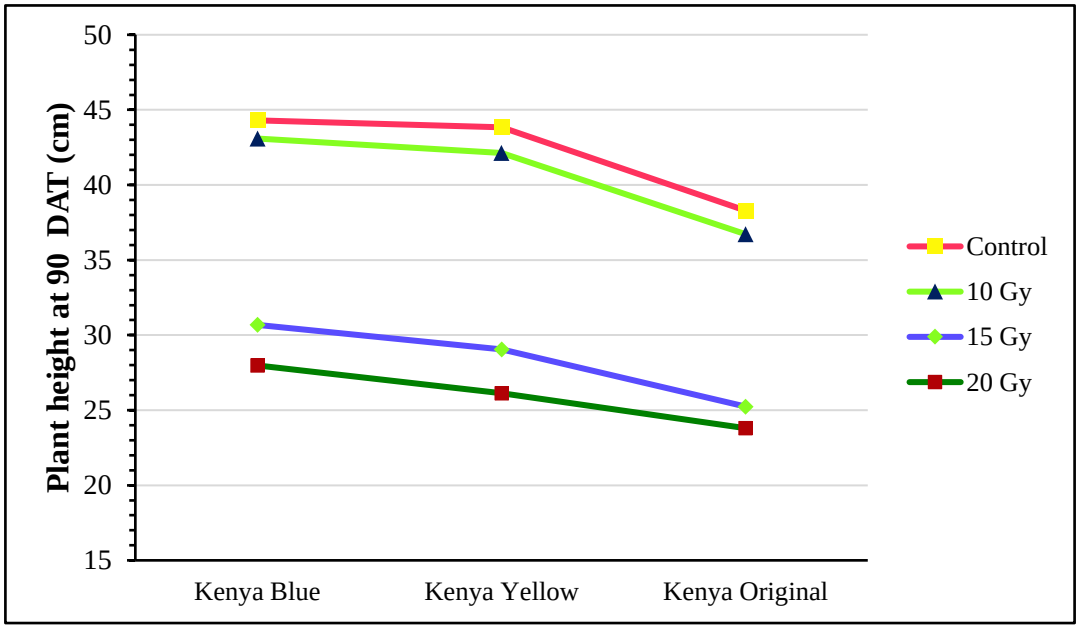

Fig. 4.9: Effect of gamma radiations on plant height at 90 DAT in dahlia cultivars

4.1.2.2 Number of leaves plant^{-1}

Results pertaining to the effect of gamma radiations, dahlia cultivars and their interaction on number of leaves plant^{-1} of at 60 and 90 DAT are presented in Table 4.10 and 4.11 and Fig. 4.10 and 4.11.

4.1.2.2.1 Number of leaves plant^{-1} at 60 DAT

The data presented in Table 4.10 and Fig. 4.10 reveals that decrease in number of leaves plant^{-1} as the gamma radiations dose increased. Maximum number of leaves plant^{-1} (40.39) at 60 DAT were significantly recorded in untreated plants while minimum (18.80) recorded in plants treated with higher dose (20 Gy) gamma radiations. The cultivar differences for number of leaves plant^{-1} at 60 DAT were also highly significant. Observations recorded reveals that cultivar Kenya Blue resulted significantly maximum number of leaves plant^{-1} (35.66), while Kenya Original (23.56) had minimum number of leaves plant^{-1}, which was significantly lesser than other cultivars.

Interaction between two factors gamma radiations and cultivars were also found to be significant. Interaction of cultivar Kenya Blue and control recorded significantly maximum number of leaves plant^{-1} (48.74) at 60 DAT, whereas, minimum number of leaves plant^{-1} (17.33) was observed in cultivar Kenya Yellow treated with 20 Gy gamma radiations, which was *at par* with Kenya Original (17.42) at same radiation dose.

It has been observed that all the treatments of gamma rays significantly reduced the number of leaves and decrease in number of leaves increased with the increased doses. This decrease is mainly due the decrease in number of branches plant^{-1} reported by Misra *et al.* (2009). The number of leaves plant^{-1} was significantly affected by gamma radiations. These results are in conformity with the work of Pal (2015) in dahlia, Srivastava *et al.* (2007) in gladiolus and Mubarok *et al.* (2011) in tuberose, who reported decrease in number of leaves plant^{-1} with increase in dose of mutagen.

Table 4.10: Effect of gamma radiations on number of leaves plant^{-1} at 60 DAT in dahlia cultivars

Radiation dose / Cultivar	Number of leaves plant^{-1} at 60 DAT				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	48.74	41.50	30.75	21.67	35.66
Kenya Yellow	42.58	38.83	19.43	17.33	29.54
Kenya Original	29.83	28.34	18.67	17.42	23.56
Mean	40.39	36.22	22.95	18.80	
	CD at 5%			**S.Em±**	
Radiation Dose	0.67			0.23	
Cultivar	0.58			0.20	
R×C	1.17			0.40	

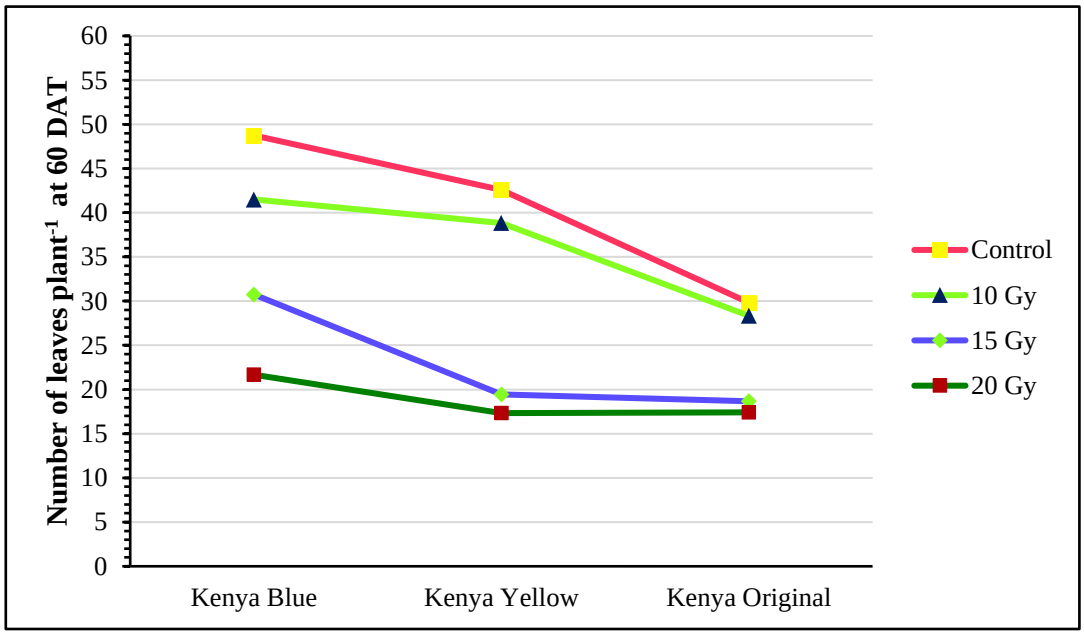

Fig. 4.10: Effect of gamma radiations on number of leaves plant^{-1} at 60 DAT in dahlia cultivars

4.1.2.2.2 Number of leaves plant^{-1} at 90 DAT

The data on number of leaves plant^{-1} presented in Table 4.11 and graphically represented by Fig. 4.11. The data clearly indicates that gamma radiations, cultivars and their interactions significantly influenced the number of leaves plant^{-1}. Among the gamma radiation doses, significantly highest number of leaves plant^{-1} (65.00) at 90 DAT was recorded in untreated plants followed by 10 Gy (60.31), whereas, minimum number of leaves was noted in 20 Gy (45.17). As regards to cultivars of dahlia, significantly highest number of leaves plant^{-1} (64.72) at 90 DAT was recorded in cultivar Kenya Blue followed by cultivar Kenya Yellow (57.08), while, minimum number of leaves plant^{-1} was noted in cultivar Kenya Original (45.54).

Interaction of various gamma doses with different cultivars exhibited significant effect on number of leaves plant^{-1} at 90 DAT. Interaction between control and cultivar Kenya Blue resulted significantly maximum number of leaves plant^{-1} (72) at 90 DAT followed by 10 Gy gamma radiation in the same cultivar (68.02), whereas, minimum number of leaves plant^{-1} was recorded under 20 Gy in cultivar Kenya Original (36.25).

The number of leaves per plant^{-1} decreased in all cultivars with increased dose of mutagen, when compared to control. Decrease in number of leaves plant^{-1} was lesser in lower doses as compared to higher dose (20 Gy) of mutagenic treatments. These findings are in line with the work of Dube *et al.* (1980) in dahlia, Datta *et al*. (2005) in chrysanthemum and Tiwari *et al.* (2010) in gladiolus, who reported decrease in number of leaves plant^{-1} with increase in dose of mutagen.

Table 4.11: Effect of gamma radiations on number of leaves plant^{-1} at 90 DAT in dahlia cultivars

Radiation dose / Cultivar	Number of leaves plant^{-1} at 90 DAT				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	72.00	68.02	60.84	58	64.72
Kenya Yellow	67.58	64.83	54.67	41.25	57.08
Kenya Original	55.42	48.08	42.43	36.25	45.54
Mean	65.00	60.31	52.65	45.17	
	CD at 5%			**S.Em±**	
Radiation Dose	0.94			0.32	
Cultivar	0.81			0.26	
R×C	1.63			0.56	

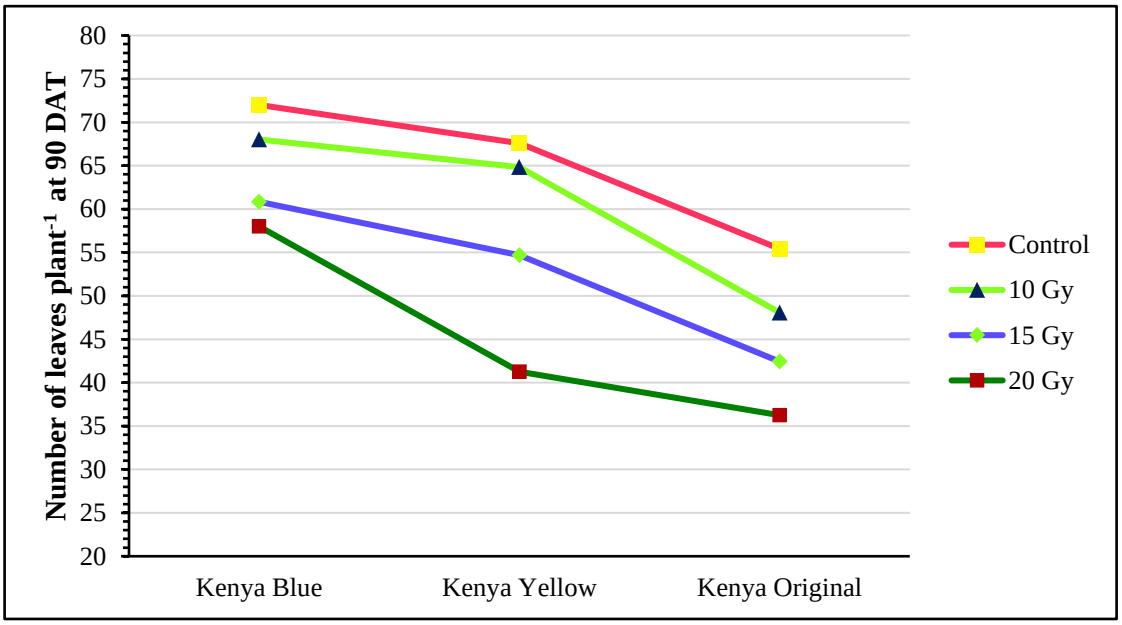

Fig. 4.11: Effect of gamma radiations on number of leaves plant^{-1} at 90 DAT in dahlia cultivars

4.1.2.3 Total number of branches plant^{-1}

The data presented in Table 4.12 for total number of branches plant-^{1} showed significant effect due to various doses of gamma irradiation and different cultivars of dahlia. The observation of untreated plants resulted significantly maximum number of branches plant^{-1} (5.18) followed by 10 Gy, 15 Gy and 20 Gy gamma rays treatments. The significant reduction in number of branches plant^{-1} was recorded as doses of gamma radiation increase, higher dose (20 Gy) of gamma radiation resulted in lower number of branches plant^{-1} (2.53), among the cultivars, significantly maximum number of branches plant^{-1} (4.10) was recorded in cultivar Kenya Blue which was significantly more than the rest of the cultivars. However, minimum number of branches plant^{-1} (3.42) recorded in cultivar Kenya Original, which was significantly lesser than rest of cultivars.

The interaction effect of various gamma radiation doses and different cultivars of dahlia were found non-significant on total number of branches plant^{-1}.

The number of branches plant^{-1} was slightly increased at lower doses but suppressed at higher dose. The less number of branches may be due to inhibitory effect of higher mutagenic doses of gamma radiations. These results are in close conformity with results of Banerji and Datta (2002) in chrysanthemum. Higher dose of gamma radiations i.e. 20 Gy drastically reduced the number of branches plant^{-1} by 2.53 in comparison with control. These results corroborate with the results of Lee *et al.* (2010) in chrysanthemum, Singh and Kumar (2013) in gladiolus and Majumder *et al.* (2018).

Table 4.12: Effect of gamma radiations on total number of branches plant^{-1} in dahlia cultivars

Radiation dose / Cultivar	Total number of branches plant^{-1}				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	5.50	4.75	3.42	2.75	4.10
Kenya Yellow	5.38	4.25	3.58	2.58	3.95
Kenya Original	4.67	3.83	2.92	2.27	3.42
Mean	5.18	4.28	3.31	2.53	
	CD at 5%			**S.Em±**	
Radiation Dose	0.18			0.06	
Cultivar	0.15			0.05	
R×C	NS			0.11	

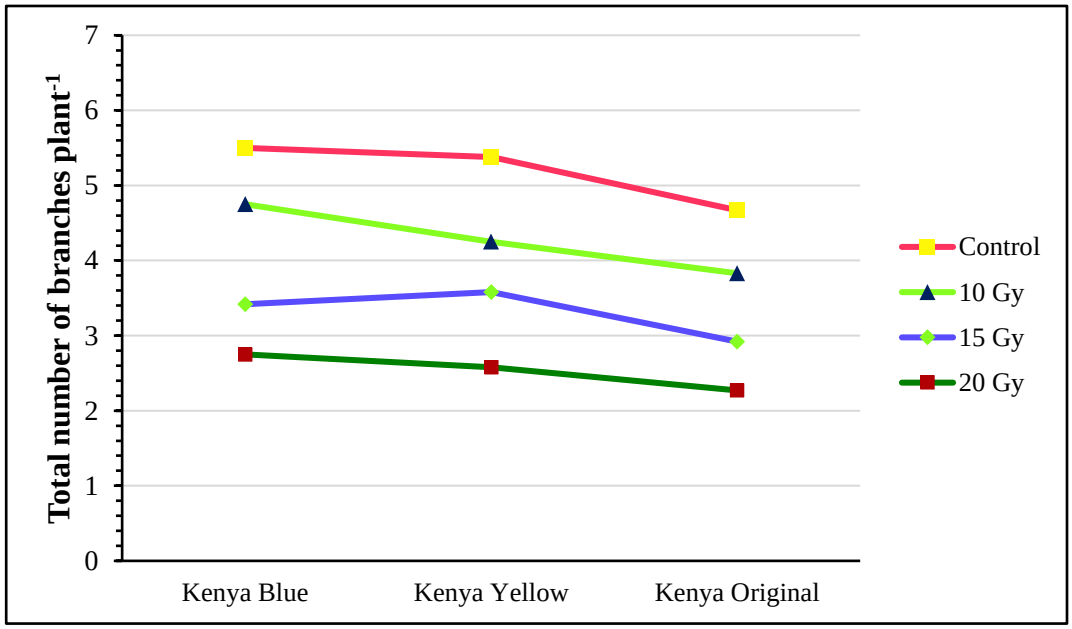

Fig. 4.12: Effect of gamma radiations on total number of branches plant^{-1} in dahlia cultivars

4.1.2.4 Plant spread (cm)

The data regards to difference in plant spread due to gamma radiation doses and different cultivars have been presented in Table 4.13 with graphical representation in Fig. 4.13. The significant reduction in plant spread was recorded after treatment of gamma rays, although untreated plants of dahlia was exhibited significantly maximum plant spread (28.81cm), which was significantly *at par* with 10 Gy gamma rays dose (27.49 cm). However, 20 Gy gamma radiation treatment gave minimum plant spread (24.36 cm). The cultivars also differ highly significant for plant spread, cultivar Kenya Blue exhibited significantly maximum plant spread (27.51 cm), which was statistically at *par with* cultivar Kenya Blue (26.68 cm). In the meanwhile, minimum plant spread (26.33 cm) observed in cultivar Kenya Original.

The interaction effects of gamma radiation doses and different cultivars were non-significant on plant spread.

Reduction in vegetative growth after exposure to radiations might be due to interference in normal mitosis and frequent occurrence of mitotic aberrations, inhibition of rate of assimilation and also due to changes in auxin level or due to inactivation of auxin. The range in plant spread among the treatments showed that there was a significant reduction in plant spread at higher doses of gamma rays as compared to lower doses. Manu (2017) also recorded decrease in plant spread at higher doses of gamma radiations. This decrease was inversely proportional to the dose employed. Similar results of decrease in plant spread were also reported by Misra *et al*. (2009) and Mahure *et al*. (2010) in chrysanthemum.

Table 4.13: Effect of gamma radiation on plant spread plant^{-1} in dahlia cultivars

Radiation dose / Cultivar	Plant spread plant^{-1}				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	27.67	27.30	26.67	25.08	26.68
Kenya Yellow	30.03	28.05	27.33	24.17	27.51
Kenya Original	28.75	26.66	26.08	23.82	26.33
Mean	28.81	27.49	26.69	24.36	
	CD at 5%			**S.Em±**	
Radiation Dose	1.00			0.34	
Cultivar	0.86			0.30	
R×C	NS			0.60	

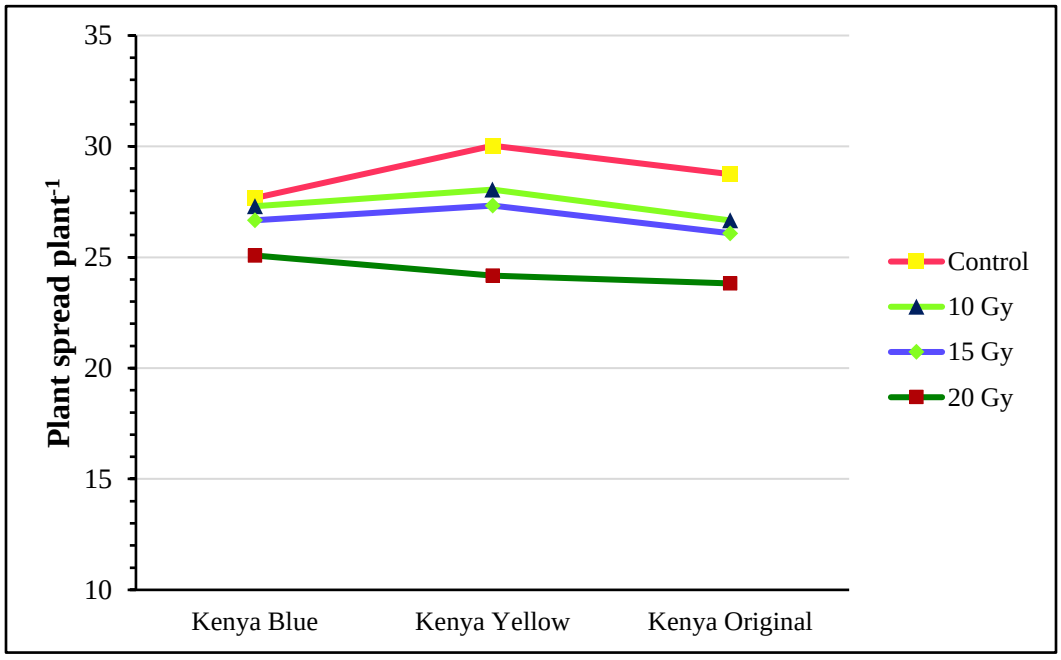

Fig 4.13: Effect of gamma radiation in plant spread plant^{-1} at maturity in dahlia cultivars

4.1.3 Effect of gamma radiations on floral characters

Effect of different doses of gamma radiations was studied on floral characters in dahlia cultivars viz. Kenya Blue, Kenya Yellow and Kenya Original.

4.1.3.1 Days taken for first bud appearance

Data presented in Table 4.14 as well as Fig. 4.14 reveals that gamma radiations had significant effect on days taken for first bud appearance. It is evident from the data that, days taken for first bud appearance (81.12 days) recorded under lower dose (10 Gy) was significantly earlier as compared to untreated plants. However, the dose increased above 10 Gy, days taken for first bud appearance was delayed significantly. Untreated plants took 88.28 days for first bud appearance and it was delayed to 101.39 days at 20 Gy treatment. The comparison among different cultivars, Kenya Original recorded significantly longer days for first bud appearance (103.50 days), followed by cultivar Kenya Blue (88.69 days), while minimum days were taken by cultivar Kenya Yellow (84.96 days), exhibiting first bud appearance significantly earlier than other cultivars.

The effect of interaction of gamma rays and cultivars on days taken for first bud appearance was also significant. Cultivar Kenya Blue treated with 10 Gy gamma rays treatment took significantly minimum days for first bud appearance (72.24 days). However, these were significantly earlier than other treatment combinations. Cultivar Kenya Original took significantly more time for first bud appearance under 15 Gy gamma rays treatment (111.83 days).

These results are in accordance with Dwivedi and Banerji (2008), who irradiated dahlia cultivar “Pnki” and found that lower-dose resulted in early bud appearance. Current finding is also in line with Pal (2015), who found that bud initiation at lower dose was earlier as compared to untreated plant. Similar type of stimulatory effect was observed earlier by Patil (2009) and Karki and Srivastava (2010) in gladiolus. Dube *et*

al. (1980) were also noted that the flowering was delayed significantly at 3-4 Krad doses in dahlia cultivars.

Table 4.14: Effect of gamma radiations on number of days taken for first bud appearance in dahlia cultivars

Radiation dose / Cultivar	Days taken for first bud appearance				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	82.66	78.21	95.08	98.83	88.69
Kenya Yellow	79.33	72.24	89.33	98.92	84.96
Kenya Original	102.83	92.92	111.83	106.42	103.50
Mean	88.28	81.12	98.75	101.39	
	CD at 5%			**S.Em±**	
Radiation Dose	1.51			0.52	
Cultivar	1.30			0.45	
R×C	2.61			0.91	

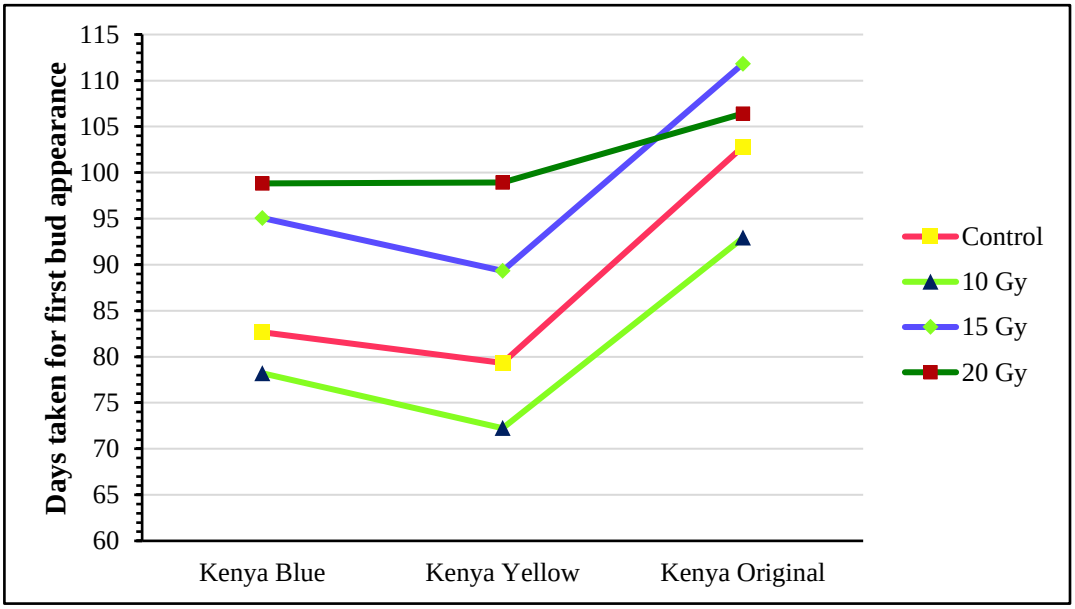

Fig. 4.14: Effect of gamma radiations on number of days taken for first bud appearance in dahlia cultivars

4.1.3.2 Number of days taken for flower opening

Observations on number of days taken for flower opening were presented in Table 4.15 as well as Fig 4.15 and revealed that significant effect of gamma radiation doses and different cultivars of dahlia. Days taken for flower opening (17.77 days) at lower dose (10 Gy) was significantly earlier as compared to untreated plants. It is also clear that as the dose increased above 10 Gy, days taken for flower opening was delayed significantly. However, the untreated plants took significantly maximum days for flower opening (20.33 days), which was *at par* with treatment of 20 Gy gamma dose (20.20 days), as respect to various cultivars, Kenya Yellow recorded significantly maximum days for flower opening (19.72 days), which was statistically *at par* with days taken for flower opening in Kenya Original (19.65 days). However, minimum days taken by cultivar Kenya Blue (18.83 days) which exhibited significantly earlier flower opening than the other cultivars.

The effect on interaction of gamma rays and cultivars on number of days taken for flower opening were found non-significant.

It was noticed from the investigation that as the dose of gamma rays was increased, the days taken for flower opening were also increased. Flowering at lower dose (10 Gy) was earlier as compared to untreated plants of dahlia was observed by Manu (2017), similar results were confirmed by Patil (2009) when corms of different varieties of gladiolus were exposed to different doses of gamma rays. Kumari *et al.* (2013) also found the delay in flowering of chrysanthemum var. “Thai Chen Queen” when treated with gamma rays. Delay in flowering due to gamma rays was may be due to the reduction in rate of physiological processes which assists in synthesis of flower inducing substances.

Table 4.15: Effect of gamma radiation on number of days taken for flower opening in dahlia cultivars

Radiation dose / Cultivar	Number of days taken for flower opening				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	20.17	17.50	18.17	19.48	18.83
Kenya Yellow	20.25	18.15	19.31	21.17	19.72
Kenya Original	20.58	17.67	20.15	20.20	19.65
Mean	20.33	17.77	19.21	20.29	
	CD at 5%			**S.Em±**	
Radiation Dose	0.86			0.30	
Cultivar	0.75			0.26	
R×C	NS			0.52	

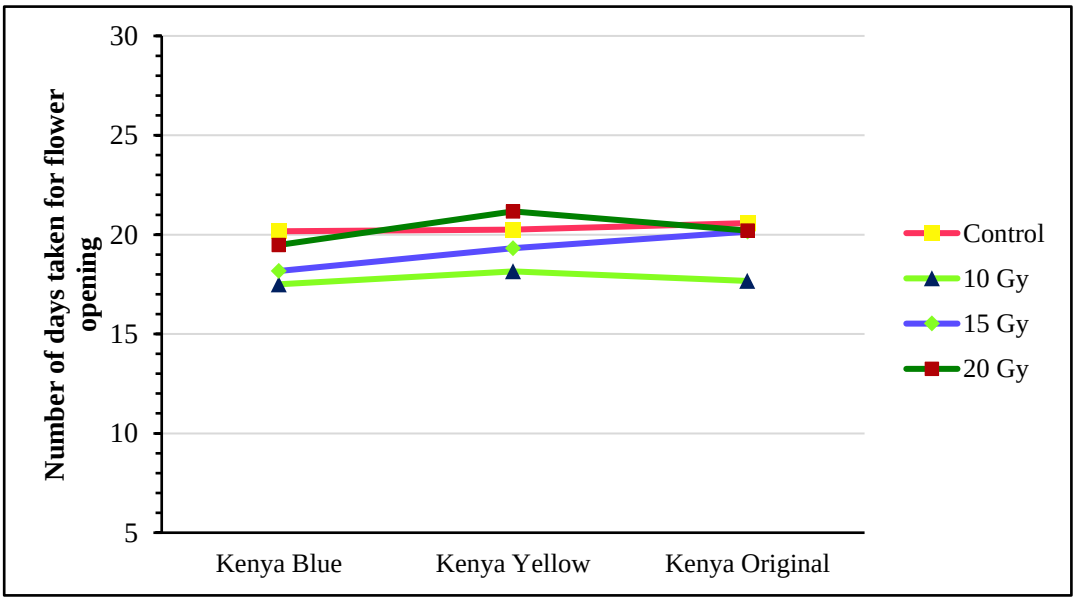

Fig. 4.15: Effect of gamma radiation on number of days taken for flower opening in dahlia cultivars

4.1.3.3 Number of days taken for full bloom

The Table 4.16 compiles the data recorded in various cultivars and doses of gamma radiation for number of days taken for full bloom in dahlia. A perusal of the data reveals that gamma irradiation had significant effect on the number of days to full bloom, increase in gamma rays dose significantly delayed to full bloom. Untreated plants had taken significantly maximum number of days for full bloom (10.16 days) followed by 10 Gy gamma radiation treatment (8.58 days). Whereas, significantly minimum number of days for full bloom (7.43 days) was recorded under 20 Gy gamma irradiation, which was found statistically *at par* with 15 Gy (7.86 days). The cultivar differences were also highly significant on number of days taken for full bloom, cultivar Kenya Blue recorded significantly minimum number of days for full bloom (7.58 days) followed by Kenya Original (8.73 days). Whereas, maximum days taken for full bloom observed in Kenya Yellow (9.20 days).

An interaction of cultivars and gamma radiation treatments on number of days taken for full bloom were found to be non-significant.

The delay in bud initiation ultimately resulted in late blooming, which may be due to reduction in the rate of various physiological processes and inhibition of plant growth. Patil (2017) observed 9 days delay for full bloom when treated in 2.5 Krad dose of gamma rays in chrysanthemum. The blooming of dahlia was delayed at untreated plants. These results are in conformity with work of Misra *et al*. 2009 in chrysanthemum, Kole and Meher (2005) in zinnia and Banerji *et al*. (1994) in gladiolus.

Table 4.16: Effect of gamma radiation on number of days taken for full bloom in dahlia cultivars

Radiation dose / Cultivar	Number of days taken for full bloom				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	9.97	7.48	6.41	6.48	7.58
Kenya Yellow	10.49	9.22	8.94	8.15	9.20
Kenya Original	10.03	9.03	8.23	7.66	8.73
Mean	10.16	8.58	7.86	7.43	
	CD at 5%			**S.Em±**	
Radiation Dose	0.50			0.17	
Cultivar	0.44			0.15	
R×C	NS			0.30	

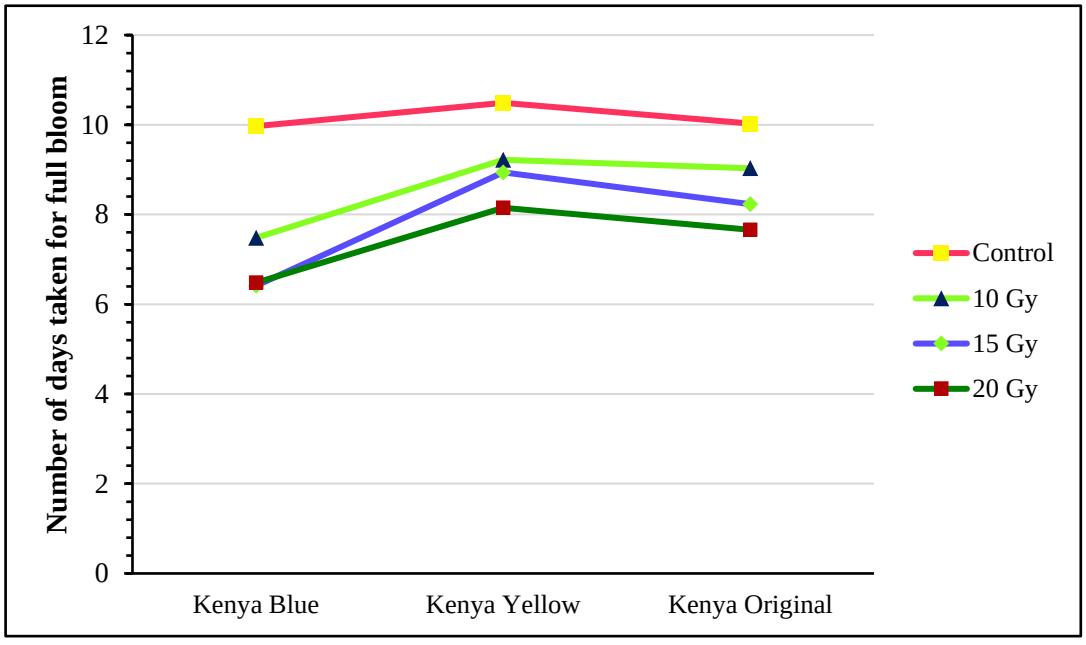

Fig. 4.16: Effect of gamma radiation on number of days taken for full bloom in dahlia cultivar

4.1.3.4 Flower diameter (cm)

The data pertaining to the effect of gamma radiations on the flower diameter have been presented in Table 4.17 and Fig 4.17. It is evident from the data that the effect of gamma radiation doses and different cultivars on flower diameter were recorded highly significant, as regards to different gamma radiation doses, un-irradiated plants had significantly larger flower size (16.53 cm) followed by treatment of 10 Gy gamma dose (14.62 days) while exposure to gamma rays reduced the flower size significantly. However, the higher dose (20 Gy) of gamma radiation treatment recorded lowest flower diameter (10.96 cm). Among the cultivars, Kenya Blue exhibited significantly maximum flower diameter (15.24 cm), whereas, minimum flower diameter was recorded in cultivar Kenya Original (12.32 cm).

The critical perusal of data revealed that the interaction effect of different dahlia cultivars and gamma radiation doses were found to be non-significant on flower diameter.

The flower size was reduced drastically when treated with higher doses of gamma radiations, this might be reduction in vegetative growth due to physiological, morphological and cytological disturbance by gamma irradiation (Singh and Bala, 2015). The findings on size of florets are supported by the findings of Majumder *et al.* (2018) in marigold, Kumari *et al.* 2013 in chrysanthemum and Hamatani *et al.* (2001) in dahlia. The decrease in flower head size could be attributed to the poor growth of plant on the irradiated plants due to radiation damage.

Table 4.17: Effect of gamma radiations on flower diameter (cm) in dahlia cultivars

Radiation dose / Cultivar	Flower diameter (cm)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	18.18	16.36	14.18	12.26	15.24
Kenya Yellow	16.02	14.91	13.15	10.54	13.65
Kenya Original	15.38	12.60	11.22	10.09	12.32
Mean	16.53	14.62	12.85	10.96	
	CD at 5%			**S.Em±**	
Radiation Dose	0.54			0.19	
Cultivar	0.47			0.16	
R×C	NS			0.32	

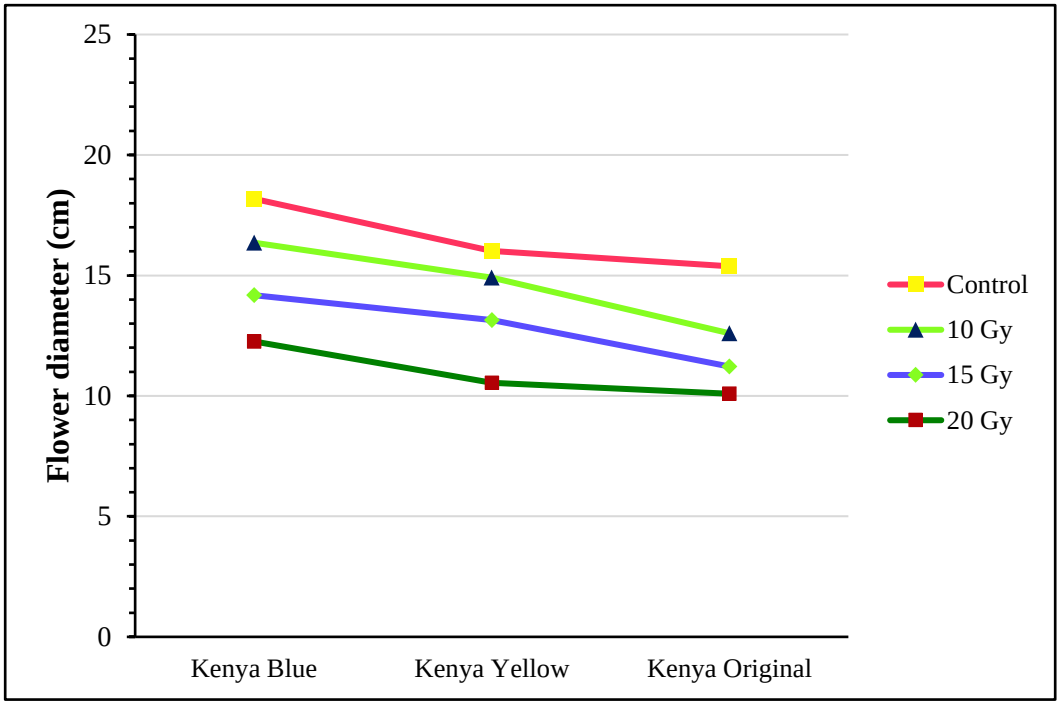

Fig. 4.17: Effect of gamma radiations on flower diameter (cm) in dahlia cultivars

4.1.3.5 Number of ray florets flower^{-1}

The data presented in Table 4.18 and Fig. 4.18 reveals that there was significant effect of gamma radiations, cultivars their interactions on number of ray florets flower^{-1}. The treatment of plants with gamma radiation caused significant reduction in number of ray florets flower^{-1}, untreated plants recorded significantly maximum number of ray florets flower^{-1} (143.20), which was significantly higher than the rest of the treatments. However, increase in gamma radiation dose beyond 10 Gy caused significant reduction in ray floret number. The higher gamma radiations dose (20 Gy) resulted in minimum number of ray florets flower^{-1} (87.33). As respect to different cultivars of dahlia, Kenya Blue exhibited significantly maximum number of ray florets flower^{-1} (125.37), whereas, minimum number of ray florets flower^{-1} were observed in cultivar Kenya Original (99.93).

Untreated plants of cultivar Kenya Blue exhibited maximum number of ray florets flower^{-1} (158.42) followed by interaction of Kenya Yellow with 10 Gy treatment (145.41). However, minimum number of ray florets flower^{-1} (81.42) was recorded in interaction of Kenya Original and 20 Gy gamma radiation treatment, which was statistically *at par* with interaction of Kenya Yellow and 20 Gy treatment (83.75).

There was drastic reduction in ray florets number flower^{-1} at higher dose of gamma rays (20 Gy) as compared to control. Decrease in ray florets number with higher doses is mainly due to disturbance in plant physiological process and reduction in vegetative growth of plant. Singh *et al.* (2015) also recorded increase in ray florets number at lower dose of gamma radiations in marigold whereas, number of flower heads reduced drastically at higher doses of gamma rays. These results are in conformity with the findings of Pal (2015), who recorded maximum number of ray florets flower^{-1} in untreated plants and reduction in ray florets at higher doses of gamma rays in dahlia. These results are also in parallel line with findings of Patil *et al.* (2015) in chrysanthemum and Misra and Choudhary (1979) in gladiolus.

Table 4.18: Effect of gamma radiations on number of ray florets flower^{-1} in dahlia cultivars

Radiation dose / Cultivar	No. of ray florets flower^{-1}				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	158.42	134.50	111.75	96.82	125.37
Kenya Yellow	140.70	145.41	115.50	83.75	121.34
Kenya Original	130.50	96.66	91.16	81.42	99.93
Mean	143.20	125.52	106.14	87.33	
	CD at 5%			**S.Em±**	
Radiation Dose	1.92			0.67	
Cultivar	1.66			0.58	
R×C	3.33			1.16	

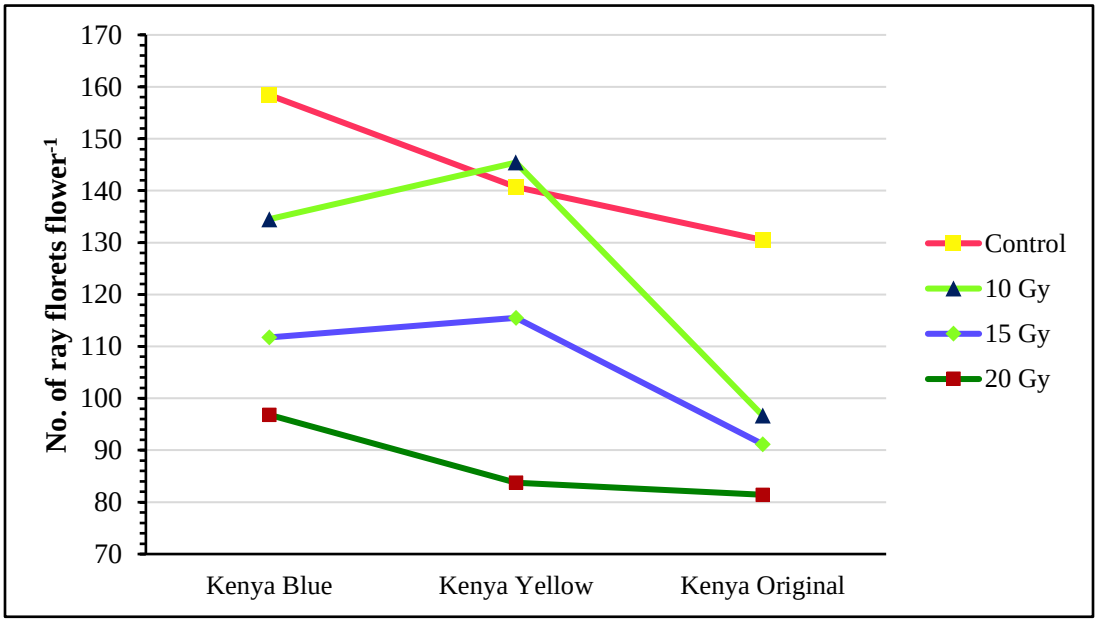

Fig. 4.18: Effect of gamma radiations on number of ray florets flower^{-1} in dahlia cultivars

4.1.3.6 Flower stalk length

The data pertaining to effect of gamma rays, cultivars and their interactions on flower stalk length are presented in Table 4.19 and Fig. 4.19. The perusal of the data depicts that, effect of gamma radiations was significant on flower stalk length, untreated plants resulted significantly longest flower stalk length (47.92 cm) followed by 10 Gy treatment (40.87 cm), whereas, shortest flower stalk length of dahlia (36.24 cm) recorded in plants treated with 20 Gy gamma rays followed by 15 Gy of gamma radiation treatment (39.62 cm). Cultivars differences for flower stalk length of dahlia were also highly significant, flower stalk length of cultivar Kenya Blue was longest (43.41 cm) followed by Kenya Yellow (41.94 cm), whereas, cultivar Kenya Original produced shortest flower stalk length (38.41 cm).

The result of interaction effect of cultivars and gamma radiation treatments on flower stalk length of dahlia were also showed significant effect. The interactions of all the cultivars with control resulted significantly longer flower stalk length and interaction with higher dose (20 Gy) caused more reduction in flower stalk length in all the cultivars as compared to lower doses, among the interactions, untreated plants of Kenya Blue were longest flower stalk length (53 cm), whereas, cultivar Kenya Original treated with 20 Gy produced shortest flower stalk length (38.41 cm).

The length of flower stalk decreased in all the cultivars with increased dose of mutagen as compared to control. The decrease in quantitative traits has been attributed to physiological disturbances or chromosomal damage of the cells of the plants caused by the mutagens. Dwivedi and Banerji (2008) recorded short flower stalk length in dahlia cultivar ‘Pinki’ treated with higher doses of gamma rays. Dhara and Bhattacharya (1972) also reported that spikes were in general short with lesser number of flowers in the gamma rays treated gladiolus plants. These results are in close conformity with the findings of Misra (1990) and Pal (2015) in gamma irradiated dahlia.

Table 4.19: Effect of gamma radiations on flower stalk length in dahlia cultivars

Radiation dose / Cultivar	Flower stalk length (cm)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	53.00	42.02	40.49	37.06	43.14
Kenya Yellow	48.60	41.58	39.90	37.66	41.94
Kenya Original	42.17	39.00	38.48	34.00	38.41
Mean	47.92	40.87	39.62	36.24	
	CD at 5%			**S.Em±**	
Radiation Dose	0.77			0.27	
Cultivar	0.67			0.23	
R×C	1.34			0.46	

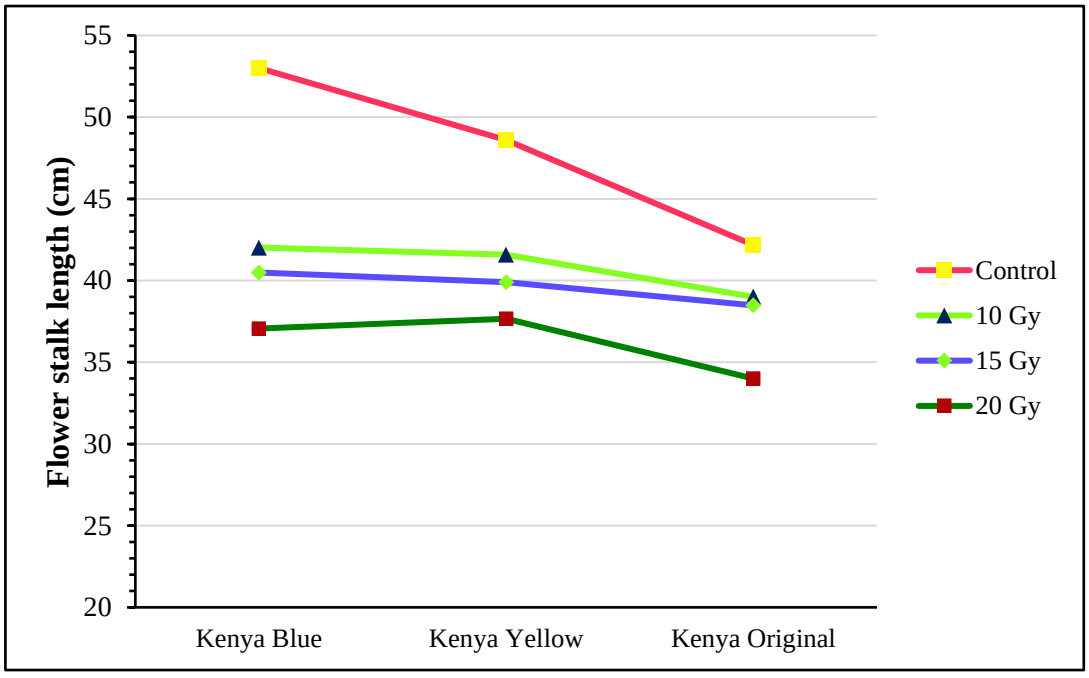

Fig. 4.19: Effect of gamma radiations on flower stalk length in dahlia cultivars

4.1.3.7 Flower stalk diameter (cm)

Observations on the flower stalk diameter were recorded at full bloom stage and data have been presented in Table 4.20 and Fig. 4.20. It is evident from the data that the effect of gamma rays, cultivars and their interaction on flower stalk diameter were found significant. A significant reduction in flower stalk diameter was recorded after gamma radiations, although untreated plants exhibited significantly maximum flower stalk diameter (2.51 cm), which was *at par* with 10 Gy and 15 Gy gamma radiations treatments i.e. 2.48 and 2.45 cm, respectively. Flower stalk diameter was recorded minimum (2.40 cm) in 20 Gy gamma radiation dose, among the cultivars, Kenya Original exhibited highest flower stalk diameter (2.51 cm), which was *at par* with Kenya Blue (2.46 cm). However, minimum flower stalk diameter was observed in cultivar Kenya Yellow (2.42cm).

Interactions among gamma radiation treatments and cultivars were also significant on flower stalk diameter. Interaction of control treatment and cultivar Kenya Blue recorded significantly maximum flower stalk diameter (2.58cm) which were *at par* with interactions of cultivar Kenya Blue with 10 Gy (2.54 cm), Kenya Blue with 10 Gy (2.54 cm), Kenya Original with 15 Gy (2.53 cm), Kenya Original with 10 Gy (2.52 cm), Kenya Original with control (2.49 cm), Kenya Original with 20 Gy (2.49 cm) and Kenya Yellow with control (2.45 cm). However, minimum flower stalk diameter (2.30 cm) was recorded in 20 Gy treated plants of cultivar Kenya Blue.

The flower stalk diameter became narrow at higher doses of gamma rays as compare to untreated plants. Progressive reduction in growth parameters can be interpreted on cytological physiological and anatomical viewpoints. These include interference in normal mitosis and frequent occurrence of mitotic aberrations, inhibition of rate of assimilation and consequent change in the nutrient level in the plant (Ehrenberg, 1995) and inactivation of vital enzymes especially those associated with respiration (Cesarett, 1968). These results are in parallel line with the findings of Rather

and Jhon (1996), who recorded reduced flower stalk diameter due to application of higher gamma doses in Dutch iris.

Table 4.20: Effect of gamma radiations on flower stalk diameter in dahlia cultivars

Radiation dose / Cultivar	Flower stalk diameter (cm)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	2.58	2.54	2.42	2.30	2.46
Kenya Yellow	2.45	2.39	2.40	2.42	2.42
Kenya Original	2.49	2.52	2.53	2.49	2.51
Mean	2.51	2.48	2.45	2.40	
	CD at 5%			**S.Em±**	
Radiation Dose	0.07			0.02	
Cultivar	0.06			0.02	
R×C	0.12			0.04	

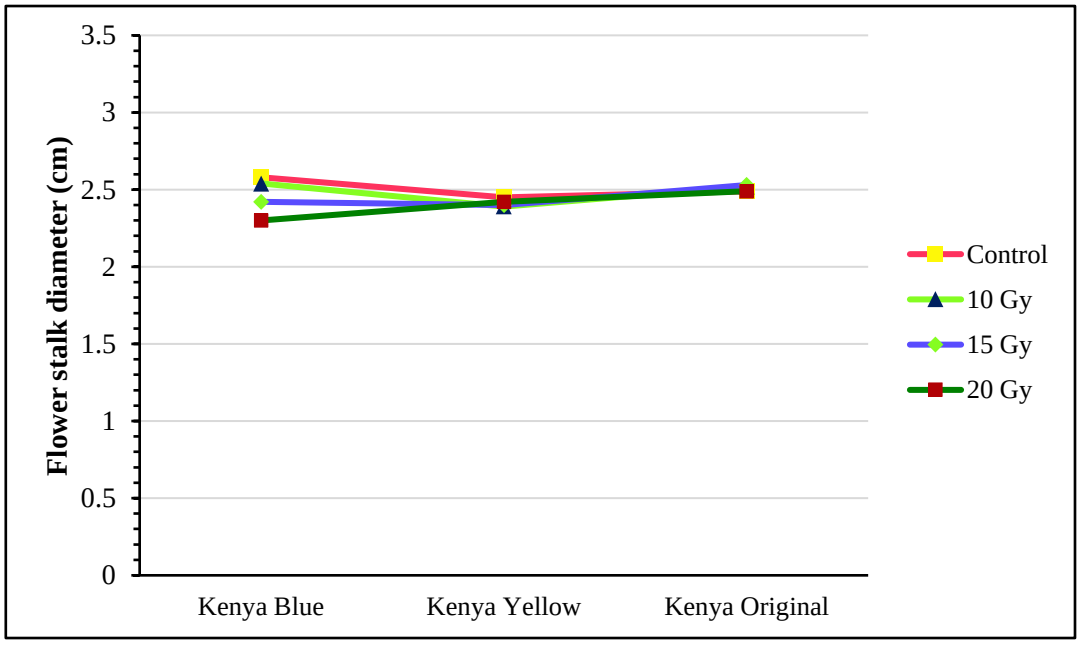

Fig. 4.20: Effect of gamma radiations on flower stalk diameter in dahlia cultivars

4.1.3.8 Longevity of flowers (days)

It is evident from the data presented in Table 4.21 and Fig. 4.21, the effect of gamma radiations and cultivars was significant, whereas, interactions effect of cultivars and gamma radiations was non-significant on longevity of flowers of dahlia. Longevity of flower was significantly longer in untreated plants and subsequent delayed with increased dose of gamma radiations. Untreated plants lasted for 10.31 days while plants treated with 20 Gy dose remained for 7.53 days. Plants treated with 20 Gy gamma rays recorded smallest longevity periods (7.53 days) as compared to other treatment doses. As regards to various cultivar, Kenya Blue showed significantly least longevity of 8.50 days, which was *at par* with cultivar Kenya Original (8.71 days). However, maximum longevity was exhibited by cultivar Kenya Yellow (9.27 days).

A critical rummage of data reveals that interactions among radiations doses and cultivars were non-significant on longevity of flowers, treated plants of cultivars had least longevity and maximum time for longevity of flowers was observed in untreated plants.

The enhanced effect on longevity of the dahlia flowers may be due to the positive effect of lower doses of gamma radiations on growth hormones. The delay in flowering ultimately resulted in least longevity, which may be due to reduction in the rate of various physiological processes and inhibition of plant growth. These results are in conformity with work of Dube *et al.* (1980) in dahlia, Khan *et al.* (2015) in chrysanthemum and Shrivastava *et al.* (2007) in gladiolus.

Table 4.21: Effect of gamma radiations on longevity of flowers (days) in dahlia cultivars

Radiation dose / Cultivar	Longevity of flowers (days)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	10.25	8.92	7.83	7.00	8.50
Kenya Yellow	10.50	9.75	8.92	7.92	9.27
Kenya Original	10.17	8.83	8.17	7.67	8.71
Mean	10.31	9.17	8.31	7.53	
	CD at 5%			**S.Em±**	
Radiation Dose	0.35			0.12	
Cultivar	0.30			0.10	
R×C	NS			0.21	

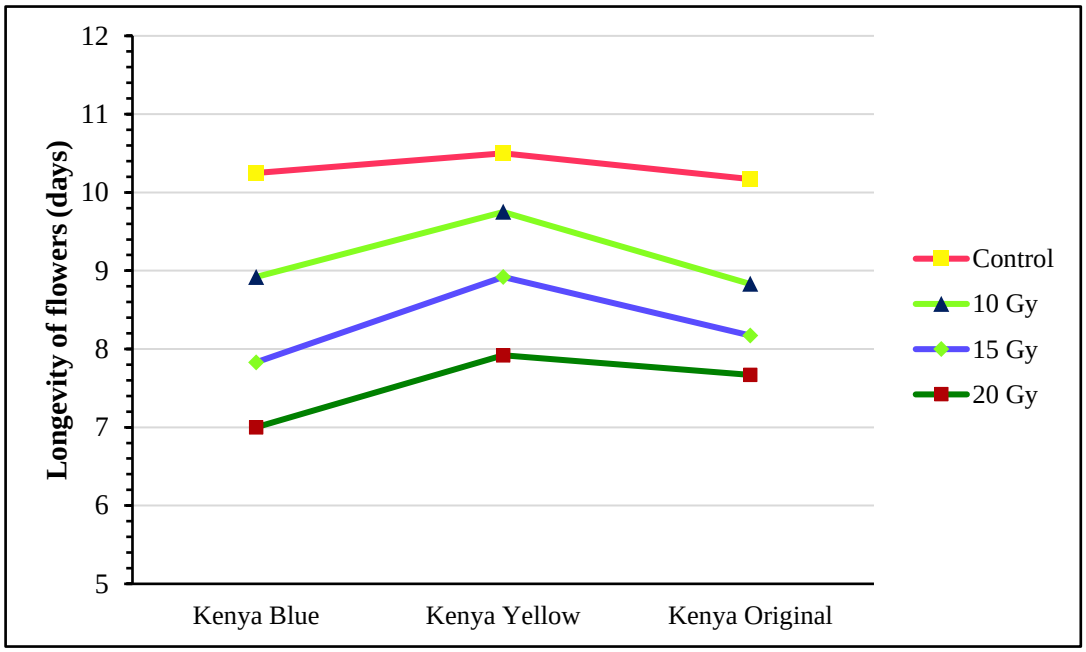

Fig. 4.21: Effect of gamma radiations on longevity of flowers (days) in dahlia cultivars

4.1.3.9 Number of flowers plant^{-1}

The data presented in Table 4.22 and Fig. 4.22 reveals that there was significant effect of gamma radiations, cultivars as well as interactions of gamma radiations and cultivars on number of flowers plant^{-1}. The irradiation of plants with gamma radiation caused significant reduction in number of flowers plant^{-1}, significantly maximum number of flowers plant^{-1} (5.61) were recorded in control and also significantly higher than the rest of treatments. Further, increase in gamma radiation dose caused significant reduction in flower number. The highest doses of gamma radiations (20 Gy) resulted in minimum number of flowers plant^{-1} (2.04). Among the cultivars, Kenya Blue exhibited significantly maximum number of flowers plant^{-1} (4.06), which was statistically *at par* with Kenya Yellow (3.95), whereas, minimum number of flowers plant^{-1} were observed in cultivar Kenya Original (3.04).

The interaction of cultivar Kenya Yellow and control recorded significantly maximum number of flowers plant^{-1} (6.34) followed by untreated plants of cultivar Kenya Blue (5.83). However, the interaction of cultivar Kenya Original with highest dose (20 Gy) caused more reduction in number of flowers (1.58).

The number of flowers got significant reduction with increasing rate of gamma irradiation. The decreases in number of flowers plant^{-1} may be due to decrease in number of branches plant^{-1}. A significant reduction in number of flowers in chrysanthemum cv 'Gulmohar' when exposed to 1.0, 1.5, 2.0, 2.5 and 3.0 kR doses of gamma radiation were recorded by Dilta *et al.* (2003). These results also corroborate with the findings of Pal (2015) in dahlia, Kapadiya *et al*. (2014) and Singh *et al.* (2019) in gladiolus, who recorded maximum number of flowers plant^{-1} in untreated plants and reduction in flowers at higher doses of gamma rays.

Table 4.22: Effect of gamma radiations on number of flowers plant^{-1} in dahlia cultivars

Radiation dose / Cultivar	Number of flowers plant^{-1}				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	5.83	4.58	3.42	2.42	4.06
Kenya Yellow	6.34	4.00	3.33	2.14	3.95
Kenya Original	4.67	3.33	2.58	1.58	3.04
Mean	5.61	3.97	3.11	2.04	
	CD at 5%			**S.Em±**	
Radiation Dose	0.18			0.06	
Cultivar	0.15			0.05	
R×C	0.31			0.11	

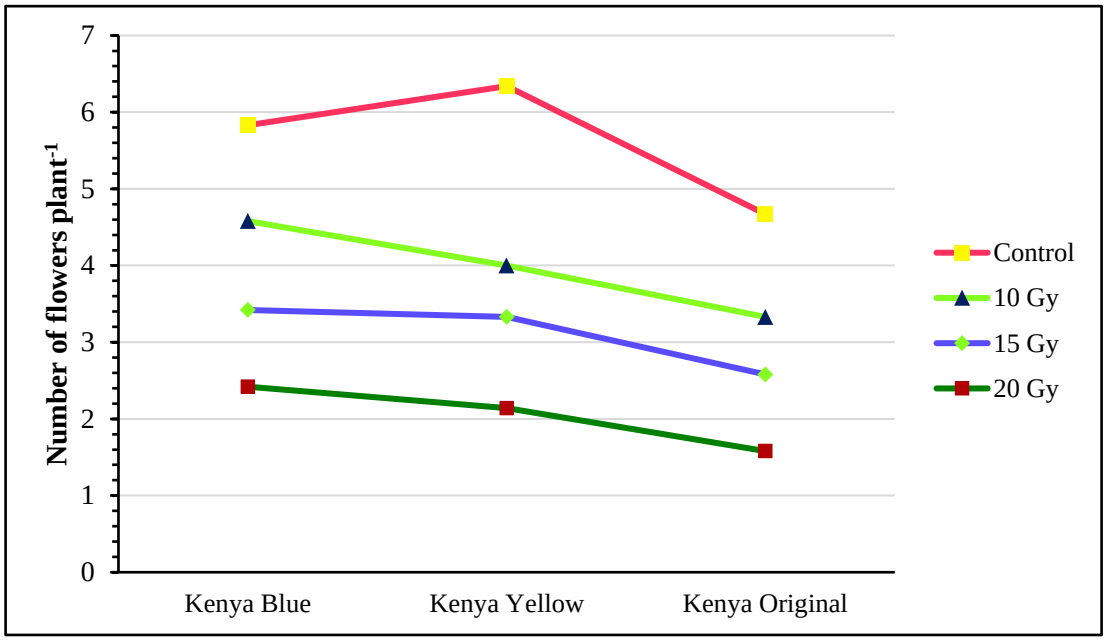

Fig. 4.22: Effect of gamma radiations on number of flowers plant^{-1} in dahlia cultivars

4.1.3.10 Flower weight plant^{-1} (g)

The weight of flower plant^{-1} was influenced by gamma radiation doses and cultivars, the data related to it was depicted in Table 4.23 while graphically represented by Fig. 4.23. The gamma radiation treatments significantly affect the weight of flower plant^{-1}. Among the gamma radiation doses, untreated plants of dahlia recorded significantly higher flowers weight plant^{-1} (44.16 g) followed by 10 Gy gamma radiation treatment (44.16 g), whereas, significantly lowest weight of flower plant^{-1} (37.38 g) was found at 20 Gy gamma radiation treatment. The significant variations obtained in weight of flowers plant^{-1} due to different cultivars of dahlia. Cultivar Kenya Blue had increased weight of flower plant^{-1} (42.48 g) that was significantly maximum then other two cultivars. The mean weight of flower plant^{-1} was found minimum in cultivar Kenya Original (38.75 g).

The data related to weight of flowers plant^{-1} clearly indicates that the interaction of different doses of gamma radiations and cultivars of dahlia did not affect the weight of flowers plant^{-1} significantly.

The flower weight decreased inversely with increasing doses of gamma radiations, reduction in weight was recorded but was not overly affected by gamma radiations. These reductions in flower weight may be due to reduced size of flower head, reduced number of petals in flower head and different types of cultivars (Singh and Bala, 2015). Similar trend was observed by Singh *et al*. (2009) where he found the reduction of flower weight plant^{-1} in African marigold cv. Pusa Narangi Gainda.

Table 4.23: Effect of gamma radiations on flower weight plant^{-1} in dahlia cultivars

Radiation dose / Cultivar	Flower weight plant^{-1} (g)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	45.94	43.46	41.43	39.10	42.48
Kenya Yellow	43.86	41.73	39.67	37.26	40.63
Kenya Original	42.67	38.94	37.64	35.77	38.75
Mean	44.16	41.38	39.58	37.38	
	CD at 5%			**S.Em±**	
Radiation Dose	0.71			0.24	
Cultivar	0.61			0.21	
R×C	NS			0.42	

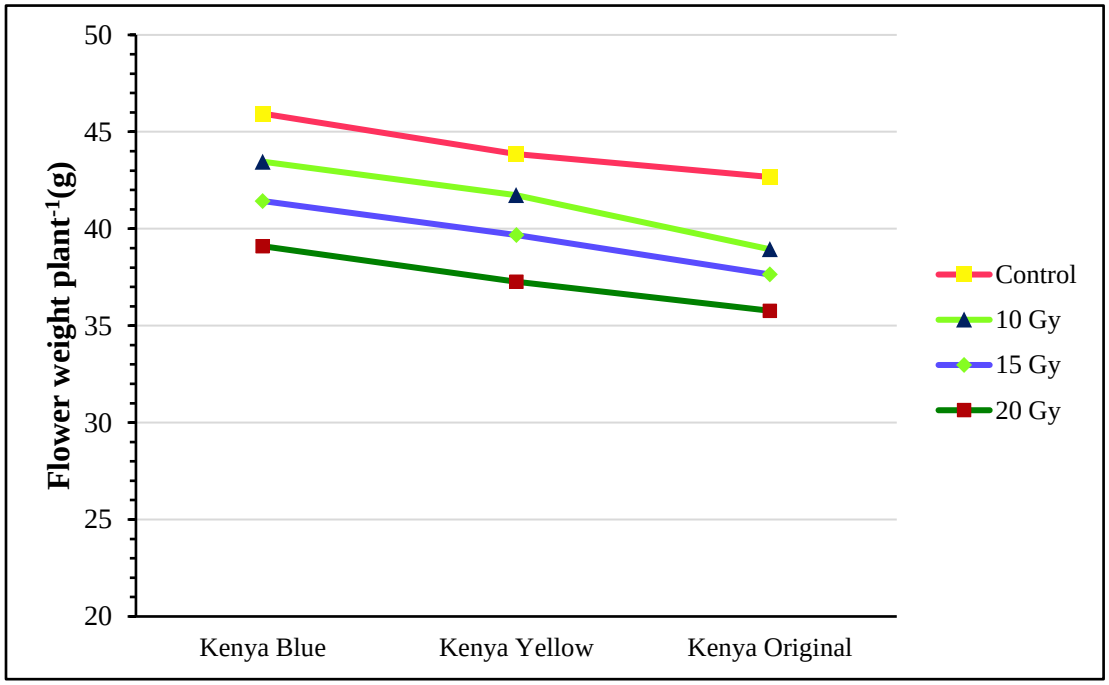

Fig. 4.23: Effect of gamma radiations on flower weight plant^{-1} (g) in dahlia cultivars

4.1.3.11 Duration of flowering (days)

The data related to flowering period have been presented in Table 4.24 and Fig. 4.24. It is evident from the data that the effect of gamma radiations and cultivars was significant on duration of flowering of dahlia whereas, interactions effect of cultivars and gamma radiations was non-significant. A study of the data presented for duration of flowering indicates that, there was decrease in flowering period with increased dose of gamma rays but at 10 Gy slight increase was recorded as compared to control. Plants treated with 10 Gy gamma radiation had significantly longest flowering period (47.51 days) followed by untreated plants (45.83 days). However, the shortest duration of flowering (43.50 days) recorded in 20 Gy gamma irradiated plants, among the cultivars, Kenya Yellow had recorded significantly maximum flowering period (48.93 days), whereas, minimum flowering period (42.15 days) recorded in cultivar Kenya Original followed by Kenya Blue cultivar (45.50 days).

The interactions among radiation doses and cultivars were non-significant on duration of flowering, though Kenya yellow treated with 10 Gy recorded maximum duration of flowering (50 days) and minimum flowering duration was recorded in interaction of Kenya Original with 20 Gy gamma radiation (41.26 days).

There was decrease in flowering period with increased dose of gamma rays, control was slightly lower than radiation dose 10 Gy but higher than other doses. These results are in congruence with the observations made by Singh and Kumar (2013), who reported beneficial effect of lower doses of gamma rays on various flowering parameters, whereas 3.0 Krad to 7.0 Krad dose declined different flowering parameters. Flowering duration may be affected as a result of irradiation because many biosynthetic pathways are believed to be altered, which are directly as well as indirectly associated with the flowering physiology (Mahure *et al.* 2010). Similar results were also reported by Kole and Meher (2005), while studying the effect of gamma rays in zinnia.

Table 4.24: Effect of gamma radiations on duration of flowerings in dahlia cultivars

Radiation dose / Cultivar	Duration of flowering (days)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	46.60	49.35	44.63	41.43	45.50
Kenya Yellow	49.01	50.00	48.92	47.81	48.93
Kenya Original	41.88	43.19	42.25	41.26	42.15
Mean	45.83	47.51	45.27	43.50	
	CD at 5%			**S.Em±**	
Radiation Dose	1.64			0.57	
Cultivar	1.42			0.49	
R×C	NS			0.99	

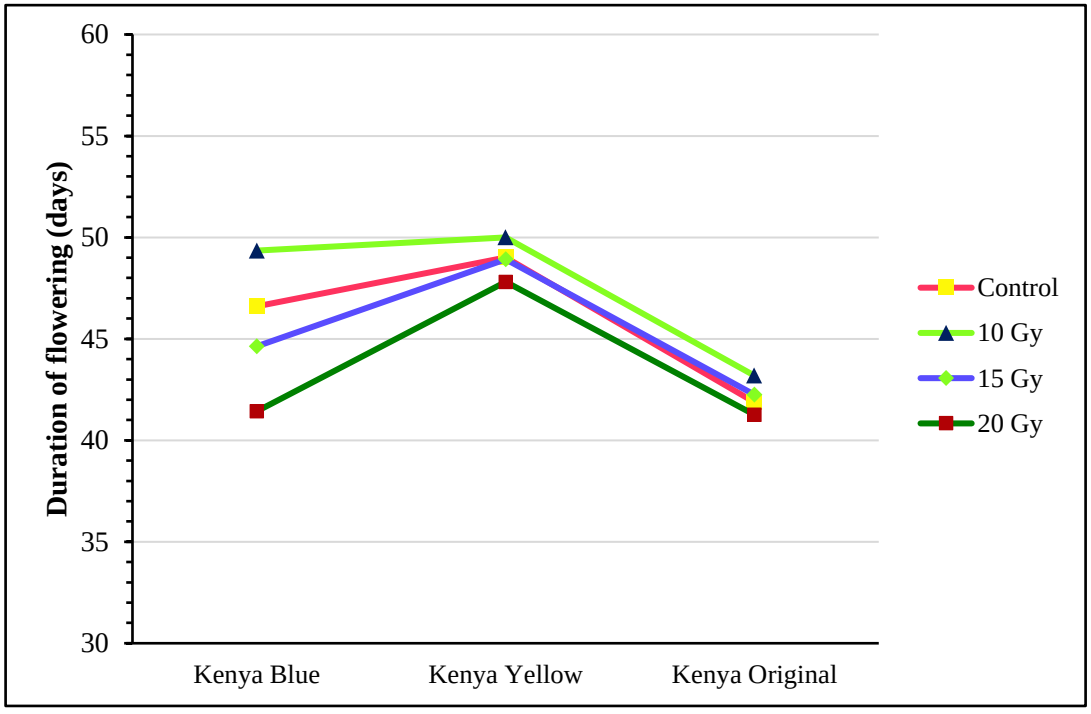

Fig. 4.24: Effect of gamma radiations on duration of flowerings in dahlia cultivars

4.1.4 Effect of gamma radiations on tuber characters

4.1.4.1 Number of tubers plant^{-1}

Data presented in Table 4.25 and Fig. 4.25 for number of tubers plant^{-1} found statistically significant due to different treatments of gamma irradiation and cultivars of dahlia. Untreated plants of dahlia produced significantly more number of tubers plant^{-1} (6.16), followed by 10 Gy gamma radiation treatment (5.14). However, minimum number of tubers plant^{-1} (4.24) recorded with higher dose 20 Gy gamma radiation treatment, among the cultivars studied, Kenya Blue registered significantly maximum number of tubers plant^{-1} (5.79), which was recorded significantly higher than the other two cultivars. While minimum number of tubers plant^{-1} (4.64) was observed with cultivar Kenya Yellow, which was statistically *at par* with cultivar Kenya Original (4.87).

The interaction effect of cultivars and gamma rays treatment was non-significant on number of leaves plant^{-1}. Untreated plants of cultivar Kenya Blue resulted in maximum number of tuber plant^{-1} (6.96) while interaction effect of cultivar Kenya Original and 20 Gy gamma rays treatment resulted in less number of tubers plant^{-1} (3.90).

It is evident that at higher doses of gamma rays, number of tubers plant^{-1} was reduced significantly, whereas at lower dose, it was increased. Van Harten (2002) found similar results that the number of new corms was greater as compared to control in gladiolus. Misra and Bajpai (1983) also reported increase in number of corms per plant at lower dose of mutagens, whereas subsequent increase in dose decreased corm production. The results are in close conformity with the work of Dhaduk (1992) and Isaev *et al*. (1970) in gladiolus.

Table 4.25: Effect of gamma radiations on number of tubers plant^{-1} in dahlia cultivars

Radiation dose / Cultivar	Numbers of tubers plant^{-1}				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	6.96	5.57	5.86	4.77	5.79
Kenya Yellow	5.48	4.75	4.28	4.05	4.64
Kenya Original	6.03	5.11	4.43	3.90	4.87
Mean	6.16	5.14	4.86	4.24	
	CD at 5%			**S.Em±**	
Radiation Dose	0.30			0.10	
Cultivar	0.26			0.09	
R×C	NS			0.18	

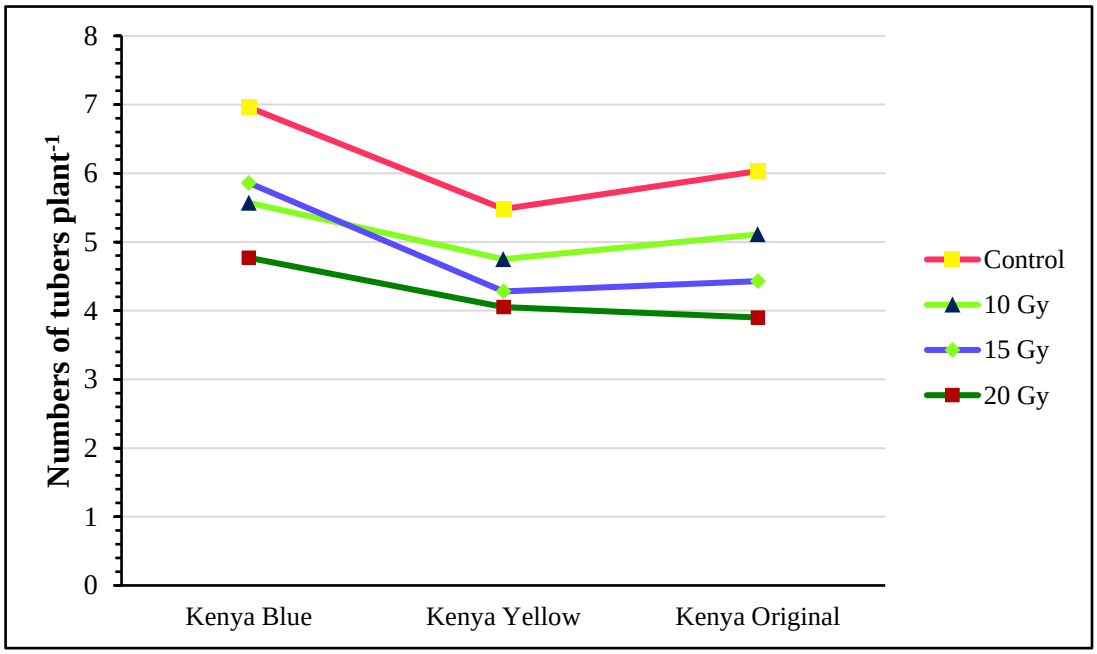

Fig. 4.25: Effect of gamma radiations on number of tubers plant^{-1} in dahlia cultivars

4.1.4.2 Weight of tubers plant^{-1} (g)

It is evident from the data (Table 4.26) that the effect of gamma radiation on weight of tubers plant^{-1} was highly significant. Weight of tubers plant^{-1} decreased with the increase in dose of gamma radiations, significantly maximum weight of tubers plant^{-1} (82.68 g) was observed in untreated plants of dahlia cultivars followed by 10 Gy gamma radiation treatment (75.69 g). Whereas, minimum weight (69.75 g) of tubers plant^{-1} was recorded under 20 Gy gamma radiation treatment. As respect to cultivars, Kenya Yellow exhibited significantly maximum weight of tubers plant^{-1} (78.95 g), which was significantly higher than the other cultivars. However, minimum tuber weight (78.95 g) was exhibited by cultivar Kenya Original (71.40 g) followed by cultivar Kenya Blue (74.89 g).

The interaction among doses of gamma irradiation and different cultivars of dahlia was also found significant. Untreated plants of cultivar Kenya Blue resulted significantly maximum tuber weight plant^{-1} (87.51 g) followed by untreated plants of cultivar Kenya Yellow (81.32 g), while interaction effect of cultivar Kenya Yellow with 20 Gy gamma radiation treatment resulted in minimum tuber weight of tubers plant^{-1} (65.89 g), which was statistically *at par* with interaction of Kenya blue and 20 Gy gamma rays treatment (66.83 g).

It was found from the study that the different treatments of gamma radiations had significant effect on weight of tubers and the significantly maximum weight of tubers was noticed at control. It is clear that the higher doses of gamma rays significantly reduced weight of tubers per plant. Singh *et al*. (2011) noticed similar trend when tuberose was treated with different doses of gamma rays. These results are also in parallel line with the findings of Rather and John (2000), who recorded reduction in weight of bulbs after gamma irradiation of Iris.

Table 4.26: Effect of gamma radiations on weight of tubers plant^{-1} in dahlia cultivars

Radiation dose / Cultivar	Weight of tubers plant^{-1} (g)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	87.51	73.73	71.48	66.83	74.89
Kenya Yellow	81.32	80.77	77.19	76.53	78.95
Kenya Original	79.20	72.58	67.94	65.89	71.40
Mean	82.68	75.69	72.20	69.75	
	CD at 5%			**S.Em±**	
Radiation Dose	1.16			0.40	
Cultivar	1.00			0.35	
R×C	2.01			0.70	

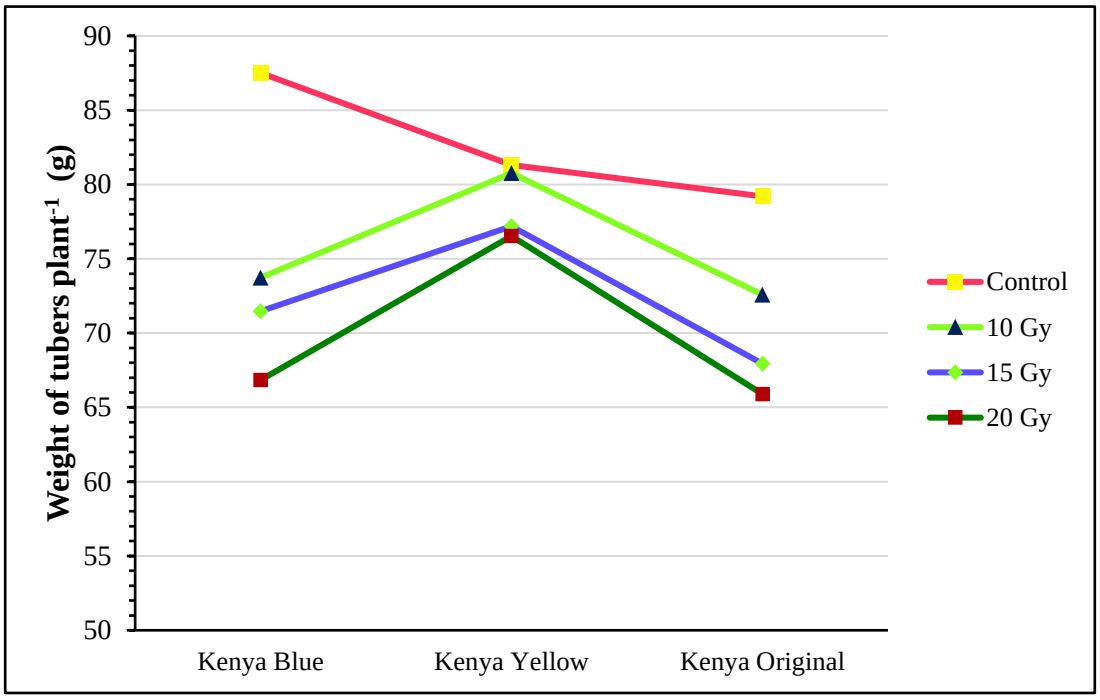

Fig. 4.26: Effect of gamma radiations on weight of tubers plant^{-1} in dahlia cultivars

4.1.4.3 Diameter of tuber (cm)

It is apparent from the data presented in Table 4.27 and Fig. 4.27 that the effect of gamma irradiation on diameter of tuber was highly significant. After studying the data, significantly maximum diameter of tuber (5.05 cm) recorded in untreated plants, which was statistically *at par* with 10 Gy gamma rays treatment (4.77 cm). Whereas, minimum tuber diameter (4.05 cm) was recorded at highest dose i.e. 20 Gy, among the cultivars, Kenya Yellow exhibited significantly maximum diameter of tuber (4.93 cm), which was *at par* with Kenya Blue (4.66 cm). Whereas, minimum diameter of tuber (4.17 cm) was recorded in cultivar Kenya Original.

The interaction effect of doses of gamma irradiation and cultivars was non-significant but here exhibited the maximum diameter of tuber (5.85 cm) observed in untreated plants of cultivar Kenya Yellow.

The size of tuber was increased at lower doses and reduced at higher doses. Similar result was obtained by Banerji *et al.* (1994) in gladiolus where he found the decreasing size of corms with increasing dose. The low yield at higher doses might be due to the reduced vegetative growth as a result of gamma treatments. Reduction in corm diameter after irradiation was also reported by Banerji *at al.* (1994) in gladiolus, when the corms are exposed to different doses of gamma rays.

Table 4.27: Effect of gamma radiations on diameter of tuber in dahlia cultivars

Radiation dose / Cultivar	Diameter of tuber (cm)				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	5.01	4.92	4.72	4.00	4.66
Kenya Yellow	5.85	5.03	4.60	4.25	4.93
Kenya Original	4.28	4.36	4.13	3.90	4.17
Mean	5.05	4.77	4.48	4.05	
	CD at 5%			**S.Em±**	
Radiation Dose	0.33			0.11	
Cultivar	0.29			0.10	
R×C	NS			0.20	

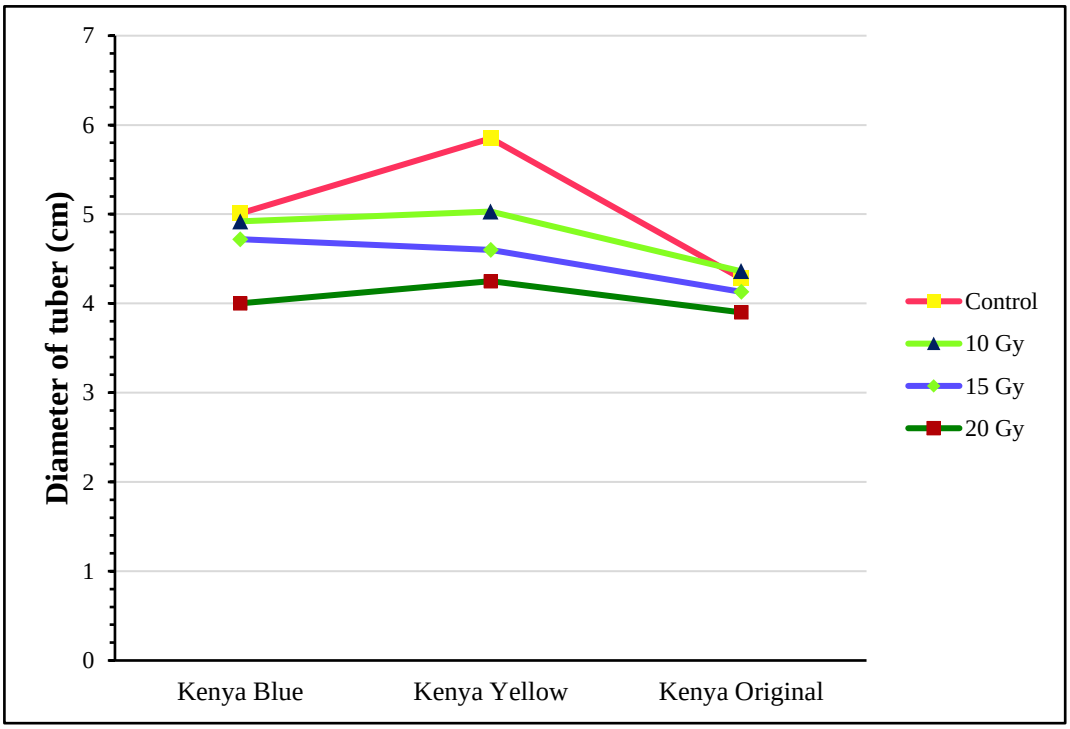

Fig.4.27: Effect of gamma radiations on diameter of tuber in dahlia cultivars

4.1.5 Effect of gamma radiations on physiological characters

4.1.5.1 Leaf chlorophyll content (mg g^{-1})

The observations of leaf chlorophyll content presented in Table 4.28 and Fig. 4.28 were significantly influenced with cultivars and different doses of gamma rays, cultivars and their interaction. Controlled plants recorded significantly maximum leaf chlorophyll content (47.53 mg g^{-1}) followed by 10 Gy treatment of gamma rays (43.11 mg g^{-1}), whereas, minimum leaf chlorophyll content (39.72 mg g^{-1}) obtained under higher dose (20 Gy) gamma rays treatment. The chlorophyll content was significantly affected due to effect of cultivars, significant maximum leaf chlorophyll content (44.69 mg g^{-1}) recorded under cultivar Kenya Blue, which was closely followed by Kenya Yellow (43.98 mg g^{-1}), whereas, minimum leaf chlorophyll content (40.56 mg g^{-1}) was noted with cultivar Kenya Original.

The interaction of cultivars and gamma rays are also highly significant in the leaf chlorophyll content. The data showed that significantly maximum leaf chlorophyll content (50.50 mg g^{-1}) was recorded in untreated plants of Kenya Blue, which was *at par* with untreated plants of cultivar Kenya Yellow (49.51 mg g^{-1}). However, interaction of 20 Gy gamma radiation treatment with Kenya Original recorded minimum leaf chlorophyll content (38.20 mg g^{-1}).

Chlorophyll is a pigment that gives plant their characteristic green colour. Chlorophyll pigments occupy a unique role in physiology, productivity, economy and productivity of green plants (Palta, 1990). Higher doses of gamma radiations caused a great reduction in chlorophyll contents in all the dahlia varieties. All the irradiated plants exhibited less amount of chlorophyll contents as compared to the non-irradiated plants. Giacomelli *et al.* (1967) reported that irradiation accelerated the degradation of chlorophyll in leaves. These results are also in agreement with Hasbullah *et al.* (2012), where chlorophyll was visually insensitive to low doses gamma irradiation.

Table 4.28: Effect of gamma radiations on leaf chlorophyll content in dahlia cultivars

Radiation dose / Cultivar	Leaf chlorophyll content (mg g^{-1})				
	Control	**10 Gy**	**15 Gy**	**20 Gy**	**Mean**
Kenya Blue	50.50	45.15	42.63	40.48	44.69
Kenya Yellow	49.51	43.86	42.08	40.49	43.98
Kenya Original	42.58	40.32	41.15	38.20	40.56
Mean	47.53	43.11	41.95	39.72	
	CD at 5%			**S.Em±**	
Radiation Dose	0.72			0.25	
Cultivar	0.62			0.21	
R×C	1.24			0.43	

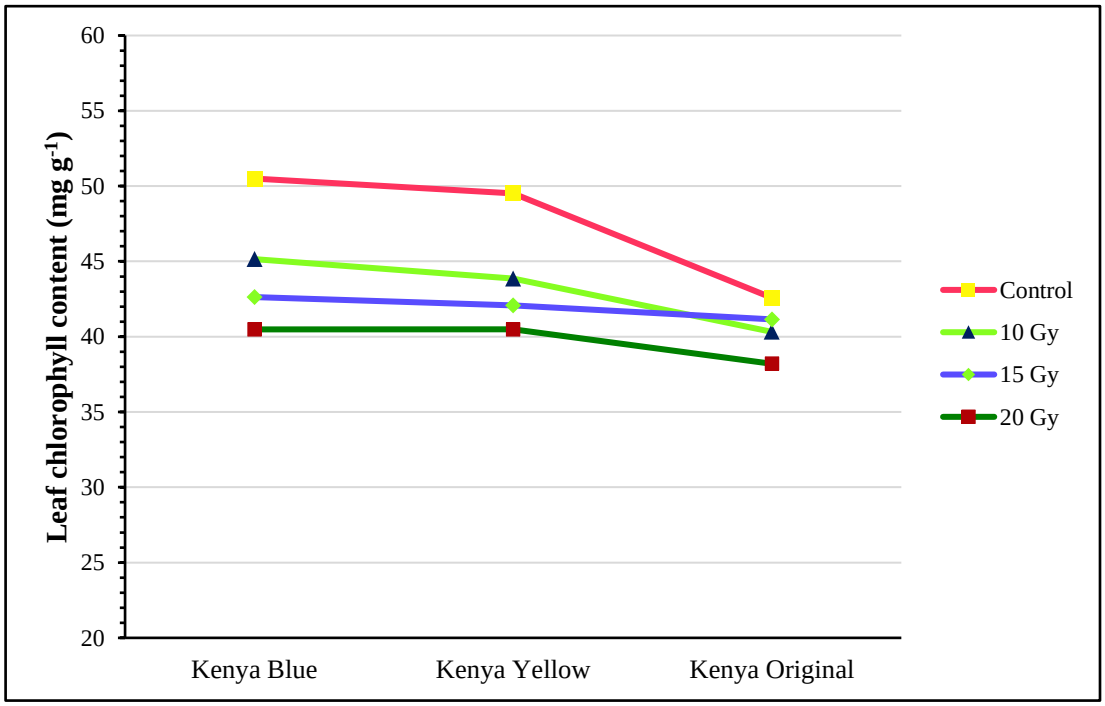

Fig. 4.28: Effect of gamma radiations on leaf chlorophyll content in dahlia cultivars

4.1.6 Screening of mutants in vM_1 population and their characterization

In vM_1 generation, total 24 mutants were screened out for ornamental traits (colour) from three cultivars of dahlia. Most of the colour mutants were in the form of solid and chimera mutants. All the mutants were recorded in 10 Gy gamma rays irradiated plants. The observation was recorded on vegetative and floral characters of the mutants screened after gamma radiations in all the cultivars of dahlia under study during 2018-19 and mean values of mutants are presented in Table 4.29 to 4.31 and Plate 4.1, 4.2, 4.2a and 4.3.

4.1.6.1 Mutants of Kenya Blue cultivar

This cultivar produced six mutants (KBM_1 – KBM_6) which were screened, tagged and checked for the stability of the characters in next generation. All the mutants of this cultivar were developed at 10 Gy dose of gamma radiations (Table 4.29 and Plate 4.1).

Mutant KBM_1

The plant height of mutant (11.5 and 41.9 cm) was lesser than of the original cultivar at 30 DAT and 90 DAT. The number of leaves and number of branches plant^{-1} was less (61 and 5, respectively) than the original. Mutant KBM_1 took slightly longer time for days taken for first bud appearance than the original cultivar with 82 days. Number of days taken for flower opening and number of days taken for full bloom took lesser time (20 and 7 days, respectively) than the original cultivar. The flower diameter and number of ray florets flower^{-1} were lesser than the original cultivar *i.e.* 12.67 cm and 110 cm, respectively. The longevity of flowers 6 days was less than the original cultivar. However, the duration of flowering (48 days) was more than the original cultivar. The number of flowers plant^{-1} (6) and weight of the mutant flower (38.63 g) were reduced than the original. The colour of flower was matched as Red Purple Group 68 A + Yellow Group 4 C with R.H.S. Colour Chart. The changes were recorded in

Table 4.29: Mean performance of mutants of Kenya Blue cultivar in vM_1 generation

Characters	Parent	Mutants					
		KBM_1	KBM_2	KBM_3	KBM_4	KBM_5	KBM_6
Radiation doses	0.0 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy
Plant height (30 DAT)	14.16	11.5	10.5	9.53	17.68	15.5	8.9
Plant height (90 DAT)	48.39	41.9	39.65	46.85	50.1	51.70	37.82
Total number of branches plant^{-1}	5.34	5	4	5	6	4	5
Days taken for first bud appearance (days)	81.56	82	69	87	66	78	71
Number of days taken for flower opening (days)	21.34	20	16	19	12	14	16
Number of days taken for full bloom (days)	7.31	7	5	5	4	7	3
Flower diameter (cm)	18.9	12.67	11.80	11.71	12.76	14.72	13.8
Number of ray florets flower^{-1}	157	110	104	102	113	142	139
Longevity of flower (days)	9.97	6	7	6	6	7	8
Numbers of flower plant^{-1}	6.64	6	7	6	5	4	6
Duration of flowering (days)	47.8	48	51	46	49	56	51
Flower colour as per RHS Colour Chart	RPG 68B	RPG 68 A + YG C4	RPG N74 B + RPG 63 D	RPG N74 B + RPG 69 D	RPG N57 B	RPG 73 A + YG 11 D	YG 9 D + RPG 74 D
Flower form	GD	SC	SD	SD	SD	MD	MD

GD: Giant Decorative, SC: Semi Cactus, SD: Small Decorative, MD: Medium Decorative, RPG: Red Purple Group, YG: Yellow Group

flower form from giant decorative to semi cactus type in this mutant than the original flower form.

Mutant KBM_2

The mutant KBM_2 grew to a plant height of 10.5 cm and 39.65 cm which was lesser than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} and number of branches plant^{-1} was less (58 and 4, respectively) than the original cultivar. Mutant KBM_2 took lesser time for days taken for first bud appearance, number of days for flower opening and number of days taken for full bloom than the original cultivar with (69, 16 and 5 days respectively). The flower diameter and number of ray florets flower^{-1} were lesser than the original cultivar *i.e.* 11.80 cm and 104 cm, respectively. The longevity of flowers 7 days and flower weight plant^{-1} (41.54 g) was less than that of the original cultivar. However, the duration of flowering (51 days) and number of plant^{-1} (7) was more than the original cultivar. The weight of mutant flower plant^{-1} (41.54 g) were reduced than the original. The colour of flower was matched as Red Purple Group N74 B + Red Purple Group 63 D with R.H.S. Colour Chart. The changes were recorded in flower form from giant decorative to small decorative type in mutant KBM_2 than the original form.

Mutant KBM_3

The mutant attained a plant height 9.53 cm and 46.85 cm was lesser than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} and number of branches plant^{-1} was less (69 and 5, respectively) than the original cultivar. This mutant took longer time for days taken for first bud appearance than the original cultivar with 87 days. The number of days for flower opening and number of days taken for full bloom were lesser than the original cultivar *i.e.* 19 and 5 days, respectively. The flower diameter (11.71 cm), number of ray florets flower^{-1} (102), longevity of flowers (6 days), flower weight plant^{-1} (45.05 g), duration of flowering (46 days) and number of flowers plant^{-1} (6) were also lesser than the original cultivar. The colour of flower was matched as Red Purple Group N74 B + Red Purple Group 69 D with R.H.S. Colour Chart. The

changes in flower form was recorded from giant decorative to small decorative in mutant KBM_3 than the original form.

Mutant KBM_4

The mutant KBM_4 grew to a plant height 17.68 cm and 50.1 cm which were higher than that of the original cultivar at 30 DAT and 90 DAT. The number of leaves $plant^{-1}$ 76 was higher than the original cultivar while number of branches $plant^{-1}$ 5 was less than the original cultivar. This mutant took smaller time for number of days taken for first bud appearance (87 days), the number of days for flower opening (12 days), the number of days taken for full bloom (4 days), flower diameter (12.76 cm), number of ray florets $flower^{-1}$ (113), longevity of flowers (6 days), flower weight $plant^{-1}$ (38.68 g) and number of flowers $plant^{-1}$ (5) were lesser than the original cultivar. However, duration of flowering (49 days) were higher than the original cultivar. The colour of flower was matched as Red Purple Group N57 B with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to small decorative in mutant KBM_4 than the original form.

Mutant KBM_5

The plant height of mutant was recorded as 15.5 cm and 51.70 cm which were higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves and number of branch $plant^{-1}$ was less (54 and 4, respectively) than the original cultivar. Mutant KBM_5 took lesser time for days taken for first bud appearance (78 days) and the number of days taken for flower opening (14 days) than the original cultivar. Likewise, the number of days taken for full bloom and longevity of flowers took lesser time than original cultivar with 7 days. The flower diameter (14.72 cm) and number of ray florets $flower^{-1}$ (142) was lesser than the original cultivar. However, the weight of mutant flower $plant^{-1}$ (47.23 g) and duration of flowering (56 days) were higher than original cultivar but number of flowers $plant^{-1}$ (4) were lesser than the original cultivar. The colour of flower was matched as Red Purple Group 73 A + Yellow Group 11 D with

R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to medium decorative in mutant KBM_5 than the original form.

Mutant KBM_6

The mutant KBM_6 grew to a plant height of 8.9 cm and 37.82 cm which was lesser than of the original cultivar at 30 DAT and 90 DAT. The number of leaves and number of branches plant^{-1} were less (51 and 5, respectively) than the original cultivar. Mutant KBM_6 took smaller time for days taken for first bud appearance (71 days), the number of days for flower opening (16 days) and days taken for full bloom (3 days) than the original cultivar. The flower diameter and number of ray florets flower^{-1} were less (13.8 cm and 139, respectively) than the parental cultivar. The longevity of flowers was less (8.65 days) than that of the original cultivar. The number of flowers plant^{-1} were reduced to 6 as compared to the original cultivar. Also the duration of flowering (51 days) and flower weight plant^{-1} (46.1 g) were lesser than the original cultivar. The colour of flower was matched as Yellow Group 9 D + Red Purple Group 74 D with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to medium decorative in mutant KBM_6 than the original form.

4.6.2 Mutants of Kenya Yellow cultivar

This cultivar produced fifteen mutants (KYM_1- KYM_{15}) which were screened, tagged and checked for the stability of the characters in next generation. All the mutants of this cultivars were also developed at 10 Gy dose of gamma radiations (Table 4.30 and Plate 4.2 and 4.2a).

Mutant KYM_1

The mutant KYM_1 grew to a plant height 12.5 cm and 31.34 cm which was lesser than of the original cultivar at 30 DAT and 90 DAT. Also the number of leaves plant^{-1} 51 was lesser than the original. However, number of branches plant^{-1} (6) was higher than the original cultivar. Mutant KYM_1 took smaller time for days taken for first bud appearance and number of days for flower opening than the original cultivar

corresponding to 81 and 19 days, respectively. The longevity of flowers was less (9 days) than that of the original cultivar. Days taken for full bloom (5 days) and duration of flowering (51 days) was lesser than the parental cultivar. The flower diameter (12.01 cm), number of ray florets flower^{-1} (108), number of flowers plant^{-1} (5) and flower weight plant^{-1} (38.01 g) were also lesser than the original cultivar. The colour of flower was matched as White Group NN155 D + Yellow Group 3 C with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to small decorative in mutant KYM_1 than the original form.

Mutant KYM_2

The plant height of mutant was recorded as 13.8 cm and 37.71 cm which was smaller than that of the original cultivar at 30 DAT and 90 DAT. The number of leaves and number of branches plant^{-1} (62 and 4, respectively) were less than the original cultivar. Plants of this mutant took lesser time for days taken for first bud appearance and number of days for flower opening than the original cultivar with 64 and 18 days, respectively. Days taken for full bloom and longevity of flowers were reduced marginally to 7 and 10 days as compared to the original cultivar. The longevity of flowers was less than that of the original cultivar *i.e.* 10 days. Likewise, duration of flowering (48 days) was less than the parental cultivar. The flower diameter (16.34 cm), number of ray florets flower^{-1} (149), number of flowers plant^{-1} (3) and flower weight plant^{-1} (44.35 g) were lesser than the original cultivar. The colour of flower was matched as Yellow Group 9 D with R.H.S. Colour Chart. No change was recorded in flower from in mutant KYM_2 than the original form.

Mutant KYM_3

The mutant KYM_3 grew to a plant height 10.5 cm and 38.64 cm which was lesser than of the original cultivar at 30 DAT and 90 DAT. The number of leaves and number of branch plant^{-1} (64 and 3, respectively) were less than the original cultivar. This mutant took less time for days taken for first bud appearance (82 days) and higher time (22days) for flower opening. Days taken for full bloom (7 days), longevity of flowers (10 days)

and duration of flowering (48 days) took the smaller time than the parent cultivar. Likewise, the flower diameter (13.97 cm), number of ray florets flower^{-1} (138), number of flowers plant^{-1} (4) and flower weight plant^{-1} (40.32 g) were lesser than the original cultivar. The colour of flower was matched as Yellow Group 7 A with R.H.S. Colour Chart. No change was recorded in flower from in mutant KYM_3 than the original form.

Mutant KYM_4

The mutant attained a plant height of 10.75 cm and 35.33 cm which was less than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (85) were higher and number of branches plant^{-1} was reduced to 4. This mutant took lesser time for days taken for first bud appearance (75 days), the number of days for flower opening (13 days), days taken for full bloom (4 days) and longevity of flowers (8 days). The flower diameter, number of ray florets flower^{-1} and flower weight were lesser than the original cultivar *i.e.* 13.8 cm, 117 and 38.65 g, respectively. The number of flowers plant^{-1} were reduced to 4 as compared to the original cultivar. The duration of flowering (49 days) was less than the original cultivar. The colour of flower was matched as Orange Red Group N34 B + Yellow Group 1 B with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to small decorative in mutant KYM_4 than the original form.

Mutant KYM_5

The mutant KYM_5 grew to a plant height of 13.91 cm and 40.55 cm which was lesser than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} and number of branch plant^{-1} (77 and 6, respectively) were more than the original cultivar. This mutant took smaller time for days taken for first bud appearance (78 days), the number of days for flower opening (14 days) and days taken for full bloom (6 days). Likewise, longevity of flowers and duration of flowering (11 and 49 days, respectively) were less than the original cultivar. The flower diameter, number of ray florets flower^{-1} and flower weight were reduced to 16.32 cm, 147 and 42.29 g as compared to the

Table 4.30: Mean performance of screened out mutants of Kenya yellow cultivar in vM_1 generation

Characters	Parent	Mutants						
		KYM_1	**KYM_2**	**KYM_3**	**KYM_4**	**KYM_5**	**KYM_6**	**KYM_7**
Radiation doses	0.0 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy
Plant height (30 DAT)	14.65	12.5	13.8	10.5	10.75	13.91	13.35	14.25
Plant height (90 DAT)	45.66	31.34	37.71	38.64	35.33	40.55	41.8	41.93
Total number of branches $plant^{-1}$	5	6	4	3	4	6	5	5
Days taken to first bud appearance (days)	82.9	81	64	82	75	78	66	71
Number of days taken for flower opening (days)	19.67	19	18	22	13	14	16	14
Number of days taken for full bloom (days)	8	5	7	7	4	8	8	4
Flower diameter (cm)	16.51	12.01	16.34	13.97	13.8	16.32	16.45	13.38
Number of ray florets $flower^{-1}$	158	108	149	138	117	147	155	113
Longevity of flower (days)	12	9	10	10	8	11	11	8
Numbers of flower $plant^{-1}$	5.66	5	3	4	4	3	4	5
Duration of flowering (days)	51.36	51	48	48	49	49	44	45
Flower colour as per RHS Colour Chart	YG 3 A	WG NN155 D + YG 3 C	YG 9 D	YG 7 A	ORG N34 B + YG 1 B	YG B 5 + YOG 22 B	YG 5 C + RG 48 D	RG 51 A + GYG 1 A
Flower form	GD	SD	GD	GD	SD	SC	SC	SC

GD: Giant Decorative, SC: Semi Cactus, SD: Small Decorative, YG: Yellow Group, WG: White Group, ORG: Orange Red Group, YOG: Yellow Orange Group, RG: Red Group, GYG: Green Yellow Group

Table 4.30 Contd……

Characters	Parent	Mutants							
		KYM_8	**KYM_9**	**KYM_{10}**	**KYM_{11}**	**KYM_{12}**	**KYM_{13}**	**KYM_{14}**	**KYM_{15}**
Radiation doses	0.0 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy
Plant height (30 DAT)	14.65	13.33	15.13	16.85	18.9	15.33	9.1	8.9	15.65
Plant height (90 DAT)	45.66	40.66	51.85	50.55	50.33	49.45	39.8	38.9	42.3
Total number of branches $plant^{-1}$	5	3	4	5	3	4	4	7	6
Days taken to first bud appearance (days)	82.9	64	73	66	76	64	78	69	81
Number of days taken for flower opening (days)	19.67	12	14	14	13	19	17	21	19
Number of days taken for full bloom (days)	8	7	4	5	7	6	6	8	6
Flower diameter (cm)	16.51	18.37	13.5	13.3	11.99	15.34	10.42	12.86	10.64
Number of ray florets $flower^{-1}$	158	167	111	109	121	132	108	129	109
Longevity of flower (days)	12	10	9	8	7	7	6	8	6
Numbers of flower $plant^{-1}$	5.66	4	5	5	3	4	4	5	3
Duration of flowering (days)	51.36	48	55	48	47	50	51	53	47
Flower colour as per RHS Colour Chart	YG 3 A	RPG 72 C + YG 5 B	WG NN155 D + PG 77 D	YG 2 D + Pink Group NN74 D	YG 154 B + ORG 34 D	GYG 1 B + YG 12 C	OG 24 C	WG NN155 A + PG 77 B	WG NN155 C
Flower form	GD	GD	SD	SD	SD	GD	SD	MD	MD

GD: Giant Decorative, SC: Semi Cactus, SD: Small Decorative, MD: Medium Decorative, RPG: Red Purple Group, YG: Yellow Group, WG: White Group, ORG: Orange Red Group, OG: Orange Group, PG: Purple Group, GYG: Green Yellow Group

original cultivar. The number of flowers plant^{-1} were reduced to 3 as compared to the original cultivar. The colour of flower was matched as Yellow Group B 5 + Yellow Orange Group 22 B with R.H.S. Colour The changes in flower form was recorded from giant decorative to semi cactus in mutant KYM_5 than the original form.

Mutant KYM_6

The mutant attained a plant height of 13.35 cm and 41.8 cm which was lesser than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} and number of branches plant^{-1} (63 and 4, respectively) were less than the original cultivar. In this mutant, plant took lesser time for days taken for first bud appearance (66 days), the number of days for flower opening (16 days) and days taken for full bloom was reduced to 8 days than the original cultivar. The flower diameter and number of ray florets flower^{-1} were lesser than the original cultivar i.e. 16.45 cm and 155, respectively. The longevity of flowers was less than that of the original cultivar i.e. 11 days. The duration of flowering (44 days) was less than the original cultivar. The number of flowers plant^{-1} and flower weight were reduced to (4 and 39.64 g, respectively) as compared to the original cultivar. The colour of flower was matched as Yellow Group 5 C + Red Group 48 D with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to semi cactus in mutant KYM_6 than the original form.

Mutant KYM_7

The mutant KYM_7 grew to a plant height of 14.25 cm and 41.93 cm which was lesser than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} and number of branches plant^{-1} (70 and 4, respectively) were less than the original cultivar. Mutant KYM_7 took lesser time for days taken to first bud appearance (71 days), the number of days for flower opening (14 days) and days taken for full bloom to 4 days than the original cultivar. The flower diameter and number of ray florets flower^{-1} (13.38 cm and 113, respectively) were less than the original cultivar. Also the longevity of flowers (8 days) and duration of flowering (45 days) were lesser than the original cultivar. Likewise, number of flowers plant^{-1} and flower weight plant^{-1} were reduced to

5 and 37.64 g as compared to the parental cultivar. The colour of flower was matched as Red Group 51 A + Green Yellow Group 1 A with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to semi cactus in mutant KYM_7 than the original form.

Mutant KYM_8

The mutant attained a plant height of 13.33 cm and 40.66 cm which was lesser than of the original cultivar 30 DAT and 90 DAT, also the number of leaves plant^{-1} (61) and number of branch plant^{-1} (3) were lesser than the original. Mutant KYM_8 took lesser time for days taken for first bud appearance (64 days), the number of days for flower opening (12 days), days taken for full bloom (7 days), longevity of flowers (10 days) and duration of flowering (48 days) were lesser than the original cultivar. Number of flowers plant^{-1} were reduced to 4 as compared to the parental cultivar. However, the flower diameter (18.37 cm), number of ray florets flower^{-1} (167) and flower weight plant^{-1} (46.45 g) were higher than the original cultivar. The colour of flower was matched as Red Purple Group 72 C + Yellow Group 5 B with R.H.S. Colour Chart. No change was recorded in flower from in mutant KYM_8 than the original cultivar.

Mutant KYM_9

Plant height recorded in this mutant was 15.13 cm and 51.85 cm which was higher than of the original cultivar 30 DAT and 90 DAT. The number of leaves plant^{-1} (72) was higher than original but number of branch plant^{-1} (4) were lesser than the original. This mutant took smaller time for days taken for first bud appearance, the number of days for flower opening and days taken for full bloom (73, 14 and 4 days, respectively) than the original parent. Also the longevity of flowers (9 days) was less than that of the original cultivar. However, the duration of flowering (55 days) were higher than the original cultivar. The flower diameter and number of ray florets flower^{-1} (13.5 cm and 111, respectively) were less than the original cultivar. Mutant flower weight and number of flowers plant^{-1} were reduced to 39.68 g and 5 as compared to the original cultivar. The colour of flower was matched as White Group NN155 D + Purple

Group 77 D with R.H.S. Colour Chart. Colour The changes in flower form was recorded from giant decorative to small decorative in mutant KYM_9 than the original form.

Mutant KYM_{10}

The mutant attained a plant height of 16.85 cm and 50.55 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. However, the number of leaves plant^{-1} (66) was lesser than original but number of branch plant^{-1} (6) were higher than the original. Mutant KYM_{10} take less days for days taken for first bud appearance (66 days), the number of days for flower opening (14 days) and days taken for full bloom (5 days) than the original cultivar. The flower diameter, number of ray florets flower^{-1} and flower weight plant^{-1} (13.3 cm, 109 and 40.5 g, respectively) than the parental cultivar. The longevity of flowers and duration of flowering were taking less time with 48 and 8 days respectively. The number of flowers plant^{-1} were reduced to 5 as compared to the parental cultivar. The colour of flower was matched as Yellow Group 2 D + Pink Group NN74 D with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to small decorative in mutant KYM_{10} than the original form.

Mutant KYM_{11}

The mutant KYM_{11} grew to a plant height of 18.9 cm and 50.33 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. However, the number of leaves plant^{-1} (59) and number of branch plant^{-1} (3) were lesser than original. Plant of this mutant took lesser time for days taken for first bud appearance, the number of days for flower opening and days taken for full bloom (76, 13 and 7 days, respectively) than the parental cultivar. The mutant flower diameter (11.99 cm), number of ray florets flower^{-1} (121) and flower weight plant^{-1} (38.97 g) were lesser than the original cultivar. The longevity of flowers and duration of flowering were reduced to 7 and 47 days respectively than the original cultivar. Likewise, the number of flowers plant^{-1} (3) were lesser than the original cultivar. The colour of flower was matched as Yellow Group 154 B + Orange Red Group 34 D with R.H.S. Colour Chart. The changes in flower form

was recorded from giant decorative to small decorative in mutant KYM_{11} than the original form.

Mutant KYM_{12}

The plant height of mutant was recorded as 15.33 cm and 49.45 cm which were higher than that of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} and number of branch plant^{-1} were less (65 and 4, respectively) than the original cultivar. This mutant took less time for days taken for first bud appearance (64 days), the number of days for flower opening (19 days) and days taken for full bloom (6 days) than the parental cultivar. The flower diameter (15.34 cm), number of ray florets flower^{-1} (132) and flower weight plant^{-1} (43.24 g) were also smaller than the original cultivar. Likewise, longevity of flowers (7 days) and duration of flowering (50 days) were lesser than the original cultivar. The number of flowers plant^{-1} were reduced to 4 as compared to the original cultivar. The colour of flower was matched as Green Yellow Group 1 B + Yellow Group 12 C with R.H.S. Colour Chart. No change was recorded in flower from in mutant KYM_{12} than the original form.

Mutant KYM_{13}

The mutant attained a plant height of 9.1 cm and 39.8 cm which was smaller than of the original cultivar at 30 DAT and 90 DAT, also the number of leaves plant^{-1} (68) and number of branch plant^{-1} (4) were little less than the original. This mutant took less time for days taken for first bud appearance, the number of days for flower opening and days taken for full bloom (78, 17 and 6 days, respectively) than the parental cultivar. The flower diameter (10.42 cm), number of ray florets flower^{-1} (108) and flower weight plant^{-1} (38.69 g) were less than the original cultivar. The longevity of flowers (6 days) and duration of flowering (51 days) were took least time than the original cultivar. The number of flowers plant^{-1} were reduced to 4 as compared to the original cultivar. The colour of flower was matched as Orange Group 24 C with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to small decorative in mutant KYM_{13} than the original form.

Mutant KYM_{14}

The mutant KYM_{14} grew to a plant height of 8.9 cm and 38.9 cm which was lesser than of the original cultivar at 30 DAT and 90 DAT, also the number of leaves plant^{-1} (64) was lesser than original but number of branch plant^{-1} (7) were higher than the original. Mutant KYM_{14} took less time for days taken for first bud appearance (69 days) and days taken for full bloom to 5 days. The flower diameter and number of ray florets flower^{-1} were less (12.86 cm and 129, respectively) than the original cultivar. However, the number of days for flower opening, longevity of flowers and duration of flowering (21, 8 and 53 days, respectively) were more than the parental cultivar. The number of flowers plant^{-1} were reduced to 5 as compared to the original cultivar, but flower weight plant^{-1} (44.94 g) and were higher than the original cultivar. The colour of flower was matched as White Group NN155 A + Purple Group 77 B with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to medium decorative in mutant KYM_{14} than the original form.

Mutant KYM_{15}

The mutant attained a plant height of 15.65 cm and 46.3 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. However, the number of leaves plant^{-1} (70) was lesser than the original but number of branch plant^{-1} (6) were lesser than original. This mutant took less time for days taken for first bud appearance, the number of days for flower opening and days taken for full bloom (81, 19 and 6 days, respectively) than the original cultivar. Likewise, longevity of flowers and duration of flowering also took less time with 6 and 47 days, respectively. The flower diameter (10.64 cm), number of ray florets flower^{-1} (109), flower weight plant^{-1} (40.23 g) and number of flowers plant^{-1} (3) were lesser than the original cultivar. The colour of flower was matched as White Group NN155 C with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to medium decorative in mutant KYM_{15} than the original form.

4.1.6.3 Mutants of Kenya Original cultivar

This cultivar produced three mutants (KOM_1- KOM_3) which were screened, tagged and checked for the stability of the characters in next generation. All the mutants were developed at 10 Gy dose of gamma radiations (Table 4.31 and Plate 4.3).

Mutant KOM_1

The mutant KOM_1 grew to a plant height of 13.55 cm and 35.95 cm which was lesser than of the original cultivar at 30 DAT and 90 DAT. The number of leaves and number of branch plant^{-1} were less than the original cultivar (58 and 4, respectively). This mutant took less time for days taken to first bud appearance, the number of days for flower opening and days taken for full bloom to the original cultivar with 82, 19 and 4 days, respectively. The flower diameter and number of ray florets flower^{-1} were less than the original cultivar *i.e.* 11.52 cm and 98, respectively. The longevity of flowers was less than that of the original cultivar *i.e.* 10 days. The duration of flowering (44 days) was more than the original cultivar. However, the number of flowers (2) and flower weight plant^{-1} (37.84 g) were lesser than the original cultivar. The colour of flower was matched as Red Group 36 D with R.H.S. Colour Chart. The changes in flower form was recorded from stellar flowered to small decorative in mutant KOM_1 than the original form.

Mutant KOM_2

The mutant attained a plant height 18.16 cm and 45.35 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (64) was higher but number of branch plant^{-1} (4) were lesser than the original cultivar. Mutant KOM_2 took less time for days taken to first bud appearance, the number of days for flower opening and days taken for full bloom than the original cultivar with 66, 18 and 6 days, respectively. The flower diameter and number of ray florets flower^{-1} were less than the original cultivar *i.e.* 14.6 cm and 126, respectively. The longevity of flowers was less than that of the original cultivar *i.e.* 10 days. Likewise, the duration of

flowering (40 days) was slightly less than the original. The number of flowers plant^{-1} and flower weight plant^{-1} were reduced to 4 and 40.31 g as compared to the original cultivar. The colour of flower was matched as Red Group 39 D with R.H.S. Colour Chart. No change was recorded in flower from in mutant KOM_2 than the original form.

Mutant KOM_3

The plant height of mutant was recorded as 12.98 cm and 31.65 cm which was less than that of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (59) was lesser but number of branch plant^{-1} (6) were higher than the original cultivar. This mutant took higher time for days taken to first bud appearance (104 days) but the number of days for flower opening (16 days), days taken for full bloom (6 days) and longevity of flowers (8 days) were lesser than of the original cultivar. The flower diameter (16.2 cm), number of ray florets flower^{-1} (134) and duration of flowering (46 days) were higher than the original cultivar. However, number of flowers plant^{-1} (4) and flower weight plant^{-1} (40.61 g) were lesser than the original. The colour of flower was matched as Red Purple Group 58 D + White Group N155 B with R.H.S. Colour. The changes in flower form was recorded from stellar flower to giant decorative in mutant KOM_3 than the original form.

Table 4.31: Mean performance of mutants of Kenya Original cultivar in vM_1 generation

Characters	Parent	Mutants		
		KOM_1	**KOM_2**	**KOM_3**
Radiation doses	0.0 Gy	10 Gy	10 Gy	10 Gy
Plant height at 30 DAT (cm)	17.19	13.55	18.16	12.98
Plant height 90 DAT (cm)	38.64	35.95	45.35	31.65
Total number of branches plant^{-1}	5	4	4	6
Days taken to first bud appearance	101	82	66	104
Number of days taken for flower opening	21	19	18	16
Number of days taken for full bloom	7.33	4	6	6
Flower diameter (cm)	15.84	11.52	14.6	16.2
Number of ray florets flower^{-1}	151	98	126	134
Longevity of flower (days)	12	10	10	8
Numbers of flower plant^{-1}	4.33	2	4	4
Duration of flowering (days)	41.88	44	40	46
Flower colour as per RHS Colour Chart	RG 36 D	RG 36 D	RG 39 D	RPG 58 D + WG N155 B
Flower form	SF	SD	SF	GD

SF: Stellar flowered, GD: Giant Decorative, SD: Small Decorative, RPG: Red Purple Group, WG: White Group, RG: Red Group

4.2 EXPERIMENT II - Effect of rooting hormones on the propagation of dahlia mutants through stem cuttings

4.2.1 Effect of rooting hormones on rooting characters in the propagation of dahlia mutants

4.2.2 Effect of rooting hormones on vegetative characters in the propagation of dahlia mutants

4.2.3 Effect of rooting hormones on floral characters in the propagation of dahlia mutants

4.2.4 Effect of rooting hormones on tuber characters in the propagation of dahlia mutants

4.2.5 Effect of rooting hormones on physiological characters in the propagation of dahlia mutants

4.2.6 Screening of mutants in vM_2 population and their characterization

4.2.1 Effect of rooting hormones on rooting characters in the propagation of dahlia mutants

4.2.1.1 Days required for root initiation

The data presented in Table 4.32 and Fig. 4.29 showed that significant influence of rooting hormones and dahlia mutants on days required for root initiation. The treatment application of IBA @ 250 ppm + NAA @ 250 ppm resulted in minimum days required for root initiation (17.21days) over remaining treatments, which was *at par* with treatment application of NAA @ 500 ppm (17.83 days) and IBA @ 500 ppm + NAA @ 500 ppm (17.98 days). The maximum days required for root initiation of cuttings were recorded in control treatment (24.66 days), among the mutants of two dahlia cultivars for the days required for root initiation, significantly minimum days for

Table 4.32: Effect of rooting hormones on days required for root initiation in dahlia mutants

Cultivar / Rooting hormones	Days required for root initiation		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	23.40	25.91	24.66
IBA @ 250 ppm	20.03	25.14	22.58
IBA @ 500 ppm	19.17	22.38	20.77
IBA @ 1000 ppm	17.79	23.90	20.85
NAA @ 250 ppm	17.54	21.24	19.39
NAA @ 500 ppm	16.28	19.39	17.83
NAA @ 1000 ppm	17.32	20.53	18.92
IBA @ 125 ppm + NAA @ 125 ppm	17.34	21.47	19.40
IBA @ 250 ppm + NAA @ 250 ppm	15.99	18.44	17.21
IBA @ 500 ppm + NAA @ 500 ppm	16.29	19.68	17.98
Mean	18.11	21.81	
	CD at 5%		**S.Em±**
Rooting hormone	1.14		0.40
Cultivar	0.51		0.17
Rooting hormone × Cultivar	NS		0.56

root initiation (18.11 days) recorded in mutants of Kenya Blue compared to the mutants of Kenya Yellow (21.81 days).

Interaction between different concentration of rooting hormones and dahlia mutants were found to be non-significant and minimum days (15.99 days) required for rooting were recorded in interaction of mutants of Kenya Blue with IBA @ 250 ppm + NAA @ 250 ppm.

Treatment of auxin reduces time of rooting significantly and early rooting was also produced (Malik *et al*., 2018). This might be due to the internal auxin amount is not enough for root induction and treatment increase considerable amount for root initiation. Maximum time taken to root initiation (24.66 days) resulted in untreated cuttings in control. These results are in close conformity with the findings of Bharathy *et al*. (2004) in carnation and Kazankaya *et al.* (2005) in rose.

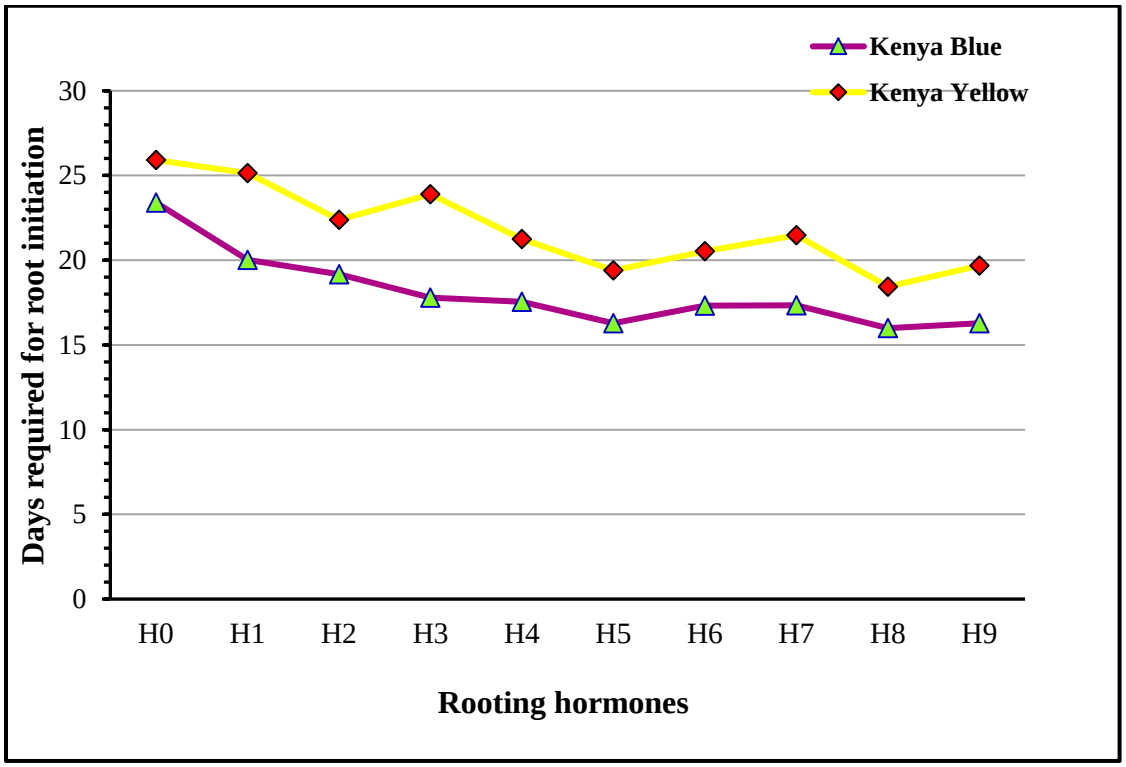

Fig. 4.29: Effect of rooting hormones on days required for root initiation in dahlia mutants

4.2.1.2 Rooting percentage (%)

The data related to rooting percentage have been presented in Table 4.33 and Fig. 4.30. The rooting hormones, dahlia mutants and interaction of both had significant effect on rooting percentage.

Table 4.33: Effect of rooting hormones on rooting percentage in dahlia mutants

Cultivar / Rooting hormones	Rooting percentage (%)		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	32.03	40.01	36.02
IBA @ 250 ppm	63.93	66.20	65.07
IBA @ 500 ppm	68.37	67.37	67.87
IBA @ 1000 ppm	71.16	68.47	69.82
NAA @ 250 ppm	59.70	65.64	62.67
NAA @ 500 ppm	64.22	73.85	69.03
NAA @ 1000 ppm	65.37	53.94	59.66
IBA @ 125 ppm + NAA @ 125 ppm	58.29	57.77	58.03
IBA @ 250 ppm + NAA @ 250 ppm	69.38	61.65	65.51
IBA @ 500 ppm + NAA @ 500 ppm	72.15	58.78	65.46
Mean	62.46	61.37	

	CD at 5%	**S.Em±**
Rooting hormone	1.37	0.48
Cultivar	0.61	0.21
Rooting hormone × Cultivar	1.94	0.68

The perusal of the data depicts that, rooting hormones treatment significantly improved rooting percentage, high rate of rooting (69.82%) recorded in IBA @ 1000 ppm which was statistically *at par* with NAA @ 500 ppm (69.03%), whereas control resulted lowest rooting percentage (36.02%) followed by IBA @ 125 ppm + NAA @ 125 ppm (58.03%). As respect to mutants, Kenya Blue resulted significantly higher percentage of rooting (62.46%) over mutants of Kenya Yellow (61.37%).

The interaction of NAA @ 500 ppm with mutants of Kenya Blue cultivar recorded significantly highest rooting percentage (73.85%) which was *at par* with treatment combination of IBA @ 500 ppm + NAA @ 500 ppm and mutants of Kenya Blue *i.e.* 72.15%. However, lowest rooting percentage (32.03%) recorded in mutants of Kenya Blue in control.

The rooting hormones increases the overall percentage of rooting, facilitate initiation of adventitious roots and enhance the number and quality of adventitious roots (Dirr and Heuser, 2006). Carnation treated with IBA recorded significant improvement in rooting percentage and other rooting parameters by Gowda *et al*. (2017). Similar result found by Prince *et al*. (2017), Kumar *et al*. (2014) in carnation, Ghofrani (2013) and Zeinab and Hossein (2014) in *Hibiscus rosa-sinensis*.

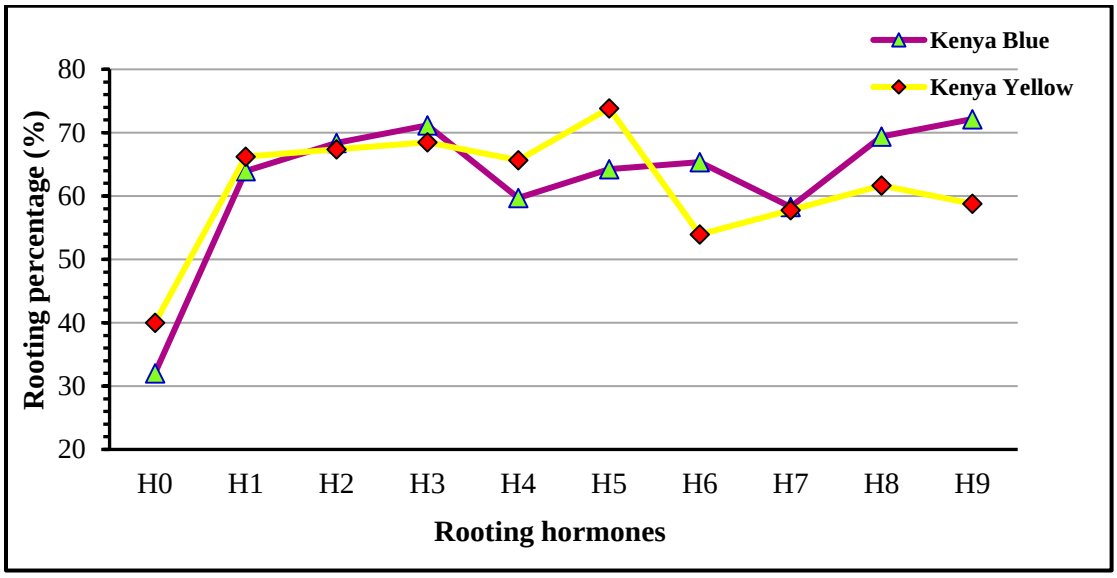

Fig. 4.30: Effect of rooting hormones on rooting percentage in dahlia mutant

4.2.1.3 Survival percentage (%)

The data pertaining to survival of cuttings after treatment of rooting hormones have been presented in Table 4.34 and Fig. 4.31. It is evident from the data that barring effect of mutants and rooting hormones had significant effect on survival percentage, significantly maximum survival percentage (63.96%) recorded at the treatment of NAA @ 500 ppm followed by NAA @ 1000 ppm (56.39%), whereas, minimum survival percentage was significantly recorded in control treatment (16.14%).

Table 4.34: Effect of rooting hormones on survival percentage in dahlia mutants

Cultivar / Rooting hormones	Survival percentage (%)		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	14.65	17.62	16.14
IBA @ 250 ppm	53.21	49.98	51.60
IBA @ 500 ppm	57.19	51.32	54.25
IBA @ 1000 ppm	54.29	53.03	53.66
NAA @ 250 ppm	53.88	53.66	53.77
NAA @ 500 ppm	62.41	65.51	63.96
NAA @ 1000 ppm	56.89	55.89	56.39
IBA @ 125 ppm + NAA @ 125 ppm	49.15	37.82	43.49
IBA @ 250 ppm + NAA @ 250 ppm	50.38	55.65	53.02
IBA @ 500 ppm + NAA @ 500 ppm	53.17	54.25	53.71
Mean	50.52	49.47	
	CD at 5%		**S.Em±**
Rooting hormone	1.39		0.48
Cultivar	0.62		0.21
Rooting hormone × Cultivar	1.96		0.68

Dahlia mutants Kenya Blue exhibited significantly maximum percentage of survival (50.52%) which was significantly higher than the other one.

Interaction among rooting hormones treatments and mutants were also significant on survival percentage. Plants of mutants of Kenya Yellow treated with NAA @ 500 ppm treatment recorded significantly maximum survival percentage (65.51%) followed by mutants of Kenya Blue (62.41%) at same treatment dose while untreated mutants of Kenya Blue resulted in minimum survival percentage (14.65%), which were statistically significant than the rest of treatment combinations.

The data on the plant survival indicated that plant survival was significantly influenced by different treatments of rooting hormones. The survival percentage increased proportionally with increase in certain level of rooting hormones. Maximum survival percentage was recorded in the cuttings treated with NAA @ 500 ppm while the minimum survival percentage was observed in the absence of any rooting hormones application. These differences might be due to positive correlation between survival percentage and number of roots. These results were supported by Constanzi *et al.*1988 and Bibhaskumar (2003) in rose.

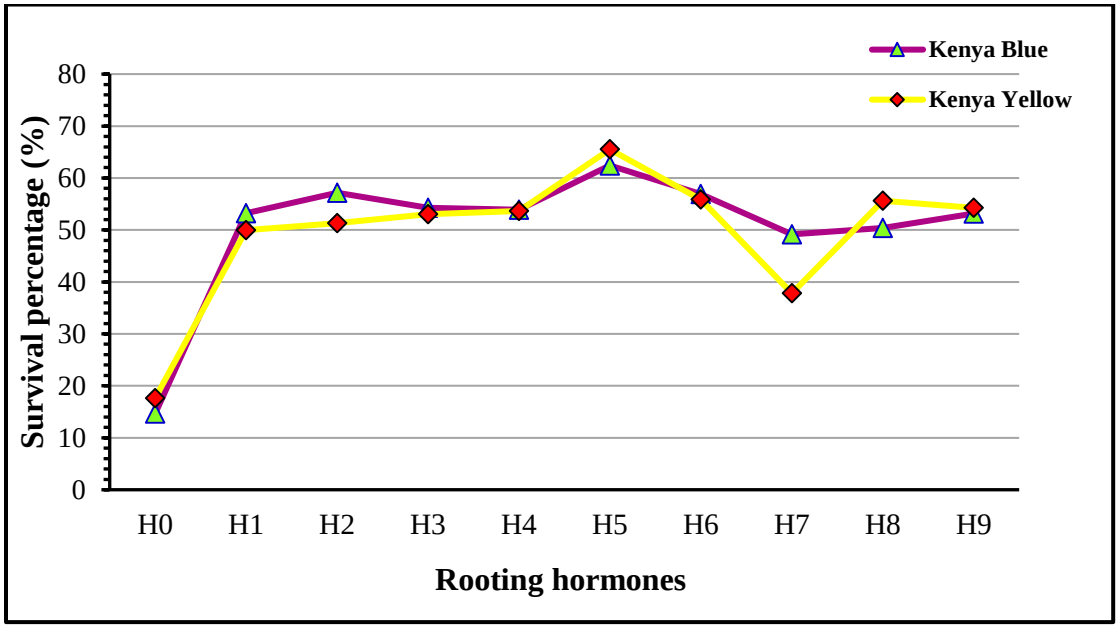

Fig. 4.31: Effect of rooting hormones on survival percentage in dahlia mutants

4.2.1.4 Number of roots cutting^{-1}

The data presented in Table 4.35 and Fig. 4.32 reveals that irrespective of mutants of dahlia cultivar, number of roots cutting^{-1} (9.69) were significantly recorded minimum in untreated plants, while maximum number of roots cutting^{-1} (22.74) recorded in plants treated with IBA @ 1000 ppm and NAA @ 500 ppm which was statistically *at par* with IBA @ 500 ppm (22.67). The significant difference was noted for number of roots cutting^{-1} due to effect of mutants of dahlia.

Table 4.35: Effect of rooting hormones on number of roots cutting^{-1} in dahlia mutants

Cultivar / Rooting hormones	Number of roots cutting^{-1}		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	8.94	10.44	9.69
IBA @ 250 ppm	20.02	15.25	17.64
IBA @ 500 ppm	24.03	21.32	22.67
IBA @ 1000 ppm	25.13	20.35	22.74
NAA @ 250 ppm	19.39	13.26	16.32
NAA @ 500 ppm	26.12	19.36	22.74
NAA @ 1000 ppm	18.93	14.99	16.96
IBA @ 125 ppm + NAA @ 125 ppm	18.08	14.84	16.46
IBA @ 250 ppm + NAA @ 250 ppm	23.09	19.53	21.31
IBA @ 500 ppm + NAA @ 500 ppm	19.56	18.22	18.89
Mean	20.33	16.76	
	CD at 5%		**S.Em±**
Rooting hormone	0.76		0.26
Cultivar	0.34		0.12
Rooting hormone × Cultivar	1.08		0.37

Among the mutants of cultivar, mutants of Kenya Blue gave significantly maximum number of roots cutting^{-1} (20.33) compared to the mutants of Kenya Yellow (16.76).

Interaction effect also showed significant results in respect to number of roots cutting^{-1} and the maximum number of roots cutting^{-1} (26.12) observed in interaction of NAA @ 500 ppm and mutants of cultivar Kenya Blue, which was *at par* with IBA @ 1000 ppm treatment in same mutants of Kenya Blue (25.13). Minimum number of roots cutting^{-1} (8.94) recorded in controlled plants of mutants of Kenya Blue, which was significantly lower than the other treatment combinations.

The effect of auxins has been reported to enhance rooting through the translocation of carbohydrates and other nutrients to the rooting zone. Different auxins and their level on rooting parameters of marigold resulted in improved rooting percentage, root length, number of roots and dry weight of roots (Bhatt *et al*. 2012, Sharma 2014 and Majumder *et al*. 2014). Confirmatory result was also reported by Singh and Singh (2005) in poinsettia, Ullah *et al*. (2013) and Malik *et al*. (2018) in dianthus.

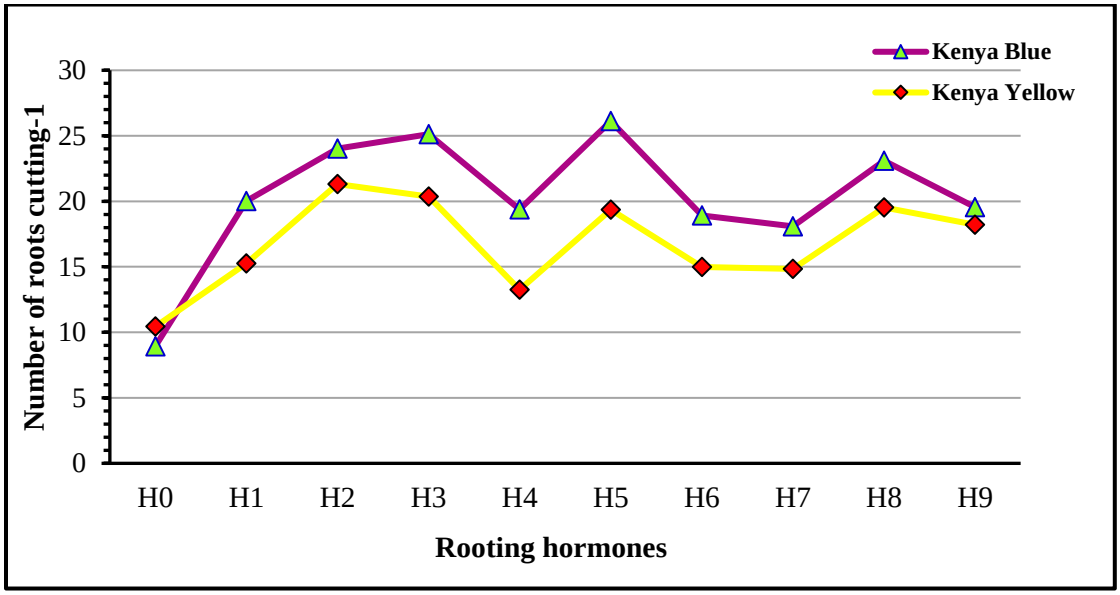

Fig. 4.32: Effect of rooting hormones on number of roots cutting^{-1} in dahlia mutants

4.2.1.5 Root length (cm)

The data on root length is presented in Table 4.36 and Fig. 4.33. The data clearly indicated that different doses of rooting hormones, mutants of dahlia cultivar and their interactions significantly influenced root length. The result reveals that poorest root length (2.53 cm) were significantly recorded in untreated plants followed by IBA @ 125 ppm + NAA @ 125 ppm treatment dose (2.93 cm), whereas, longest root length (5.57 cm) observed in treated with IBA @ 500 ppm which was *at par* with IBA @ 1000 ppm (5.56 cm). As respect to mutants of dahlia cultivars, mutants of Kenya Blue resulted significantly longer root length (4.16 cm) over mutants of Kenya Yellow (3.96 cm).

Table 4.36: Effect of rooting hormones on root length in dahlia mutants

Cultivar / Rooting hormones	Root length (cm)		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	2.91	2.15	2.53
IBA @ 250 ppm	4.40	4.34	4.37
IBA @ 500 ppm	6.16	4.98	5.57
IBA @ 1000 ppm	5.86	5.26	5.56
NAA @ 250 ppm	3.31	3.64	3.47
NAA @ 500 ppm	5.29	5.11	5.20
NAA @ 1000 ppm	3.58	4.24	3.91
IBA @ 125 ppm + NAA @ 125 ppm	3.13	2.73	2.93
IBA @ 250 ppm + NAA @ 250 ppm	4.02	3.79	3.90
IBA @ 500 ppm + NAA @ 500 ppm	2.96	3.35	3.15
Mean	4.16	3.96	
	CD at 5%		**S.Em±**
Rooting hormone	0.23		0.08
Cultivar	0.10		0.03
Rooting hormone × Cultivar	0.33		0.11

The interaction between two factors, rooting hormones and mutants also show significant effect on root length, mutants of cultivar Kenya Blue treated with dose IBA @ 500 ppm recorded significantly longest root length (6.16 cm) which was *at par* with interaction of treatment dose IBA @ 1000 ppm with same mutant of dahlia (5.86 cm), whereas, untreated plants of mutants of Kenya Yellow noted lowest (2.15 cm) root length.

There was increase in root length with treatment of higher doses of IBA, similar results found in hardwood cuttings of hibiscus and mussaenda pink when treated with the IBA reported by Shiva and Nair 2009, Bhandari 2014 and Patel 2009, who observed that maximum number of primary roots cutting^{-1}, longest root and maximum leaf size and rooting percentage.

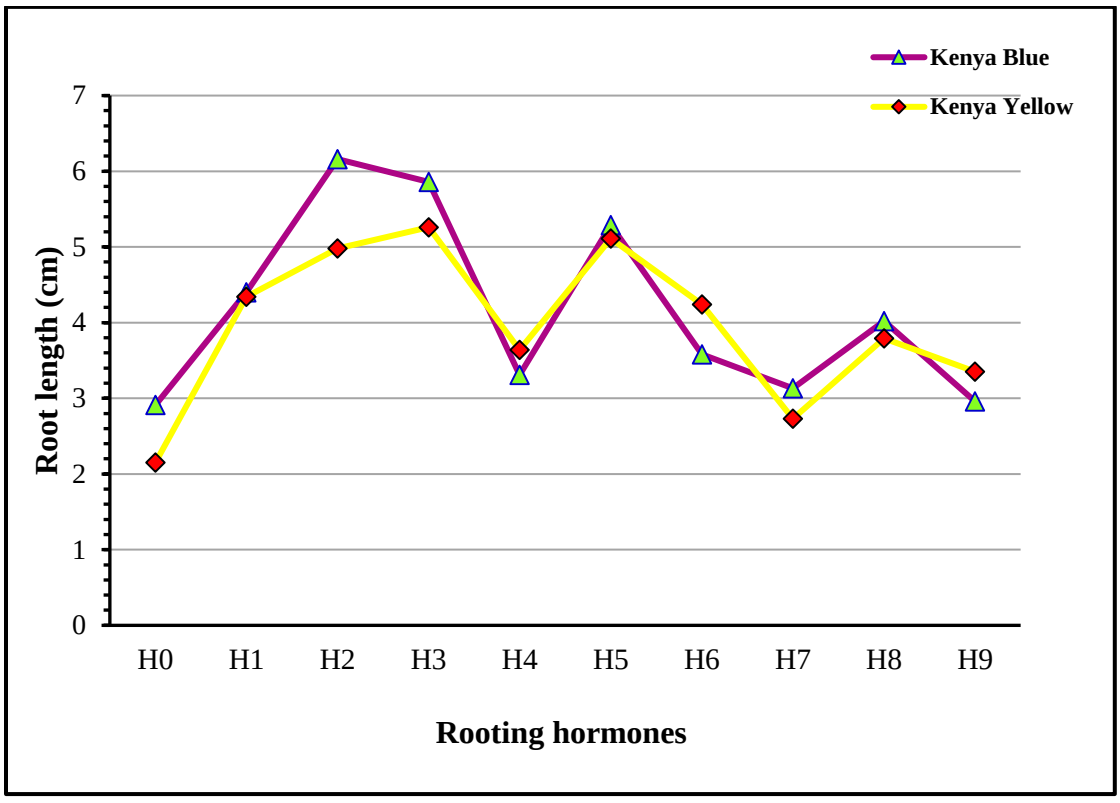

Fig. 4.33: Effect of rooting hormones on root length in dahlia mutants

4.2.2 Effect of rooting hormones on vegetative characters in the propagation of dahlia mutants

4.2.2.1 Plant height (cm)

The observation of plant height influenced with mutants of dahlia cultivars and different doses of rooting hormones is recorded in Table 4.37, 4.38 and 4.39 and graphically depicted in Fig. 4.34, 4.35 and 4.36. The plant height was increased progressively from root initiation to flowering.

4.2.2.1.1 Plant height (cm) at 30 DAT

Table 4.37: Effect of rooting hormones on plant height after 30 DAT in dahlia mutants

Cultivar / Rooting hormones	Plant height (cm) at 30 DAT		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	13.50	14.67	14.08
IBA @ 250 ppm	16.83	18.00	17.42
IBA @ 500 ppm	18.67	20.50	19.58
IBA @ 1000 ppm	14.67	19.33	17.00
NAA @ 250 ppm	13.83	16.33	15.08
NAA @ 500 ppm	14.00	19.83	16.92
NAA @ 1000 ppm	17.17	22.17	19.67
IBA @ 125 ppm + NAA @ 125 ppm	15.67	19.33	17.50
IBA @ 250 ppm + NAA @ 250 ppm	18.13	20.17	19.15
IBA @ 500 ppm + NAA @ 500 ppm	14.18	16.83	15.51
Mean	15.66	18.72	
	CD at 5%		**S.Em±**
Rooting hormone	0.77		0.27
Cultivar	0.34		0.12
Rooting hormone × Cultivar	1.10		0.38

Treatment of rooting hormones showed significant effect on plant height at 30 DAT. It was evident from the Table 4.37 that the treatment NAA @ 1000 ppm recorded significantly maximum plant height at 30 days after transplanting (19.67 cm) which was *at par* with treatment IBA @ 500 ppm and IBA @ 250 ppm + NAA @ 250 ppm (19.58 and 19.15 cm, respectively), whereas, untreated plants recorded minimum height at 30 DAT (14.08 cm). The mutants of cultivar differences also show significant influenced on plant height at 30 DAT, as respect to mutants of cultivar, plants of mutants of Kenya yellow resulted significantly maximum plant height (18.72 cm) compared to that mutants of Kenya Yellow (15.66 cm).

An interaction effect of different concentration of rooting hormones and mutants of dahlia cultivars were found to be significant on plant height at 30 DAT. The minimum plant height (13.50 cm) was recorded in untreated plants of mutants of Kenya Blue closely followed by interaction of treatment of NAA @ 250 ppm with mutants of Kenya Blue (13.83 cm), whereas, significantly maximum plant height (22.17 cm) recorded in mutants of Kenya Yellow treated with NAA @ 1000 ppm.

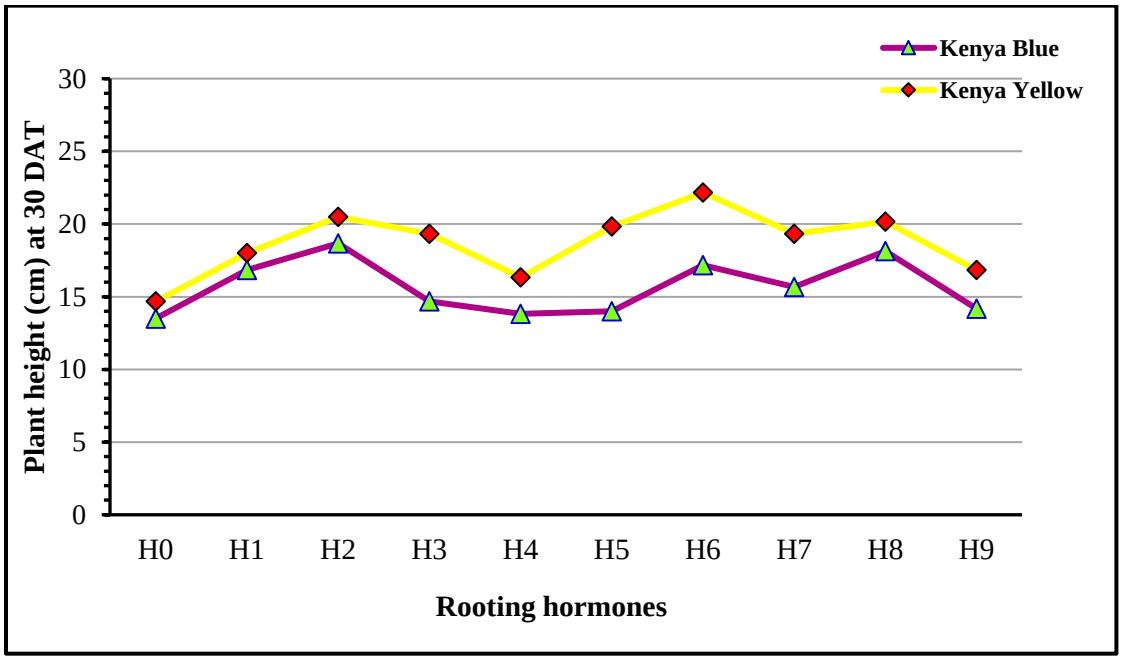

Fig. 4.34: Effect of rooting hormones on plant height after 30 DAT in dahlia mutants

4.2.2.1.2 Plant height (cm) at 60 DAT

It is evident from data (Table 4.38) the plant height at 60 days DAT was noted significantly higher over to untreated plants. Plants which was untreated recorded minimum height at 60 DAT (21.83 cm) while significantly maximum plant height (30.50 cm) observed in NAA @ 1000 ppm treatment, which was statistically *at par* with IBA @ 500 ppm (30.25 cm).

Table 4.38: Effect of rooting hormones on plant height after 60 DAT in dahlia mutants

Cultivar / Rooting hormones	Plant height (cm) at 60 DAT		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	19.00	24.67	21.83
IBA @ 250 ppm	24.17	28.17	26.17
IBA @ 500 ppm	29.00	31.50	30.25
IBA @ 1000 ppm	27.83	29.17	28.50
NAA @ 250 ppm	24.33	28.50	26.42
NAA @ 500 ppm	25.50	30.67	28.08
NAA @ 1000 ppm	29.83	31.17	30.50
IBA @ 125 ppm + NAA @ 125 ppm	24.67	27.83	26.25
IBA @ 250 ppm + NAA@ 250 ppm	27.83	29.50	28.67
IBA @ 500 ppm + NAA @ 500 ppm	23.00	24.83	23.92
Mean	25.52	28.60	
	CD at 5%		**S.Em±**
Rooting hormone	0.70		0.24
Cultivar	0.31		0.11
Rooting hormone × Cultivar	0.99		0.35

Differences in mutants of cultivars were also significant, mutants of cultivar Kenya Yellow recorded significantly maximum plant height at 60 DAT (28.60 cm) which was significantly higher than the other one mutants of cultivar Kenya Yellow (25.52 cm).

The untreated plants of mutants of cultivar Kenya Blue resulted in minimum plant height (19 cm) followed by interaction of IBA @ 500 ppm + NAA @ 500 ppm with mutants of the same cultivar (23 cm), whereas, mutants of cultivar Kenya Yellow with treatment IBA @ 500 ppm resulted significantly maximum plant height (31.50 cm), which was at par with mutants of Kenya Yellow treated with NAA @ 1000 ppm and 500 ppm (31.17 and 30.67 cm, respectively).

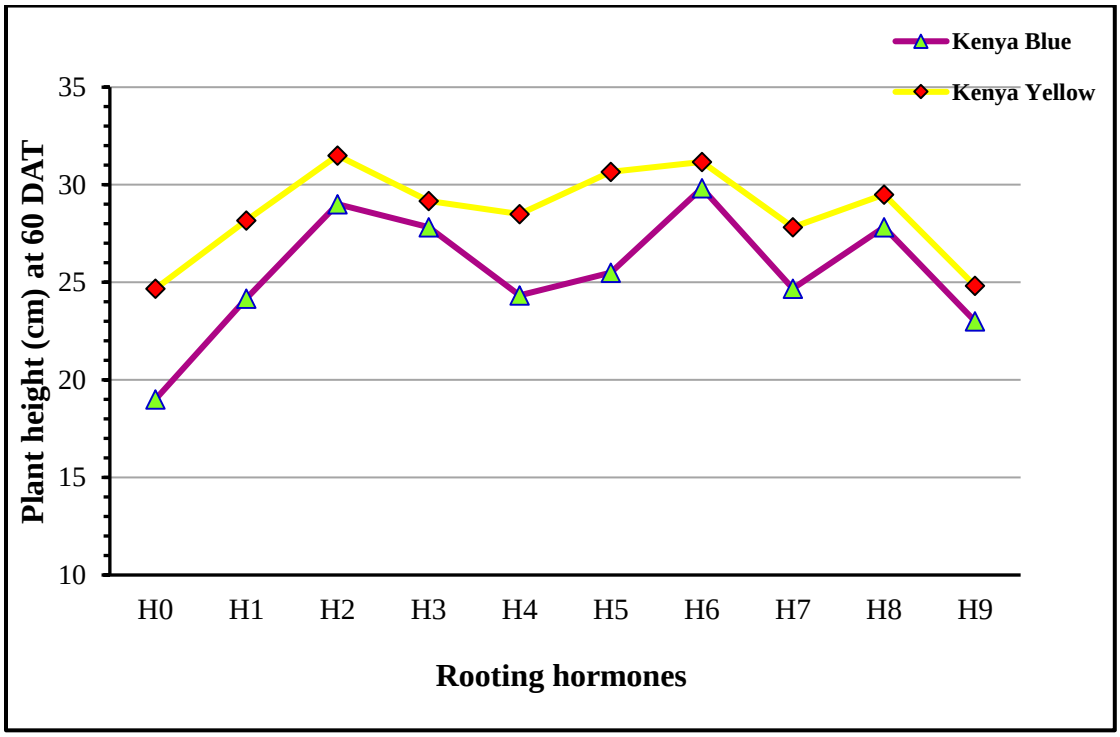

Fig. 4.35: Effect of rooting hormones on plant height after 60 DAT in dahlia mutants

4.2.2.1.3 Plant height (cm) at 90 DAT

It was evident from the Table 4.39 that treatment IBA @ 500 ppm was statistically superior over the remaining treatments. The significantly maximum plant height at 90 DAT (45.56 cm) recorded in the treatment IBA @ 500 ppm, which was *at par* with NAA @ 1000 ppm (44.66 cm). However, minimum plant height (29.45 cm) recorded in control treatment followed by treatment IBA @ 500 ppm + NAA @ 500 ppm (36.11 cm). As respect to mutants of cultivar significantly maximum plant height (41.31 cm) recorded under mutants of cultivar Kenya Yellow, which was statistically superior over the other one.

Table 4.39: Effect of rooting hormones on plant height after 90 DAT in dahlia mutants

Cultivar / Rooting hormones	Plant height (cm) at 90 DAT		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	28.73	30.17	29.45
IBA @ 250 ppm	38.65	40.67	39.66
IBA @ 500 ppm	45.97	45.14	45.56
IBA @ 1000 ppm	42.73	42.73	42.73
NAA @ 250 ppm	33.32	42.01	37.67
NAA @ 500 ppm	39.83	44.14	41.99
NAA @ 1000 ppm	38.27	51.05	44.66
IBA @ 125 ppm + NAA @ 125 ppm	30.72	41.82	36.27
IBA @ 250 ppm + NAA @ 250 ppm	41.23	42.97	42.10
IBA @ 500 ppm + NAA @ 500 ppm	39.85	32.37	36.11
Mean	37.93	41.31	
	CD at 5%		**S.Em±**
Rooting hormone	1.36		0.47
Cultivar	0.61		0.21
Rooting hormone × Cultivar	1.93		0.67

The data on interaction of mutants of cultivar with different doses of rooting hormones was found significant on plant height at 90 DAT. The plant height was significantly enhanced in mutants of Kenya Yellow treated with NAA @ 1000 ppm (51.05 cm) followed by interaction of treatment IBA @ 500 ppm with mutants of cultivar Kenya Blue (45.97 cm), whereas, untreated plant of mutants of both cultivars showed minimum plant height which was 28.73 cm in mutants of cultivar Kenya Blue and 30.17 cm in mutants of cultivar Kenya Yellow.

The data regarding plant height showed that it was gradually increased with increase in growth regulator concentration at certain level. This may be due to early and more number of roots produced in treated plants which leads the more absorption of water and nutrients thus good growth allow maximum height. These results were confirmed by the findings of Khuriwal *et al.* 2018 in dahlia and Grzesik (1989) in damask rose. The another reason is may be due to enhanced cell division and cell enlargement, promotion of protein synthesis which might have resulted in enhanced vegetative growth (Evans, 1973).

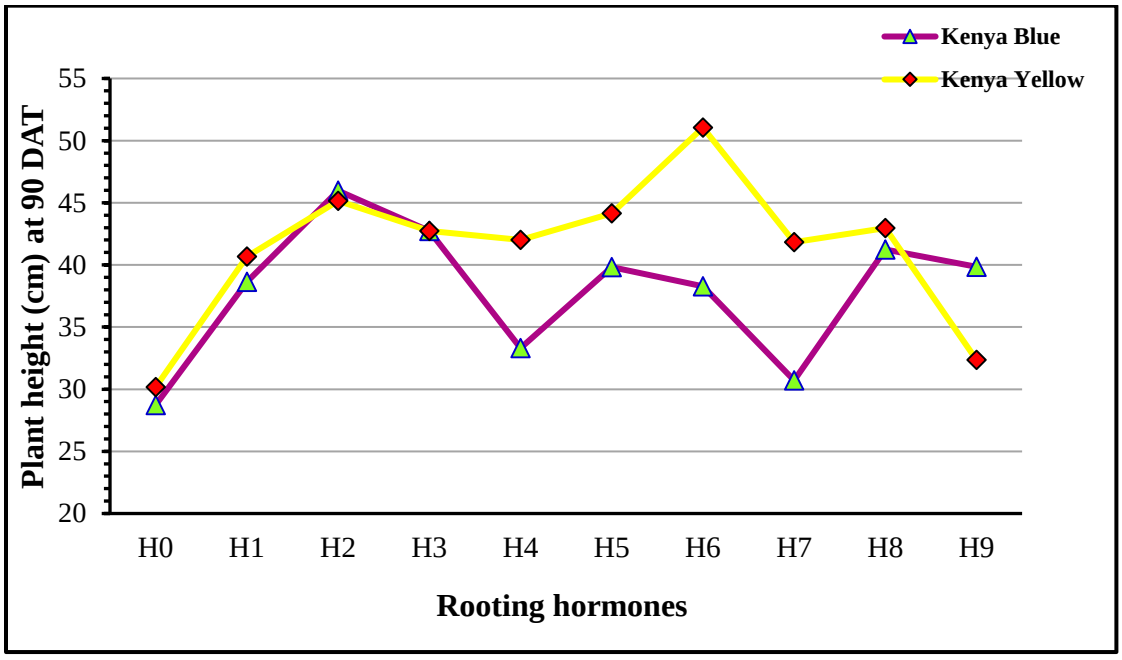

Fig. 4.36: Effect of rooting hormones on plant height after 90 DAT in dahlia mutants

4.2.2.2 Number of leaves plant^{-1}

The data on number of leaves plant^{-1} is presented in Table 4.40 and 4.41 and graphically represented in Fig. 4.37 and 4.38. The data clearly indicated that mutants of dahlia cultivar, different concentrations of rooting hormones and their interactions significantly influenced the number of leaves plant^{-1} at 60 and 90 DAT.

4.2.2.2.1 Number of leaves plant^{-1} at 60 DAT

Table 4.40: Effect of rooting hormones on number of leaves plant^{-1} at 60 DAT in dahlia mutants

Cultivar / Rooting hormones	Number of leaves plant^{-1} at 60 DAT		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	17.33	29.33	23.33
IBA @ 250 ppm	27.17	31.67	29.42
IBA @ 500 ppm	43.73	39.31	41.52
IBA @ 1000 ppm	37.54	31.00	34.27
NAA @ 250 ppm	34.17	30.33	32.25
NAA @ 500 ppm	36.83	34.00	25.42
NAA @ 1000 ppm	33.33	29.67	31.50
IBA 125 @ ppm + NAA @ 125 ppm	35.63	34.17	34.90
IBA @ 250 ppm + NAA @ 250 ppm	39.08	37.00	38.04
IBA @ 500 ppm + NAA @ 500 ppm	33.33	30.20	31.77
Mean	33.82	32.67	
	CD at 5%		**S.Em±**
Rooting hormone	0.94		0.33
Cultivar	0.42		0.14
Rooting hormone × Cultivar	1.33		0.46

The number of leaves plant^{-1} at 60 DAT was found to be significant due to effect of different concentrations of rooting hormones. The treatment of IBA @ 500 ppm enhanced number of leaves plant^{-1} at 60 DAT (41.52), which was followed by treatment IBA @ 250 ppm + NAA @ 250 ppm (38.04). Significantly maximum reduction in number of leaves plant^{-1} was noted at untreated plants i.e. 23.33.

Mutants of both cultivars also show significant effect on number of leaves plant^{-1} at 60 DAT, significantly highest number of leaves plant^{-1} was recorded in mutants of Kenya Blue (33.82) which was *at par* with other mutants of Kenya yellow (32.67).

Interaction of mutants of Kenya Blue and IBA @ 500 ppm recorded significant enhanced mean number of leaves plant^{-1} (43.73) followed by mutants of Kenya Yellow (39.31) treated with same concentration dose of rooting hormones. However, minimum number of leaves plant^{-1} at 60 DAT (17.33) recorded in untreated plants of mutants of Kenya Blue cultivar followed by treatment of same mutant cultivar with IBA @ 250 ppm treatment dose (27.17).

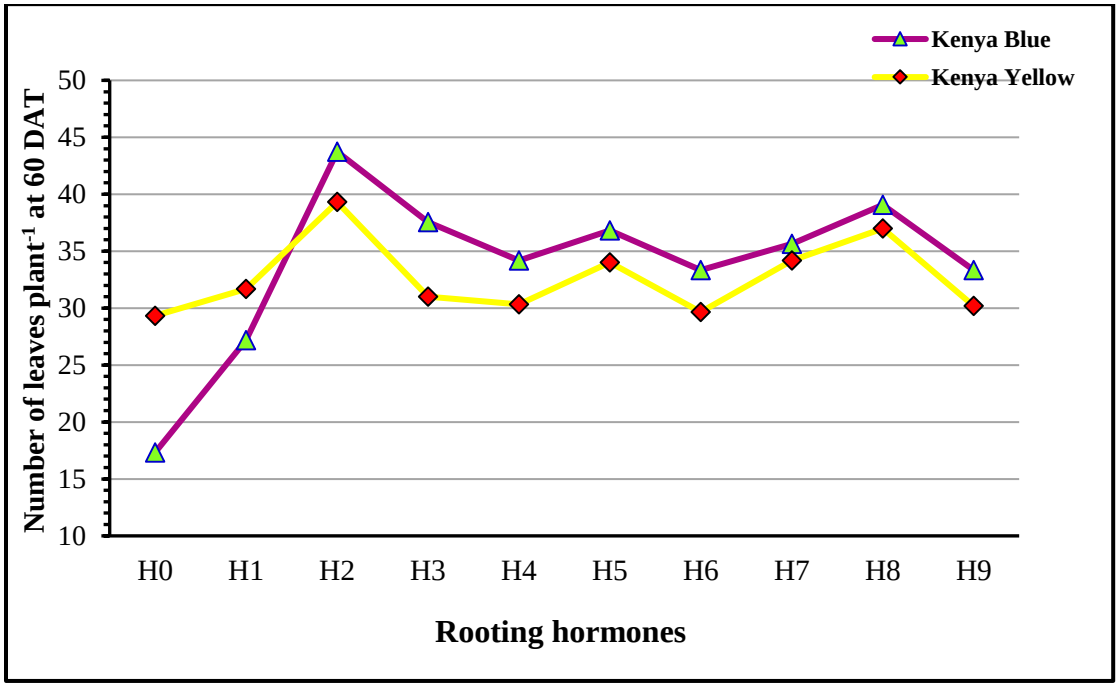

Fig. 4.37: Effect of rooting hormones on number of leaves plant^{-1} at 60 DAT in dahlia mutants

4.2.2.2.2 Number of leaves plant^{-1} at 90 DAT

Data presented in Table 4.41 reveals that irrespective of mutants of cultivar, significantly maximum number of leaves plant^{-1} at 90 DAT (77.98) recorded in treatment IBA @ 500 ppm, while minimum numbers of leaves plant^{-1} at 90 DAT (48.58) were recorded in untreated plants. The mutants of cultivar differences for number of leaves plant^{-1} after transplanting was also highly significant, the result reveals that plants of mutants of cultivar Kenya Blue resulted significantly maximum number of leaves plant^{-1} (63.26) while plants of mutants of cultivar Kenya Yellow had minimum number of leaves (62.38 cm).

Table 4.41: Effect of rooting hormones on number of leaves plant^{-1} at 90 DAT in dahlia mutants

Cultivar / Rooting hormones	Number of leaves plant^{-1} at 90 DAT		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	47.50	49.67	48.58
IBA @ 250 ppm	59.03	70.17	64.60
IBA @ 500 ppm	81.55	74.41	77.98
IBA @ 1000 ppm	65.45	61.83	63.64
NAA @ 250 ppm	65.51	57.47	61.49
NAA @ 500 ppm	69.59	65.30	67.44
NAA @ 1000 ppm	56.50	51.17	53.83
IBA @ 125 ppm + NAA @ 125 ppm	64.50	65.70	65.10
IBA @ 250 ppm + NAA @ 250 ppm	67.40	69.77	68.59
IBA @ 500 ppm + NAA @ 500 ppm	55.55	58.33	56.94
Mean	63.26	62.38	
	CD at 5%		**S.Em±**
Rooting hormone	1.47		0.51
Cultivar	0.65		0.23
Rooting hormone × Cultivar	2.08		0.72

The interaction effect of rooting hormones and mutants of cultivars was also significant on number of leaves plant^{-1}. Interaction of mutant cultivar Kenya Blue and IBA @ 500 ppm recorded significantly maximum number of leaves plant^{-1} (81.55), which significantly higher than the other interactions. However, the minimum number of leaves plant^{-1} (47.50) at 90 DAT were observed in untreated plant of mutants of cultivar Kenya Blue.

The data indicated that number of leaves cutting^{-1} was significantly maximum in IBA 500 ppm and minimum was recorded in control. This might be due to vigorous root system and absorption of more nutrients along with moisture as compared to cuttings in all other treatments which in turn increased the more number of leaves. The results are in conformity with finding of Khan *et al.* (2003) in dahlia and Ullah *et al.* (2013) in marigold.

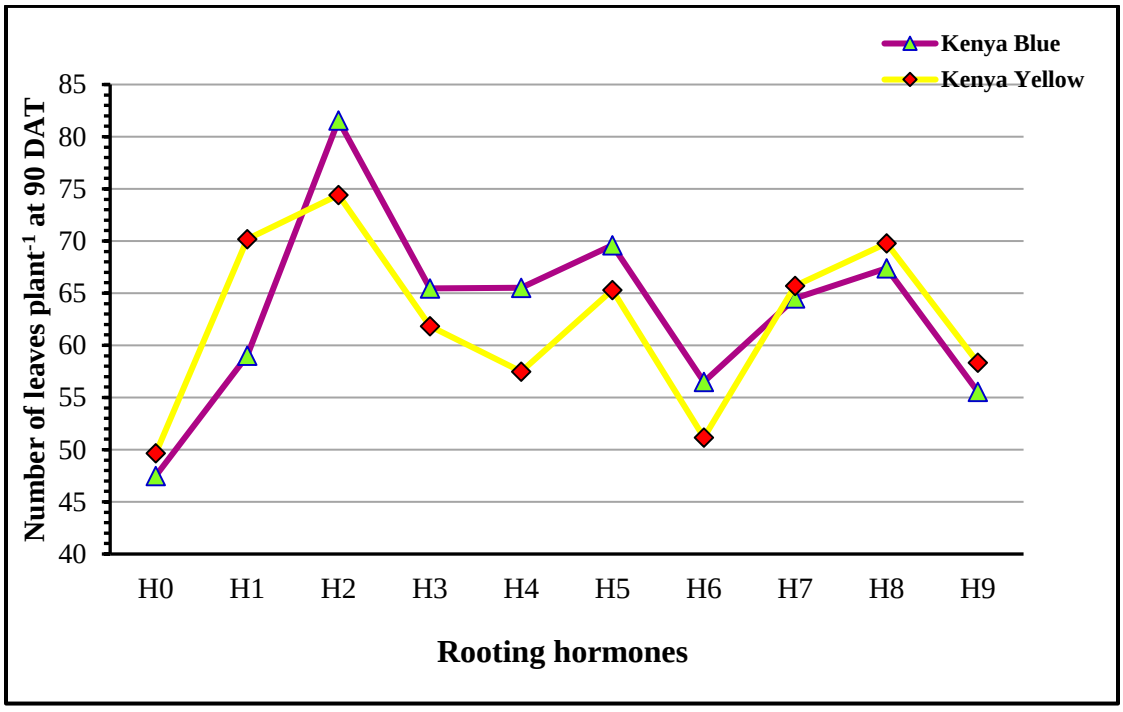

Fig. 4.38: Effect of rooting hormones on number of leaves plant^{-1} at 90 DAT in dahlia mutants

4.2.2.3 Total number of branches plant^{-1}

The data pertaining to number of branches plant^{-1} have been presented in Table 4.42 and graphically illustrated in Fig. 4.39. It is evident from critical rummage of data that rooting hormones had significant effect on number of branches plant^{-1}. Untreated plants recorded minimum number of branches plant^{-1} (2.83), whereas, treatment IBA @ 1000 ppm gave significantly maximum number of branches plant^{-1} (7.31) which was *at par* with treatment IBA @ 500 ppm (7.03).

Table 4.42: Effect of rooting hormones on total number of branches plant^{-1} in dahlia mutants

Cultivar / Rooting hormones	Total number of branches plant^{-1}		
	Kenya Blue	Kenya Yellow	Mean
Control	2.33	3.33	2.83
IBA @ 250 ppm	5.10	6.00	5.55
IBA @ 500 ppm	6.73	7.33	7.03
IBA @ 1000 ppm	7.79	6.83	7.31
NAA @ 250 ppm	4.80	4.00	4.40
NAA @ 500 ppm	5.67	4.60	5.13
NAA @ 1000 ppm	5.53	5.47	5.50
IBA @ 125 ppm + NAA @ 125 ppm	4.50	4.00	4.25
IBA @ 250 ppm + NAA @ 250 ppm	6.10	5.47	5.78
IBA @ 500 ppm + NAA @ 500 ppm	5.00	3.13	4.07
Mean	5.36	5.02	
	CD at 5%		**S.Em±**
Rooting hormone	0.29		0.10
Cultivar	0.13		0.04
Rooting hormone × Cultivar	0.41		0.14

Among the plants of mutants of dahlia for the trait under study, significantly maximum mean number of branches plant^{-1} (5.36) was recorded in mutants of cultivar Kenya Blue, which was significantly higher than the rest one.

Interaction effect of mutants of dahlia cultivar Kenya Blue with IBA @ 1000 ppm reported significantly maximum number of branches plant^{-1} (7.79), whereas, untreated plants of mutants of Kenya Blue reported minimum number of branches plant^{-1} (2.33).

Number of branches plant^{-1} were slightly increased with higher concentration of rooting hormones but suppressed at control. It appears that the above stated doses of rooting hormones are mainly concerned with enhanced development of shoot initials and their further development. The same conclusions were made by Ahmed (1983). Comparative effects of both the hormone as depicted in table showed that IBA had stronger synergistic effect on number of branches as compared to NAA. This may have been due to more physiologically activity of IBA in the intact dahlia cuttings. These results corroborate with the results of Khan *et al.* (2007) in rose and Ranipise *et al.* (2012) in chrysanthemum.

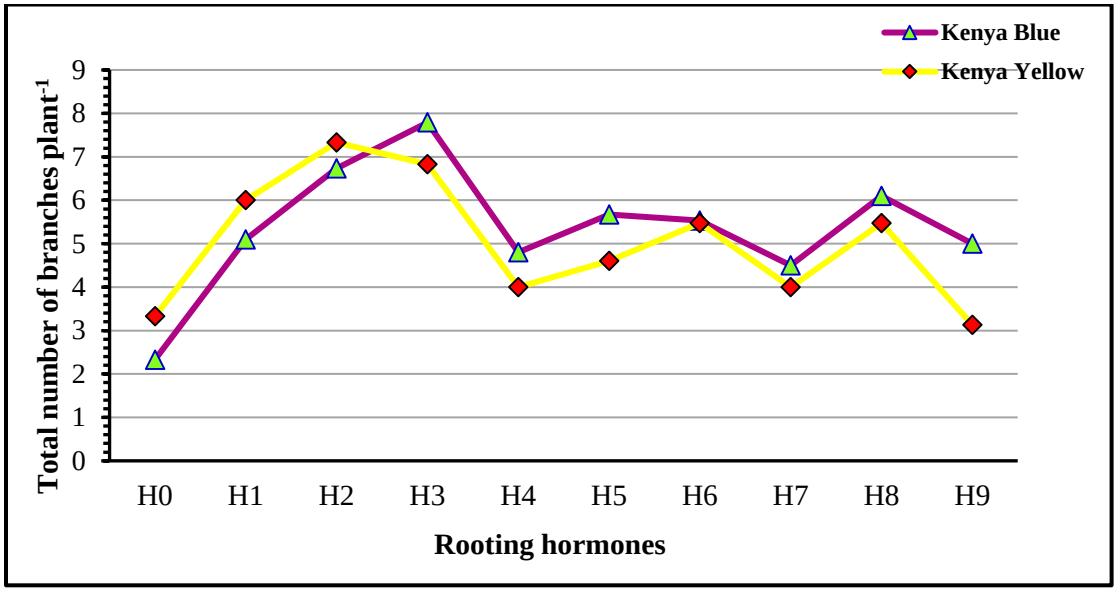

Fig. 4.39: Effect of rooting hormones on total number of branches plant^{-1} in dahlia mutants

4.2.2.3 Plant spread (cm)

The data on plant spread is presented in Table 4.43 and graphically represented in Fig. 4.40. The data clearly indicated the significant effect of rooting hormones but non-significant effect of mutants of cultivar and its interaction with rooting hormones in plant spread. The treatment of IBA @ 500 ppm enhanced plant spread (29.50 cm), which was statistically *at par* with treatment IBA @ 1000 ppm (28.40 cm), whereas, minimum plant spread (24.43 cm) was recorded in untreated plants, which was *at par* with treatment IBA @ 125 ppm + NAA @ 125 ppm (25.33 cm), IBA @ 500 ppm + NAA @ 500 ppm (25.65 cm) and NAA @ 250 ppm (25.90 cm).

Table 4.43: Effect of rooting hormones on plant spread (cm) in dahlia mutants

Cultivar / Rooting hormones	Plant spread (cm)		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	25.08	23.77	24.43
IBA @ 250 ppm	26.67	28.92	27.79
IBA @ 500 ppm	28.96	30.03	29.50
IBA @ 1000 ppm	27.30	29.50	28.40
NAA @ 250 ppm	26.67	25.13	25.90
NAA @ 500 ppm	27.33	26.17	26.75
NAA @ 1000 ppm	25.80	27.67	26.73
IBA @ 125 ppm + NAA @ 125 ppm	26.17	24.50	25.33
IBA @ 250 ppm + NAA @ 250 ppm	27.08	26.17	26.63
IBA @ 500 ppm + NAA @ 500 ppm	26.50	24.80	25.65
Mean	26.76	26.66	
	CD at 5%		**S.Em±**
Rooting hormone	1.68		0.58
Cultivar	NS		0.26
Rooting hormone × Cultivar	NS		0.83

Mutants of both cultivars were non-significantly affected on plant spread. The maximum plant spread (26.76 cm) was recorded in mutants of cultivar Kenya Blue.

The interaction effect of mutants of cultivar and rooting hormones was also non-significant on plant spread, interaction of mutants of Kenya Yellow and IBA @ 500 ppm had maximum plant spread (30.03 cm).

The analysis of variance for plant spread revealed that different rooting hormone treatments had significant effect on the plant spread. Maximum plant spread was recorded when the dahlia cuttings were treated with IBA @ 500 ppm whereas, minimum plant spread was recorded in the absence of any rooting hormones. This might have been due to the inhibition caused by the downward transport of endogenous plant hormones from the dominant shoot as stated by Sun *et al.* (1998) causing a phenomenon of partial apical dominance, while in case of rooting hormone treatments this inhibitory effect of the endogenous hormones is counteracted by the exogenous applications of hormones especially IBA resulting in to the cancellation of apical dominance and more plant spread. Similar result found in Ranpise *et al.* 2004 in chrysanthemum and Shepherd and Winston (2000) in bougainvillea.

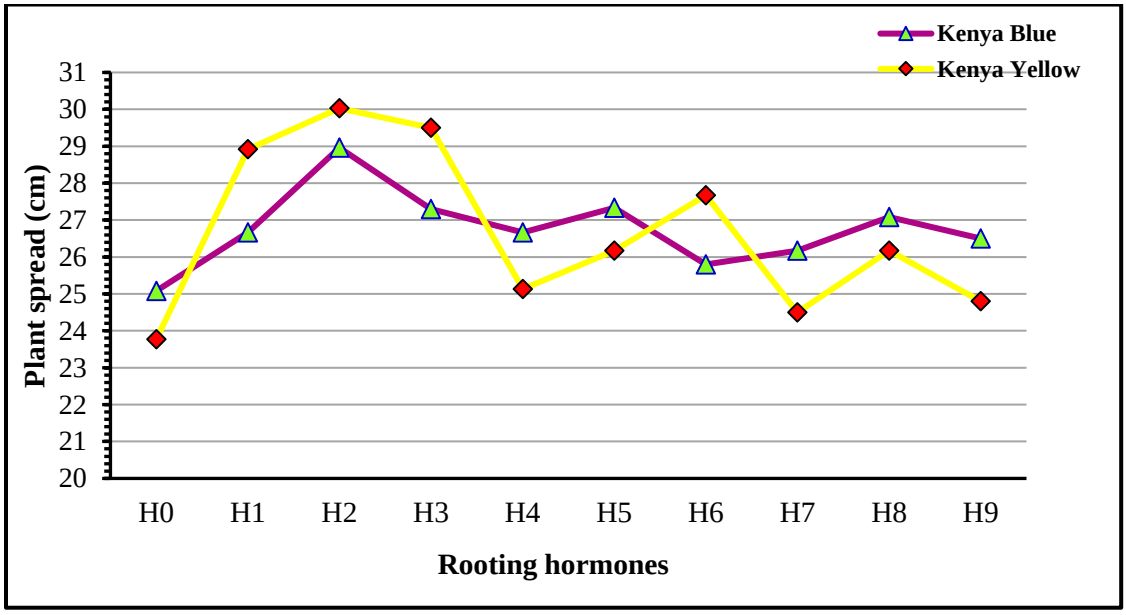

Fig. 4.40: Effect of rooting hormones on plant spread (cm) in dahlia mutants

4.2.3 Effect of rooting hormones on floral characters in the propagation of dahlia mutants

4.2.3.1 Days taken for first bud appearance

The data presented in Table 4.44 for days taken for first bud appearance reveals that rooting hormones had significant effect, untreated plants reported significantly maximum days taken for first bud appearance (99.03 days), which was followed by treatment IBA 125 ppm + NAA 125 ppm (96.06 days). However, treatment IBA @ 500 ppm took minimum days for first bud appearance (5.99 days), which was significantly earlier than the other treatment.

Table 4.44: Effect of rooting hormones in days taken for first bud appearance in dahlia mutants

Cultivar / Rooting hormones	Days taken for first bud appearance		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	96.17	101.90	99.03
IBA @ 250 ppm	91.80	87.43	89.62
IBA @ 500 ppm	74.50	77.48	75.99
IBA @ 1000 ppm	77.37	82.21	79.79
NAA @ 250 ppm	93.33	93.23	93.28
NAA @ 500 ppm	86.83	79.00	82.92
NAA @ 1000 ppm	93.67	95.27	94.47
IBA @ 125 ppm + NAA @ 125 ppm	96.27	95.85	96.06
IBA @ 250 ppm + NAA @ 250 ppm	73.72	85.49	79.60
IBA @ 500 ppm + NAA @ 500 ppm	88.20	90.87	89.53
Mean	87.19	88.87	
	CD at 5%		**S.Em±**
Rooting hormone	2.10		0.73
Cultivar	0.94		0.33
Rooting hormone × Cultivar	2.97		1.04

The mutant of cultivar differences was also highly significant on days taken for first bud appearance, significantly minimum number of days taken for first bud appearance was recorded in mutants of cultivar Kenya Blue (87.19 days).

The interaction of different concentration of rooting hormones and mutants of cultivar were highly significant on number of days taken for first bud appearance, untreated plants of mutants of Kenya Yellow took significantly maximum days (101.90) for first bud appearance, whereas interaction of mutants of Kenya Blue treated with IBA 250 ppm + NAA 250 ppm took minimum (73.72) days, which was *at par* with interaction of treatment IBA @ 500 ppm and the same mutants of cultivar (74.50 days).

Auxin significantly influenced the number of days taken for first bud appearance. The early bud appearance noticed in IBA 500 ppm. This might be due to increase in cell elongation and rapid mobilization and accumulation of metabolites which properly influences the floral morphogenesis which rendered the early flowering. The results of this study are in close conformity with Bharmal *et al.* (2005) in chrysanthemum and Haider *et al.* (2006) in rose.

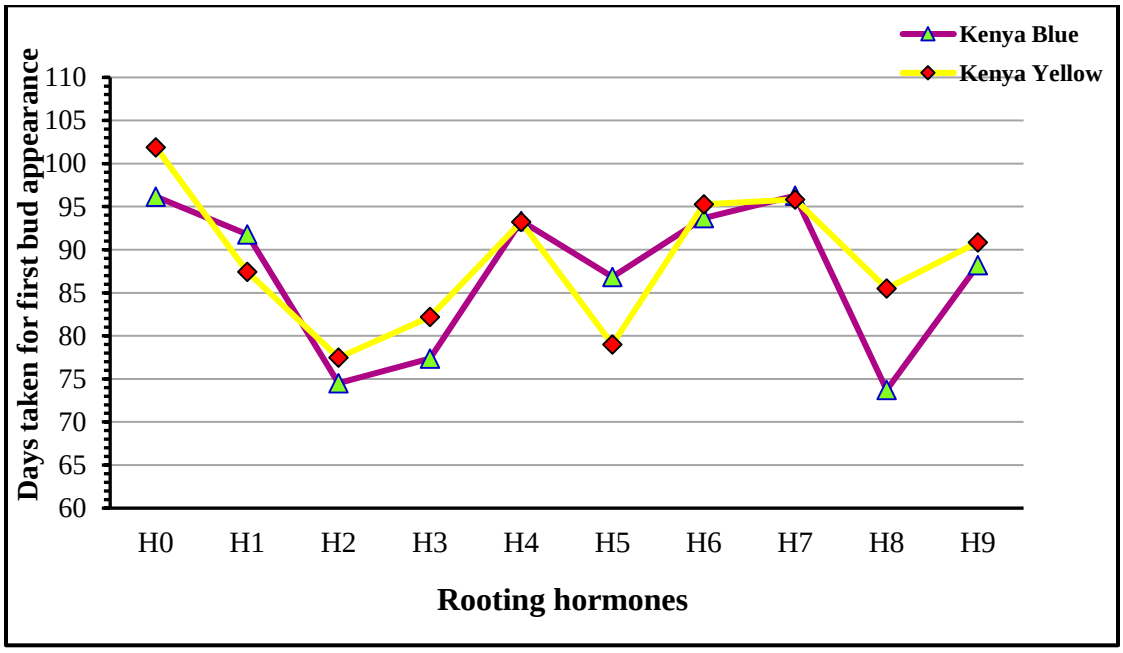

Fig. 4.41: Effect of rooting hormones on number of days taken for first bud appearance in dahlia mutants

4.2.3.2 Number of days taken for flower opening

It is apparent from the data presented in Table 4.45 and graphically represented in Fig. 4.42. The effect of rooting hormones on number of days taken for flower opening was highly significant, treatment IBA @ 250 ppm + NAA @ 250 ppm took significantly least number of days for flower opening (10.63 days) followed by treatment IBA @ 500 ppm (11.47 days), whereas, a significant delay in flower opening was recorded in untreated plants (19.21 days).

Table 4.45: Effect of rooting hormones on number of days taken for flower opening in dahlia mutants

Cultivar / Rooting hormones	Number of days taken for flower opening		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	19.99	18.43	19.21
IBA @ 250 ppm	14.65	12.67	13.66
IBA @ 500 ppm	12.67	10.27	11.47
IBA @ 1000 ppm	13.10	12.47	12.78
NAA @ 250 ppm	13.83	17.22	15.53
NAA @ 500 ppm	12.67	14.78	13.72
NAA @ 1000 ppm	14.50	15.07	14.78
IBA @ 125 ppm + NAA @ 125 ppm	18.00	14.33	16.17
IBA @ 250 ppm + NAA @ 250 ppm	9.33	11.92	10.63
IBA @ 500 ppm + NAA @ 500 ppm	16.83	13.83	15.33
Mean	14.56	14.10	
	CD at 5%		**S.Em±**
Rooting hormone	0.69		0.24
Cultivar	0.31		0.10
Rooting hormone × Cultivar	0.98		0.34

Among the mutants of both cultivars, plants of mutants of cultivar Kenya Blue took significantly maximum number of days (14.56) for the opening of flower, which was closely followed by mutants of another cultivar Kenya Yellow (14.10 days).

The interaction between rooting hormones and mutants of cultivars differ significantly, the untreated plants of mutants of cultivar Kenya Blue took significantly maximum number of days for flower opening (19.99 days) followed by untreated plants of mutants of cultivar Kenya Yellow (18.43 days), whereas, plants of mutants of cultivar Kenya Yellow treated with IBA @ 250 ppm + NAA @ 250 ppm took significantly least number of days taken for flower opening (9.33 days), which was *at par* with IBA @ 500 ppm (10.27 days).

Earliness in flower opening by the combination of both NAA and IBA, leading to the early transformation of vegetative to reproductive phase shows a relation in earliness to flower opening (Zimmerman and Wilcoxon, 1935). It has been seen always that NAA or IBA alone cause early outbreak of bud, resulting in early flowering as reported by Singh (1919) in hybrid tomato and Pandey and Chandra (2008) in French marigold. These result has been unequivocally demonstrated by several workers Dawa *et al.* (2017) in rose and Ullah *et al*. (2013) in marigold.

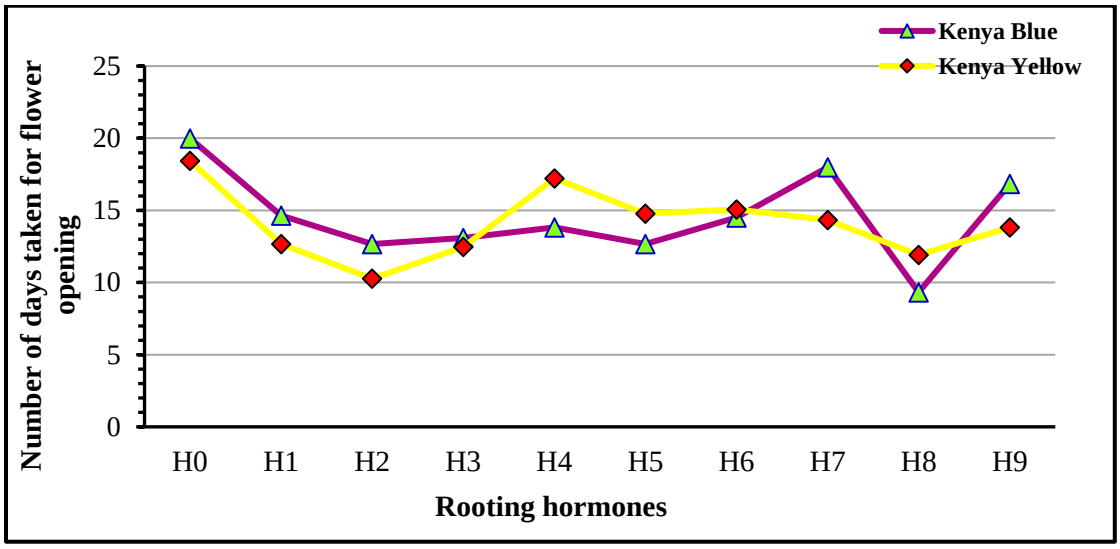

Fig. 4.42: Effect of rooting hormones on number of days taken for flower opening in dahlia mutants

4.2.3.3 Number of days taken for full bloom

The effect of different doses of rooting hormones, mutants of cultivar and their interactions was found significant for number of days taken for full bloom. The observations are reported in Table 4.46 with graphical presentation by Fig. 4.43. The observation clearly indicates that the treatment of IBA @ 500 ppm induced significantly earliness in full blooming by taking only 4.99 days, which was followed by treatments of NAA @ 500 ppm (5.62 days). It is clear that IBA @ 500 ppm doses of rooting hormones proved beneficial to induce earliness in dahlia compared to control (13.04 days).

Table 4.46: Effect of rooting hormones on number of days taken for full bloom in dahlia mutants

Cultivar / Rooting hormones	Number of days taken for full bloom		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	13.21	12.87	13.04
IBA @ 250 ppm	8.69	7.44	8.06
IBA @ 500 ppm	5.74	4.25	4.99
IBA @ 1000 ppm	7.68	9.09	8.38
NAA @ 250 ppm	6.93	7.56	7.24
NAA @ 500 ppm	4.98	6.26	5.62
NAA @ 1000 ppm	9.29	9.63	9.46
IBA @ 125 ppm + NAA @ 125 ppm	11.72	9.47	10.60
IBA @ 250 ppm + NAA @ 250 ppm	6.41	7.37	6.89
IBA @ 500 ppm + NAA @ 500 ppm	8.90	7.43	8.17
Mean	8.35	8.14	
	CD at 5%		**S.Em±**
Rooting hormone	0.47		0.16
Cultivar	0.21		0.07
Rooting hormone × Cultivar	0.67		0.23

Among the mutants of cultivar, minimum days required for full bloom was observed in plants of mutants of cultivar Kenya Yellow (8.14 days), which was *at par* with mutants of other one Kenya Blue *i.e.* 8.35 days.

Interaction of mutants of Kenya Yellow and IBA @ 500 ppm gave significantly minimum days for full blooming (4.25 days) which was closely followed by mutants of Kenya blue treated with NAA @ 500 ppm (4.98 days). However, untreated plants of mutants of cultivar Kenya Blue took maximum days (13.21) which was *at par* with untreated plants of mutants of another cultivar Kenya Yellow (12.87 days).

Auxin significantly influenced the number of days taken for full bloom. In case of mutants of dahlia plants treated with IBA @ 500 ppm took minimum time for days taken for full bloom. The delay in late flower initiation ultimately resulted in full bloom, which may be due to reduction in the rate of various physiological processes and inhibition of plant growth. These results are in conformity with work of Susaj *et al.* (2012) in rose and Ranipise *et al.* (2004) chrysanthemum.

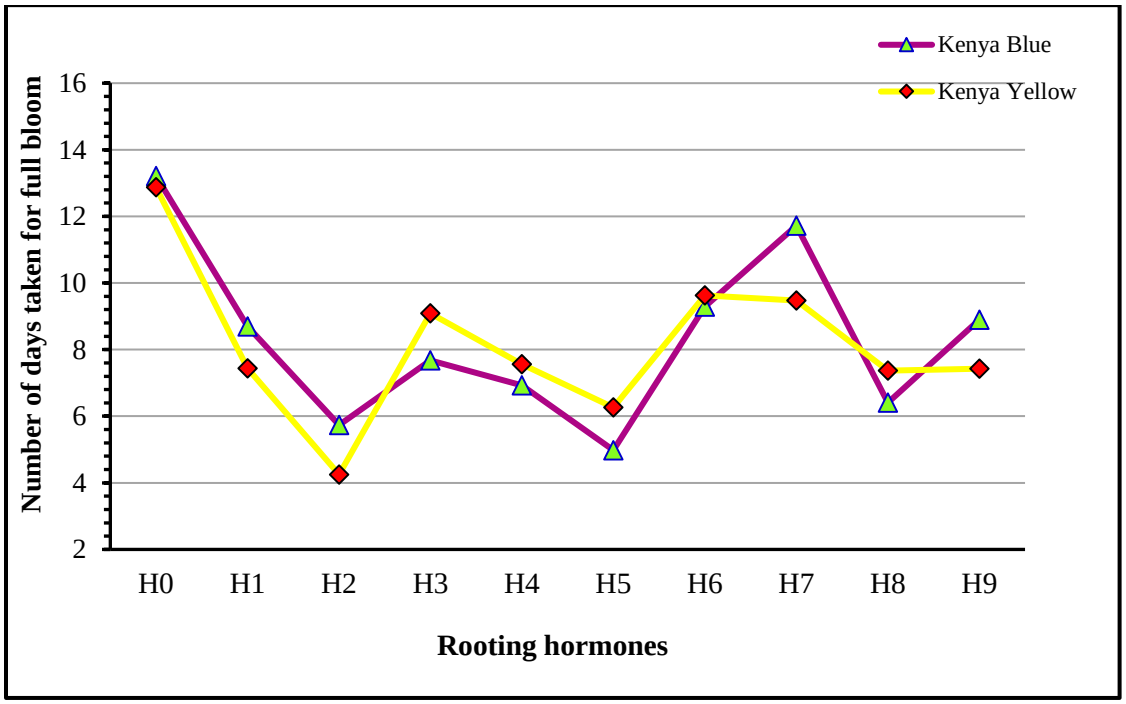

Fig. 4.43: Effect of rooting hormones on number of days taken for full bloom in dahlia mutants

4.2.3.4 Flower diameter (cm)

The data pertaining to the effect of treatment of rooting hormones on the diameter of flower have been presented in Table 4.47 and Fig. 4.44. It is evident from the data that highly significant differences for this chapter were recorded, plants treated with IBA @ 500 ppm had largest flower size (18.05 cm) which was *at par* with treatment of IBA @ 1000 ppm *i.e.* 17.81 cm. However, the untreated plants had smallest diameter (12.96 cm). The mutants of cultivars differences for diameter of flower were also highly significant, mutants of cultivar Kenya Blue exhibited significantly maximum diameter of flower (15.66 cm) which was higher than the rest one.

Table 4.47: Effect of rooting hormones flower diameter (cm) in dahlia mutants

Cultivar / Rooting hormones	Flower diameter (cm)		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	13.55	12.36	12.96
IBA @ 250 ppm	15.86	10.56	13.21
IBA @ 500 ppm	18.95	17.16	18.05
IBA @ 1000 ppm	18.87	16.75	17.81
NAA @ 250 ppm	13.37	13.53	13.45
NAA @ 500 ppm	15.84	15.68	15.76
NAA @ 1000 ppm	14.41	15.40	14.91
IBA @ 125 ppm + NAA @ 125 ppm	16.45	15.50	15.98
IBA @ 250 ppm + NAA @ 250 ppm	15.93	14.14	15.03
IBA @ 500 ppm + NAA @ 500 ppm	13.33	13.05	13.19
Mean	15.66	14.41	
	CD at 5%		**S.Em±**
Rooting hormone	0.83		0.29
Cultivar	0.37		0.13
Rooting hormone × Cultivar	1.17		0.41

A critical rummages of data revealed that the plants of mutants of cultivar Kenya Blue treated with IBA @ 500 ppm exhibited significantly largest flower (18.95 cm), which was *at par* interaction of treatment of IBA @ 1000 ppm with mutants of same cultivar (18.87 cm). However, the smallest diameter of flower (10.56 cm) was recorded in mutants of cultivar Kenya Yellow treated with IBA @ 250 ppm**.**

Plants treated with IBA @ 500 ppm produced flowers of significantly higher diameter. The higher diameter might be due to increase in cell elongation and rapid mobilization and accumulation of metabolites which properly influences the floral morphogenesis rendered the bigger size of the flowers. The results regarding diameter of the flowers are in agreement with Gupta and Datta, (2000) in chrysanthemum, Shivangowda (2000) in china aster and Anil (2004) in French marigold.

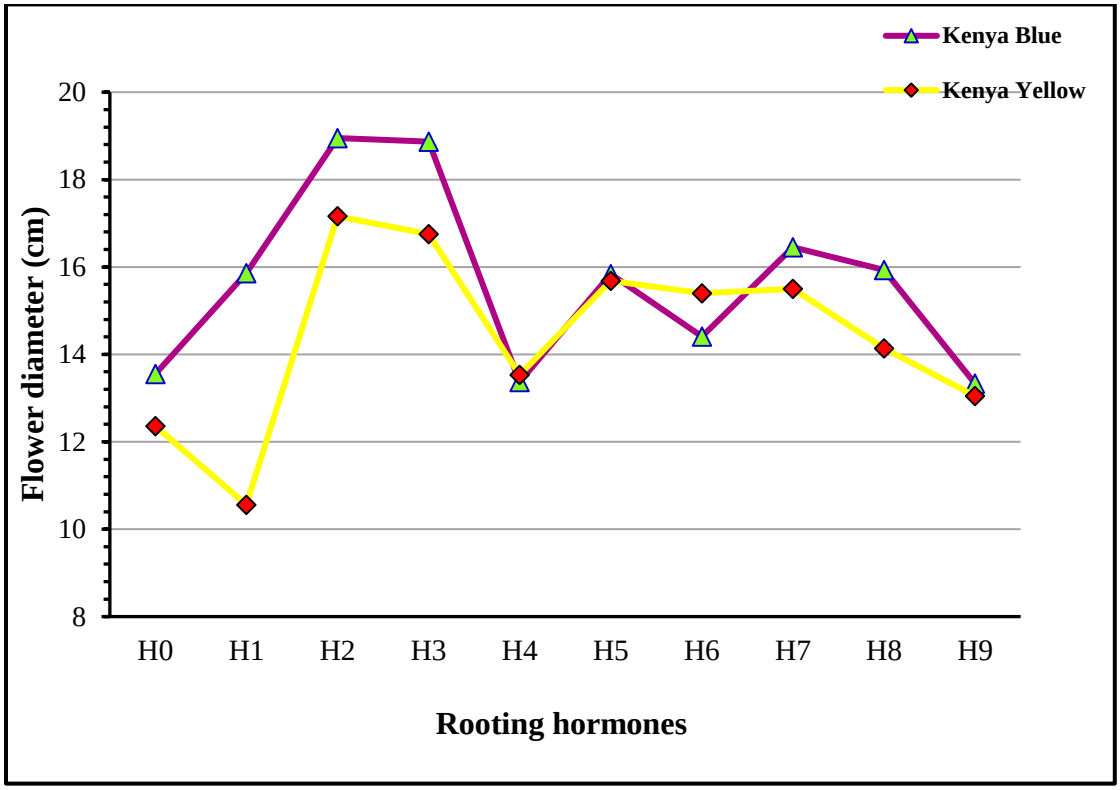

Fig. 4.44: Effect of rooting hormones flower diameter (cm) in dahlia mutants

4.2.3.5 Number of ray florets flower^{-1}

The data presented in Table 4.48 envisages that rooting hormones had significant effect on number of ray florets flower^{-1}. Among the treatments, significantly maximum number of ray florets flower^{-1} (146) was recorded in plants treated with IBA @ 500 ppm, which was statistically *at par* with IBA @ 1000 ppm (140.17). However, minimum number of ray florets flower^{-1} (115.50) recorded at treatment IBA @ 500 ppm + NAA @ 500 ppm, which was *at par* with treatment NAA @ 250 ppm, NAA @ 500 ppm and IBA @ 250 ppm (116, 119.25 and 123.08, respectively).

Table 4.48: Effect of rooting hormones on number of ray florets flower^{-1} in dahlia mutants

Cultivar / Rooting hormones	Number of ray florets flower^{-1}		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	134.67	125.50	130.08
IBA @ 250 ppm	129.33	116.83	123.08
IBA @ 500 ppm	148.67	143.33	146.00
IBA @ 1000 ppm	143.33	137.00	140.17
NAA @ 250 ppm	128.83	103.17	116.00
NAA @ 500 ppm	122.00	116.50	119.25
NAA @ 1000 ppm	124.00	131.67	127.83
IBA @ 125 ppm + NAA @ 125 ppm	132.33	130.33	131.33
IBA @ 250 ppm + NAA @ 250 ppm	137.83	126.67	132.25
IBA @ 500 ppm + NAA @ 500 ppm	119.83	111.17	115.50
Mean	132.08	124.22	
	CD at 5%		**S.Em±**
Rooting hormone	8.31		2.90
Cultivar	3.71		1.30
Rooting hormone × Cultivar	NS		4.11

As regards to mutants of cultivars, Kenya Blue had significantly maximum number of ray florets flower^{-1} (132.08), which was significantly higher than other one.

The interaction effect of mutants of cultivar and rooting hormones was non-significant on number of ray florets flower^{-1}, interaction of mutants of cultivar Kenya Blue treated with IBA @ 500 ppm resulted significantly maximum number of ray florets flower^{-1} (148.67).

There was drastic reduction in number of ray florets flower^{-1} with increase in dose of NAA but highest number of ray florets was recorded at IBA @ 500 ppm. Doddagoudar *et al.* (2004) stated that rapid mobilization and accumulation of metabolites influence the floral morphogenesis resulting in increase in number of ray florets in china aster. These results are in conformity with findings of Girisha *et al.* (2012) in daisy and Ranipise *et al.* (2004) in chrysanthemum.

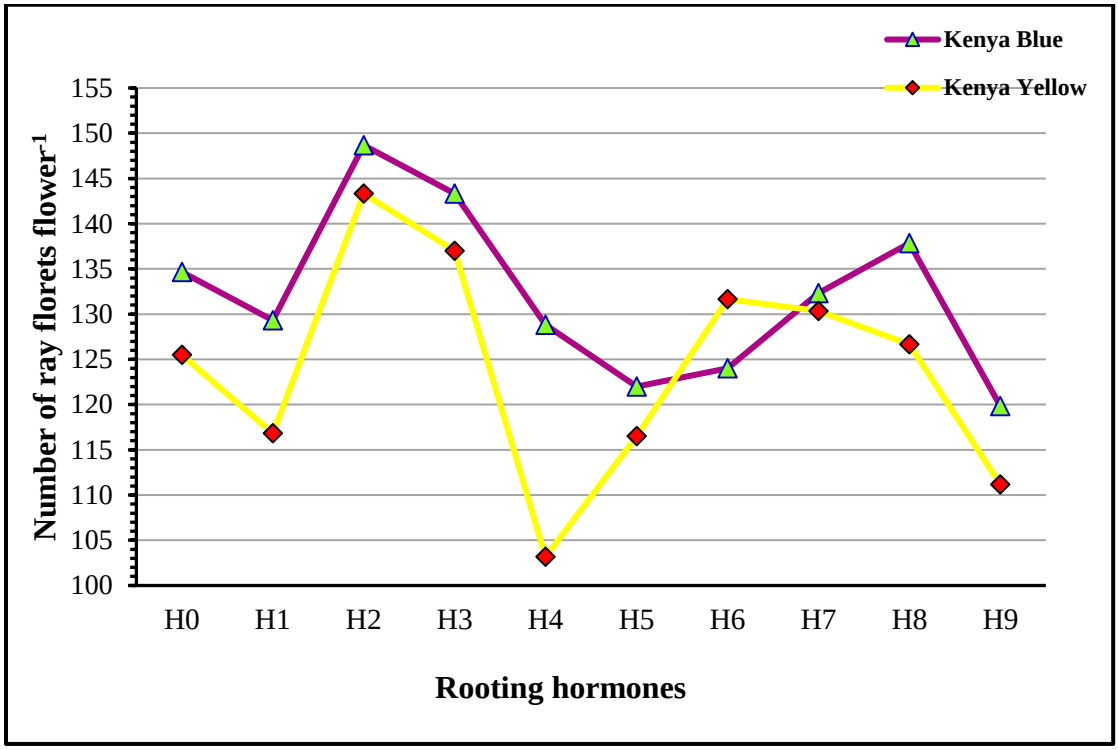

Fig. 4.45: Effect of rooting hormones on number of ray florets flower^{-1} in dahlia mutants

4.2.3.6 Flower stalk diameter (cm)

The data recorded for flower stalk diameter have been presented in Table 4.51 revealed that the effect of rooting hormones on flower stalk diameter was highly significant. The maximum flower stalk diameter (5.61 cm) was recorded in treatment IBA @ 1000 ppm, which was significantly higher than the rest of the rooting hormone treatments. Whereas, minimum flower stalk diameter (2.59 cm) was recorded at control.

Table 4.49: Effect of rooting hormones on flower stalk diameter (cm) in dahlia mutants

Cultivar / Rooting hormones	Flower stalk diameter (cm)		
	Kenya Blue	Kenya Yellow	Mean
Control	2.38	2.80	2.59
IBA @ 250 ppm	3.73	3.43	3.58
IBA @ 500 ppm	4.75	5.11	4.93
IBA @ 1000 ppm	5.00	6.22	5.61
NAA @ 250 ppm	2.75	3.17	2.96
NAA @ 500 ppm	5.16	4.85	5.01
NAA @ 1000 ppm	3.51	4.61	4.06
IBA @ 125 ppm + NAA @ 125 ppm	4.27	3.07	3.67
IBA @ 250 ppm + NAA @ 250 ppm	4.65	4.70	4.68
IBA @ 500 ppm + NAA @ 500 ppm	4.70	4.37	4.53
Mean	4.09	4.23	
	CD at 5%		**S.Em±**
Rooting hormone	0.23		0.08
Cultivar	0.10		0.03
Rooting hormone × Cultivar	0.33		0.11

Mutants of cultivar differences for flower stalk diameter were also significant, plants of mutants of cultivar Kenya Yellow had significantly maximum flower stalk diameter 4.23 cm, which was recorded significantly higher than the other mutants of cultivar Kenya Blue (4.09 cm).

It is clear from data that an interaction among rooting hormones treatments and mutants of cultivar was also significant, untreated plants of mutants of cultivar Kenya Blue exhibited significantly minimum flower stalk diameter 2.38 cm, which was followed by interaction of mutants of Kenya Blue treated with NAA @ 250 ppm (2.75 cm), whereas, maximum flower stalk diameter (6.22 cm) was recorded in interaction of mutants of Kenya Yellow treated with IBA @ 1000 ppm.

Flower stalk diameter increased in mutants of both cultivars with increased dose of rooting hormones. Highest flower stalk diameter was noticed in plants treated with IBA @ 1000 ppm. Reduction in flower stalk diameter due to changes in auxin level or due to inactivation of auxin was hypothesized by Grewal (2005) in chrysanthemum. These results are in conformity with the work of Akhtar *et al.* (2002) and Nasri *et al.* (2015) in rose.

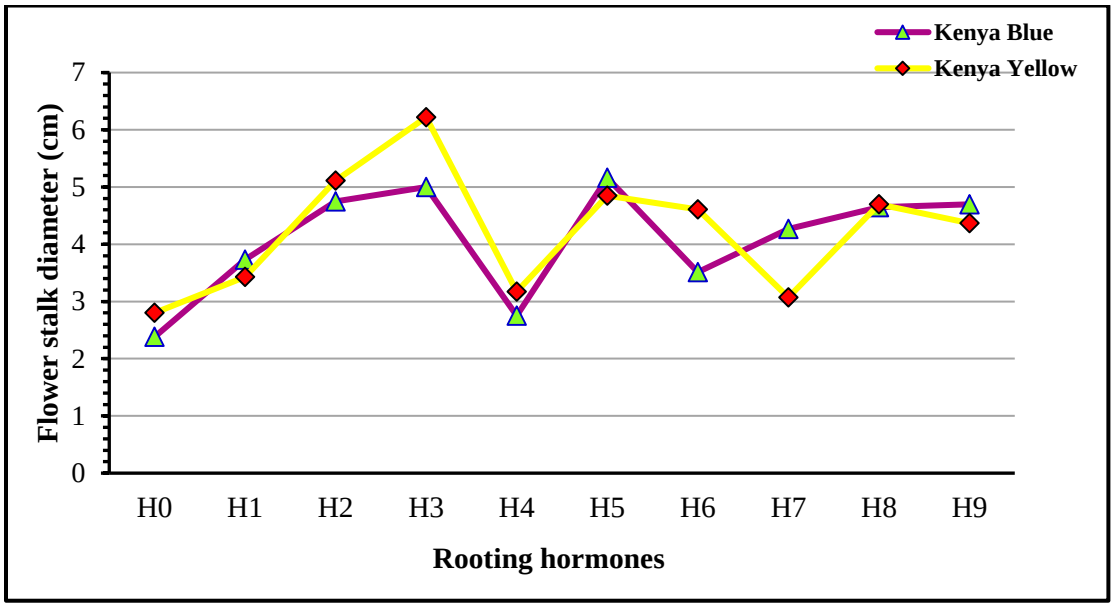

Fig. 4.46: Effect of rooting hormones on flower stalk diameter (cm) in dahlia mutants

4.2.3.7 Flower stalk length (cm)

The data pertaining to effect of rooting hormones, mutants of cultivar and their interactions on flower stalk length in Table 4.50 and Fig. 4.47. The perusal of the data depicts that the effect of rooting hormones was highly significant, untreated plants resulted significantly shortest flower stalk (27.63 cm), whereas, longest flower stalk was recorded in plants treated with IBA @ 250 ppm + NAA @ 250 ppm (44.23 cm). Mutants of cultivar of dahlia for flower stalk length were also highly significant, flower stalk length of mutants of cultivar Kenya Yellow were longest (38.47 cm), whereas, mutants of cultivar Kenya Blue produced shortest flower stalk length (36.78 cm).

Table 4.50: Effect of rooting hormones on flower stalk length (cm) in dahlia mutants

Cultivar / Rooting hormones	Flower stalk length (cm)		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	29.86	25.39	27.63
IBA @ 250 ppm	33.66	32.92	33.29
IBA @ 500 ppm	34.18	36.52	35.35
IBA @ 1000 ppm	36.14	39.63	37.89
NAA @ 250 ppm	36.48	45.91	41.19
NAA @ 500 ppm	34.11	51.83	42.97
NAA @ 1000 ppm	48.10	36.96	42.53
IBA @ 125 ppm + NAA @ 125 ppm	36.44	39.22	37.83
IBA @ 250 ppm + NAA @ 250 ppm	43.82	44.64	44.23
IBA @ 500 ppm + NAA @ 500 ppm	35.03	31.66	33.35
Mean	36.78	38.47	
	CD at 5%		**S.Em±**
Rooting hormone	0.96		0.33
Cultivar	0.43		0.15
Rooting hormone × Cultivar	1.35		0.47

Interaction effect of rooting hormones and mutants of cultivar were also found significant, untreated plants of mutants of cultivar Kenya Yellow had shortest flower stalk (25.39 cm) followed by untreated plants of mutants of cultivar Kenya Blue (29.86 cm). However, the plants of mutants of cultivar treated with NAA @ 500 ppm exhibited significantly longest flower stalk length (51.83 cm).

With respect to mutants of cultivar, plants treated with IBA @ 250 ppm + NAA @ 250 ppm were found superior over control. Adventitious root formation is a key step in vegetative propagation of horticultural species and problems associated with rooting of cuttings frequently result in significant increase of length of stalk (De Klerk *et al.* 1999). These results are in parallel line with the findings of Ranipise *et al.* (2012), who recorded increase in flower stalk length with increase in dose of rooting hormones in chrysanthemum.

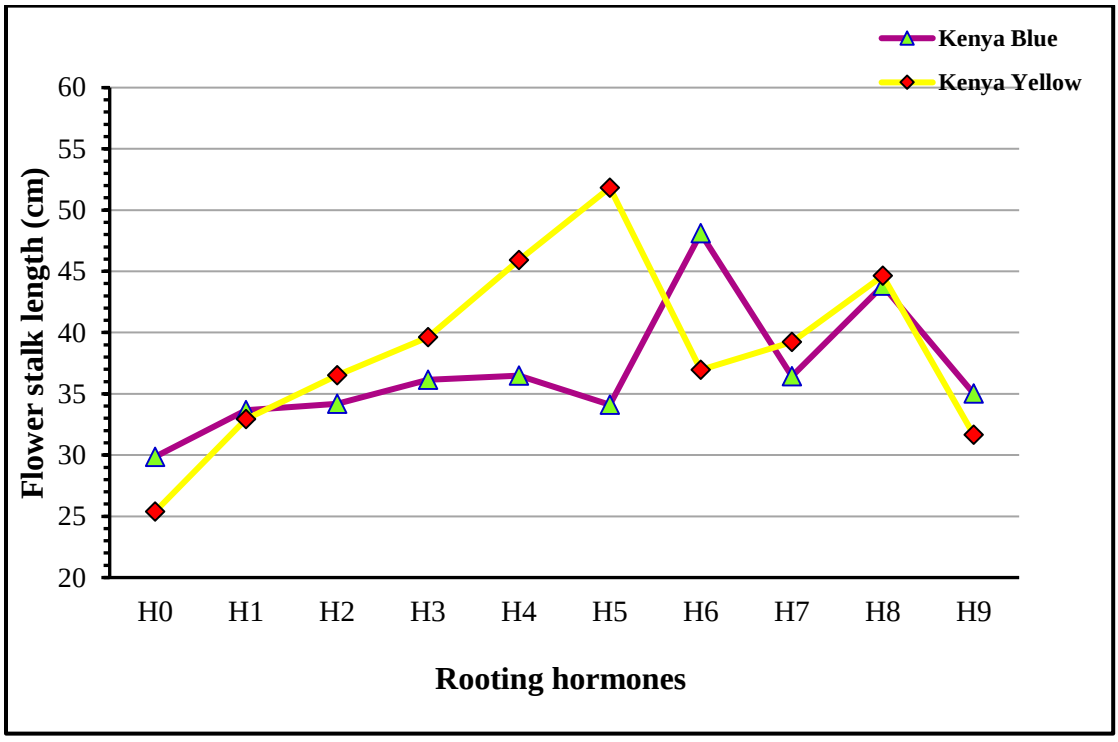

Fig. 4.47: Effect of rooting hormones on flower stalk length (cm) in dahlia mutants

4.2.3.8 Longevity of flower (days)

The data pertaining to longevity of flower in days presented in Table 4.51 and Fig. 4.48, which influenced by mutants of two dahlia cultivar and different concentrations of rooting hormones. Irrespective of mutants of cultivars, untreated plants had lowest longevity (5.60 days), which was statistically *at par* with treatment IBA @ 125 ppm + NAA @ 125 ppm (5.95 days). However, significantly maximum longevity of flower was recorded in IBA @ 500 ppm (7.63 days), which was *at par* with treatment IBA @ 1000 ppm (7.45 days).

Table 4.51: Effect of rooting hormones on longevity of flower (days) in dahlia mutants

Cultivar / Rooting hormones	**Longevity of flower (days)**		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	5.79	5.41	5.60
IBA @ 250 ppm	6.01	6.42	6.22
IBA @ 500 ppm	7.99	7.26	7.63
IBA @ 1000 ppm	8.10	6.80	7.45
NAA @ 250 ppm	6.78	5.82	6.30
NAA @ 500 ppm	7.08	6.58	6.83
NAA @ 1000 ppm	7.05	6.10	6.57
IBA @ 125 ppm + NAA @ 125 ppm	5.99	5.90	5.95
IBA @ 250 ppm + NAA @ 250 ppm	7.19	6.74	6.97
IBA @ 500 ppm + NAA @ 500 ppm	6.90	6.19	6.54
Mean	6.89	6.32	
	CD at 5%		**S.Em±**
Rooting hormone	0.47		0.16
Cultivar	0.21		0.07
Rooting hormone × Cultivar	NS		0.23

Among the mutants of cultivars, plants of mutants of Kenya Blue had recorded significantly maximum longevity of flower (6.89 days), whereas, minimum longevity of flower was recorded in mutants of Kenya Yellow (6.32 days).

It is clearly revealed from the data that the longevity of flower was non-significantly affected by mutants of cultivar and rooting hormones. Whereas, maximum longevity of flower was recorded in interaction of mutants of Kenya Blue treated with IBA @ 1000 ppm (8.10 days).

Longevity of flower was significantly influenced by rooting hormones. Highest longevity was noticed in IBA @ 500 ppm. The highest longevity of flower might be due to rapid mobilization and accumulation of metabolites by IBA which properly influences the floral morphogenesis rendered the longevity of flower. The result regarding longevity of flower are in agreement with the results of Kumar *et al.* (2014) in carnation and Khuriwal *et al.* (2018) in dahlia.

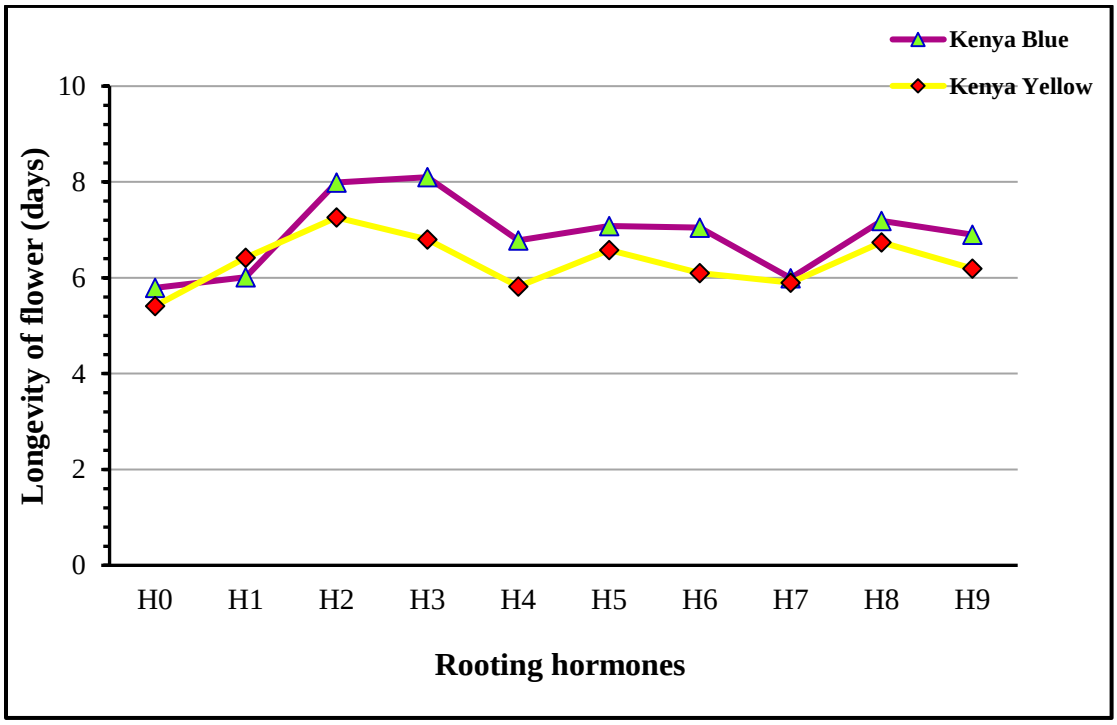

Fig. 4.48: Effect of rooting hormones on longevity of flower (days) in dahlia mutants

4.2.3.9 Number of flower plant^{-1}

The data presented in Table 4.52 envisages that rooting hormones had significant effect on number of flower plant^{-1}. Among the treatments, IBA @ 1000 ppm recorded significantly maximum number of flower plant^{-1} (9.53), which was significantly higher than the other treatment while untreated plants recorded minimum number of flower plant^{-1} (4.63) followed by NAA @ 250 ppm (5.24). The comparison among response of mutants of two cultivars revealed that plants of mutants of cultivar Kenya Yellow had significantly maximum number of flower plant^{-1} (7.71), which was significantly higher than the other one.

Table 4.52: Effect of rooting hormones on number of flower plant^{-1} in dahlia mutants

Cultivar / Rooting hormones	Number of flower plant^{-1}		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	3.92	5.34	4.63
IBA @ 250 ppm	3.98	7.92	5.95
IBA @ 500 ppm	6.45	8.72	7.58
IBA @ 1000 ppm	8.69	10.38	9.53
NAA @ 250 ppm	5.13	5.35	5.24
NAA @ 500 ppm	5.69	8.26	6.98
NAA @ 1000 ppm	5.60	7.23	6.41
IBA @ 125 ppm + NAA @ 125 ppm	5.12	7.06	6.09
IBA @ 250 ppm + NAA @ 250 ppm	5.58	8.68	7.13
IBA @ 500 ppm + NAA @ 500 ppm	5.45	8.18	6.81
Mean	5.56	7.71	
	CD at 5%		**S.Em±**
Rooting hormone	0.423		0.148
Cultivar	0.189		0.066
Rooting hormone × Cultivar	0.598		0.209

The interaction effect of mutants of cultivar and rooting hormones was also significant on number of flowers plant^{-1}, untreated plants of mutants of Kenya Blue exhibited significantly minimum number of flower plant^{-1} (3.92), which was *at par* with interaction of mutants of Kenya Blue treated with IBA @ 250 ppm i.e. 3.98, whereas plants of mutants of Kenya Yellow treated with IBA @ 1000 ppm recorded significantly maximum number of flower plant^{-1} (10.38).

Number of flowers plant^{-1} were significantly increased by different levels of IBA and NAA at all successive stages of growth. Similarly, observations were recording in Sekar and Sujata, (2001). The number of flowers plant^{-1} was closely correlated with number of branches plant^{-1}. The results of this study is in close conformity with the findings of Anil (2004) in French marigold.

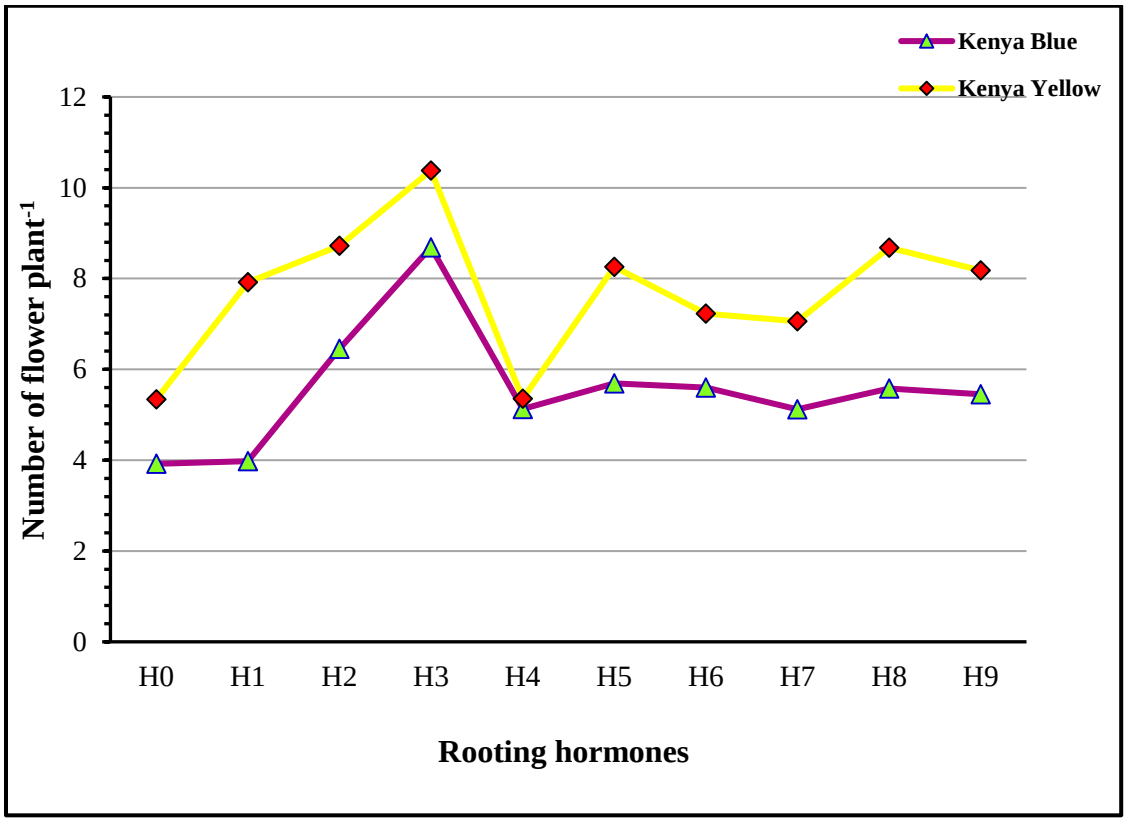

Fig. 4.49: Effect of rooting hormones in number of flower plant^{-1} in dahlia mutants

4.2.3.10 Flower weight plant^{-1} (g)

Data related to flower weight plant^{-1} have been presented in Table 4.53 and Fig. 4.50. It is evident from the data that the effect of rooting hormones, mutants of cultivar of dahlia and their interactions on flower weight plant^{-1} was significant, untreated plants exhibited minimum weight of flower plant^{-1} (14.66 g), whereas, treatment IBA @ 1000 ppm resulted significantly maximum flower weight (34.91 g). Irrespective of rooting hormones, plants of mutants of cultivar Kenya Blue had significantly maximum flower weight (32.83 g), which was significantly higher as compared to the mutants of cultivar Kenya Yellow (20.44 g).

Table 4.53: Effect of rooting hormones in flower weight plant^{-1} (g) dahlia mutants

Cultivar / Rooting hormones	Flower weight plant^{-1} (g)		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	18.58	10.74	14.66
IBA @ 250 ppm	32.14	21.57	26.85
IBA @ 500 ppm	41.51	28.31	34.91
IBA @ 1000 ppm	47.93	27.56	37.75
NAA @ 250 ppm	21.40	10.88	16.14
NAA @ 500 ppm	39.74	22.43	31.08
NAA @ 1000 ppm	26.92	20.11	23.52
IBA @ 125 ppm + NAA @ 125 ppm	26.12	15.95	21.04
IBA @ 250 ppm + NAA @ 250 ppm	40.32	26.54	33.43
IBA @ 500 ppm + NAA @ 500 ppm	33.63	20.29	26.96
Mean	32.83	20.44	
	CD at 5%		**S.Em±**
Rooting hormone	0.90		0.31
Cultivar	0.40		0.14
Rooting hormone × Cultivar	1.28		0.44

Interaction effect of rooting hormones and mutants of cultivars revealed that the untreated plants of mutants of cultivar Kenya Yellow resulted in minimum weight of flower plant^{-1} (10.74 g), which was *at par* with flower weight of interaction of mutants of same cultivar with NAA @ 250 ppm (10.88 g), whereas, plants of mutants of cultivar Kenya Blue treated with IBA @ 1000 ppm resulted significantly maximum flower weight (47.93 g).

The flower weight plant^{-1} varied significantly due to treatment of rooting hormones. Rooted cuttings treated with IBA @1000 ppm recorded significantly higher weight, this may have attributed to availability of higher photosynthesis towards the sink *i.e.* flowers due to increased photosynthetic surface area and photosynthetic activity in leaves due to increase in chlorophyll content leaves. The results are in agreement with Khuriwal *et al.* (2018) in dahlia, Bharmal *et al.* (2005) in chrysanthemum and Ullah *et al.* (2013) in marigold.

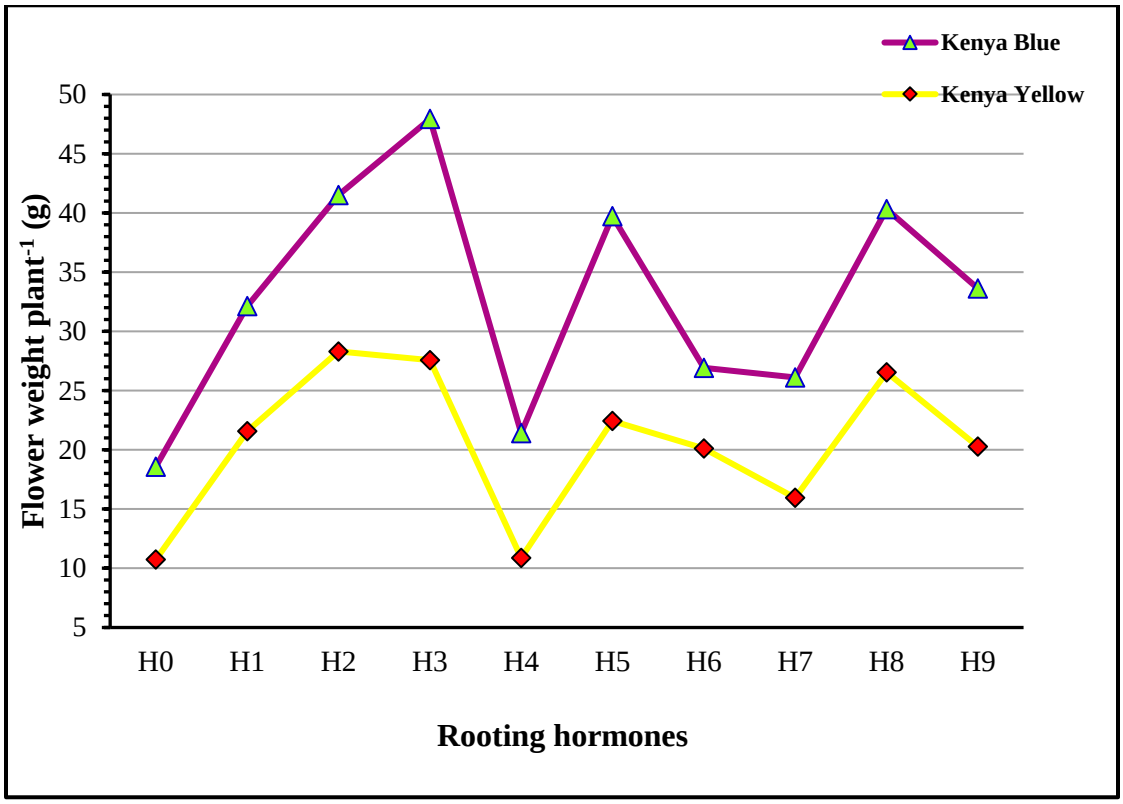

Fig. 4.50: Effect of rooting hormones in flower weight plant^{-1} in dahlia mutants

4.2.3.11 Duration of flowering (days)

The data related to duration of flowering have been presented in Table 4.54 and Fig. 4.51. It is evident from the data that rooting hormones, mutants of cultivars and interactions of both had significant effect on flowering duration, untreated plants had shortest duration of flowering (42.75 days) while significantly longest duration of flowering (62.06 days) were observed in treatment in IBA @ 500 ppm followed by treatment IBA @ 250 ppm + NAA @ 250 ppm (54.25 days).

Table 4.54: Effect of rooting hormones in duration of flowering (days) in dahlia mutants

Cultivar / Rooting hormones	Duration of flowering (days)		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	40.61	44.89	42.75
IBA @ 250 ppm	45.49	51.15	48.32
IBA @ 500 ppm	58.12	65.99	62.06
IBA @ 1000 ppm	57.61	49.03	53.32
NAA @ 250 ppm	45.48	46.88	46.18
NAA @ 500 ppm	51.25	56.95	54.10
NAA @ 1000 ppm	44.51	47.21	45.86
IBA @ 125 ppm + NAA @ 125 ppm	42.89	48.29	45.59
IBA @ 250 ppm + NAA @ 250 ppm	51.33	57.17	54.25
IBA @ 500 ppm + NAA @ 500 ppm	63.41	44.93	54.17
Mean	50.07	51.25	
	CD at 5%		**S.Em±**
Rooting hormone	1.37		0.48
Cultivar	0.61		0.21
Rooting hormone × Cultivar	1.93		0.67

Among the mutants of two cultivars, mutants of Kenya Yellow had recorded significantly maximum duration of flowering (51.25 days), whereas, minimum duration of flowering was 50.7 days recorded in mutants of cultivar Kenya Blue.

Interaction of control treatment and mutants of cultivar Kenya Blue exhibited shortest duration of flowering (40.61 days). However, significantly longest duration of flowering (65.99 days) recorded in plants of mutants of cultivar Kenya Yellow treated with IBA @ 500 ppm, which was followed by interaction of mutants of Kenya Yellow with IBA @ 500 ppm + NAA @ 500 ppm (63.41 days).

The longest duration of flowering was recorded under treatment of IBA @500 ppm although it had no positive effect on flower yield. In fact, late bud initiation caused longer flowering period that was possibly due to late flower opening, these results were supported by Saffari *et al*. (2004) in *Rosa damascene* and Masen (1993), who observed inhibition in shooting with increased concentration of IBA in other species.

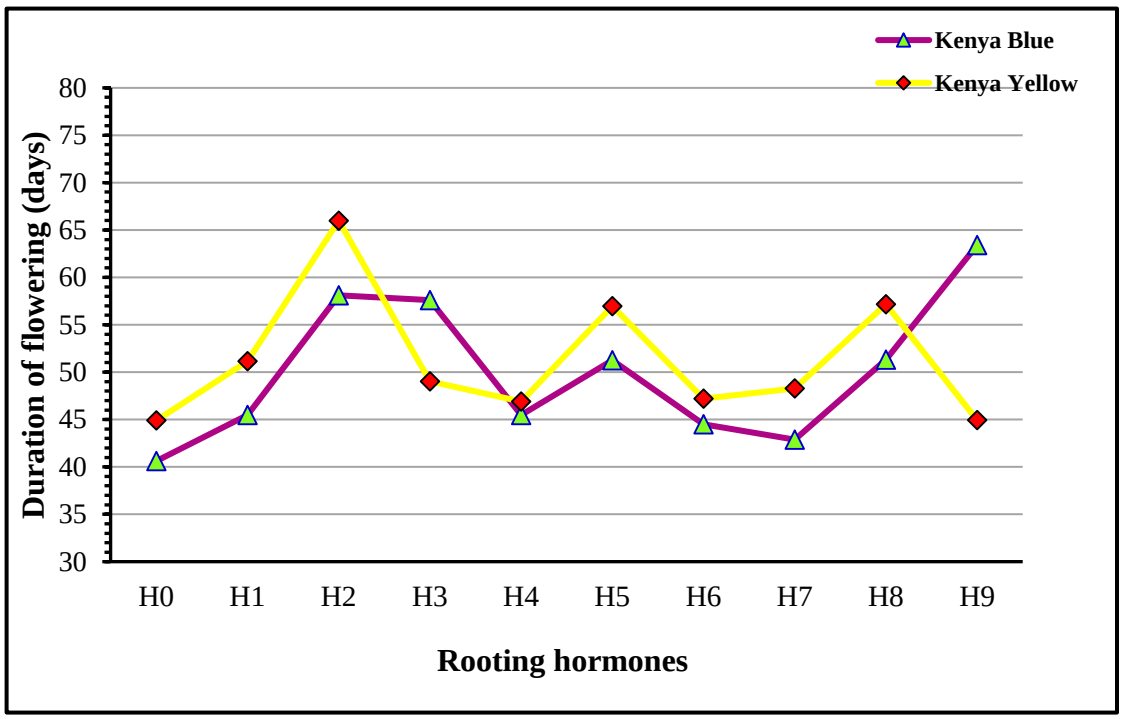

Fig.4.51: Effect of rooting hormones in duration of flowering (days) in dahlia mutants

4.2.4 Effect of rooting hormones on tuber characters in the propagation of dahlia mutants

4.2.4.1 Number of tubers plant^{-1}

A perusal of data presented in Table 4.55 and Fig. 4.52 revealed that different concentrations of rooting hormones, mutants of dahlia cultivar and their interactions had significant effect on number of tubers plant^{-1}. Amongst all the treatments, significantly maximum number of tubers plant^{-1} (10.81) recorded in plants treated with IBA @ 500 ppm, whereas untreated plants recorded minimum number of tubers plant^{-1} (6.82).

Table 4.55: Effect of rooting hormones in number of tubers plant^{-1} in dahlia mutants

Cultivar / Rooting hormones	Number of tubers plant^{-1}		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	6.30	7.34	6.82
IBA @ 250 ppm	8.06	9.58	8.82
IBA @ 500 ppm	10.44	11.17	10.81
IBA @ 1000 ppm	9.33	10.48	9.91
NAA @ 250 ppm	6.95	9.13	8.04
NAA @ 500 ppm	9.71	10.24	9.98
NAA @ 1000 ppm	9.36	9.22	9.29
IBA @ 125 ppm + NAA @ 125 ppm	9.12	6.01	7.56
IBA @ 250 ppm + NAA @ 250 ppm	9.57	10.68	10.12
IBA @ 500 ppm + NAA @ 500 ppm	9.44	10.18	9.81
Mean	8.83	9.40	
	CD at 5%		**S.Em±**
Rooting hormone	0.32		0.11
Cultivar	0.14		0.05
Rooting hormone × Cultivar	0.45		0.15

The comparison among response of mutants of both cultivars revealed that plants of mutants of cultivar Kenya Yellow had significantly maximum number of tubers plant^{-1} (9.40), which was significantly higher than rest of the rest one.

All interactions of mutants of cultivar with rooting hormones were influenced the production of tubers plant^{-1} significantly, minimum number of tubers plant^{-1} (6.01) was recorded in interaction of mutants of Kenya Yellow treated with IBA 125 ppm + NAA 125 ppm, which was significantly *at par* with untreated plants of mutants of Kenya Blue (6.30), while significantly maximum number of tubers plant^{-1} produced by mutants of Kenya Yellow treated with treatment IBA @ 500 ppm (11.17).

Total number of tubers plant^{-1} increased when plants treated with IBA and NAA. Highest number of tubers recorded in IBA at the rate of 500 ppm. Similar results were reported by Sharma *et al.* (1998) and Alexios *et al.* (2006) in potato.

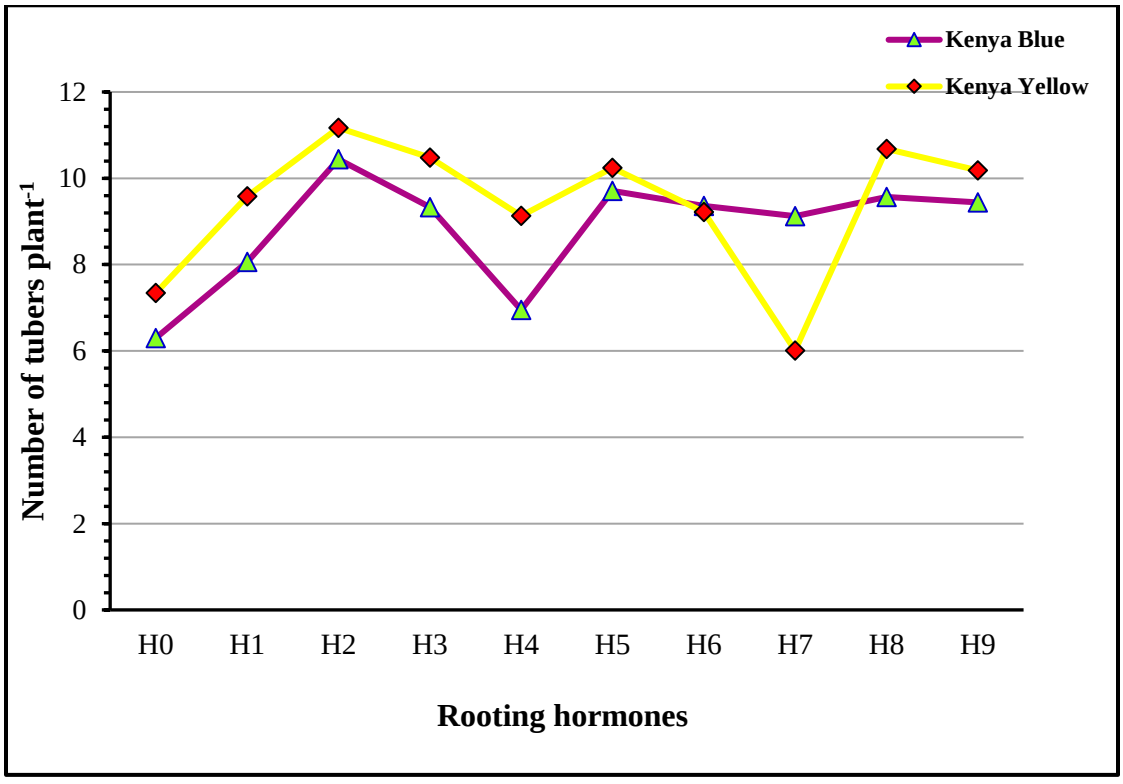

Fig.4.52: Effect of rooting hormones in number of tubers plant^{-1} in dahlia mutants

4.2.4.2 Weight of tubers plant^{-1} (g)

It is evident from the data (Table 4.56) that effect of rooting hormones, mutants of dahlia cultivars and their interactions on weight of tubers plant^{-1} were highly significant. Irrespective of mutants of cultivars, untreated plants recorded minimum (71.33 g) weight of tubers plant^{-1}, whereas, significantly maximum weight of tubers plant^{-1} was recorded at treatment IBA @ 500 ppm (108 g), which was followed by treatment NAA @ 500 ppm (102.20 g).

Table 4.56: Effect of rooting hormones on weight of tubers plant^{-1} (g) in dahlia mutants

Cultivar / Rooting hormones	Weight of tubers plant^{-1} (g)		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	75.35	67.31	71.33
IBA @ 250 ppm	82.96	95.47	89.22
IBA @ 500 ppm	104.33	111.67	108.00
IBA @ 1000 ppm	93.34	106.41	99.88
NAA @ 250 ppm	91.27	93.62	92.44
NAA @ 500 ppm	101.06	103.35	102.20
NAA @ 1000 ppm	93.47	101.71	97.59
IBA @ 125 ppm + NAA @ 125 ppm	89.78	74.67	82.23
IBA @ 250 ppm + NAA @ 250 ppm	105.26	96.18	100.72
IBA @ 500 ppm + NAA @ 500 ppm	101.56	94.72	98.14
Mean	93.84	94.51	
	CD at 5%		**S.Em±**
Rooting hormone	1.23		0.43
Cultivar	0.55		0.19
Rooting hormone × Cultivar	1.74		0.61

Among the mutants of cultivars, plants of mutants of Kenya Yellow exhibited significantly maximum weight of tubers plant^{-1} (94.51 g), which was significantly higher than the other mutants of cultivar.

Interaction of control treatment with plants of mutants of Kenya Yellow resulted in minimum weight of tubers plant^{-1} (67.31 g), while mutants of cultivar Kenya Yellow treated with IBA @ 500 ppm resulted significantly maximum tuber weight plant^{-1} (111.67 g) which was followed by interaction of mutants of Kenya Yellow and IBA @ 1000 ppm (106.41 g).

Average weight of tubers plant^{-1} produced maximum in IBA @ 500 ppm and minimum in control. Average weight of tubers plant^{-1} was significantly increased at certain levels of IBA and NAA at all successive stages of growth. Similarly, observation was recorded by Khan and Tiwari (2003) and Khuriwal *et al.* (2018).

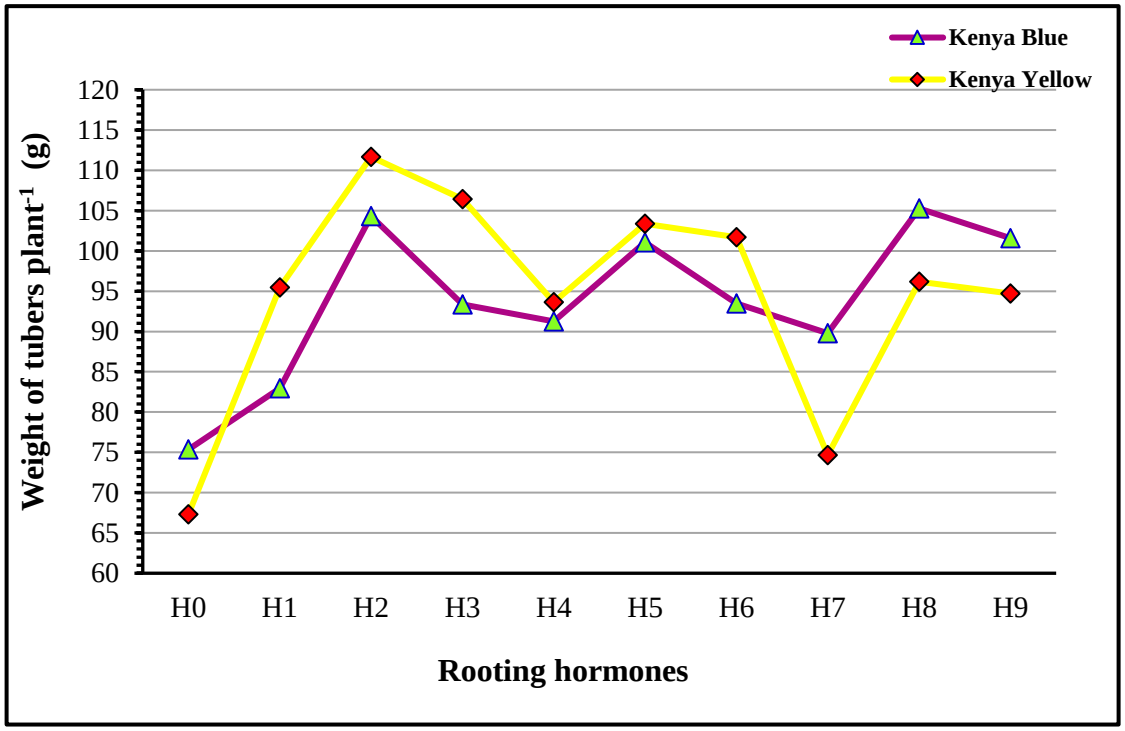

Fig.4.54: Effect of rooting hormones on weight of tubers plant^{-1} in dahlia mutants

4.2.4.3 Diameter of tuber (cm)

The data recorded for this trait have been presented in Table 4.57 and graphically represented in Fig. 4.54. The data revealed that the effect of rooting hormones was significant on diameter of tuber, significantly maximum tuber diameter (5.52 cm) was recorded in treatment IBA 125 ppm + NAA 125 ppm, which was statistically *at par* with treatment IBA @ 250 ppm (5.30 cm), IBA @ 250 ppm + NAA @ 250 ppm (5.30 cm) and NAA @ 500 ppm (5.31 cm), whereas, minimum diameter of tuber (4.58 cm) was recorded at treatment IBA 1000 ppm.

Table 4.57: Effect of rooting hormones on diameter of tubers (cm) dahlia mutants

Cultivar / Rooting hormones	Diameter of tuber (cm)		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	4.74	5.72	5.23
IBA @ 250 ppm	4.83	5.78	5.30
IBA @ 500 ppm	5.25	4.86	5.06
IBA @ 1000 ppm	4.01	5.14	4.58
NAA @ 250 ppm	4.13	5.77	4.95
NAA @ 500 ppm	5.71	4.91	5.31
NAA @ 1000 ppm	4.70	4.89	4.80
IBA @ 125 ppm + NAA @ 125 ppm	5.31	5.72	5.52
IBA @ 250 ppm + NAA @ 250 ppm	5.57	5.02	5.30
IBA @ 500 ppm + NAA @ 500 ppm	4.91	4.51	4.71
Mean	4.92	5.23	
	CD at 5%		**S.Em±**
Rooting hormone	0.17		0.05
Cultivar	0.07		0.02
Rooting hormone × Cultivar	0.24		0.08

Mutants of cultivar differences for tuber diameter were also significant, mutants of cultivar Kenya Yellow had significantly maximum diameter of tuber (5.23 cm), which was comparatively higher than the mutants of another cultivar.

It is clear from the data that an interaction among rooting hormones and mutants of cultivars was also found significant on diameter of tuber, plants of mutants of cultivar Kenya Yellow treated with IBA @ 250 ppm exhibited significantly larger tuber with diameter 5.78 cm, which was statistically *at par* with tuber diameter in interaction of mutants of Kenya Yellow with NAA @ 250 ppm (5.77 cm), IBA 125 ppm + NAA 125 ppm (5.72 cm), control (5.72 cm) and interaction of mutants of Kenya Blue with NAA @ 500 ppm (5.71 cm) and IBA @ 250 ppm + NAA 250 ppm (5.57 cm). However, minimum (4.01 cm) diameter of tuber was recorded in mutants of Kenya Blue treated with IBA @ 1000 ppm.

The diameter of the tubers was significantly influenced by the different treatments of rooting hormones in mutants of cultivar. The tuber size was increased with 250-1000 ppm of IBA and interaction of IBA and NAA. The diameter of tuber may be attributed to the fact that due to treatment of rooting hormones, physiology of plant at higher doses was disturbed which affected photosynthesis and root system resulting in the improper growth of the plants by hampering root system. Similar results were reported by Alexios *et al*. (2006) and Kaur *et al.* (2018).

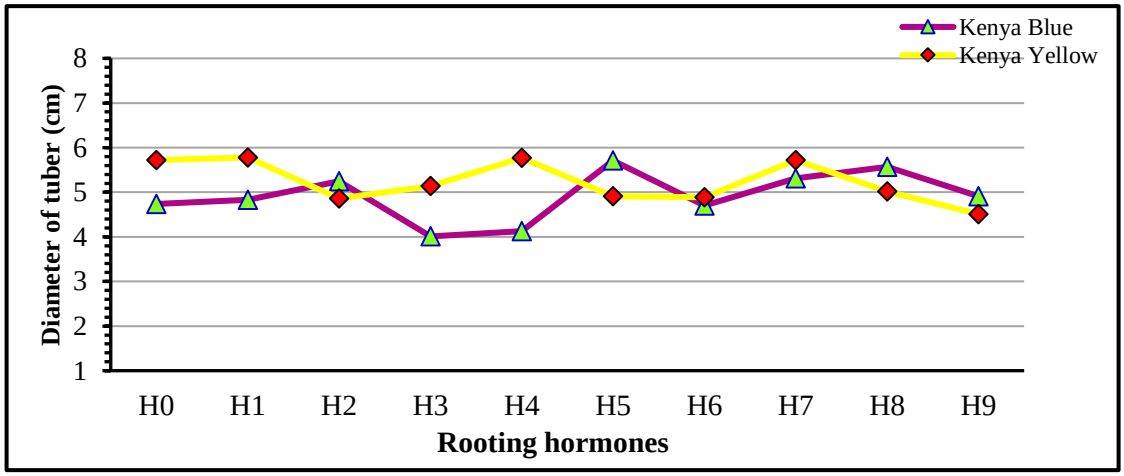

Fig.4.53: Effect of rooting hormones on diameter of tubers (cm) in dahlia mutants

4.2.5 Effect of rooting hormones on physiological characters in the propagation of dahlia mutants

4.2.5.1 Leaf chlorophyll content (mg g^{-1})

A critical rummage of data presented in Table 4.58 reveals that rooting hormones, mutants of cultivars and their interactions had significant effect on leaf chlorophyll content in dahlia plant, significantly maximum leaf chlorophyll content (47.26 mg g^{-1}) was recorded in treatment IBA @ 250 ppm which was followed by NAA @ 250 ppm (44.83 mg g^{-1}), whereas, plants treated with IBA 500 ppm + NAA 500 ppm recorded (38.36 mg g^{-1}).

Table 4.58: Effect of rooting hormones on leaf chlorophyll content (mg g^{-1}) in dahlia mutants

Cultivar / Rooting hormones	Leaf chlorophyll content (mg g^{-1})		
	Kenya Blue	**Kenya Yellow**	**Mean**
Control	47.41	39.64	43.53
IBA @ 250 ppm	52.69	41.84	47.26
IBA @ 500 ppm	45.46	38.05	41.76
IBA @ 1000 ppm	49.71	39.34	44.52
NAA @ 250 ppm	45.19	44.47	44.83
NAA @ 500 ppm	42.04	41.93	41.98
NAA @ 1000 ppm	43.13	37.64	40.38
IBA @ 125 ppm + NAA @ 125 ppm	41.65	46.58	44.11
IBA @ 250 ppm + NAA @ 250 ppm	39.28	46.72	43.00
IBA @ 500 ppm + NAA @ 500 ppm	30.90	45.81	38.36
Mean	43.75	42.20	
	CD at 5%		**S.Em±**
Rooting hormone	1.30		0.45
Cultivar	0.58		0.20
Rooting hormone × Cultivar	1.84		0.64

Among the mutants of dahlia, plants of mutants of cultivar Kenya Blue had significantly maximum leaf chlorophyll content (43.75 mg g^{-1}) which was significantly higher than the rest one.

Interaction of mutants of cultivar Kenya Blue with treatment IBA @ 250 ppm resulted significantly maximum leaf chlorophyll content (52.69 mg g^{-1}) followed by interaction of IBA @ 1000 ppm with mutants of same cultivar (49.71 mg g^{-1}), whereas, minimum leaf chlorophyll content was recorded in mutants of cultivar Kenya Blue treated with IBA 500 ppm + NAA 500 ppm (30.90 mg g^{-1}).

In the studied treatments, leaf chlorophyll content reduced gradually from higher to lower concentration tried. The induction of chlorophyll increased from 38.36 mg g^{-1} up to 47.26 mg g^{-1}. However, its influence on total chlorophyll were negative in different doses of NAA and different combinations of NAA and IBA. Similar results were obtained with Moacir *et al.* (2004) and Mervat and Far (2007) in sweet potato.

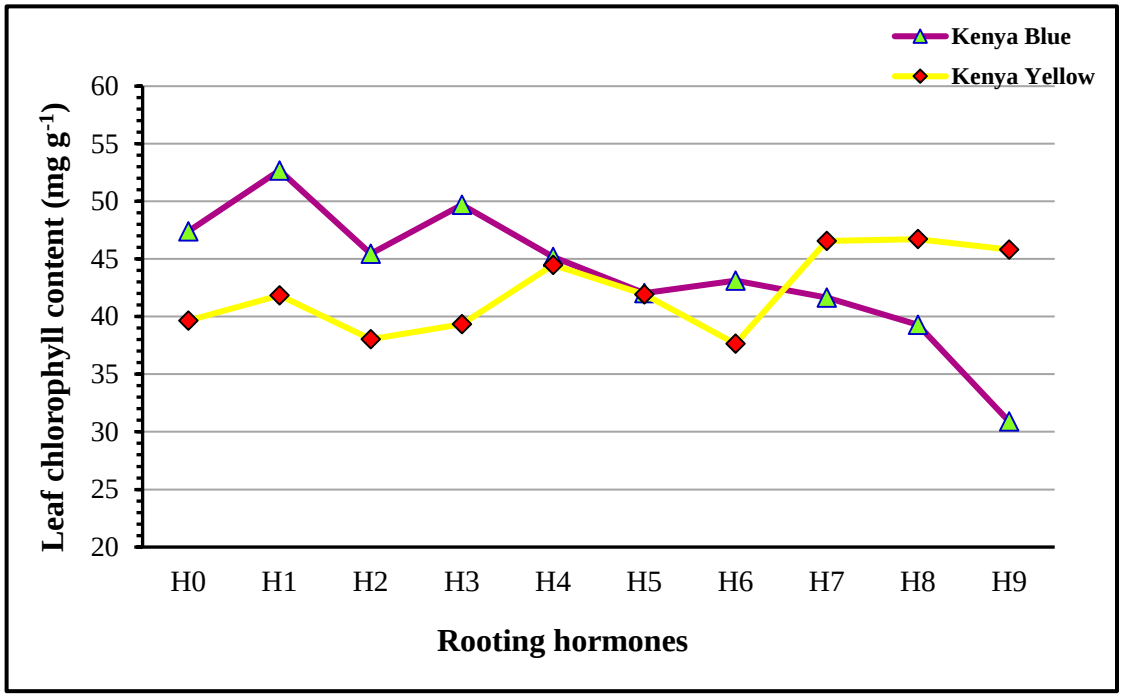

Fig.4.55: Effect of rooting hormones on leaf chlorophyll content (mg g^{-1}) in dahlia mutants

4.2.6 Screening of mutants in vM_2 population and their characterization

Screening of mutants for ornamental traits (colour) in vM_2 generation from mutants of vM_1 generation of dahlia cultivars (Kenya Blue and Kenya Yellow), total 26 mutants were screened out. Most of the colour mutants were in the form of solid and chimera mutants and recorded in 10 Gy gamma rays irradiated plants. Most of the mutations noticed in vM_1 generation were observed again in vM_2 generation. The observation was recorded on floral characters of the mutants screened after gamma radiations in all the cultivars of dahlia under study during 2019-20 and mean values of mutants are presented in Table 4.59 to 4.61 and Plate 4.4, 4.5 and 4.5a.

4.2.6.1 Mutants of Kenya Blue cultivar

The mutants of cultivar Kenya Blue produced eight mutants (KBM_1- KBM_8) which were screened, tagged and checked for the stability of the characters in next generation. The mutants were developed at 10 Gy dose of gamma radiations (Table 4.62 and Plate 4.4).

Mutant KBM_1

The plant height of mutant was recorded as 18.54 cm and 49.67 cm which were higher than the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (68) and total number of branches plant^{-1} (8) were minimum than original cultivar. Plant of this mutant took lesser days taken for first bud appearance, number of days taken for flower opening and longevity of flower than the original cultivar with 63, 18 and 5 days, respectively. However, the number of days taken for full bloom (11 days) was higher than original cultivar. The flower diameter and number of ray florets flower^{-1} were smaller than the original cultivar *i.e.* 10.12 cm 107, respectively. The number of flower plant^{-1} and flower weight were reduced marginally to 4 and 25.45 g plant^{-1} as compared to the original cultivar. Also the duration of flowering (39 days) was lower than the original cultivar. The colour of flower was matched as Purple Group NN78 A with

R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to small decorative in this mutant than the original flower form.

Mutant KBM_2

The mutant KBM_2 grew to a plant height of 16.36 cm and 52.79 cm which was higher than original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} and total number of branches plant^{-1} were higher (97 and 10, respectively) than the original cultivar. This mutant took lesser time for days taken for first bud appearance, number of days taken for flower opening, days taken for full bloom and longevity of flower than the original cultivar with 49, 21, 4 and 5 days, respectively. Also flower diameter, number of floret flower^{-1} and flower weight plant^{-1} were less than the original cultivar i.e. 9.9 cm, 62 and 8.42 g, respectively. However, the duration of flowering (54 days) was more than the original cultivar. The colour of flower was matched as Pink Group NN 74 A + Purple Group 75 C with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to small decorative in this mutant than the original flower form.

Mutant KBM_3

The mutant attained a plant height 15 cm and 51.63 cm which was higher than the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (43) was reduced than the original cultivar but total number of branches plant^{-1} (7) were higher than the original cultivar. Mutant KBM_3 took lesser time for days taken for first bud appearance (53 days), number of days taken for flower opening (11 days) and longevity of flower (7 days) but days taken for full bloom (12 days) and duration of flowering (66 days) were higher than the original cultivar with. Flower diameter, number of floret flower^{-1}, flower weight and number of flower plant^{-1} were lesser than the original cultivar i.e. 13.2 cm, 133, 16.5 g and 3, respectively. The colour of flower was matched as Pink Group NN 74 C with R.H.S. Colour Chart. No change was recorded in flower form in this mutant than the original flower form.

Table 4.59: Mutation spectrum and colour of mutants isolated from vM_2 generation

S. No.	Mutant	Gamma rays dose	Colour in vM_2 as per RHS Colour Chart
1.	KBM_1	10 Gy	Purple Group NN78 A
2.	KBM_2	10 Gy	Pink Group NN 74 A + Purple Group 75 C
3.	KBM_3	10 Gy	Pink Group NN 74 C
4.	KBM_4	10 Gy	Purple Group N78 A
5.	KBM_5	10 Gy	Red Purple Group 71 C
6.	KBM_6	10 Gy	Red Group 50 A + Red Group 56 A
7.	KBM_7	10 Gy	Red Purple Group 71 C
8.	KBM_8	10 Gy	Red Purple Group N57 B + Red Purple Group 70 D
9.	KYM_1	10 Gy	Grayed- Orange Group 165 C
10.	KYM_2	10 Gy	Grayed- Orange Group 164 D
11.	KYM_3	10 Gy	Grayed- Yellow Group 162 C
12.	KYM_4	10 Gy	Yellow Group 12 C
13.	KYM_5	10 Gy	Yellow Group 8 A
14.	KYM_6	10 Gy	Red Group 53 D + Yellow Group 10 B
15.	KYM_7	10 Gy	Red Group 51 A
16.	KYM_8	10 Gy	Red Purple Group 58 A
17.	KYM_9	10 Gy	Red Group 50 C + Orange White Group 159 A
18.	KYM_{10}	10 Gy	Red Group 38 A
19.	KYM_{11}	10 Gy	Red Group 36 D
20.	KYM_{12}	10 Gy	Red Group 45 C
21.	KYM_{13}	10 Gy	Red Group N45 D + White Group NN155 D
22.	KYM_{14}	10 Gy	White Group NN155 A + Red Group 45 B
23.	KYM_{15}	10 Gy	Red Group 45 B + Red Group 56 D
24.	KYM_{16}	10 Gy	Red Purple Group 65 D + Red Group 43 A
25.	KYM_{17}	10 Gy	Red Purple Group 69 D
26.	KYM_{18}	10 Gy	Orange Group 29 D

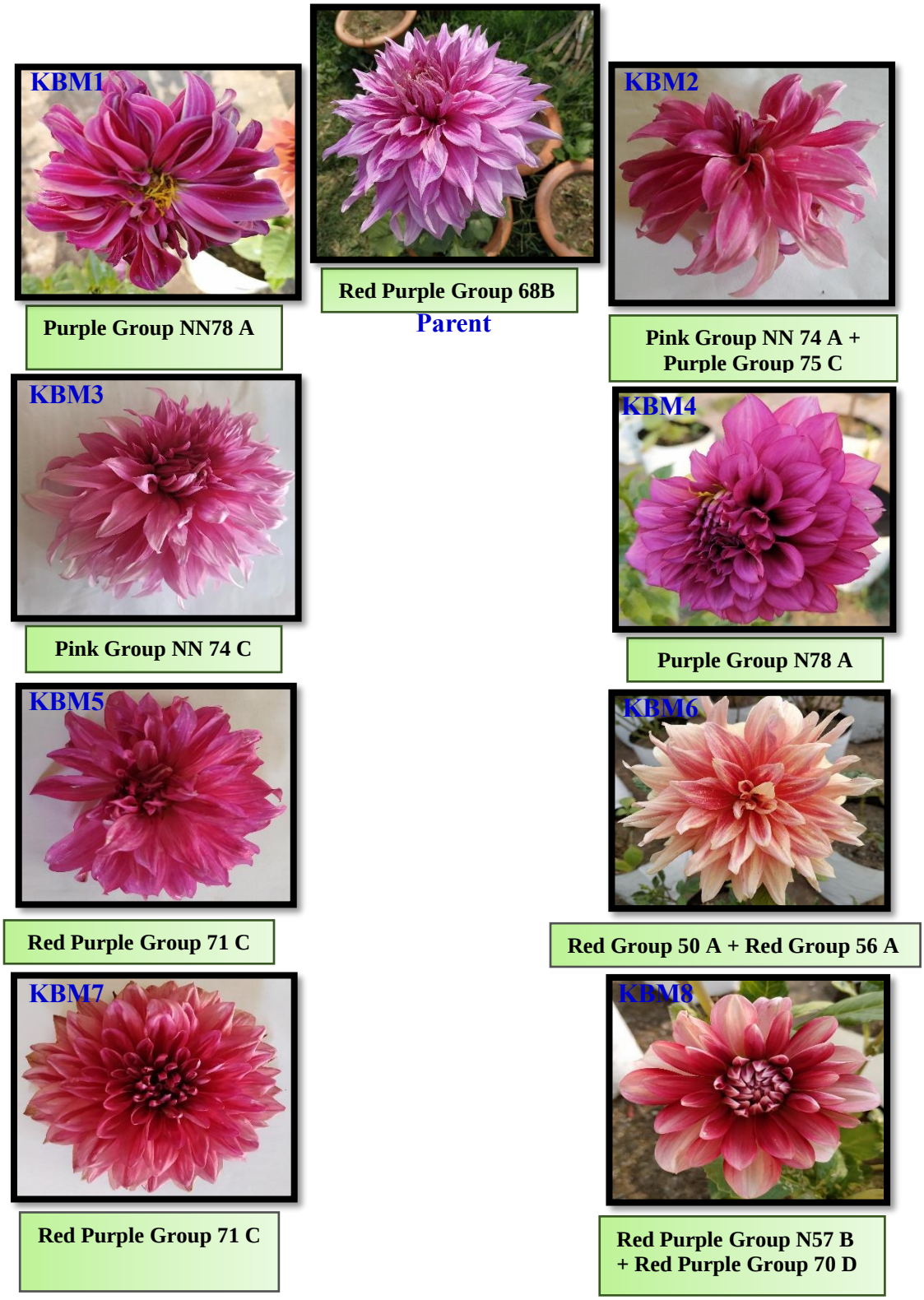

Plate 4.4: Mutation spectrum and colour mutants isolated from cultivar Kenya Blue in vM_2 generation

Mutant KBM_4

The mutant KBM_4 grew to a plant height of 14 cm and 41.8 cm which was less than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (50) was less than the original cultivar but total number of branches plant^{-1} (6) were higher than the original cultivar. Mutant KBM_4 took lesser time for days taken for first bud appearance (48 days), number of days taken for flower opening (17 days) and longevity of flower (6 days) but days taken for full bloom (8 days) and duration of flowering (48 days) were higher than the original cultivar with. Flower diameter, number of floret flower^{-1}, flower weight and number of flower plant^{-1} were lesser than the original cultivar *i.e.* 10.18 cm, 127, 28.17 g and 4, respectively. The colour of flower was matched as Purple Group N78 A with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to double orchid in this mutant than the original flower form.

Mutant KBM_5

The plants grew to a plant height of 15 cm and 53 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves and total number of branches plant^{-1} were less (70 and 6, respectively) than the original cultivar. This mutant took lesser time for days taken for first bud appearance (61 days), number of days taken for flower opening (12 days), days taken for full bloom (7 days) and longevity of flower (6 days) than the original cultivar. The flower diameter, number of ray floret flower^{-1} and flower weight plant^{-1} were smaller than the original cultivar i.e. 11.5 cm, 84 and 21.8 g, respectively. The number of flower plant^{-1} was reduced to 4 as compared to the original cultivar. The duration of flowering (57 days) was significantly higher than the original cultivar. The colour of flower was matched as Red Purple Group 71 C with R.H.S. Colour Chart. No change was recorded in flower form in this mutant than the original flower form.

Table 4.60: Mean performance of screened out mutants of Kenya Blue cultivar in vM_2 generation

Characters	Parent	Mutants							
		KBM_1	**KBM_2**	**KBM_3**	**KBM_4**	**KBM_5**	**KBM_6**	**KBM_7**	**KBM_8**
Radiation doses	0.0 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy
Plant height (30 DAT)	14.16	18.54	16.36	15	14	15	22.13	26.54	16.83
Plant height (90 DAT)	48.39	49.67	52.79	51.63	41.8	53	50.94	52.98	46.37
Total number of branches $plant^{-1}$	5.34	8	10	7	6	2	8	5	7
Days taken to first bud appearance	81.56	63	49	53	48	61	72	98	93
Number of days taken for flower opening	21.34	18	21	11	17	12	17	13	10
Number of days taken for full bloom	7.31	11	4	12	8	7	13	6	9
Flower diameter (cm)	18.9	10.12	9.9	13.2	10.18	11.5	13.5	11.96	9.5
Number of ray florets $flower^{-1}$	157	107	62	133	127	84	110	99	108
Longevity of flower (days)	9.97	5	5	7	6	6	9	5	5
Numbers of flower $plant^{-1}$	6.64	4	8	3	4	4	6	3	6
Duration of flowering (days)	47.8	39	54	66	48	57	45	49	51
Flower colour as per RHS Colour Chart	RPG 68 B	PG NN78 A	Pink Group NN 74 A + PG 75 C	Pink Group NN 74 C	PG N78 A	RPG 71 C	RG 50 A + RG 56 A	RPG 71 C	RPG N57 B + RPG 70 D
Flower Form	GD	SD	SD	GD	DO	GD	GD	GD	DO

GD: Giant Decorative, Small Decorative, DO: Double Orchid, RPG: Red Purple Group, PG: Purple Group, RG: Red Group

Mutant KBM_6

The mutant grew to a plant height of 22.13 cm and 50.94 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves $plant^{-1}$ (73) were slightly less than the original cultivar. However, the total number of branches $plant^{-1}$ (8) was higher than the original cultivar. Mutant KBM_6 took lesser time for days taken for first bud appearance (72 days), number of days taken for flower opening (17 days), longevity of flower (9 days) and duration of flowering (45 days) than the original cultivar. However, days taken for full bloom was higher than that of the original cultivar *i.e.* 13 days. The flower diameter, number of ray floret $flower^{-1}$ and flower weight $plant^{-1}$ were smaller than the original cultivar *i.e.* 13.5 cm, 110 and 21.46 g, respectively. The number of flower $plant^{-1}$ was slightly reduced to 6 as compared to the original cultivar. The colour of flower was matched as Red Group 50 A + Red Group 56 A with R.H.S. Colour Chart. No change was recorded in flower form in this mutant KBM_6 than the original flower form.

Mutant KBM_7

The final plant height of mutant grew to 26.54 cm and 52.98 cm which were higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves and total number of branches $plant^{-1}$ was less (57 and 5, respectively) than the parent. Plant of this mutant took longer time for days taken for first bud appearance (98 days) than the original cultivar. Number of days taken for flower opening, number of days taken for full bloom and longevity of flower were reduced to 13, 6 and 5 days respectively as compared to the original cultivar. The duration of flowering (49 days) was higher than the original cultivar. The flower diameter, number of ray floret $flower^{-1}$ and flower weight $plant^{-1}$ were smaller than the original cultivar i.e. 11.96 cm, 99 and 27.89 g, respectively. The number of flower $plant^{-1}$ (3) was less than the original cultivar. The colour of flower was matched as Red Purple Group 71 C with R.H.S. Colour Chart. No change was recorded in flower form in this mutant KBM_7 than the original flower form.

Mutant KBM_8

This mutant KBM_8 grew to a plant height of 16.83 cm and 46.37 cm which was less than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (49) was less than the original cultivar but the total number of branches plant^{-1} (7) was higher than the original cultivar. Plant of this mutant took longer time for days taken for first bud appearance (93 days) but the number of days taken for flower opening (10 days) was less than the parent. Number of days taken for full bloom was slightly higher than that of the original cultivar (9 days). However, the longevity of flower (5 days) was lower than the parent. The duration of flowering (51 days) was higher as compared to the parental cultivar. The flower diameter, number of ray floret flower^{-1} and flower weight plant^{-1} were lesser than the original cultivar *i.e.* 9.5 cm, 108 and 14.3 g, respectively. The number of flower plant^{-1} (6) was less than the original cultivar. The colour of flower was matched as Red Purple Group N57 B + Red Purple Group 70 D with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to double orchid in this mutant than the original flower form.

4.2.6.2 Mutants of Kenya Yellow cultivar

This cultivar produced eighteen mutants (KYM_1- KYM_{18}) which were screened, tagged and checked for the stability of the characters in next generation. The mutants were developed at 10 Gy dose of gamma radiations (Table 4.63 to 4.64 and Plate 4.5 and 4.5a)

Mutant KYM_1

The mutant KYM_1 grew to a plant height of 12.72 cm and 32.39 cm was lesser than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (51) was less than the original cultivar but the total number of branches plant^{-1} (8) was higher than the original cultivar. This mutant took lesser time for days taken for first bud appearance (80 days), number of days taken for flower opening (13 days), days taken for full bloom (7 days) and longevity of flower (8 days) than the original cultivar. The

flower diameter, number of ray floret flower^{-1} and flower weight plant^{-1} were smaller than the original cultivar i.e. 13.3 cm, 134 and 22.14 g, respectively. The number of flower plant^{-1} was reduced to (4) as compared to the original cultivar. Also the duration of flowering (44 days) was less than the original cultivar. The colour of flower was matched as Grayed- Orange Group 165 C with R.H.S. Colour Chart. No change was recorded in flower form in this mutant KYM_1 than the original flower form.

Mutant KYM_2

The plant height of mutant KYM_2 recorded (14.98 cm) at 30 days and (48.64 cm) at 90 DAT were slightly higher than of the original cultivar. However, the number of leaves plant^{-1} (54) was less than the original cultivar but the total number of branches plant^{-1} (6) was higher than the original cultivar. Mutant KYM_2 took lesser time for days taken for first bud appearance (57 days), number of days taken for flower opening (15 days), days taken for full bloom (6 days) and longevity of flower (6 days) than the original cultivar, whereas, duration of flowering (63 days) was higher than the original cultivar. The flower diameter, number of ray floret flower^{-1} and flower weight plant^{-1} were smaller than the original cultivar *i.e.* 12.1 cm, 94 and 16.73 g, respectively. The number of flower plant^{-1} was reduced to (5) as compared to the original cultivar. Also the. The colour of flower was matched as Grayed- Orange Group 164 D with R.H.S. Colour Chart. No change was recorded in flower form in this mutant KYM_2 than the original flower form.

Mutant KYM_3

The mutant KYM_3 grew to a plant height of (20.42 cm) and (52.93 cm) which was higher than of the original cultivar at 30 DAT and 90 DAT. However, the number of leaves plant^{-1} (68) and the total number of branches plant^{-1} (4) was lesser than the original cultivar. Mutant KYM_3 took longer time for days taken for first bud appearance (91 days) and days taken for full bloom (9 days) but number of days taken for flower opening (12 days), the longevity of flower (8 days) and the duration of flowering (45 days) took lesser time than the original cultivar. The flower diameter, number of ray

floret flower^{-1} and flower weight plant^{-1} were smaller than the original cultivar i.e. 15.98 cm, 138 and 27.31 g, respectively. The number of flower plant^{-1} was reduced to 5 as compared to the original cultivar. The colour of flower was matched as Grayed- Yellow Group 162 C with R.H.S. Colour Chart. No change was recorded in flower form in this mutant KYM_3 than the original flower form.

Mutant KYM_4

The plants height observed in this mutant was 15.93 cm and 50.83 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (49) was less than the original cultivar but the total number of branches plant^{-1} 8 was higher than the original cultivar. This mutant took lesser time for days taken for first bud appearance (53 days), number of days taken for flower opening (9 days) and the longevity of flower (7 days). However, the number of days taken for full bloom and the duration of flowering took longer time than parental cultivar *i.e.* 12 and 59 days, respectively. The flower diameter (16.7 cm), number of ray floret flower^{-1} (176) and the number of flower plant^{-1} (6) were higher than the original cultivar. The flower weight plant^{-1} was reduced to 39.8 g to the original cultivar. The colour of flower was matched as Yellow Group 12 C with R.H.S. Colour Chart. No change was recorded in flower form in this mutant than the original flower form.

Mutant KYM_5

The mutant KYM_5 grew to a plant height of 18.14 cm and 50.67 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. Also the number of leaves plant^{-1} and total number of branches plant^{-1} (93 and 8, respectively) was higher than the original cultivar. Mutant KYM_5 took lesser time for days taken for first bud appearance (53 days), number of days taken for flower opening (14 days), and longevity of flower (6 days) than the original cultivar. However, days taken for full bloom took more time than the original cultivar (10 days). The flower diameter, number of ray floret flower^{-1} and flower weight plant^{-1} were lesser than the original cultivar *i.e.* 12.4 cm, 110 and 21.16 g, respectively. The number of flower plant^{-1} (4) was higher as compared to the

original cultivar. The duration of flowering (59 days) was more than the original cultivar. The colour of flower was matched as yellow group 8 A with R.H.S. Colour Chart. No change was recorded in flower form in this mutant than the original flower form.

Mutant KYM_6

The plants height of this mutant was higher than of the original cultivar that was 25.35 cm and 47.92 cm at 60 DAT and 90 DAT. The number of leaves plant^{-1} (91) and the total number of branches plant^{-1} (6) were higher than the original cultivar. Plant of this mutant took lesser days for first bud appearance (53 days), number of days taken for full bloom (7 days) and the longevity of flower (8 days). However, the number of days taken for flower opening (21 days) was higher than the parental cultivar. The flower diameter number of ray floret flower^{-1} and the flower weight plant^{-1} were 12.5 cm, 134 and 26.83 g respectively which were lesser than the original cultivar. The duration of flowering (51 days) was slightly lesser than the original cultivar. The number of flower plant^{-1} were reduced to 4 as compared to the original cultivar. The colour of flower was matched as Red Group 53 D + Yellow Group 10 B with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to miscellaneous in this mutant KYM_6 than the original flower form.

Mutant KYM_7

The mutant grew to a plants height of 22.06 cm and 56.34 cm which was higher than of the original cultivar at 60 DAT and 90 DAT. The number of leaves plant^{-1} (85) was higher than the original cultivar. The total number of branches plant^{-1} (3), flower diameter (13.8 cm), numbers of flower plant^{-1} (5) and flower weight plant^{-1} (27.79 g) were reduced as compared to the parental cultivar. Number of ray floret flower^{-1} was higher than that of the original cultivar *i.e.* 162. Plant of this mutant took smaller time for days taken for first bud appearance, number of days taken for flower opening, longevity of flower and duration of flowering with 58, 16, 7 and 42 days, respectively.

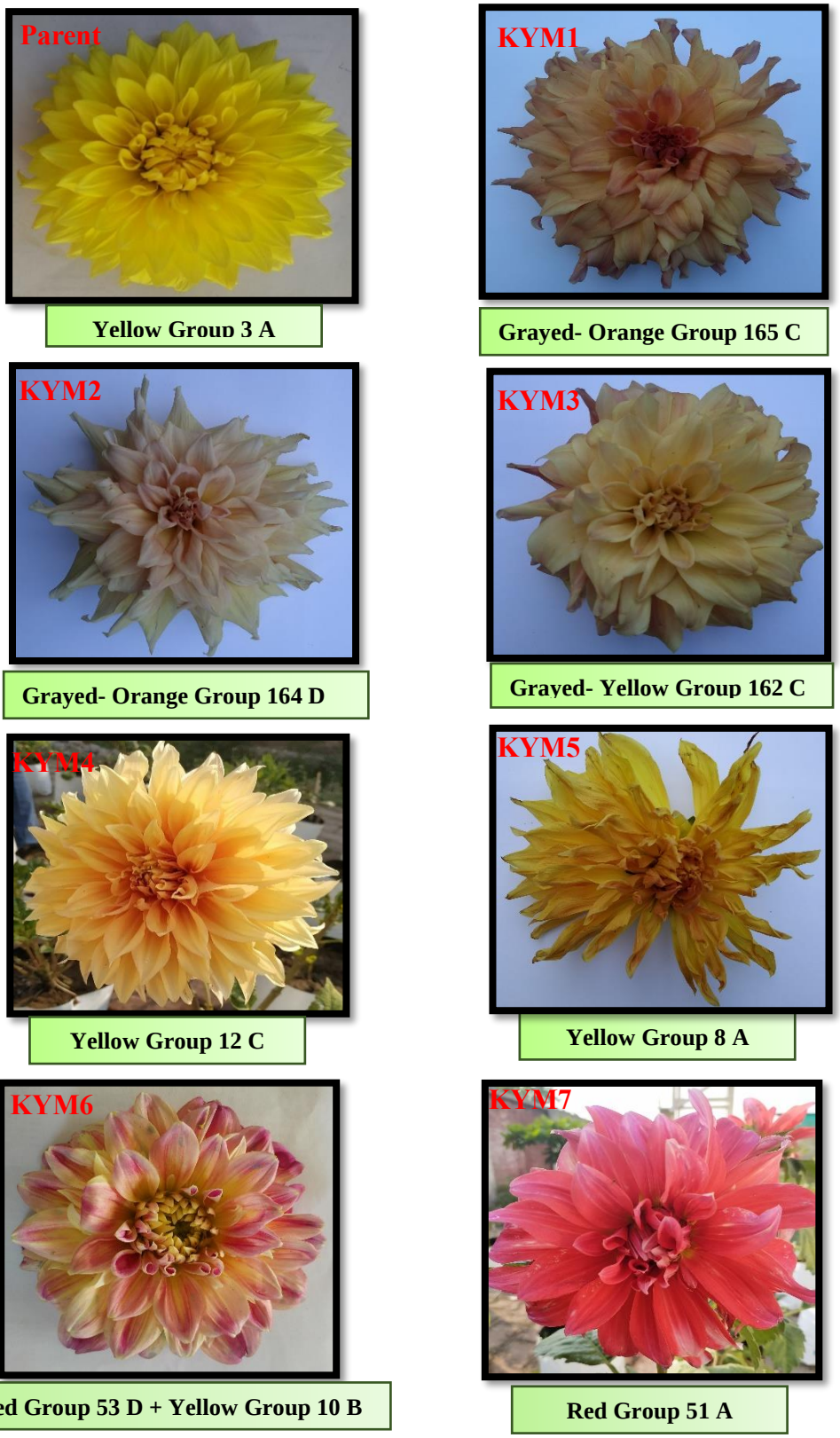

Plate 4.5: Mutation spectrum and colour mutants isolated from cultivar Kenya Yellow in vM_2 generation

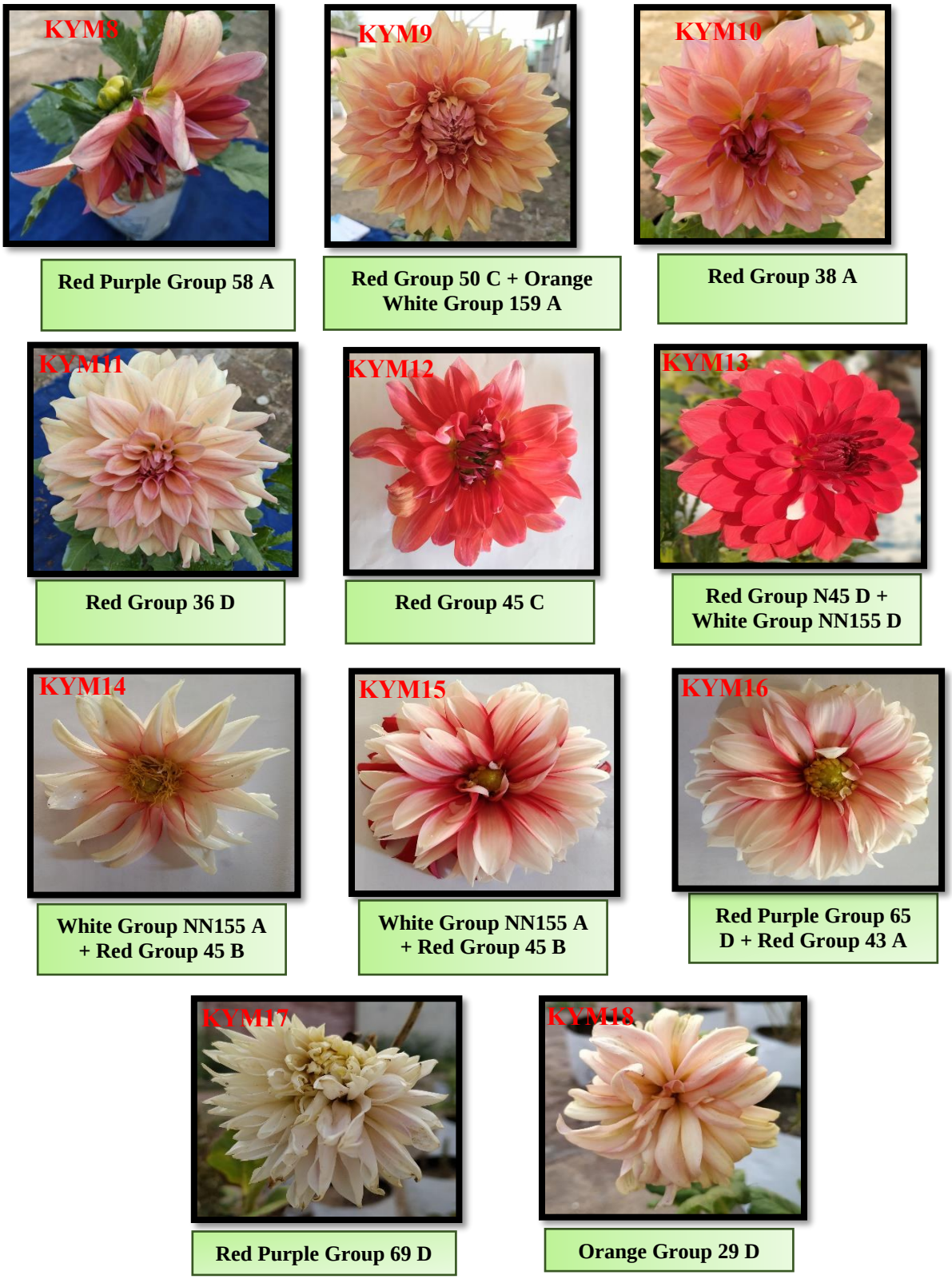

Plate 4.5 a: Mutation spectrum and colour mutants isolated from cultivar Kenya Yellow in vM_2 generation

However, number of days taken for full bloom (13 days) was higher than the original cultivar. The colour of flower was matched as Red Group 51 A with R.H.S. Colour Chart. No change was recorded in flower form in this mutant KYM_7 than the original flower form.

Mutant KYM_8

The plants of this mutant grew to a plant height of 22.61 cm and 56.93 cm, which was higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves and the total number of branches plant^{-1} were higher (95 and 6, respectively) than the parent. Mutant KYM_8 took lesser time for days taken for first bud appearance (58 days), number of days taken for flower opening (13 days), longevity of flower (8 days) and duration of flowering (48 days) as compared to the original cultivar. However, the number of days taken for full bloom was higher than the original cultivar *i.e.* 11days. The flower diameter, number of ray floret flower^{-1} and the flower weight plant^{-1} were 11.65 cm, 108 and 25.8 g respectively which were lesser than the original cultivar. The number of flower plant^{-1} were reduced to 5 as compared to the original cultivar. The colour of flower was matched as Red Purple Group 58 A with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to small decorative in this mutant KYM_8 than the original flower form.

Mutant KYM_9

The plant height of this mutant was less than of the original cultivar at 30 DAT (18.71 cm) and at 90 DAT (46.55 cm). The number of leaves and the total number of branches plant^{-1} were lower than the original (59 and 4, respectively). This mutant took smaller time for days taken for first bud appearance (61 days) and number of days taken for flower opening (14 days) as compared to the original cultivar. However, the number of days taken for full bloom was equal to the original cultivar *i.e.* 8 days. Longevity of flower (8 days) and duration of flowering (46 days) was also took less time than the original cultivar. The flower diameter, number of ray floret flower^{-1} and the flower weight plant^{-1} were 14.6 cm, 151 and 38.2 g respectively which were lesser than the

original cultivar. The number of flower plant^{-1} were reduced to 3 as compared to the original cultivar. The colour of flower was matched as Red Group 50 C+ Orange White Group 159 A with R.H.S. Colour Chart. No change was recorded in flower form.

Mutant KYM$_{10}$

The plants height observed in this mutant was 17.64 cm and 34.73 cm which was less than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (70) was little less than the parental cultivar. However, the total number of branches plant^{-1} (7) were higher than the original cultivar. Plants took slightly longer time for days taken for first bud appearance than the original cultivar with 53 days. Number of days taken for flower opening and number of days taken for full bloom were less than the original cultivar i.e. 10 and 5 days, respectively. Likewise, the longevity of flower and duration of flowering were reduced to 6 and 50 days as compare to parental cultivar. The flower diameter, number of ray floret flower^{-1} and the flower weight plant^{-1} were 11.6 cm, 95 and 25.96 g respectively which were also lesser than the original cultivar. The number of flower plant^{-1} (4) was less than the parental cultivar. The colour of flower was matched as Red Group 38 A with R.H.S. Colour Chart. No change was recorded in flower form in this mutant than the original flower form.

Mutant KYM$_{11}$

The mutant attained a plant height 17.82 and 34.45 cm was lesser than of the original cultivar at 30 and 90 DAT. The number of leaves plant^{-1} (70) was slightly less than the original cultivar but the total number of branches plant^{-1} (7) was higher than the original cultivar. The mutant KYM$_{11}$ took longer time for days taken to first bud appearance than the original cultivar with 84 days. However, days taken for full bloom was equal to the original cultivar (8). Number of days taken for flower opening and longevity of flower were shorter than the original cultivar *i.e.* 15 and 7 days, respectively. Also the duration of flowering (49 days) was shorter than the original cultivar. Likewise, the flower diameter, number of ray floret flower^{-1} and flower weight plant^{-1} were smaller than the original cultivar i.e. 13.64 cm, 146 and 27.46 g,

respectively. The number of flower plant^{-1} were reduced to 4 as compared to the original cultivar. Also the. The colour of flower was matched as Red Group 36 D with R.H.S. Colour Chart. No change was recorded in flower form in this mutant KYM_{11} than the original flower form.

Mutant KYM_{12}

The mutant KYM_{12} attained a plant height 19.64 cm at 30 DAT that was higher than the original cultivar and 39.95 cm at 90 DAT was smaller than of the original cultivar. The number of leaves plant^{-1} (58) were reduced as compared to the original cultivar. Total number of branches plant^{-1} was equal to the original cultivar *i.e.* 5. Mutant KYM_{12} took lesser time for days taken for first bud appearance with 53 days. Number of days taken for flower opening and days taken for full bloom was more (21 and 11days, respectively) than the original cultivar. However, longevity of flower took less time than the original cultivar *i.e.* 4 days. The flower diameter, number of ray floret flower^{-1} and flower weight plant^{-1} were lesser than the original cultivar i.e. 12.7 cm, 141 and 28.94 g, respectively. The number of flower plant^{-1} (6) was higher as compared to the original cultivar. The duration of flowering (47 days) was less than the original cultivar. The colour of flower was matched as Red Group 45 C with R.H.S. Colour The changes in flower form was recorded from giant decorative to miscellaneous in this mutant KYM_{12} than the original flower form.

Mutant KYM_{13}

Plants height recorded in this mutant was 26.64 cm and 49.35 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} (62) was little less than the parental cultivar. However, the total number of branches plant^{-1} (5) were same as the original cultivar. Mutant KYM_{13} took lesser time for days taken for first bud appearance (68 days) and number of days taken for flower opening to 13 days. Number of days taken for full bloom were higher than the original cultivar with 9 days. Longevity of flower and duration of flowering were reduced to 6 and 50 days as compare to parental cultivar. The flower diameter, number of ray floret flower^{-}

^{1} and the flower weight plant^{-1} (12.5 cm, 127 and 26.59 g, respectively) which were lesser than the original cultivar. The number of flower plant^{-1} (3) was less than the parental cultivar. The colour of flower was matched as Red Group N45 D + White Group NN 155 D with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to stellar in this mutant KYM_{13} than the original flower form.

Mutant KYM_{14}

The mutant KYM_{14} grew to a plant height of 27.5 cm and 51.75 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} and the total number of branches plant^{-1} were higher (93 and 8, respectively) than the parent. Mutant KYM_{14} took lesser time for days taken for first bud appearance, number of days taken for flower opening, number of days taken for full bloom and longevity of flower than the original cultivar with 47, 15, 7 and 6 days, respectively. The flower diameter (8.9 cm), number of ray floret flower^{-1} (121) and the flower weight plant^{-1}(12.45 g) which were also showed reduced than the original cultivar. The duration of flowering took more time than original cultivar with 66 days. The number of flower plant^{-1} were higher to 7 as compared to the original cultivar. The colour of flower was matched as White Group NN155 A + Red Group 45 B with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to double orchid in this mutant KYM_{14} than the original flower form.

Mutant KYM_{15}

The mutant KYM_{15} grew to a plant height of 19.65 cm and 51.15 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} and the total number of branches plant^{-1} were higher (93 and 8, respectively) than the parent. Mutant KYM_{14} took lesser time for days taken for first bud appearance, number of days taken for flower opening, number of days taken for full bloom and longevity of flower than the original cultivar with 47, 17, 6 and 5 days, respectively. The flower diameter (9.2 cm), number of ray floret flower^{-1} (132) and the flower weight plant^{-1} (13.01 g) which were also showed reduced than the original cultivar. The duration of

flowering took more time than original cultivar with 66 days. The number of flower plant^{-1} were higher to 7 as compared to the original cultivar. The colour of flower was matched as Red Group 45 B + Red Group 56 D with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to Paeony flowered in this mutant KYM_{15} than the original flower form.

Mutant KYM_{16}

The plant height observed in this mutant at 30 DAT was 20.65 cm which was higher than the original cultivar but plant height recorded at 90 DAT was 40.95 cm which was less than of the original cultivar. The number of leaves plant^{-1} and total number of branches plant^{-1} were less (61 and 4, respectively) than the original cultivar. Plant took slightly longer time for days taken for first bud appearance and days taken for full bloom than the original cultivar with 91 and 10 days, respectively. Likewise, the longevity of flower and duration of flowering were higher to 8 and 46 as compare to parental cultivar, but number of days taken for flower opening (10 days) was more than the original cultivar. The flower diameter, number of ray floret flower^{-1} and flower weight plant^{-1} were lesser than the original cultivar i.e. 9.6 cm, 140 and 14.03 g, respectively. The number of flower plant^{-1} were higher to 7 as compared to the original cultivar. The colour of flower was matched as Red Purple Group 65 D + Red Group 43 A with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to Paeony flower in this mutant KYM_{16} than the original flower form.

Mutant KYM_{17}

The mutant KYM_{17} grew to a plant height of 15.7 cm and 53.85 cm which was higher than of the original cultivar at 30 DAT and 90 DAT. The number of leaves plant^{-1} were and the total number of branches plant^{-1} were higher (93 and 8, respectively) than the parent. Mutant KYM_{14} took lesser time for days taken for first bud appearance, number of days taken for flower opening, number of days taken for full bloom and longevity of flower than the original cultivar with 47, 15, 7 and 6 days, respectively. The flower diameter (8.9 cm), number of ray floret flower^{-1} (121) and the flower weight

plant^{-1} (12.45 g) which were also showed reduced than the original cultivar. The duration of flowering took more time than original cultivar with 66 days. The number of flower plant^{-1} were higher to 7 as compared to the original cultivar. The colour of flower was matched as Red Purple Group 69 D with R.H.S. Colour Chart. No change was recorded in flower form.

Mutant KYM$_{18}$

Plants of this mutant was smaller plant height of 13.85 cm and 40.55 cm which was lesser than that of the original cultivar at 30 DAT and 90 DAT. Mutant also took lesser number of leaves (53) and total number of branches plant^{-1} (4) than the parent. It took lesser time for days taken for first bud appearance and number of days taken for flower opening than the original cultivar with 67 and 14 days, respectively. Whereas, the number of days taken for full bloom (12 days) was than the original cultivar. The flower diameter, number of ray floret flower^{-1} and the flower weight were reduced than the original cultivar *i.e.* 8.10 cm, 96 and 20.34 g, respectively. The longevity of flowers was less than that of the original cultivar (4 days). The duration of flowering took more time than original cultivar with 58 days. The number of flower plant^{-1} were reduced to 3 as compared to the original cultivar. The colour of flower was matched as Orange Group 29 D with R.H.S. Colour Chart. The changes in flower form was recorded from giant decorative to small decorative in this mutant KYM$_{18}$ than the original flower form.

Table 4.61: Mean performance of screened out mutants of Kenya Yellow cultivar in vM_2 generation

Characters	Parent	Mutants								
		KYM_1	**KYM_2**	**KYM_3**	**KYM_4**	**KYM_5**	**KYM_6**	**KYM_7**	**KYM_8**	**KYM_9**
Radiation doses	0.0 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy
Plant height (30 DAT)	14.65	12.72	14.98	20.42	15.93	18.14	25.35	22.06	22.61	18.71
Plant height (90 DAT)	45.66	32.39	48.64	52.93	50.83	50.67	47.92	56.34	56.93	46.55
Total number of branches $plant^{-1}$	5	8	6	4	8	8	6	3	6	4
Days taken to first bud appearance	82.9	80	57	91	53	53	61	58	58	61
Number of days taken for flower opening	19.67	13	15	12	9	14	21	16	13	14
Number of days taken for full bloom	8	7	6	9	12	10	7	13	11	8
Flower diameter (cm)	16.51	13.3	12.1	15.98	16.7	12.4	12.5	13.8	11.56	14.6
Number of ray florets $flower^{-1}$	158	134	94	138	176	110	135	162	108	151

Table 4.61: Contd…..

Characters	Parent	Mutants								
		KYM_1	**KYM_2**	**KYM_3**	**KYM_4**	**KYM_5**	**KYM_6**	**KYM_7**	**KYM_8**	**KYM_9**
Longevity of flower (days)	12	8	6	8	7	6	8	7	8	8
Numbers of flower plant^{-1}	5.66	4	5	5	6	6	4	5	5	3
Duration of flowering (days)	51.36	44	63	45	59	59	51	42	48	46
Flower colour as per RHS Colour Chart	YG 3 A	GOG 165 C	GOG 164 D	GYG 162 C	YG 12 C	YG 8 A	RG 53 D + YG 10 B	RG 51 A	RPG 58 A	RG 50 C + OWG 159 A
Flower form	GD	GD	GD	GD	GD	GD	Miscellaneous	GD	SD	GD

GD: Giant Decorative, SD: Small Decorative, RPG: Red Purple Group, YG: Yellow Group, OWG: Orange White Group, RG: Red Group, GYG: Green Yellow Group, GOG: Grayed Orange Group

Table 4.61: Mean performance of screened out mutants of Kenya Yellow cultivar in vM_2 generation

Characters	Parent	Mutants								
		KYM_{10}	**KYM_{11}**	**KYM_{12}**	**KYM_{13}**	**KYM_{14}**	**KYM_{15}**	**KYM_{16}**	**KYM_{17}**	**KYM_{18}**
Radiation doses	0.0 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy	10 Gy
Plant height (30 DAT)	14.65	17.64	17.82	19.64	26.64	27.5	19.65	20.65	15.7	13.85
Plant height (90 DAT)	45.66	34.73	34.45	39.95	49.35	51.75	51.15	40.95	53.85	40.55
Total number of branches $plant^{-1}$	5	7	7	5	5	8	8	4	6	4
Days taken to first bud appearance	82.9	84	84	53	68	47	47	91	61	67
Number of days taken for flower opening	19.67	10	15	21	13	15	17	9	15	14
Number of days taken for full bloom	8	5	8	11	9	7	6	10	9	12
Flower diameter (cm)	16.51	11.6	13.64	12.7	12.5	8.9	9.2	9.6	9.8	8.10
Number of ray florets $flower^{-1}$	158	95	146	141	127	121	132	140	138	96

Table 4.61: Contd…..

Characters	Parent	Mutants								
		KYM_{10}	**KYM_{11}**	**KYM_{12}**	**KYM_{13}**	**KYM_{14}**	**KYM_{15}**	**KYM_{16}**	**KYM_{17}**	**KYM_{18}**
Longevity of flower (days)	12	6	7	4	6	6	5	8	5	4
Numbers of flower plant^{-1}	5.66	4	4	6	3	7	7	7	4	3
Duration of flowering (days)	51.36	50	49	47	55	66	66	46	60	58
Flower colour as per RHS Colour Chart	YG 3A	RG 38A	RG 36D	RG 45C	RG N45 D + WG NN155 D	WG NN155 A + RG 45 B	RG 45 B+ RG 56 D	RPG 65 D+ RG 43A	RPG 69D	OG 29D
Flower form	GD	GD	GD	Miscellaneous	Stellar	DO	Paeony	Paeony	GD	SD

GD: Giant Decorative, SD: Small Decorative, DO: Double Orchid, RPG: Red Purple Group, YG: Yellow Group, WG: White Group, RG: Red Group, OG: Orange Group

CHAPTER - V
SUMMARY AND CONCLUSIONS

The present study entitled "**Gamma rays induced mutagenesis in Dahlia (*Dahlia variabilis* L.) and propagation of mutants obtained through stem cuttings."** was carried out in the field of Horticultural Research cum Instructional Farm, Department of Floriculture and Landscape Architecture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), during 2018-19 and 2019-20. The Experiment- I entitled **"Gamma rays induced mutagenesis in dahlia"** was conducted during winter season of 2018-19, whereas, Experiment-II entitled **"Effect of rooting hormones in the propagation of dahlia mutants through stem cuttings"** was conducted during winter season of 2019-20. The main objective of study is induction of flower mutants in dahlia and to find out the effect of rooting hormones on propagation of dahlia mutants. Experiment wise salient features of the findings are summarized below.

5.1 EXPERIMENT I - Gamma rays induced mutagenesis in dahlia

The experiment was laid out in Factorial Completely Randomized Design (FCRD) with four replications. The experimental material comprised uniform rooted cuttings of three cultivars of dahlia, which were irradiated with four different doses of gamma radiations (0.0 Gy, 10 Gy, 15 Gy and 20 Gy). The salient findings of this experiment are summarized below to derive meaningful conclusions.

5.1.2 Mutational characters

- The minimum mortality percentage (19.55%) was observed at the dose of 10 Gy gamma rays treatment while, maximum mortality percentage (38.81%) was recorded at the dose of 20 Gy gamma rays treatment in vM_1 generation. However, cultivar Kenya Original exhibited minimum

percentage of mortality (16.44 %), whereas, maximum mortality percentage (30.80 %) was recorded in Kenya Yellow.

- Survival percentage was 80.39 percent at 10 Gy dose, whereas further increase in higher doses, reduced plant survival percentage. The cultivar, Kenya Original (83.30% survival) was more tolerant to gamma irradiations in vM_1 generation.
- Untreated plants recorded zero percent of abnormality while in case of treated plants, minimum percentage of abnormal plants (6.31%) were recorded at the dose of 10 Gy and cultivar Kenya Original exhibited minimum percentage of abnormal plant (8.01 %), which was significantly lesser than the other cultivars.
- The probit analysis indicated the extrapolated LD_{50} value based on mortality percent, for dahlia cultivar of Kenya Blue (27.54 Gy), Kenya Yellow (20.89 Gy) and Kenya Original (33.11 Gy). This indicated the higher sensitivity of Kenya Yellow cultivars thus LD_{50} could be beyond this dose.
- In vM_1 generation, 6 flower colour mutations in cultivar Kenya Blue, 15 flower colour mutations in cultivar Kenya Yellow and 3 flower colour mutations was recorded in cultivar Kenya Original at 10 Gy gamma rays dose. Highest mutation frequency (62.50 %) was found in cultivar Kenya Yellow treated with 10 Gy gamma rays dose.

5.1.3 Vegetative characters

- Plants treated with 10 Gy gamma radiation recorded maximum plant height (11.53 cm, 22.95 cm and 40.65 cm at 30, 60 and 90 DAT, respectively), which were significantly higher than the rest of gamma doses whereas, 20 Gy gamma rays recorded minimum plant height at (8.71 cm, 13.82 cm and 25.97 cm, respectively), among the cultivars, Kenya Blue exhibited maximum plant height i.e. 10.93 cm, 20.64 cm and 36.65 cm, respectively.
- The significantly maximum number of leaves plant^{-1} (40.39 and 60.31 at 60 and 90 DAT, respectively) were recorded in 10 Gy treated plants, which

were less than the untreated plants but higher than the rest of gamma rays doses while, minimum number of leaves plant^{-1} (18.80 and 45.17, respectively) were recorded at higher dose (20 Gy) gamma rays treatment. However, cultivar Kenya Blue recorded maximum number of leaves plant^{-1} (35.66 and 64.72 at 60 and 90 DAT, respectively), which were higher as compared to rest of cultivars.

- The maximum number of branches plant^{-1} was recorded in control (5.18), whereas, in irradiated plants, lower dose (10 Gy) noted maximum number of branches per plant^{-1} (4.28) and minimum number of branches plant^{-1} (2.53) was observed in plants treated with 20 Gy gamma rays treatment. Meanwhile, cultivar Kenya Blue recorded maximum number of branches plant^{-1} (4.10). In contrast, minimum number of branches plant^{-1} was recorded in cultivar Kenya Original (3.42).
- In vM_1 generation, maximum plant spread (28.81 cm) was observed in untreated plants while in case of treated plants, 10 Gy gamma rays showed maximum plant spread (27.49 cm), whereas, minimum plant spread 24.36 cm was recorded at 20 Gy and cultivar Kenya Yellow had maximum plant spread (27.51 cm) but minimum plant spread was observed in cultivar Kenya Original 26.33 cm.

5.1.4 Floral characters

- Days taken for first bud appearance (81.12 days) at lower dose (10 Gy) was earlier as compared to untreated plants while, plants treated with higher dose (20 Gy) took 101.39 days taken for first bud appearance. However, significantly minimum days taken for first bud appearance by cultivar Kenya Yellow (84.96) and maximum days (103.50) were taken by cultivar Kenya Original.
- Number of days taken for flower opening (17.77 days) at lower dose (10 Gy) was earlier as compared to untreated plants in vM_1 generation. Untreated plants had taken 20.33 days for flower opening whereas, minimum days taken for flower opening (18.83) were taken by cultivar

Kenya Blue and maximum days (19.72) were taken by cultivar Kenya Yellow.

- Number of days taken for full bloom (8.58 days) at lower dose (10 Gy) was earlier as compared to untreated plants but higher than the rest of gamma doses. The plants treated with 20 Gy of gamma rays recorded minimum number of days for full bloom (7.43 days). Least time taken for full bloom was observed in cultivar Kenya Blue (7.58 days) while, cultivar Kenya Yellow had highest number of days taken for full bloom i.e. 9.20 days.
- Unirradiated plants had largest flower size (16.53 cm) while in case of treated plants, maximum flower diameter (14.62 cm) recorded in 10 Gy gamma rays treatment. However, the plants treated with 20 Gy gamma rays recorded lowest flower diameter (10.96 cm). The cultivar Kenya Blue exhibited maximum flower diameter (15.24 cm), whereas, minimum flower diameter (12.32 cm) was recorded in cultivar Kenya Original in vM_1 generation.
- The maximum number of ray florets flower^{-1} (125.52) were recorded in 10 Gy, which was less as compared to control but higher than the rest of the treatments whereas, minimum ray florets flower^{-1} (87.33) resulted in the higher dose of gamma radiations (20 Gy). Among the cultivars, Kenya Blue exhibited maximum number of ray florets flower^{-1} (125.37), whereas, minimum number of ray florets flower^{-1} were observed in cultivar Kenya Original (99.93).
- Plants treated with 10 Gy recorded maximum flower stalk length (40.87 cm) which was larger as compared as unirradiated plants but lower than the rest of gamma doses whereas, shortest flower stalk length (36.24 cm) of flowers were recorded in plants treated with 20 Gy gamma rays. Flower stalk length of cultivar Kenya Blue were largest (43.14 cm), whereas, cultivar Kenya Original produced shortest flower stalk length (38.41 cm).
- Untreated plants exhibited highest flower stalk diameter (2.51 cm) but in case of irradiated plants, 10 Gy dose gave highest flower stalk diameter (2.48 cm) the cultivars treated with 20 Gy of gamma rays recorded minimum flower stalk diameter (2.40 cm). However, maximum flower

stalk diameter was observed in cultivar Kenya Original (2.51 cm), while cultivar Kenya Yellow had minimum flower stalk diameter (2.42 cm).

- Untreated plants exhibited highest longevity of flower (10.31 days) while in case of treated plants, lower dose (10 Gy) recorded higher longevity of flower (9.17 days), whereas, plants treated with 20 Gy dose had shortest longevity of flower (7.53 days). The cultivar Kenya Yellow showed maximum longevity (9.27 days), whereas, least longevity (8.50 days) was exhibited by cultivar Kenya Blue.
- The maximum number of flowers plant^{-1} (5.61) were recorded in control followed by 10 Gy (3.97), whereas, the higher gamma rays irradiation dose (20 Gy) resulted in minimum number of flowers plant^{-1} (2.04). The cultivar, Kenya Blue exhibited maximum number of flowers plant^{-1} (4.06) and minimum number of flowers plant^{-1} were seen in cultivar Kenya Original (3.04).
- The highest flower weight plant^{-1} (44.16 g) were recorded in untreated plants but in irradiated plants, 10 Gy dose gave maximum flower weight plant^{-1} (41.38 g) and higher dose 20 Gy recorded minimum (37.28 g) flower weight plant^{-1}. The cultivar Kenya Blue showed highest weight (42.48 g) while lowest weight of flower noted in cultivar Kenya Original (38.75 g).
- Plants treated with 10 Gy gamma rays had longest duration of flowering (47.51 days), whereas, shortest duration of flowering was recorded in 20 Gy gamma irradiated plants (43.50 days). The cultivar Kenya Yellow had recorded significantly maximum duration of flowering (48.93 days), whereas, minimum duration of flowering (42.15 days) was observed in Kenya Original.

5.1.5 Tuber characters

- The highest number of tubers plant^{-1} (6.16) were obtained at untreated plants, which was closely followed by 10 Gy (5.14), whereas, lowest was recorded in plants treated with higher dose 20 Gy (4.24). The cultivar

Kenya Blue recorded maximum number of tubers plant^{-1} (5.79), whereas, lowest number of tuber plant^{-1} was noted in Kenya Yellow (4.64).

- The weight of tubers plant^{-1} was found maximum (82.68 g) at untreated plants while in case of treated plants 10 Gy gave highest weight of tuber plant^{-1} (75.69 g), whereas, the minimum weight was recorded at 20 Gy (69.75 g). It was also noticed that the weight of tuber plant^{-1} was highest (78.95 g) in cultivar Kenya Yellow while minimum (71.40 g) was noticed in cultivar Kenya Original.
- The size of tubers was found significantly maximum (5.05 cm) at untreated plants followed by 10 Gy (4.77 cm), while the minimum tuber diameter was observed at 20 Gy (4.05 cm). As respect to the cultivars, Kenya Yellow reported maximum tuber size (4.93 cm), whereas, minimum diameter of tuber was recorded in Kenya Original (4.17 cm).

5.1.6 Physiological characters

- Leaf chlorophyll content reduced with increase in radiation dose. Maximum leaf chlorophyll content was recorded in untreated plant (47.53 mg g^{-1}), whereas, cultivar Kenya Blue had maximum leaf chlorophyll content (44.69 mg g^{-1}) and minimum leaf chlorophyll content was recorded in cultivar Kenya Original (40.56 mg g^{-1}).

Conclusion

It may be concluded that, gamma rays dose of 10 Gy was most effective for enhancement of few vegetative, floral, tuber, physiological and mutational characters, which was also best for induction of colour mutation, among the cultivars, Kenya Yellow were found most sensitive to gamma rays. The mutation frequency was higher in Kenya Blue whereas, most of the mutations were in chimeric form and stable in next generation. In the study, 24 mutants were screened from three cultivars (Kenya Blue, Kenya Yellow and Kenya Original), which were found stable till further generation for their flower colour traits and exhibited slight variation than their parent cultivars in quantitative traits. These

mutants can further be multiplied and studied for their stable economic ornamental characters and can also be utilized in future breeding programmes.

5.2 EXPERIMENT II - Effect of rooting hormones on the propagation of dahlia mutants through stem cuttings

The experiment was laid out in Factorial Completely Randomized Design (FCRD) with three replications. The experimental material comprised of uniform terminal shoot cuttings of mutants of two dahlia cultivars (Kenya Blue and Kenya Yellow) in which desirable mutants for trait (colour) obtained after screening of vM_1 population. Planting materials were treated with ten different combinations of rooting hormones included control. The salient findings of this experiment are summarized below to drive meaningful conclusions.

5.2.1 Rooting characters

- Root initiation with treatment IBA @ 250 ppm + NAA @ 250 was earlier as compare to untreated cuttings (17.21days), whereas, untreated cuttings took 24.66 days for root initiation. Minimum days (18.11 days) to rooting were recorded in mutants of Kenya Blue.
- The high rate of rooting (69.82%) was recorded in IBA @ 1000 ppm, whereas control resulted lowest rooting percentage (36.02%). However, maximum (62.46%) rooting percentage exhibited by mutants of Kenya Blue.
- The maximum survival percentage (63.96%) was recorded at the treatment of NAA @ 500 ppm whereas, minimum survival percentage was recorded in control treatment (16.14%). Plants of mutants of Kenya Blue recorded maximum survival percentage (50.52%).
- Number of roots cutting^{-1} (22.74) was recorded maximum in plants treated with IBA @ 1000 ppm and NAA @ 500 ppm, while minimum number of roots cutting^{-1} (9.69) were recorded in control. The maximum number of roots cutting^{-1} was observed mutants of Kenya Blue (20.33).

- Longest root length (5.57 cm) were observed in treated with IBA @ 500 ppm whereas, shortest root length (2.53 cm) were recorded in untreated plants. Meanwhile, the mutants of cultivar Kenya Blue recorded longest root length (4.16 cm).

5.2.2 Vegetative characters

- The plant height at 30 DAT was higher (19.67 cm) at NAA @ of 1000 ppm treatment and minimum at untreated plants (14.08 cm). Whereas, cultivar Kenya Yellow registered maximum plant height (18.72).
- The plant height at 60 DAT was maximum (30.50 cm) under treatment of NAA @ 1000 ppm while control recorded minimum plant height (21.83 cm). Likewise, the mutants of cultivar Kenya Yellow recorded maximum plant height (28.60 cm).
- The treatment of plants at IBA @ 500 ppm recorded maximum plant height at 90 DAT (45.56 cm), whereas, minimum plant height (29.45 cm) was observed in control. The mutants of cultivar Kenya Yellow noted highest plant height (41.31 cm).
- The maximum number of leaves plant^{-1} was recorded in plants treated with IBA @ 500 ppm (41.52 am and 77.98 at 60 and 90 days DAT, respectively), while minimum number of leaves plant^{-1} was recorded in untreated plants of mutants of cultivar Kenya Blue (23.33 cm and 48.58 at 60 and 90 DAT, respectively.)
- The maximum number of branches plant^{-1} (7.31) was recorded at IBA @ 1000 ppm while, minimum number of branches plant^{-1} (2.83) was observed in untreated plants. The maximum number of branches plant^{-1} (5.36) recorded in mutants of Kenya Blue.
- The maximum plant spread (29.50 cm) was observed in IBA @ 500 ppm whereas, minimum (24.43 cm) recorded at untreated plants. However, mutants of cultivar Kenya Blue recorded maximum (26.76 cm) plant spread.

5.2.3 Floral characters

- The minimum days taken to first bud appearance (75.99 days) recorded in IBA @ 500 ppm while in control noted maximum days to first bud appearance (99.03 days). However, the mutants of cultivar Kenya Blue took minimum days taken to first bud appearance (87.19 days).
- The plants treated with IBA @ 250 ppm + NAA @ 250 ppm took minimum days taken for flower opening (10.63 days), whereas, control recorded maximum days for flower opening (19.21 days). Mutants of cultivar Kenya Yellow recorded minimum days (14.10 days) for flower opening.
- Untreated plants of mutants took maximum taken for full bloom (13.04 days), while minimum time recorded in treatment of IBA @ 500 ppm (4.99 days). Mutants of cultivar Kenya Blue recorded maximum time for full bloom (8.35 days).
- The plant treated with IBA @ 500 ppm recorded largest flower diameter and highest number of ray florets flower^{-1} (18.05 cm and 146, respectively). The minimum flower diameter (12.96 cm) was recorded in untreated plants and minimum number of ray floret flower^{-1} (115.50) had recorded in IBA @ 500 ppm + NAA @ 500 ppm. Mutants of cultivar Kenya Blue observed maximum flower size (15.66 cm) and highest number of ray floret flower^{-1} (132.08).
- The maximum flower stalk diameter (5.61 cm) was obtained in treatment of IBA @ 1000 ppm whereas, minimum was recorded in control (2.59 cm). Mutants of cultivar Kenya Yellow recorded maximum (4.23 cm) flower stalk diameter.
- The plants treated with IBA @ 250 ppm + NAA @ 250 ppm recorded longer flower stalk length (44.23 cm), while shorter flower stalk length were obtained in untreated plants (27.63 cm). Mutants of cultivar Kenya Yellow produced longest flower stalk length (38.47 cm).
- The maximum longevity of flower (7.63 days) was recorded at treatment with IBA @ 500 ppm while minimum longevity of flower (5.60 days)

noted in control. Mutants of Kenya Blue recorded highest longevity of flower (6.89 days).

- The number of flowers plant^{-1} was maximum (9.53) under treatment IBA @ 1000 ppm and minimum in untreated plants (4.63). However, mutants of cultivar Kenya Yellow produced maximum number of flower plant^{-1} (7.71).
- The treatment of plants with IBA @ 1000 ppm resulted highest (37.75 g) flower weight plant^{-1} while minimum weight was recorded in control (14.66 g). Mutants of cultivar Kenya Blue exhibited maximum flower weight plant^{-1} (32.83 g).
- The flowering duration was maximum (62.06 days) under treatment IBA @ 500 ppm while minimum in untreated plants (42.75 days). Mutants of cultivar Kenya Yellow recorded maximum duration of flowering (51.25 days).

5.2.4 Tuber characters

- The maximum number of tubers and highest weight of tuber plant^{-1} (10.81 and 108 g, respectively) was recorded at treatment of IBA @ 500 ppm while minimum was recorded in untreated plants. Mutants of cultivar Kenya Yellow resulted maximum number of tubers plant^{-1} (9.40) and highest tuber weight plant^{-1} (111.67 g).
- Cuttings treated with IBA 125 ppm + NAA 125 ppm resulted in highest diameter of tuber (5.52 cm), whereas, treatment IBA 500 ppm + NAA 500 ppm had minimum diameter of tuber (4.58 cm). Mutants of cultivar Kenya Yellow exhibited maximum diameter of tuber (5.23 cm).

5.2.5 Physiological characters

- The maximum leaf chlorophyll content (47.26 mg g^{-1}) recorded in treatment of IBA @ 250 ppm, while minimum (38.36 mg g^{-1}) in treatment IBA 500 ppm + NAA 500 ppm. Plants of mutants of cultivar Kenya Blue had maximum (43.75 mg g^{-1}) leaf chlorophyll content.

5.2.6 Screening of mutations

- In vM_2 population (Experiment two) total 26 mutants were screened out for ornamental traits (colour) from mutants of two cultivars of dahlia (Kenya Blue and Kenya Yellow). Most of the color mutants were in the form of solid and chimeric form.

Conclusion

It is concluded that the effect of rooting hormones in the propagation of dahlia mutants was most effective for enhancement of rooting, vegetative, floral, tuber and physiological characters, whereas, treatment combination of IBA and NAA was found more efficient in days for rooting and rooting percentage. Treatment of NAA @ 500 ppm resulted maximum survival percentage but efficient result in number of roots and root length was recorded in treatment with IBA. Among the mutants of cultivar, Kenya Yellow were found most sensitive. Maximum plant height was recorded in NAA whereas, other vegetative characters was more efficient in treatment with IBA. The combination of IBA and NAA gave best result in days taken for flower opening and flower stalk length whereas, other treatment of IBA was best for other parameters. Efficient tuber and physiological characters was also noted in treatment with IBA. In vM_2 generation, 26 mutants were screened from the mutants of two cultivars (Kenya Blue and Kenya Yellow) which exhibited slight variation than their parent cultivars in different traits.

Suggestions for future research work:

The work on above aspect has not yet been taken in Chhattisgarh region, hence looking to the present need towards development of new dahlia varieties through mutation breeding and its successfully propagation by using best combination of rooting hormones, are need to be carried out. In light of the experience gained with this investigation, the following few suggestions are made for formulating future research programmes.

- Study on the stability of identified variants and chimeras.

- Molecular characterization of identified variants of vM_1 and vM_2 generation.
- The future studied on meiotic chromosomal behaviour of variants material and detail analysis of pigments in variants.
- The study should be carried out to know the effect of gamma rays on dark colour varieties.
- Standardization of propagation techniques for successful rooting.
- Studies on individual major rooting hormones and their combinations can be taken up.
- Investigation can also have conducted in other agro-climatic zones of Chhattisgarh.

REFERENCES

Abrol, A. and Baweja, H.S. 2019. Floriculture- Worldwide production, trade, consumption pattern, market opportunities and challenges. *https://medium.com/@preetisharma_51610 –e797d.*

Ahloowalia, B.S. and Maluszynski, M. 2001. Induced mutations- A new paradigm in plant breeding. *Euphytica*. 118(2): 167-173.

Ahmed, I., 1983. Propagation of fruit plants. Effect of some root promoting substances on stem cuttings of guava. M.Sc. Thesis, University of Agriculture Faisalabad.

Akhtar, M.S., Khan, M.A., Riaz, A. and Younis, A. 2002. Response of different rose species to different root promoting hormones. *Pak. J. Agri. Sci*., 39(4): 152-165.

Alexious, A.A., Konstantinos, A.A. and Harold, C.P. 2006. Effect of plant growth regulators on the tuberisation and physiological age of potato (*Solanum tuberosum* L.) tubers grown from true potato seed. Agricultural University of Anthens Greece.

Ali, J. 2002. Effect of gamma irradiation on vegetative and floral characteristics of tuberose corms (*Polianthes tuberosa* L.) var. single. *Agris. FAO*.: 90.

Ali, H., Ghori. Z., Sheikh, S. and Gul, A. 2016. Effects of gamma radiation on crop production. *Springer International Publishing*, Switzerland. pp. 27-78. DOI: 10.1007/978-3-319- 231624_2

Anil, K.S. 2004. Influence of plant bioregulators on growth and seed yield in French marigold (*Tagetes patula* Linn.). *J. Orn. Hort*., 7 (2): 193-195.

Anonymous. 2019. Horticulture crop estimate. Department of Agriculture cooperation and Farmers Welfare (DAC&FD), Government of India, New Delhi, India.

Anu, K.G., Geetha, C.K., Rajeevan, P.K., Valsalakumari, P.K. and Saifudeen, N. 2003. Induced mutation in tuberose (*Polianthes tuberosa* Linn) by gamma rays. *Indian Society of Ornamental Horticulture*, pp. 255-259.

Banerji, B.K. and Datta, S.K. 1992. Gamma rays induced flower shape mutation in chrysanthemum cv. "jaya". *J. Nuclear Agric. Biol*., 21: 73-79.

Banerji, B.K. and Datta, S.K. and Sharma, S.C. 1994. Gamma irradiation studied on gladiolus cv. White Friendship. *J. Nuclear Agric. Biol.*, 23(3): 127-133.

Banerji, B.K. and Datta, S.K. 2002. Induction and analysis of gamma ray-induced flower head shape mutation in Lalima chrysanthemum (*Chrysanthemum morifolium*). *Indian Journal of Agricultural Sciences*, 72(1): 6-10.

Banerji, B.K. and Datta, S.K. 2005. Induction and analysis of somatic mutation in chrysanthemum cultivar Khumaini. *Journal of Nuclear Agriculture and Biology*, 34(3-4): 196-201.

Bhandari, A.J. 2014. Effect of different growth regulators on vegetative propagation of *Hibiscus rosa-sinensis* L. M. Sc. Thesis submitted to N. A. U., Navsari.

Bharathy, P.V., Sonawane, P.C. and Sasnu, P.V. 2004. Effect of plant growth regulators, type of cutting and season on rooting of carnation (*Dianthus caryophyllus* L.) cuttings. *Indian Journal of Horticulture*, (61): 338-341.

Bharmal, V.S. Ranpise, S.A. and Darwade, R.T. 2005. Effect of different levels of indole butyric acid (IBA) on rooting, growth and flower yield of chrysanthemum cv. Sonali Tara. *Orissa Journal of Horticulture*, 33(2): 36-41.

Bhatt, S.T. and Chauhan, N.M. 2012. Effect of auxin on rooting of African marigold (*Tegetes erecta* L.). *Advance Research Journal of Crop Improvement*, 3(1): 69-70.

Bibhaskumar, D. 2003. Life functions of plants. Kalyanis Gardeners Guide. 1st Edn, Kalyani Publishers. Ludhiana, India, pp: 04-05.

Boersen, A.M., Tulmann, N.A., Latado, R.R. and Santos, P.C. 2006. Dose of effect gamma-irradiation in obtaining colour mutants of inflorescence of chrysanthemum (*Dendrenthema grandiflorum*). *Revista Brasileira De Horticulture Ornamental*, 12(2): 26-133.

Broertjes, C. 1976. Mutation breeding of auto-tetraploid Achimenes cultivars. *Euphytica*, 25: 297-304.

Broertjes, C. 1969. Induced mutation and breeding method in vegetatively propagated spiecies. *In:* Induced Mutation in Plants. (Proc. FAO/IAEA Symp. Pullman). IAEA, Vienna, pp. 325-329.

Broertjes, C. 1972. Improvement of vegetatively propagated crops by ionizing radiations. *In:* Induced Mutation in Plants Improvement. (Proc. FAO/IAEA Symp. Pullman). IAEA, Vienna, pp. 393-399.

Broertjes, C. and Ballego, J. M. 1967. Mutation breeding of *Dahlia variabilis*. *Euphytica*, 16: 171-176.

Broertjes, C. and Ballego, J. M. 1968. Addendum to: Mutation breeding of *Dahlia variabilis*. *Euphytica*, 17: 507.

Broertjes, C. and Harten, H. A.M. 1988. Applied Mutation Breeding for Vegetatively Propagated Crops. Amsterdam, Elsevier, 343 p.

Cesarett, A.P. 1968. Effect of radiation on higher plants and plant communities. *Ann. NY Acad. Sci.*, 59: 514.

Constanzi, M., Mela, L. and Garibaldi, A.E. 1988. Preliminary results on multiplication by cuttings of *Genista monosperma*. *Acta Hortic*., 226: 327-332.

Da Silva, J.A. 2006. Floriculture, ornamental and plant biotechnology: Advances and topical issues, 2(1): 238.

Das, P.K., Dube, S. and Dey, A.K. 1978. New dahlias through irradiation. *Indian Horticulture,* 23 (1): 19-21.

Das, P.K., Dube, S., Ghosh, P. and Datta, S.K. 1975. Mutation breeding in Dahlia. *Indian Journal Ornamental Horticulture,* 6 (2): 3-8.

Datta, S.K., Chakarabarty, B. and Mandal, A.K.M. 2001. Gamma ray-induced genetic manipulations in flower colour and shape in *Dendranthema grandiflorum* and their management through tissue culture. *Plant Breedig* 120, 91-92.

Datta, S.K. and Chakrabarty, D. 2005. Classical mutation breeding and molecular methods for genetic improvement of ornamentals. *In*: Role of Classical Mutation Breeding in Crop Improvement. *Daya Publishing House*, pp. 260-310.

Datta, S.K. and Teixeira da Silva, J.A. 2006. Role of induced mutagenesis for development of new flower color and type in ornamentals. *In:* Teixeira da Silva JA (Ed) Floriculture, Ornamental and Plant Biotechnology: Advances and Topical Issues Mutations and Mutagenesis, *Global Science Books, Ltd.,* Isleworth, UK, 1(3): 640-645.

Datta, S.K., Misra, K.P. and Mandal, A.K.A. 2005. In vitro mutagenesis – a quick method for establishment of solid mutant in chrysanthemum. *Current Science*, 88: 155-158.

Dawa, S., Rather, Z.A., Tundup, P. and Tamchos, T. 2017. Effect of growth regulators and growth media on rooting of semi hardwood cuttings of rose root stocks. *International Journal of Current Microbiology and Applied Sciences*, 6(4): 1042-1051.

De Klerk, G.J., Van Der Krieken W.M and De Jong, J.C. 1999. The formation of adventitious roots; new concepts, new possibilities. *In Vitro Cell Dev. Biol.*, 35: 189-199.

Devi, N.S. and Fatmi, U. 2019. Effect of gamma radiation on vegetative and floral characters of Gladiolus cultivars (Praha, Tiger flame and Snow princess). *Journal of Pharmacognosy and Phytochmistry*, 8(3): 4309-4312.

Dhaduk, B.K. 1992. Induction of mutations in garden gladiolus (*Gladiolus L.*) by gamma rays. Thesis, IARI, New Delhi.

Dilta, B.S., Sharma, Y.D., Gupta, Y.C., Bhalla, R. and Sharma, B.P. 2003. Effect of gamma rays on vegetative and flowering parameters of chrysanthemum. *Journal of Ornamental Horticulture*, 6(4): 328–334.

Dirr, M.A. and Heuser, C.H.W. 2006. The reference manual of woody plant propagation. Portland, USA: Timber Press, 410. ISBN – 13: 978-1-60469-004-0.

Dobanda, E. 2004. Evaluation of variability induced by gamma radiation on quantitative and qualitative traits in gladiolus. *Cercetari de Genetica Vegetala si Animala*, 8: 149-156.

Dube, S., Das, P.K., Dey, A.K. and Bid, N.N. 1980. Varietal improvement of Dahlia by gamma irradiation. *Indian Journal of Horticulture,* 37(1): 82-87.

Dwivedi, A.K. and Banerji, B.K. 2008. Effect of gamma irradiation on dahlia cv. Pink with particular reference to induction of somatic mutation. *Journal of Ornamental Horticulture*, 11(2): 148–151.

Ehrenberg, L. 1995. Factors influencing radiation induced lethality, sterility and mutation in barley. *Herditas.,* 41: 123-146.

Evan, M. L. 1973. Rapid stimulation of plant cell elongation by hormonal and non-hormonal factors. *Bioscience,* 23: 7-8.

Fierascu, R.C., Fierascu, I.C. and Fierascu, I. 2019. The application of essential oils as a next generation of pesticides: recent developments and future perspectives. *http://doi.org/10.1515/znc-0160*.

Ganjure, S.L., Gawande, M.B. and Golliwar, V.J. 2012. Response of IBA and rooting media on rooting of cutting in chrysanthemum. *International Journal of Science and Research,* 3(7): 1306-1308.

Gatt, M., Ding, H., Hammett, K. and Murray, B. 1998. Polyploidy and evolution in wild and cultivated *Dahlia species*. *Annals of Botany*, 81: 647-656.

Gautam, S.K., Sen, N.L., Jain, M.C. and Dashora, L.K. 2006. Effect of plant regulators on growth, flowering and yield of chrysanthemum

(*Chrysanthemum morifolium* Ram.) cv. Nilima. *Orissa Journal of Horticulture,* 34(1): 36-40.

Ghofrani, M., Ejraei, A. and Abotalebi, A. 2013. Effect of IBA on rooting cuttings of carnation flowers (*Caryophillium aromaticus*) in three environments. *J. Novel Appl. Sci.,* 32(4):1165-1169.

Giacomelli, M., Donini, M.B. and Cervigni, T. 1967. Effect of kinetin on chlorophyll breakdown and protein level in irradiated barley leaves. *Radiat. Bot.,* 7: 375-385.

Giannasi, D.E. 1998. Flavonoid chemistry and evolution in Dahlia (compositae). Bulletin of the Torry Botanical Club. 102:404-412.

Grewal, H.S., Kumar, R. and Chauhan, R. 2005. Effect of IBA and NAA on rooting in chrysanthemum (*Dendranthema grandiflora* Tzevlev) terminal cuttings. *Journal of Ornamental Horticulture New Series*, 8(3): 230-232.

Grzesik, M., 1989. Effect of growth regulators on the seedling-growth of *Lathyrus odoratus, Zinnia elegans, Matthiola incana* and *Antirrhinum majus*. *Acta Hortic*., 251: 71-74.

Godha, S., Sharma, L.K., Kumar A. 2000. Study on the influence of growth regulators on growth and flowering of chrysanthemum. *Journal of Phytological Research*, 13(2): 175-178.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedure for Agricultural Research*. (2nd ed.), New York, John Wiley and Sons. 680p.

Gowda, G. P., Dhananjaya, M.V. and Kumar, R. 2017. Effect of indole butyric acid (IBA) on rooting of different carnation (*Dianthus caryophyllus* L.) genotypes. *Int. J. Pure App. Biosci*., 5(2): 1075-1080.

Gunckel, J.E. and Sparrow, A.H. 1961. Effect of gamma rays on growth, flowering behavior and induction of somatic mutations in chrysanthemum. *SABRAO J.,* 10: 149-161.

Gupta, V. N. and Dutta, S. K., 2000, Influence of gibberlic acid on growth and flowering in chrysanthemum (*Chrysanthemum morifoliun* Ramat.) cv. Jayanthi. India *J. Plant Physiol*., 6(4): 420-422.

Haider, A., Jaskani, M.J., Hussain, Z. and Muhammad, A. 2006. Response of rose cuttings against root promoting hormones during spring and autumn. *INT. J. BIOL. BIOTECH*., 3(1): 201-204.

Hamatani, M., Iitsuka, Y., Abe, T., Miyoshi, K., Yamamoto, M. and Yoshida, S**.** 2001**.** Mutant flowers of dahlia (*Dahlia pinnata* Cav.) induced by heavy- ion beam. *RIKEN Accel. Prog. Rep.*, 34:169.

Hanafiah, D.S., Trikoesoemaningtyas, Yahya, S. and Wirnas, D. 2010. Induced mutations by gamma ray irradiation to Argomulyo soybean (*Glycine max*) variety. *Nusantara Bioscience*, 2(3): 121-125.

Hasbullah, N.A., Taha, R.M., Saleh, A. and Mahmed, N. 2012. Physiological response of callus from *Gerbera jamesonii* Bolus ex. Hook f. to gamma irradiation. *Brazi. Arch. Biol. Techn*., 55(3): 411-416.

Hetman, J., Lukawska, S., Pudelska, K. and Parzymies, M. 2017. The effect of the cutting method on rooting of *Dahlia pinnata* cav. cuttings. *Acta Sci. Pol. Hortorum Cultus.*, 16(2): 149–160.

Hubbard, C. P. 1966. Atomic irradiation of gladiolus seeds. The Gladiolus, 41: 59-65.

Iba, S., Matsurbara, H. Oka, M., Meshitsukha, G., Matsumoto, H. and Kundo, T. 1965. Effect of gamma irradiation on gladiolus. III.Ii. Tokyo Metropolian Isotope Research Center, Annual Report. 4: 85-88.

Isaev, S.I., Dryagina, I.V. and Versinkina, L.M. (1970). The effect of prolonged radiation with Co^{60} on the growth and cormel production of gladiolus. *Doklady Akad. Nauk SSSR.*, 135 (1/6): 342-344.

Ioana, M., Varga, Z.S. and Cantor, M. 2017. Dahlia an unforgettable flower- A new perspective for therapeutic medicine. *Hop and Medicinal Plants*, 2360-0179.

Jain *et al.* 1998. Biotechnology and mutagenesis in gerbera improvement. *Advances in Hort. Sci.,* 12(1): 47-53.

Jerzy, M. and Lubomski, M. 1992. In vitro adventitious bud techniques for mutation breeding of *Gerbera jamesonii*. *Acta Hortic.,* 314: 269-274.

Jyothi, R. and Singh, K.P. 2017. Effect of acute gamma irradiation on flower, bulb characters and stability of mutants in tuberose (*Polianthes tuberosa*). *Indian Journal of Agricultural Sciences,* 87(7): 968-74.

Kaicker, U.S. 1992. Rose breeding in India and cytology of induced mutation of H.T. cv. 'Folkfore'. *Acta Hortic*. 320: 105-112.

Kaintura, P., Srivastava, R. and Kapoor, M. 2016. Effect of physical and chemical mutagens on different cultivars of tuberose (*Polianthes tuberosa* Linn.) with particular reference to induction of genetic variability. *International Journal of Agriculture Sciences,* 8(15): 1257-1260.

Kapadiya, D.B., Chawla, S.L., Patel, A.I. and Ahlawat, T.R. 2014. Exploitation of variability through mutagenesis in Chrysanthemum (*Chrysanthemum morifolium* ramat.) var. maghi. *The Bioscan*, 9(4): 1799-1804.

Kalia, R. 2015. Effect of different concentrations of auxins on the regeneration of *Chrysanthemum morifolium* plantlets. *International Journal of Technical Research and Applications,* 3(6): 106-107.

Kaul, A., Kumar, S., Thakur, M. and Ghani, M. 2011. Gamma ray-induced in vitro mutations in flower colour in *Dendranthema grandiflora* Tzelev. *Floriculture and Ornamental Biotechnology Global Science Books,*102-108.

Kaur, P. Mal, D., Sheokand, A., Singh, L. and Datta, S. 2018. Role of plant growth regulators in vegetable production: A review. *International Journal of Current Microbiology and Applied Sciences,* 7(6): 2177-2183.

Karki, K. and Srivastava, R. 2010. Effect of gamma irradiation in gladiolus (*Gladiolus grandiflorus* L.). *J. Pantnagar Res*., 8(1): 55-63.

Kazankaya, A., Yoruk, E. and Dogan, A. 2005. Effect of IBA on rooting of *Rosa canina* hardwood cuttings from lake van region, turkey. *International Society for Horticultural Science/Acta Horticulturae*, 690.23.

Kazi, N.A. 2015. Mutation breeding in flower crops. *Assian Journal of Multidisiplinary Studies*, 3(3): 103-110.

Khan, R.U., Khan, M.S., Rashid, A. and Farooq, A. 2007. Effect of exogenous indole-3-acetic acid and naphthalene acetic acid on regeneration of damask rose cuttings in three growing media. *Pakistan Journal of Biological Sciences*. 10(20): 3626-3631.

Khan, F.U. and Tewari, G.N. 2003. Effect of growth regulators on growth and flowering of dahlia (*Dahlia variabilis* L.). *Indian Journal of Horticulture*, 60(2): 192-194.

Khewale, A. P., Golliwar, V. J., Poinkar, M. S., Jibhakate, S. B. and Athavale, M. P. 2005. Influence of different concentrations of IBA and media on root parameters in the propagation of carnation cv. Gaudina. *Journal of Soils and Crops*,15(2):406-410.

Khuriwal, K.S., Kumar, M., Pandey, S.K., Kasera, S. and Singh, V.K. 2018. Effect of plant growth regulators on plant growth, flower yield and quality of dahlia (*Dahlia variabilis* L.) cv. Kenya. *Journal of Pharmacognosy and Phytochemistry*, 1: 603-604.

Krasaechai, A. 1992. Effect of gamma radiation on tuberose (*Polyanthes tuberosa*). *Kasetsart Journal Natural Sciences*, 26(1): 6-11.

Koh, G.C., Kim, M.Z. and Kang, S.Y. 2010. Induction of petal colour mutants through gamma ray irradiation in rooted cuttings of rose. *Kor. J. Hort. Sci. Tech.*, 28(5): 796-80.

Kole, P.C. and Meher, S.K. 2005. Effect of gamma rays on some quantitative and qualitative charecters in zinnia (*Zinnia elegance* N.J. Jacguin) in M1 generation. *J. Orn. Hort*., 8(4): 303-305.

Kothakapu, R. and Sekhar, R.C. 2014. Studies on effect of plant growth regulators on rooting of carnation (*Dianthus cryophyllus* l.) cuttings of cv. dona under poly house conditions. *Plant Archives,* 14(2): 1135-1137.

Kumar, R., Ahmed, N., Sharma, O.C. and Lal, S. 2014. Influence of auxins on rooting efficacy in carnation (*Dianthus caryophyllus* L.) cuttings. *J. Hortl. Sci.*, 9(2): 157-160.

Kumar, S., Malik, A., Yadav, R. and Yadav, G. 2019. Role of different rooting media and auxins for rooting in floricultural crops. *International Journal of Chemical Studies*, 7(2): 1778-1783.

Kumari, K., Dhatt, K.K. and Kapoor, M. 2013. Induced mutagenesis in *Chrysanthemum morifolium* variety 'otome pink' through gamma irradiation. *The Bioscan*, 8(4): 1489-1492.

Lamseejan, S., Jompuk, P., Wongpiyasatid, A., Deeseepan, S. and Kwanthammchart, P. 2000. Gamma-rays induced morphological changes in chrysanthemum. (*Chrysanthemum morifolium*). *Journal of Natural Sciences,* 34(3): 417-422.

Laneri, U., Franconi, R. and Altavista, P. 1990. Somatic mutagenesis of *Gerbera jamesonii* irradiation and in vitro culture. *Acta Horticulturae*, 280: 395-402.

Lantin, B. and Decourtye, L. 1970. Obtention de types nouveaux chez le Dahlia par mutations provoquées. *Lein Horticulture Pepiniere*, 99: 5875-5878.

Laurence, L. and William, G.H. 2010. The population genetics of mutations: good, bad and indifferent. *Philos Trans R Soc Lond B Biol Sci.,* 365(1544): 1153-1167.

Lawrence, W.J.C. 1931. The genetics and cytology of Dahlia variabilis. *John Innes Horticultural Institution, Merton,* 24(3): 302-303.

Lee, J.H., Chung, Y.S., Joung, Y.H., Han, T.H., Kang, S.Y., Yoo, Y.K. and Lee, G.J. 2010. Induction of mutations for stem quality in chrysanthemum (*Dendranthema grandiflora*) by using gamma-ray irradiation. *Acta Horticulturae,* 855: 177-182.

Mahure, H.R., Choudhry, M. L., Prasad, K. V. and Singh, S.K. 2010. Mutation in chrysanthemum through gamma irradiation. *Ind. J. Hort.*, 67: 356-358.

Majumder, J., Singh, K.P., Singh, S.K., Prasad, K.V. and Verma, M. 2014. In vitro morphogenesis in Marigold using shoot tip as explants. *Indian J. Hort.*, 71(1): 82-86.

Majumder, J., Singh, S.K. and Verma, M. 2018. Assessment of mutation in marigold (*Tagetes erecta* L.) using morphological and molecular markers. *Int. J. Curr. Microbiol. App. Sci.*, 7(7): 2588-2597.

Malik, A., Prince, Beniwal, V. and Sehrawat, S.K. 2018. Influence of Auxins and Types of Cutting on Rooting Efficacy in Carnation (*Dianthus caryophyllus* L.). *Int. J. Pure App. Biosci.*, 6(3): 325-331.

Manu, R. 2017. Induced mutation in dahlia. M.Sc. Thesis, Department of Plant Breeding and Genetics, College of Agriculture, Vellayani.

Marina, L.J. 2015. Review- Cultivation of the Dahlia. *National Institute of Agricultural Sciences,* Cuba, 36(1): 103-110.

Mathure, H.R., Choudhary, M.L., Prasad, K.V. and Singh, S.K. 2010. Mutation in chrysanthemum through gamma irradiation. *Indian Journal of Horticulture*, 67: 356-358.

Mehrabani, L.V., Kamran, R.V., Hassanpouraghdam, M.B., Kavousi, E. and Aazami, M.A. 2016. Auxin concentration and sampling time affect rooting of *Chrysanthemum morifolium* L. and *Rosmarinus officinalis* L. *Azarian Journal of Agriculture,* (3): 11-16.

Mervat, M.M. and Far, E.L. 2007. Optimization of growth conditions during sweet potato micro-propagation. *African Potato Association Conference Proceedings*, 7: 204-211.

Mesen, J.F. (1993). Vegetative propagation of Central American hardwoods. Ph.D Thesis, University of Edinburgh, Scotland.

Mishra, P., Benerji, B. K. and Kumari, A. 2009. Effect of gamma irradiation on chrysanthemum cultivar 'Pooja' with reference to induction of somatic mutation in flower color and form. *J. Ornam. Hort.,* 12(3): 213-216.

Misra, P. and Datta, S.K. 2007. Standradization of *in vitro* protocol in Chrysanthemum cv. Madam E Roger for development of quality planting material and to induce genetic variability using gamma-radiation. *Indian J. Biotech.,* 6(1): 121-124.

Misra, P., Datta, S.K. and Chakarbarty, D. 2003. Mutation in flower colour and shape of *Chrysanthemum mrifolium* induced by gamma irradiation. *Biologia Plantarum,* 47(1), 153-156.

Misra, R.L. 1990. Mutational studies in bulbous ornamentals. *Progressive Horticulture*, 22(1-4): 36-39.

Misra, R.L. and Bajpai, P.N. 1983. Mutation studies in gladioli (Gladiolus L.): Effect of physical and chemical mutagens on sprouting and survival of corms. *Haryana Journal of Horticultural Sciences*. 12(16): 1-2.

Misra, R.L. and Chaudhary, B. 1979. Fascinatiing mutants in gladioli. *Indian Horti.,* 23(4): 21.

Moacir, P., Chrystiane, B.F., Leonardo, F.D. and Jairo, O.C. 2004. Micropropagation of Fig (*Ficus carico* L.) 'ROXO DE VALINHOS' plants. *In vitro cellular and development biology – plant,* 4: 471-474.

Mohin, K.C., Gonge, V.S., Dalal, S.R. and Bharad, S.G. 2010. Radiation induced variability studies in chrysanthemum under net house. *National Symposium on Life Style Floriculture: Challenges and Opportunities, YSPU H&F*, Nauni, Solan (HP). pp. 43.

Mubarok, S., Suminar, E. and Murgayanti, A. 2011. The effectiveness test of gamma irradiation on growth characters of *Polianthes tuberosa*. *Journal Agrivigor*, 11(1): 25-33.

Nagatomi, S. and Degi, K. 2009. Mutation Breeding of Chrysanthemum by Gamma Field Irradiation and In Vitro Culture. *Q.Y. Shu (ed.), Induced Plant*

Mutations in the Genomics Era. Food and Agriculture Organization of the United Nations, Rome, 258-261.

Nagatomi, S., Tanaka, A., Kato, A., Watanabe, H. and Tano, S. 1995. Mutation induction on chrysanthemum plants regenerated from *in vitro* cultured explants irradiated with 12 C^{5+} ion beam. *TIARA Ann. Rep.,* 5:50-52.

Nasri F, Fadakar A, Saba MK, Yousefi B. 2015. Study of Indole butyric acid (IBA) effects on cutting rooting improving some of wild genotypes of damask Roses (*Rosa damascena* mill.). *Journal of Agricultural Sciences,* 60(3):263-275.

Nencheva, D. 2010. *In vitro* propagation of chrysanthemum. *Method in Molecular Biology*. 589, 177-135.

Nogueira, M.R., Ferraz, M.V., Bezerra, A.K.D., Guedes, R.B.M., Costa, C.R.X., Almeida, L.C.P., Pereira, S.T.S. and Pivetta, K.F.L. 2018. Indol butyric acid and time of the year influence on rooting of chrysanthemum cuttings. *American Journal of Plant Sciences,* 9: 507-516.

Okunlola, A. I. 2013. The effects of cutting types and length on rooting of *Duranta repens* in the Nursery. *Global Journal of Human Social Science, Geography, Geosciences, Environmental and Disaster Management, Global journal Inc.* (USA), (13): 142-150.

Okunlola, A.I. 2016. Effects of Rooting Hormones on the Propagation of Bougainvillea from Cuttings. *International Journal of Research in Agriculture and Forestry*, 3: 57-62.

Okunlola, A.I. and Oyedokun, V. 2016. Effect of Media and Growth Hormones on the Rooting of Queen of Philippines (*Mussaenda philippica*). *Journal of Horticulture*, 3: 173.

Okunlola, A.I. 2017. Response of selected ornamentals to rooting hormone in different propagating media. *J Bot Res.*, 1(1): 22-28.

Pal, S. 2015. Induction of genetic variability through gamma radiation in dahlia (*Dahlia variabilis* Desf.) cultivars. Thesis, Ph.D. G.B. Pant University of Agriculture and technology, Pantnagar.

Palta, J.P. 1990. Leaf chlorophyll content. *Remote Sensing Reviews*. 5(1): 207-213.

Patel, P.C. 2009. Bio efficacy of plant growth regulator and bio stimulant on propagation of Mussanda Pink. M. Sc. Thesis, N. A. U., Navsari,

Patil, S. D. 2009. Gamma Rays Induced Mutations in Commercial Varieties of Gladiolus. Thesis, M.Sc., ASPEE College of Horticulture and Forestry, Navsari Agri. Univ., Navsari.

Patil, U.H., Karale, A.R., Katwate, S.M. and Patil, M.S. 2017. Mutation breeding in chrysanthemum (*Dendranthema grandiflora* T.). *Journal of Pharmacognosy and Phytochemistry,* 6(6): 230-232.

Prince, Mailk, A. and Beniwal, V. 2017. Influence of indole-3-butyric acid on rooting efficacy in different carnation (*Dianthus caryophyllus* L.) genotypes under protected condition. *Chem Sci Rev Lett.,* 6(23): 1858-1862.

Pop, T., Pamfil, D. and Bellini, C. 2011. Auxin control in the formation of adventious root. *Bot. Horti. Agrobotani.,* 39(1): 307-316.

Pudelska, K., Hetman, J., Lukawska, S. and Parzymies, M. 2015. The efficiency of mother crowns and quality of soft cuttings of a few dahlia cultivars. *Acta Sci. Pol. Hortorum Cultus.,* 14(6): 189-200.

Ranpise, S.A., Bharmal, V.S., Darwade, R.T. 2004. Effect of different levels of indole butyric acid (IBA) on rooting, growth and flower yield of chrysanthemum cv. Sonali Tara. *Journal of Ornamental Horticulture*. 7: 331-337.

Rather, Z.A., Jhon, A.Q. and Zargar, G.H. 2002. Effect of Co-60 gamma rays on Dutch Iris-II. *J. Orn. Hort*. New Series. 5(2): 1-4.

Renuka, K., Sekhar, R. C., Pratap, M. and Reddy, M. N. 2015. Effect of plant growth regulators on rooting of carnation (*Diantus caryophyllus* L.) cuttings of different cultivars under poly house conditions. *Journal of Soils and Crops,* 25(2): 266-270.

Rikken, M., 2010. The European market for fair and sustainable flowers and plants. *Pro Verde.*

Saar, D. E., Sorensen, P. D. and Hjerting, J. P. 2003. Dahlia campanulata and D. cuspidate (Asteraceae, Coreopsideae): Two New Species from Mexico. *Acta Botánica Mexicana*, 64: 19-24.

Sadhukhan, R., Swathi, K., Sarmah, D. and Mandal, T. 2015. Effect of different doses of gamma rays on survivability and rooting ability in chrysanthemum (*Chrysanthemum morifolium* Ramat.) *Journal Crop and Weed*, 11(1): 62-65.

Saffari, V.R., Khalighi, A., Lesani, H., Babalar, M. and Obermaier, J.F. 2004. Effects of different plant growth regulators and time of pruning on yield components of *Rosa damascena* Mill. *Int. J. Agric. Biol.,* 6:6.

Sarhan, A.Z., Nasr, A.A., Elsheinhab, N.A.A. and ElSawy, M.A.A. 2019. Studies on the effect of radiation mutagens on the growth and flowering of *Tagetes erecta* plants, *Middle East Journal of Agriculture Research,*8: 954-958.

Sekar, V. and Sujata, A. 2001. Effect of growing media and GA_3 on growth and flowering of gerbera, *South India Hort*., 49: 338-341.

Sharma, J.R. 1998. *Statistical and Biometrical Techniques in Plant Breeding*. New Delhi, *New Age International*, 429p.

Sharma, N., Kaur, N. and Gupta. A.K. 1998. Effects of gibberellic acid chlorocholine chloride on tuberisation and growth of potato (*Solanum tuberosum* L.), *J.Sci. Food Agric*., 78: 466-470.

Sharma R. 2014. Study on the effect of auxins on rooting, growth and flowering of African marigold (*Tagetes erecta* L.) propagated through stem cuttings. M. Sc. (Hort.) thesis. I.G.K.V., Raipur, 2014.

Sharma, S.C., Srivastava, R., Datta, S.K. and Roy, R. 2002. Gamma ray induced bract colour mutation in single bracted Bougainvillea 'Palekar'. *J. Nuclear Agric. Biol.,* 31(3-4) : 206-208.

Shepherd, H. and Winston, S. L. 2000. Effect of IBA on rooting of stem cutting of Bougainvillea (*Bougainvillea* spp.) cv. Thimma. *Bioved Research Society.* 11 (1/2): 37-40.

Shivanagowda, S. P. 2000. Effect of mother plant nutrition and chemical spray on seed yield and quality of china aster (*Callistephus chinensis* (L.) Nees. M. Sc. (Agri.). Thesis, submitted to Uni. Agric. Sci., Dharwad, Karnataka.

Shiva, K.N. and Nair, S.A. 2009. Effect of growing environment and rooting hormone on root and shoot characters of hibiscus. *Indian J Hort.,* 66(2): 233-238.

Shukla, A., Kashyap, S., Ramteke, V., Sinha, L. and Netam, M. 2018. Effect of gamma rays on flowering and vase life of gladiolus (*Gladiolus grandiflorus* L.). *Journal of Pharmacognosy and Phytochemistry,* 7(6): 558-561.

Singh, N. 2012. Effect of Indole Butyric Acid (IBA) Concentration on Sprouting, Rooting and Callusing Potential in Bougainvillea Stem Cuttings. *Journal of Horticultural Sciences,* 2: 254-260.

Singh, A. K. and Kumar, A. 2013. Studies of gamma irradiation on morphological characters in gladiolus. *Asian J. Hort*., 8(1): 299-303.

Singh, A.K. and Singh, R. 2005. Influence growth regulating substances on rooting of cuttings of poinsettia cv. Flaming Sphere. *Prog. Hort.,* 537(1):85-88.

Singh, M.K., Ram, R. and Kumar, S. 2006. Effect of Plant Growth Regulators on Rooting of Carnation *(Dianthus caryophyllus)* Cuttings. *BVAAP*., 14(1): 30-33.

Singh, M. and Bala, M. 2015. Induction of mutation in chrysanthemum (*Dendranthema grandiflorum* Tzvelev.) cultivar Bindiya through gamma irradiation. *Indian J. Hort.,* 72(3): 376-381.

Singh, M. and Bala, M. 2019. Induction of radiomutants in *Chrysanthemum morifolium* Ramat. cv. Gul-e-Sahir for novel traits. *Indian Journal of Experimental Biology*, 57: 50-54.

Singh, N. 2018. Effect of Indole Butyric Acid (IBA) Concentration on Sprouting, Rooting and Callusing Potential in Bougainvillea Stem Cuttings. *Journal of Horticultural Sciences, 7*(2): 209-210.

Singh, S., Dhyani, D. and Kumar, A. 2011. Expression of floral fasciation in gamma-ray induced *Gerbera jamesonii* mutants. *Journal of Cell & Plant Sciences,* (2): 7-11.

Singh, V. N., Banerji, B.K., Dwivedi, A.K. and Verma, A.K. 2009. Effect of gamma irradiation on African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda. *Journal of Horticulture Science*, 4(1): 36-40.

Srivastava, P., Singh, R. P. and Tripathi, V. R. 2007. Response of gamma radiation on vegetative and floral characters of gladiolus. *J. Ornam. Hort.,* 10 (2): 135-136.

Stadler, L. J. 1929. Genetic effects of X-rays in maize. *Proc. Natn. Acad. Sci.,* (U.S.A.), 15: 69-75.

Sun, Z.F., Li, S.R., Li, C.S., Li, M. and Chen, L. 1988. Effect of curposition and plant growth regulators on growth regulators on growth and flowering in cut roses. *Adv. Hortic.,* 2: 157-160.

Susaj, E., Susaj, L. and Kallco, I. 2012. Effect of different NAA and IBA concentrations on rooting of vegetative cuttings of two Rose cultivars. *Research Journal of Agricultural Science*, 44(3): 385-389.

Swaroop, K., Jain, R. and Janakiram, T. 2015. Effect of different doses of gamma rays for induction of mutation in bougainvillea cv Mahatma Gandhi. *Indian Journal of Agricultural Sciences,* 85(9): 1245–1247.

Tawfik, A. A., Ibrahim, O.H.M., Abdul-Hafeez, E. Y. and Ismail, S.A. 2018. Effect of Cutting Type, Indol-3-Butyric Acid and the Growing Season on Rooting of Stem Cuttings of *Rosa hybrida* cv Eiffel Tower. *J. Plant Production,* Mansoura Univ., 9(6): 537–542.

Tiwari, A.K. and Kumar, V. 2011. Gamma rays induced morphological changes in pot marigold (*Calendula officinalis*). *Prog. Agric*. 1: 99-102.

Tiwari, A. K., Srivastava, R. M., Kumar, V., Yadav, L. B. and Misra, S. K. 2010. Gamma rays induced morphological changes in gladiolus. *Prog. Agric*., 10: 75-82.

Ullah, Z., Abbas, S.J., Naeem, N., Lutfullah, G., Malik, T., Khan, M.A.U. and Khan I. 2013. Effect of indole butyric acid (IBA) and naphthalene acetic acid (NAA) plant growth regulators on Mari gold (*Tagetes erecta* L.). *African Journal of Agricultural Research,* 8(29): 4015-4019.

Vaclavik, J. 2000. Selection of a new group of miniature dahlias (*Dahlia pinnata* cav.). *Zahradnictvi Horticultural Sciences*, 27(3): 99-102.

Van Harten, A.M. (2002). Mutation breeding of vegetatively propagated ornamentals. *Breeding for Ornamentals: Classical and Molecular Aproaches*, pp. 105-127.

Velmurugan, M., Rajamani, K., Paramaguru, P., Gnanam, R., Kannan Bapu, J.R., Harisudan, C. and Hemalatha, P. 2010. In vitro mutation in horticultural crops- a review. *Agric. Rev.,* 31(1): 63-67.

Watane, A.A., Khobragade, Y.R., Palekar, A.R. and Singhanjude, A.R. 2018. Response of marigold cuttings to IBA and media for rooting and growth performance. *International Journal of Chemical Studies,* 6(5): 1343-1347.

Wei, J.L. 1958. The effect of plant hormones, rooting media and intermitted mist on the rooting and transplanting of herbaceous, evergreen and hardwood cuttings. Thesis, M.Sc., Montana State University.

Yamaguchi, M.A., Oshida, N., Nakayama, M., Koshioka, M. and Yamaguchi Y. 1999. Anthocyanidin 3-glucoside alonyl transferase from *Dahlia variabilis*. *Phytochemistry*, 52: 15-18.

Zimmerman, P.W. and Wilcoxon, F. 1935. Several chemical growth substances which cause initiation of roots and other responses in plants. *Contrib. Boyce.,* 7: 209-228.

Zeinab, I. and Hossein, Z. 2014. Evaluation of propagation of chinese hibiscus (*Hibiscus rosa-sinensis*) through stenting method in response to different IBA concentrations and rootstocks. *American Journal of Plant Sciences,* 5: 1836-1841

Appendix-I

Standard metrological weeks and average weather data from December 2018 to May 2019 at Indira Gandhi Agricultural University, Raipur (Chhattisgarh) - 492 012

Month	Date	Year	Temp. (°C)		Rain- fall (mm)	Relative Humidity (%)		Wind Velocity (Kmph)	Evaporrat-ion (mm)	Sun Shine (hours)
			Max.	Min.		Max.	Min.			
Dec	**03-09**	**2018**	28.2	14.3	0.0	87	38	0.9	17.4	4.4
Dec	**10-16**	**2018**	27.4	15.7	0.0	86	51	1.0	13.9	1.2
Dec	**17-23**	**2018**	22.1	11.0	47.2	90	57	3.1	15.3	4.5
Dec	**24-31**	**2018**	25.1	8.6	0.0	86	28	1.3	16.6	7.5
Jan	**01-07**	**2019**	27.4	8.5	0.0	88	28	0.7	16.8	6.6
Jan	**08-14**	**2019**	27.1	10.2	0.0	87	34	0.9	16.5	6.1
Jan	**15-21**	**2019**	28.1	9.2	0.0	85	21	0.9	18.7	6.8
Jan	**22-28**	**2019**	26.3	14.3	23.6	85	53	2.0	18.5	4.0
Jan-Feb	**29-04**	**2019**	26.4	9.5	0.0	87	24	1.3	20.6	8.2
Feb	**05-11**	**2019**	28.8	12.5	3.4	81	36	1.5	21.3	7.6
Feb	**12-18**	**2019**	30.2	13.6	9.0	84	34	1.8	20.4	8.3
Feb	**19-25**	**2019**	33.1	17.0	0.0	81	30	1.7	30.3	9.1
Feb-Mar	**26-04**	**2019**	31.0	17.3	0.2	72	36	2.4	30.7	7.8
Mar	**05-11**	**2019**	33.3	17.6	0.0	70	32	8.3	40.3	8.9
Mar	**12-18**	**2019**	35.6	21.6	0.0	72	33	3.2	36.7	6.8
Mar	**19-25**	**2019**	34.5	19.8	9.2	80	28	2.4	37.1	8.4
Mar-Apr	**26-01**	**2019**	38.2	20.6	10.8	64	19	2.0	44.5	8.7
Apr	**02-08**	**2019**	39.7	23.4	0.0	50	18	3.4	53.2	8.3
Apr	**09-15**	**2019**	40.8	24.5	0.0	47	20	4.3	60.4	8.3
Apr	**16-22**	**2019**	38.0	24.1	11.2	61	27	4.3	54.4	9.0
Apr	**23-29**	**2019**	42.0	26.3	0.0	45	15	2.9	59.6	10.1
Apr-May	**30-06**	**2019**	40.8	26.2	10.6	60	26	4.1	56.4	8.2
May	**07-13**	**2019**	40.7	26.8	0.0	42	12	2.6	68.0	9.3
May	**14-20**	**2019**	42.8	27.5	0.0	40	15	3.4	74.1	10.3
May	**21-27**	**2019**	44.2	29.5	0.0	41	18	5.1	79.5	9.8

Appendix-II

Standard metrological weeks and average weather data from December 2019 to May 2020 at Indira Gandhi Agricultural University, Raipur (Chhattisgarh) - 492 012

Month	Date	Year	Temp. (°C)		Rain- fall (mm)	Relative Humidity (%)		Wind Velocity (Kmph)	Evaporrat -ion (mm)	Sun Shine (hours)
			Max.	Min.		Max.	Min.			
Dec	**03-09**	**2019**	28.0	13.3	0.0	84	34	2.4	21.4	7.6
Dec	**10-16**	**2019**	29.5	15.3	0.0	91	48	1.7	17.3	5.2
Dec	**17-23**	**2019**	26.7	14.1	0.8	88	42	1.9	16.6	4.9
Dec	**24-31**	**2019**	26.1	11.9	0.0	81	35	2.5	21.6	5.7
Jan	**01-07**	**2020**	23.3	12.9	19.4	84	55	4.1	15.2	3.5
Jan	**08-14**	**2020**	25.1	10.8	3.2	90	46	2.1	16.4	6.2
Jan	**15-21**	**2020**	28.6	14.1	0.0	88	48	1.8	17.3	5.7
Jan	**22-28**	**2020**	28.8	13.4	0.0	87	39	1.8	19.7	7.3
Jan-Feb	**29-04**	**2020**	26.1	13.9	0.0	76	46	2.9	21.6	4.3
Feb	**05-11**	**2020**	21.3	13.6	49.6	94	66	4.1	11.9	2.4
Feb	**12-18**	**2020**	29.7	11.9	0.0	88	27	2.2	26.2	9.8
Feb	**19-25**	**2020**	31.4	15.5	35.8	87	45	2.7	24.9	6.6
Feb-Mar	**26-04**	**2020**	30.0	16.3	0.2	87	39	1.9	25.4	7.8
Mar	**05-11**	**2020**	30.1	19.4	1.8	87	52	3.7	25.5	6.7
Mar	**12-18**	**2020**	31.2	20.8	37.2	89	54	3.0	24.6	6.5
Mar	**19-25**	**2020**	33.6	20.0	1.6	84	37	3.0	31.1	8.3
Mar-Apr	**26-01**	**2020**	35.1	21.9	8.4	78	36	3.4	34.4	7.3
Apr	**02-08**	**2020**	37.5	22.0	1.0	76	30	3.6	39.9	8.5
Apr	**09-15**	**2020**	39.0	21.9	2.0	69	24	3.9	45.3	8.4
Apr	**16-22**	**2020**	40.0	24.3	6.2	66	24	6.1	56.8	9.0
Apr	**23-29**	**2020**	37.2	23.3	4.0	73	38	5.6	44.3	9.0
Apr-May	**30-06**	**2020**	40.6	25.3	0.0	61	28	4.4	53.9	10.3
May	**07-13**	**2020**	37.9	23.4	35.6	72	36	5.1	45.1	9.1
May	**14-20**	**2020**	40.0	25.5	2.2	69	32	4.7	50.7	8.1
May	**21-27**	**2020**	43.8	25.7	0.0	50	14	5.7	70.6	8.9

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Effect of rooting hormones in propagation of dahlia (*Dahlia variabilis* L.) through stem cutting

Bharti Sao and LS Verma

Abstract
A study on the impact of auxins (IBA and NAA) on two cultivars of dahlia (*Dahlia variabilis* L.) was conducted at Department of Floriculture and Landscape Architecture, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), during the year 2019-20. The study revealed that among the two cultivars (Kenya Blue and Kenya Yellow) experimented, the highest rooting percentage was recorded in the cultivar Kenya Blue (62.46%) which was significantly higher than the rest one. Similar tendency of superiority was observed for survival percentage, number of roots per cutting and root length, wherein the cultivar Kenya Blue took the least number of days for root initiation (18.11 days). As for the different concentration of auxins used, IBA at the rate of 1000 ppm resulted in the maximum rooting percentage (69.82%) as compared to the rest of the treatments. Similar tendency of superiority was observed for number of roots per cutting and root length, wherein IBA at the rate of 250 ppm + NAA at the rate of 250 ppm took the least number of days for root initiation (17.21 days). The highest survival percentage was recorded with treatment of NAA at the rate of 500 ppm (63.96%) followed by NAA at the rate of 1000 ppm (56.39%).

Keywords: dahlia, cultivar, auxin, IBA, NAA, rooting percentage, root length

Introduction
Dahlia (*Dahlia variabilis* L.) belongs to the family Asteraceae and has originated in mountainous areas of Mexico and Central America. The Dahlia flowers have great variations in shape, size, colour, prolific growing habit and easy to cultivate. Dahlias are good for garden display, exhibition, plantings for edging or for growing in beds. Dahlia plants reproduce sexually by seed and vegetatively through tuberous roots. The most widely used methods for its propagation are via cuttings or tuberous root division, however, the most commonly used is the commercial form by cuttings. The main advantages of propagation by cuttings are the relative simplicity of the operations, the low unit cost of production, and the ease with which plants will reestablish themselves. Therefore, this method of propagation is highly practical and economically important. (Wei-June Lu, 1958) [10]. Exogenous application of auxin enhances the rooting efficiency and quality of stem cuttings, while indole-3 butyric acid (IBA) and naphthalene acetic acid (NAA) and its derivative naphthalene acetamide (NAd) are the materials in most common use for rooting of cuttings. The promoting effect of IBA on rooting is mainly due to its conversion to IAA in plant tissue (Epstein and Lavee, 1984) [2]. Auxins like IBA, IAA and naphthalene acetic acid NAA were found to promote rooting in Virginia creeper (Taleb *et al.*, 2012) [9]. Hence the present study was designed to investigate the response of auxin (IBA and NAA) applied on stem cuttings of two cultivar of dahlia, for root induction.

Material and Method
The experiment was carried out at Horticultural Research cum Instructional Farm, Department of Floriculture and Landscape Architecture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), during 2019-20, to study the effect of rooting hormones in propagation of dahlia (*dahlia variabilis* l.) through stem cutting. In the experiment, 8-9 cm long stem cuttings of two dahlia cultivar *viz*. Kenya Blue and Kenya Yellow were treated with two auxins, namely, IBA and NAA, each at 250, 500 and 1000 ppm individually and their combinations each at 125, 250 and 500 ppm, along with control (distilled water), were used. The experiment was laid out in Factorial Completely Randomized Design, with three replications. The basal portion of cuttings was dipped in the respective auxins for a few seconds while the Control was dipped in distilled water. Treated cuttings were planted in planted in portrays having 9×11 cells. Cells of portray were filled well with an equal amount of coco peat sand and vermiculite. Single cutting was planted in a single cell of portray. Temperature was maintained at 18-25 °C, and relative humidity at 80-85% within the mist chamber.

The rooting substrate was treated with 0.2% Bavistin to control fungal infection. Observations were recorded on different root characteristics of the cuttings at 50 days from planting. The cuttings were picked randomly and days from planting to formation of root initials were treated as days required for root initiation. Rooting percentage was determined by counting the number of rooted cuttings per replication and dividing this by the total number of cuttings per replication. For number of roots per cutting, all the roots originating from the cuttings were counted and the total number of roots was divided by the total number of rooted cuttings. All roots produced per replication were collected and their length was measured; the sum of the length was divided by the total number of cuttings to calculate average root length and data obtained from the study was analyzed statistically.

Result and Discussions

Days required for root initiation

Application of auxins improved the rooting efficiency of dahlia cuttings over the control and cultivar Kenya Blue were found to be better than Kenya Yellow for root attributes (Table 1 and Fig. 1). Auxin treatment significantly reduced time-to rooting and early rooting was recorded with IBA @ 250 ppm + NAA @ 250 (17.21 days), at par with treatment application of NAA @ 500 ppm (17.83 days) and IBA @ 500 ppm + NAA @ 500 ppm (17.98 days) over the control (24.66 days). With regards to dahlia cultivar, Kenya Blue resulted in earliest rooting (18.11 days) compared to the Kenya Yellow (21.81 days). Interaction between auxins cultivars were found to be non-significant and minimum days (15.99 days) for rooting were recorded in interaction of mutants of Kenya Blue with IBA @ 250 ppm + NAA @ 250 ppm. It has been reported that auxin existence is necessary for induction of the root starter cells (Hartmann *et al.*, 2002) [4]. The decrease in time taken to root initiation may be attributed to the fact that application of exogenous growth regulators might have supplemented endogenous auxin levels and brought about certain anatomical and physiological changes in the cuttings leading to early root initiation. Similar findings have been reported Bharathy *et al*. (2004) [1] in carnation.

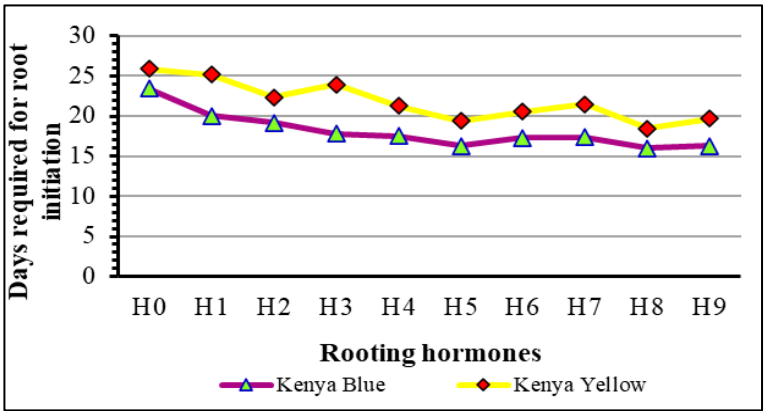

Fig 1: Effect of rooting hormones on days required for root initiation in dahlia cultivar

Table 1: Effect of rooting hormones on days required for root initiation in dahlia cultivars

Cultivar / Rooting Hormones	Days required for root initiation		
	Kenya Blue	Kenya Yellow	Mean
Control	23.40	25.91	24.66
IBA @ 250 ppm	20.03	25.14	22.58
IBA @ 500 ppm	19.17	22.38	20.77
IBA @ 1000 ppm	17.79	23.90	20.85
NAA @ 250 ppm	17.54	21.24	19.39
NAA @ 500 ppm	16.28	19.39	17.83
NAA @ 1000 ppm	17.32	20.53	18.92
IBA @ 125 ppm + NAA @ 125 ppm	17.34	21.47	19.40
IBA @ 250 ppm + NAA @ 250 ppm	15.99	18.44	17.21
IBA @ 500 ppm + NAA @ 500 ppm	16.29	19.68	17.98
Mean	18.11	21.81	
	CD at 5%	S.Em±	
Rooting hormone	1.142	0.400	
Cultivar	0.511	0.179	
Rooting hormone × Cultivar	NS	0.565	

Rooting percentage

Data presented in Table 2 and Fig. 2 showed that rooting percentage was significantly affected by auxin and different cultivar. high rate of rooting (69.82%) was recorded in IBA @ 1000 ppm, at par with NAA @ 500 ppm (69.03%), whereas, control resulted lowest rooting percentage (36.02%) followed by IBA @ 125 ppm + NAA @ 125 ppm (58.03%). As respect to cultivars, Kenya Blue resulted significantly higher percentage of rooting (62.46%) over Kenya Yellow (61.37%). Interaction between NAA @ 500 ppm and Kenya Blue recorded significantly highest rooting percentage (73.85%), at par with treatment combination of IBA @ 500 ppm + NAA @ 500 ppm and Kenya Blue i.e. 72.15%. However, lowest rooting percentage (32.03%) recorded in Kenya Blue in control. The rooting hormones increases the overall percentage of rooting, facilitate initiation of adventitious roots and enhance the number and quality of adventitious roots (Dirr and Heuser, 2006) [2]. Similar result found by Prince *et al*. (2017) [7] and Kumar *et al*. (2014) [5] in carnation.

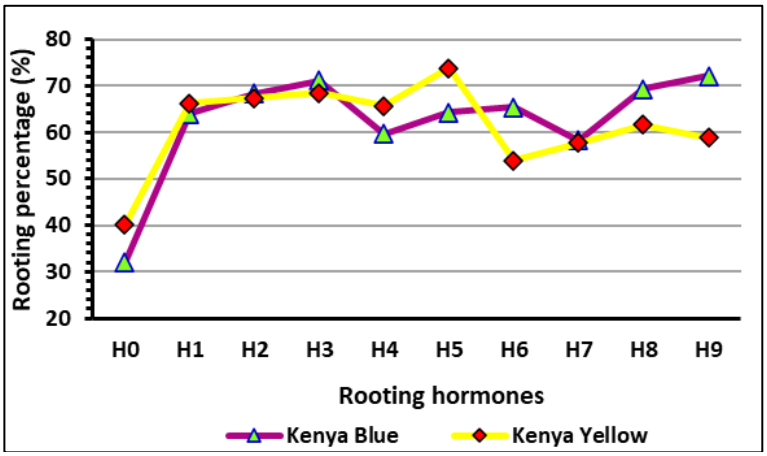

Fig 2: Effect of rooting hormones on rooting percentage in dahlia mutant

Table 2: Effect of rooting hormones on rooting percentage in dahlia cultivars

Rooting Hormones \ Cultivar	Rooting percentage (%)		
	Kenya Blue	Kenya Yellow	Mean
Control	32.03	40.01	36.02
IBA @ 250 ppm	63.93	66.20	65.07
IBA @ 500 ppm	68.37	67.37	67.87
IBA @ 1000 ppm	71.16	68.47	69.82
NAA @ 250 ppm	59.70	65.64	62.67
NAA @ 500 ppm	64.22	73.85	69.03
NAA @ 1000 ppm	65.37	53.94	59.66
IBA @ 125 ppm + NAA @ 125 ppm	58.29	57.77	58.03
IBA @ 250 ppm + NAA @ 250 ppm	69.38	61.65	65.51
IBA @ 500 ppm + NAA @ 500 ppm	72.15	58.78	65.46
Mean	62.46	61.37	
	CD at 5%	S.Em±	
Rooting hormone	1.374	0.481	
Cultivar	0.615	0.215	
Rooting hormone × Cultivar	1.943	0.680	

Number of roots per cutting

There was a significant effect of auxins and cultivars on number of roots per cutting (Table 3 and Fig. 3). Maximum number of roots per cutting (22.74) was recorded in plants treated with IBA @ 1000 ppm and NAA @ 500 ppm, at par with IBA @ 500 ppm (22.67). Among the cultivar, Kenya Blue gave significantly maximum number of roots cutting^{-1} (20.33) compared to the Kenya Yellow (16.76). Interaction effect also showed significant results in respect to number of roots per cutting and the maximum number of roots per cutting (26.12) observed in interaction of NAA @ 500 ppm and Kenya Blue, at par with IBA @ 1000 ppm treatment in same Kenya Blue (25.13). Minimum number of roots per cutting (8.94) recorded in controlled plants of Kenya Blue. The more number of roots obtained with the application of growth chemicals clearly reflects that they not only initiate rooting but also help in subsequent rapid growth of roots in numerical strength. The effect of auxins has been reported to enhance rooting through the translocation of carbohydrates and other nutrients to the rooting zone (Middleton, 1980) [6].

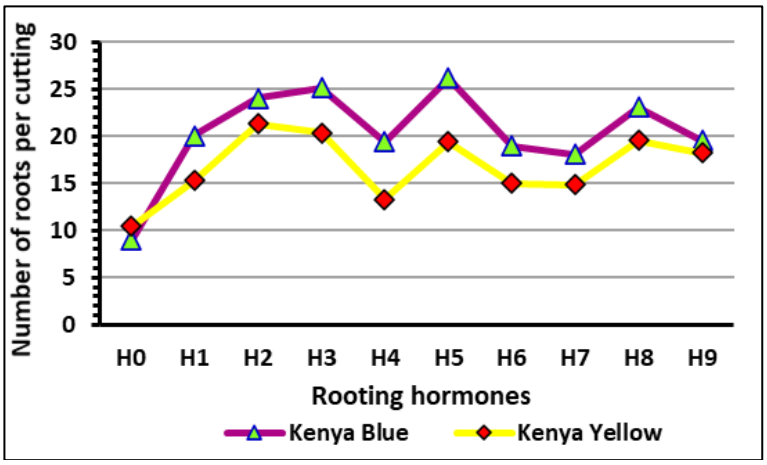

Fig 3: Effect of rooting hormones on number of roots per cutting in dahlia cultivar

Table 3: Effect of rooting hormones on number of roots per cutting in dahlia cultivars

Cultivar / Rooting Hormones	Number of roots per cutting		
	Kenya Blue	Kenya Yellow	Mean
Control	8.94	10.44	9.69
IBA @ 250 ppm	20.02	15.25	17.64
IBA @ 500 ppm	24.03	21.32	22.67
IBA @ 1000 ppm	25.13	20.35	22.74
NAA @ 250 ppm	19.39	13.26	16.32
NAA @ 500 ppm	26.12	19.36	22.74
NAA @ 1000 ppm	18.93	14.99	16.96
IBA @ 125 ppm + NAA @ 125 ppm	18.08	14.84	16.46
IBA @ 250 ppm + NAA @ 250 ppm	23.09	19.53	21.31
IBA @ 500 ppm + NAA @ 500 ppm	19.56	18.22	18.89
Mean	20.33	16.76	
	CD at 5%	S.Em±	
Rooting hormone	0.766	0.268	
Cultivar	0.342	0.120	
Rooting hormone × Cultivar	1.083	0.379	

Root length

The data (Table 4 and Fig. 4) clearly indicated that different doses of rooting hormones, dahlia cultivar and their interactions significantly influenced root length. Longest root length (5.57 cm) was observed in treated with IBA @ 500 ppm at par with IBA @ 1000 ppm (5.56 cm), whereas, poorest root length (2.53 cm) were significantly recorded in untreated plants. As respect to dahlia cultivars, Kenya Blue resulted significantly longer root length (4.16 cm) over Kenya Yellow (3.96 cm). Kenya Blue treated with dose IBA @ 500 ppm recorded significantly longest root length (6.16 cm) at par with interaction of treatment dose IBA @ 1000 ppm with same dahlia cultivar (5.86 cm), whereas, untreated plants of Kenya Yellow noted lowest (2.15 cm) root length. There was increase in root length with treatment of higher doses of IBA, similar results found in hardwood cuttings of hibiscus and mussaenda pink when treated with the IBA reported by Shiva and Nair 2009.

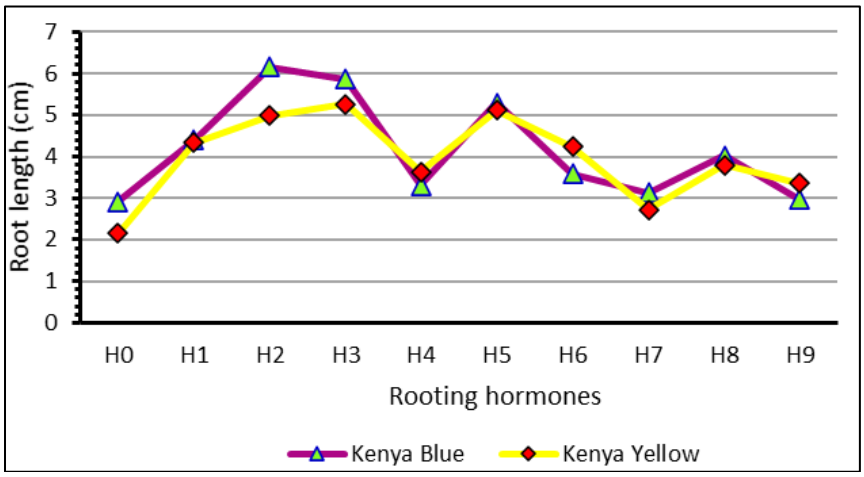

Fig 4: Effect of rooting hormones on root length in dahlia cultivars

Table 4: Effect of rooting hormones on root length in dahlia cultivars

Cultivar / Rooting Hormones	Root length (cm)		
	Kenya Blue	Kenya Yellow	Mean
Control	2.91	2.15	2.53
IBA @ 250 ppm	4.40	4.34	4.37
IBA @ 500 ppm	6.16	4.98	5.57
IBA @ 1000 ppm	5.86	5.26	5.56
NAA @ 250 ppm	3.31	3.64	3.47
NAA @ 500 ppm	5.29	5.11	5.20
NAA @ 1000 ppm	3.58	4.24	3.91
IBA @ 125 ppm + NAA @ 125 ppm	3.13	2.73	2.93
IBA @ 250 ppm + NAA @ 250 ppm	4.02	3.79	3.90
IBA @ 500 ppm + NAA @ 500 ppm	2.96	3.35	3.15
Mean	4.16	3.96	
	CD at 5%	S.Em±	
Rooting hormone	0.236	0.083	
Cultivar	0.106	0.037	
Rooting hormone × Cultivar	0.334	0.117	

Conclusion

From the above, it can be concluded that auxin and cultivars significantly affected rooting parameters in dahlia cuttings. Kenya Blue is better than Kenya Yellow in all studied parameters. IBA was found more efficient in rooting percentage, number of roots per cutting and root length whereas earliest rooting recorded in combination of both IBA and NAA.

References

1. Bharathy PV, Sonawane PC, Sasnu PV. Effect of plant growth regulators, type of cutting and season on rooting of carnation (*Dianthus caryophyllus* L.) cuttings. Indian Journal of Horticulture 2004;(61):338-341.
2. Dirr M, Heuser C. The reference manual of woody plant propagation. Portland, USA: Timber Press 2006, 410. ISBN – 13: 978-1-60469-004-0.
3. Epstein E, Lavee S. Conversion of indole-3- butyric acid to indole-3-acetic acid by cuttings of grapevine (*Vitis vinifera*) and olive (*Olea europea*). Pl. Cell Physiol 1984;25:697-703.
4. Hartmann HT, Kester DE, Davies FT, Geneve RL. Plant Propagation: Principles and Practices, Prentice Hall, New Delhi, India 2002.
5. Kumar R, Ahmed N, Sharma OC, Lal S. Influence of auxins on rooting efficacy in carnation (*Dianthus caryophyllus* L.) cuttings. J. Hortl. Sci 2014;9(2):157-160.
6. Middleton W, Jarvis BC, Booth A. The role of leaves in auxin and boron depending rooting of stem cuttings of *Phaseolus aureus* Roxb. New Phytologist 1980;84(2):251-259.
7. Prince Mailk A, Beniwal V. Influence of indole-3-butyric acid on rooting efficacy in different carnation (*Dianthus caryophyllus* L.) genotypes under protected condition. Chem Sci Rev Lett 2017;6(23):1858-1862.
8. Ranpise SA, Bharmal VS, Darwade RT. Effect of different levels of indole butyric acid (IBA) on rooting, growth and flower yield of chrysanthemum cv. Sonali Tara. J. Orn. Hort 2004;7(3-4):331-337.
9. Taleb RA, Hasan MK, Hasan HS. Effect of different auxins concentrations on Virginia creeper (*Parthenocissus quinquefolia*) rooting. World Applied Sci. J 2012;16:7-10.
10. Wei JL. The effect of plant hormones, rooting media and intermitted mist on the rooting and transplanting of herbaceous, evergreen and hardwood cuttings. Thesis, M.Sc., Montana State University 1958.

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Effect of different doses of gamma rays on mutational characters in dahlia (*Dahlia variabilis* L.)

Bharti Sao, LS Verma and GL Sharma

Abstract
Rooted cuttings of dahlia cultivars Kenya Blue, Kenya Yellow and Kenya Original were exposed to 0, 10, 15 and 20 Gy gamma rays and planted in earthen pots (8"). Each treatment consists of four replications with 12 treated rooted cuttings each. Among the irradiated population, the highest mortality percentage (38.81%) and abnormal plants percentage (15.88%) was recorded at 20 Gy dose. However, highest survival percentage (100%) observed at untreated plants. As regards to the cultivars, Kenya Yellow had maximum mortality percentage (30.80%) as well as abnormal plant percentage (10.06%). Meanwhile, significantly higher survival percentage was noted in Kenya Original (83.30%). The probit analysis indicated the extrapolated LD_{50} dose was found beyond 20 Gy for survival of cultivars, Kenya yellow had low LD_{50}.

Keywords: Dahlia, gamma irradiation, survival, mortality, abnormal, LD_{50}

Introduction
Dahlia (*Dahlia variabilis* L.) is an herbaceous perennial flowering plant belongs to the family Asteraceae and has originated in mountainous areas of Mexico and Central America. They are extensively grown all over the world for its beautiful charming flowers, but in India, commercial cultivation of dahlia is limited to the hills and plains of eastern India including Jammu and Kashmir. Dahlias are highly attractive facultative short day plant with great variations in shape, size, colour, prolific growing habit and easy to cultivate. It is used for garden display, exhibition, cut flower production, flower arrangement for borders, beds or mixed borders, growing in containers and making garlands. (Giannasi, 1998) [5].
Dahlia spp. has a high occurrence of polyploidy and thus, exhibits various colours, sizes and flower shapes. By using hybridization many new cultivars have been developed already. In general, crosses may be restricted by incompatibility or variations in ploid level and a high degree of heterozygosity, resulting in a complex genetic factor inheritance. In conventional breeding, this causes some significant problems. Here, mutation breeding gives an advantage as a large variation can be realized for the improvement of one or few characters of outstanding cultivar, without altering the remaining genotype within a short span of time. The present study aimed to study the different mutational characters such as mortality percentage, survival percentage, abnormal plant percentage associated with gamma ray irradiation.

Material and Methods
The present experiment was conducted at the Horticultural Research cum Instructional Farm, Department of Floriculture and Landscape Architecture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during the winter season of 2018-19 and 2019-20. Rooted cuttings of three dahlia cultivars *viz.* Kenya Blue, Kenya Yellow and Kenya Original were irradiated with 0, 10, 15 and 0 Gy of gamma rays and immediately planted in the pots under open field condition. The experiment was laid out in FCRD (Factorial Completely Randomized Design) with four replications for each treatment. Data were recorded on different mutational characters in the field.
To determine the mortality percentage (%), the number of rooted cuttings in each treatment in vM_1 was counted after 15 days of planting in open field condition and expressed in percentage but for survival percentage (%), the number of plants that survived out of the total number of rooted cuttings was counted after 30 days of planting and it was also expressed as a percentage. The abnormal plant percentage was recorded by counting the number of abnormal plants in each treatment at the flowering stage and it was expressed as a percentage of the total number of rooted cuttings planted.

The LD_{50} dose of irradiation was calculated by probit analysis method using observations on mortality percentage as described by Sharma (1998) [12]. The data was statistically analyzed by using the procedure of (Gomez and Gomez, 1984) [6] to evaluate the mutational potential of different cultivars with various doses of gamma rays.

Result and Discussion

Mortality percentage

There was a significant difference in the mortality percentage of plant in different cultivars as well as in different gamma radiation doses (Table 1 and Fig. 1). It is clear from the data that mortality percentage increased as the dose of gamma rays increased, as respect to different gamma radiation doses, significantly higher mortality percentage (38.81%) was recorded at 20 Gy as compared to rest of the treatments. Among the cultivars of dahlia, cultivar Kenya Yellow recorded significantly higher mortality percentage (30.80%), whereas, minimum mortality percentage (16.44%) was observed in cultivar Kenya Original. Interaction between cultivar Kenya Yellow and 20 Gy gamma radiation recorded significantly higher mortality percentage (47.82%) as compared to rest of the interactions. The results are in agreement with the work of Tiwari and Kumar (2011) [13], who recorded maximum mortality at higher gamma radiation doses. The death of plants is attributed to the interaction of molecules with other molecules in the cell which produce free radicals of H and OH. The free radicals could combine to form toxic substances such as hydrogen peroxide which contribute to destruction of cells. These results corroborate with the findings of Lamseejan *et al.* (2000) [9] in chrysanthemum and Devi *et al.* (2019) [3] in gladiolus.

Table 1: Effect of different doses of gamma radiation on mortality, survival and abnormal plant percentage

Treatment	Cultivars	Mortality percentage		Survival percentage		Abnormal plant percentage	
Control	Kenya Blue	0.00		100		0.00	
	Kenya Yellow	0.00		100		0.00	
	Kenya Original	0.00		100		0.00	
10 Gy	Kenya Blue	15.34		84.66		6.14	
	Kenya Yellow	31.62		68.20		7.92	
15 Gy	Kenya Original	11.70		88.30		4.88	
	Kenya Blue	22.28		77.48		12.15	
	Kenya Yellow	43.75		56.25		14.00	
20 Gy	Kenya Original	24.30		75.95		13.16	
	Kenya Blue	38.86		61.15		15.34	
	Kenya Yellow	47.82		52.18		18.32	
	Kenya Original	29.75		68.96		14.00	
		S.Em (±)	CD (0.05)	S.Em (±)	CD (0.05)	S.Em (±)	CD (0.05)
C		0.162	0.465	0.265	0.759	0.097	0.278
T		0.187	0.537	0.306	0.877	0.112	0.321
C x T		0.325	0.931	0.530	1.519	0.194	0.555

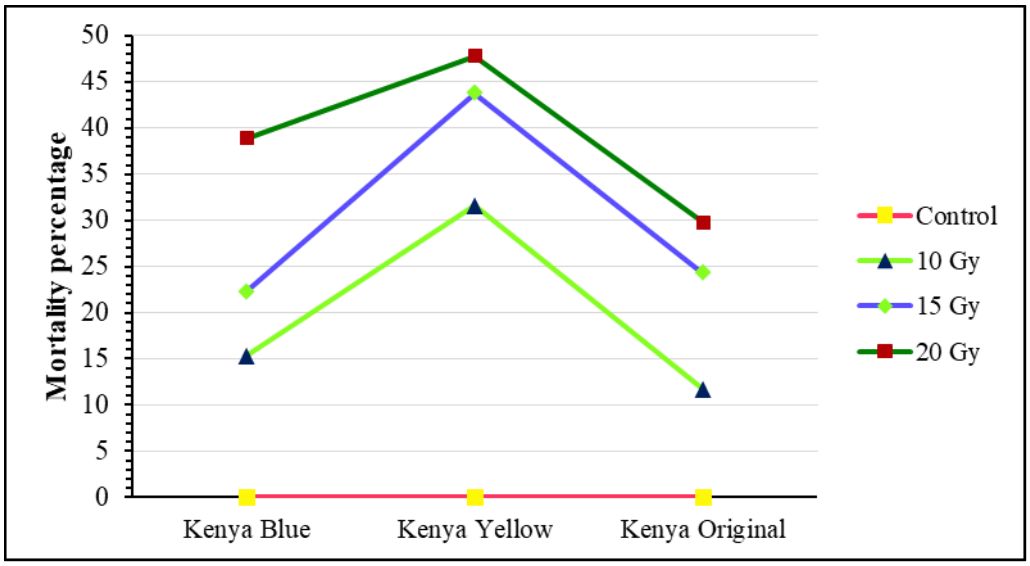

Fig 1: Effect of gamma radiations on mortality percentage in dahlia cultivars

Survival percentage

It is evident from the data (Table 1 and Fig. 2) that survival percentage decreased significantly at increased dose of gamma radiations and hundred percent survival was recorded in untreated plants. Among gamma radiation doses, control plants showed significantly maximum survival percentage (100%) followed by gamma radiation dose 10 Gy (80.39%). As respect to different cultivars, Kenya Yellow was significantly found to be more sensitive to higher exposure (69.16% survival), whereas, Kenya Original (83.30%) cultivars were significantly more tolerant to gamma radiations. The interaction of cultivar Kenya Yellow and 20 Gy gamma rays resulted significantly minimum survival (52.18%) followed by interaction of Kenya Yellow with 15 Gy gamma rays (56.25%). Kaicker (1992) [7] also stated the reduction in survival may be due to the toxic effect at higher

concentration of gamma rays. Differences for radiation sensitivity among cultivar were also reported by Broertjes and Harten (1988) [2]. Survival percent was found to be decreasing with the increasing dose of gamma radiations. Significant reduction in survival after exposure to gamma rays was also observed by Kumari *et al*. (2013) [8] and Banerji and Datta (2005) [1] in chrysanthemum.

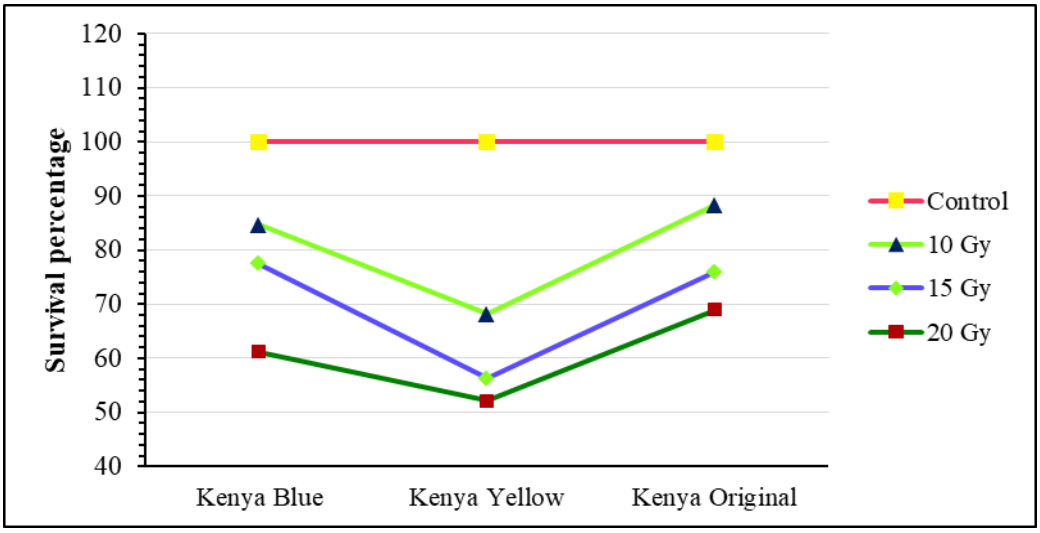

Fig 2: Effect of gamma radiations on survival percentage in dahlia cultivars

Abnormal plant percentage

It is clear from the data (Table 1 and Fig. 3) that percent abnormal plants increased with the increase in dose of gamma radiations. Among the gamma radiation doses, treatment of 20 Gy recorded significantly higher percentage of abnormal plants (15.88%) as compared to the rest of the treatments. Cultivar Kenya Yellow exhibited significantly maximum percentage of abnormal plants (10.06%), whereas, minimum abnormal plants percentage (8.01%) was recorded in cultivar Kenya Original. The interaction between cultivar Kenya Yellow and 20 Gy gamma rays treatment recorded significantly higher abnormal plants percentage (18.32%) as compared to rest of the interactions. However, minimum abnormal plant percentage (0%) was noted in untreated plants. These results are in accordance with earlier findings of Misra (1990) [10] and Dwivedi and Banerji (2008) [4], who recorded morphological abnormalities elevated with increased exposure to gamma rays.

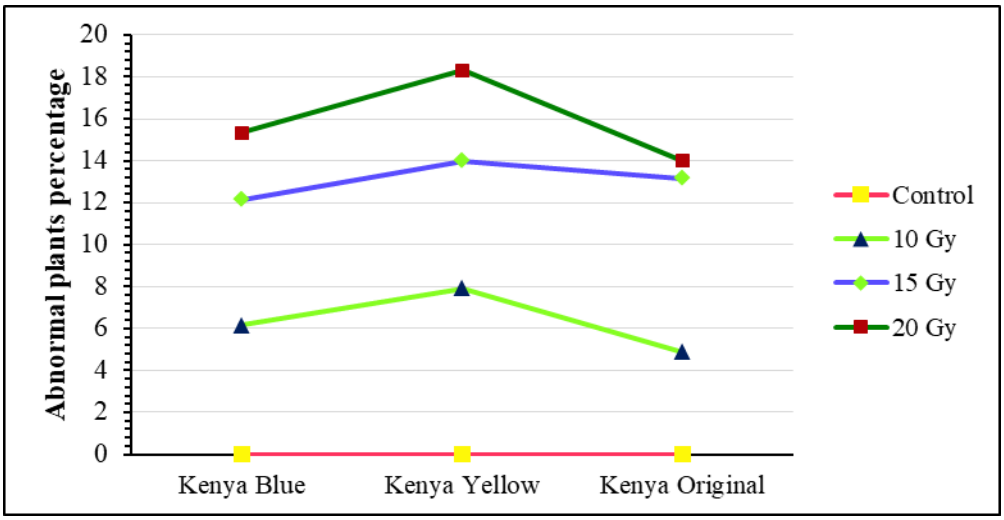

Fig 3: Effect of gamma radiations on abnormal plants percentage (%) in dahlia cultivar

The probit analysis of LD_{50} dose for individual cultivars was carried out separately and presented in Table 2 and illustrated through Fig. 4, 5 and 6. The probit analysis indicated the extrapolated LD_{50} value based on mortality percent for dahlia cultivar of Kenya Blue (27.54 Gy), Kenya Yellow (20.89 Gy) and for Kenya Original (33.11 Gy). This indicated the significantly higher sensitivity of cultivar Kenya Yellow thus LD_{50} could be beyond this dose. Determination of radio sensitivity and LD_{50} dose of gamma rays are prerequisites for a mutation breeding programme (Sadhukhan *et al.*, 2015) [11]. The LD_{50} value was estimated on the basis of percent plant survival. Broertjes and Harten (1988) [2] reported varietal differences for radiation sensitivity LD_{50} for different vegetatively propagated crops such as gladiolus, chrysanthemum and others varied from 0.5-15 kR.

The effect of gamma radiation on mutational characters of different cultivars revealed that increase in radiation dose increased the mortality and abnormal plant percentage. Enhanced survival percentage and higher LD value 50 was found with unrooted cuttings. This study indicated that cultivar Kenya Original exhibited low mortality and abnormal plant percentage but high survival and LD_{50} value.

Table 2: Probit analysis for extrapolated LD_{50} of gamma radiations in different cultivar for mortality percentage

Cultivars	LD_{50} (Gy)	Regression equation	R_2
Kenya Blue	27.54	Y= 2.46X + 1.45	0.932
Kenya Yellow	20.89	Y= 1.42X + 3.13	0.962
Kenya Original	33.11	Y= 2.21X + 1.62	0.994

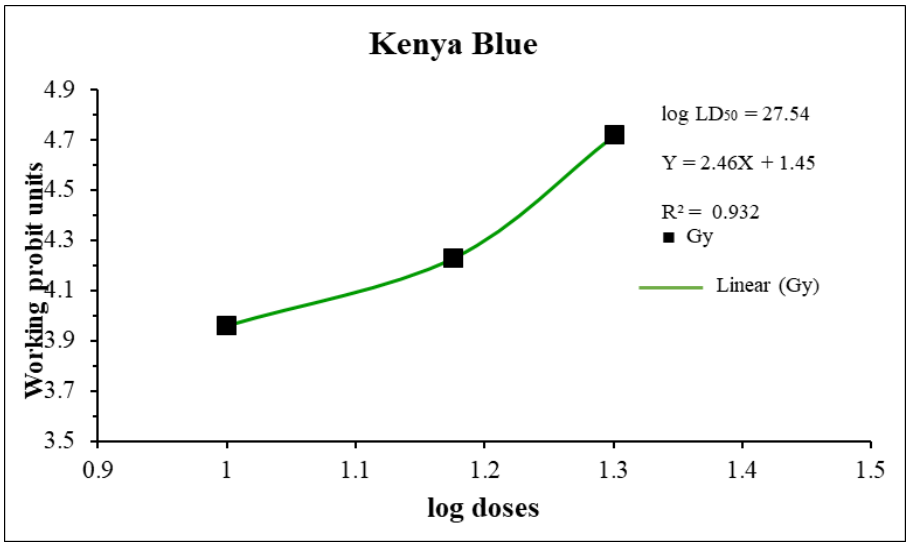

Fig 4: Probit analysis for extrapolated LD_{50} of gamma radiations in cultivar Kenya Blue for mortality percentage

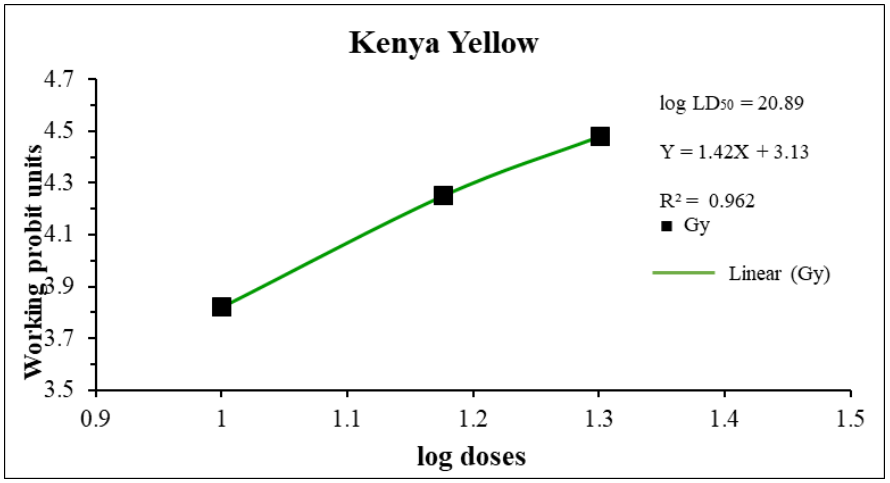

Fig 5: Probit analysis for extrapolated LD_{50} of gamma radiations in cultivar Kenya Yellow for mortality percentage

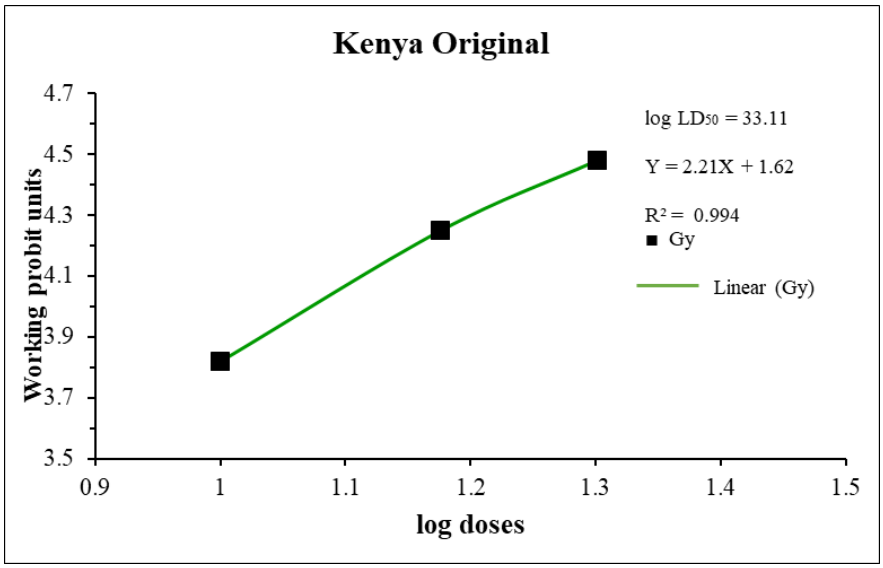

Fig 6: Probit analysis for extrapolated LD_{50} of gamma radiations in cultivar Kenya Original for mortality percentage

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References

1. Banerji BK, Datta SK. Induction and analysis of somatic mutation in chrysanthemum cultivar Khumaini. Journal of Nuclear Agriculture and Biology 2005;34(3-4):196-201.
2. Broertjes C, Harten HAM. Applied Mutation Breeding for Vegetatively Propagated Crops. Amsterdam, Elsevier 1988,343p.
3. Devi NS, Fatmi U. Effect of gamma radiation on vegetative and floral characters of Gladiolus cultivars (Praha, Tiger flame and Snow princess). Journal of Pharmacognosy and Phytochmistry 2019;8(3):4309-4312.
4. Dwivedi AK, Banerji BK. Effect of gamma irradiation on dahlia cv. Pink with particular reference to induction of somatic mutation. Journal of Ornamental Horticulture 2008;11(2):148-151.
5. Giannasi DE. Flavonoid chemistry and evolution in Dahlia (compositae). Bulletin of the Torry Botanical Club 1998;102:404-412.
6. Gomez KA, Gomez AA. Statistical Procedure for Agricultural Research. (2nd ed.), New York, John Wiley and Sons 1984,680p.
7. Kaicker US. Rose breeding in India and cytology of induced mutation of H.T. cv. 'Folkfore'. Acta Hortic 1992;320:105-112.
8. Kumari K, Dhatt KK, Kapoor M. Induced mutagenesis in *Chrysanthemum morifolium* variety 'otome pink' through gamma irradiation. The Bioscan 2013;8(4):1489-1492.
9. Lamseejan S, Jompuk P, Wongpiyasatid A, Deeseepan S, Kwanthammchart P. Gamma- rays induced morphological changes in chrysanthemum. (*Chrysanthemum morifolium*). Journal of Natural Sciences 2000;34(3):417-422.
10. Misra RL. Mutational studies in bulbous ornamentals. Progressive Horticulture 1990;22(1-4):36-39.
11. Sadhukhan R, Swathi K, Sarmah D, Mandal T. Effect of different doses of gamma rays on survivability and rooting ability in chrysanthemum (*Chrysanthemum morifolium* Ramat.) Journal Crop and Weed 2015;11(1):62-65.
12. Sharma JR. Statistical and Biometrical Techniques in Plant Breeding. New Delhi, New Age International 1998,429p.
13. Tiwari AK, Kumar V. Gamma rays induced morphological changes in pot marigold (*Calendula officinalis*). Prog. Agric 2011;1:99-102.

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