DISCUSSION
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The literature is full of instances to indicate the effect of ionizing radiations on seed germination of higher vascular plants. To mention a few important works in this regard are of Johnson (1928), Gustafsson and Simak (1958), May and Posey (1958), Heaslip (1959), Bowen and Thick (1961), Saric et al. (1961), Harring et al. (1964), Mergen and Johnsen (1964), Sen and Ghosh (1968), Chauhan (1969), Ahstrom and Natarajan (1971), Rai (1971), Chopra (1972), Nath (1974), Machaiah et al. (1976), Raghuvanshi and Singh (1977), Shamsi et al. (1978), Chaghtai and Siva Prasad (1979) and Machaiah and Vakil (1982). The reports so far published do not agree with one another. A few are of the opinion that the irradiation treatment with lower doses prove to be beneficial to the process of seed germination (Bowen and thick, 1961; Saric et al., 1961; Preobrazhenskaya and Timofeev-Resouskii, 1962; Amer and Hakeem, 1964; Rajan, 1969), while a few others like Sen (1964), Patel and Shah (1974), have, however, found that the heavy doses of gamma-rays destroy the viability of seeds to impair the process. In the present study, it has been found that the gamma ray treatments in the form of light doses do not materially affect the germination percentage of linseed variety investigated. However heavy doses of gamma-ray do influence seed germination to some extent by delaying the
process. Chopra and Singh (1978), Grover and Dhanju (1979),
Ghouse et al. (1979) and Abidi (1981) have reported a loss in
percentage of seed germination, as a result of irradiation treat­
ment with gamma rays. However, Brock and Andrew (1965) and Kumar
and Das (1978) in their studies on Medicago polymorpha and
Brassica campestris respectively, have noted no significant effect
of gamma ray irradiation on seed germination.

In the present study no stimulating effect of gamma-ray
treatment has been observed at any level of gamma ray doses employed.
In this respect, the investigated variety Mukta of Linum
usitatissimum resembles Lupinus termis (Amer and Hakeem, 1964),
Sesamum indicum (Rajan, 1969), Citrus sinensis (Spiegel Roy and
Padova 1973), Soybean (Srivastava et al., 1976), tomato (Maltseva,
1977) and Sorghum vulgare (Sharon and Muralidharan 1978). Sax
(1963) has, however, reported stimulatory effect of low intensity
gamma ray doses of minor magnitude of some significance.

The slow rate of germination and the delay caused by gamma-
ray treatments observed in the present study indicate the adverse
role of gamma-rays on germination of linseed. A similar effect
by heavy doses of gamma-rays has also been reported recently by
Abidi (1981) in another variety of linseed crop namely Neelum.
Sen and Ghosh (1968), Bajaj et al. (1970) and Patel and Shah (1974)
have also recorded a similar effect of gamma-rays resulting in
in delayed germination. The failure to get the same degree of inhibition and delay in seed germination in the subsequent generations of \( M_2 \) and \( M_3 \) in the present study indicate that the bad effects of gamma rays observed in the 1st generation happens to be a mere physiological disturbance rather than a genetic change that has been induced by irradiation treatment.

Ananthaswamy et al. (1971) are also of opinion that the metabolic disturbances occurring during germination due to gamma irradiation are responsible for the inhibitory effect of germination in wheat.

In the present study it has been found that the survival percentage of the irradiated progenies decreases with increasing intensity of gamma rays in \( M_1 \) generation. A similar situation of seedling survival has been observed by Caldecott (1955), Rai (1971), Bari (1971), Bottino and Sparrow (1971), Chopra (1972), Iqbal (1972), Killion and Constantin (1972), Raghuvanshi and Singh (1977) and Shamsi et al. (1978). No decrease in survival percentage has been observed in the present study in the subsequent generations, as has been noted by Abidi (1981) and, therefore, the after effects of irradiation treatment are not carried over to the 2nd and 3rd generations in the present case. More or less, the same conclusion has been made by an earlier worker who investigated the effects of irradiation on another variety of linseed crop (Abidi, 1981).

Growth retardation by ionizing radiations has been reported by number of workers (Gunckel and Sparrow 1961; Dumanovic and Ehrenberg 1965; Devies 1968; Taylor 1968; Chauhan 1969; Rai 1971; Chopra 1972; Nath 1974; Sharon and Muralidharan 1978; Nath 1981). Johnson (1936c) is of the opinion that the injury on growth is the most common effect which follows X-ray treatments. According to her, the light doses do not stimulate growth but heavy doses prove to be injurious. On the other hand, Timofeev-Resovsky and Poryadkova (1956) reported increased growth of many crop plants following irradiation of dry or soaked seeds with low doses of X-ray or by soaking the seeds in radioactive solution. Sparrow and Christensen (1953), Ehrenberg et al. (1954), Gunckel and
Sparrow, (1954), Sax, (1955), Sparrow and Gunckel (1956), Mikaelsen and Aastveit (1957), Saric et al. (1961), Sparrow et al. (1961), Sax (1963), Donini et al. (1964), DeNettancourt and Contant, (1966), Suess (1966), Davies (1968, 1970) and Bari (1971) have observed the occurrence of growth stimulation due to acute and chronic irradiation in some higher plants. For inhibitory effects of gamma rays, Sparrow (1955) and Sparrow and Gunckel (1956) have screened various species of seed plants numbering over 110 and found a general decrease in plant height with an increase of dose level. In the present study also the same condition has been observed. This is in close conformity with the findings of Abidi (1981) on another variety of linseed crop. High doses like 100 krad and above, adversely affect the height of the plant or root length, number of branches and leaves, at all stages of growth, the decrease being directly proportional to the exposure dose. It has also been found that the growth retardation is more pronounced in $M_1$ generation than in the subsequent ones. In the present study, growth of treated progenies has been observed to be suppressed under all doses rangings from 25 to 150 krad level at all stages of growth.

are of the opinion that the radiation treatment leads to damage of the meristematic cells. Thoday (1951), Sparrow et al. (1961), Conger and Stevenson (1969) believe that the chromosomal damage, caused by irradiation, inhibits the cell division. Schoog (1953), Smith and Kersten (1942) and Gordon (1954) have found marked decrease in the auxin level following irradiation while Gunckel and Sparrow (1961) observed disturbance in auxin synthesis. Bjornseth et al. (1957) came across the damage to respiratory enzymes due to irradiation. Quastler et al. (1952) are of the opinion that irradiation effect on mitosis and physiological disorders are responsible for stunted growth of plants after irradiation treatment.

Growth stimulation due to irradiation has also been recorded in number of cases (Johnson, 1948; Sparrow and Christensen, 1953; Sax, 1955, 1963; Gunckel, 1965; Devies, 1968, 1970; Menyhart, 1970; Saric, 1971; Sidark and Suess, 1973; Maltseva, 1978). Sparrow and Christensen (1953) and Gunckel and Sparrow (1954) have also come across stimulation of plant growth in Antirrhinum, when it is subjected to moderate exposure of chronic gamma irradiation. Sparrow and Gunckel (1956) have noticed an increase in plant height in Antirrhinum majus at exposure rates above 125 R per day. Ehrenberg et al. (1954) have observed growth stimulation in Visia feba at daily exposure rate at 16 to 28 R of gamma radiation.
Donini et al. (1964) have found increased vegetative growth in Durum and bread wheat at the daily exposure rate of 72 and 148 R of gamma irradiation. De, Nettancourt and Contant (1966) have seen a marked growth in plant height of Lycopersicum species under certain radiation exposure. Bostrack and Sparrow (1970) have also observed a significant increase in tree height at exposure rate of 1 to 2 R per day in Pinus strobus. While studying the effect of chronic gamma irradiation Mikaelsen and Aastveit (1957), have observed considerable increase in plant height at exposures ranging from 25 to 34 R per day in Oats and from 36 to 45 R per day in barley. The lower doses up to the extent of 75 krad have been found to stimulate the height of the plant in M₁ and M₂ generations of gamma-ray treated progenies of linseed crop by Abidi (1981). But in the present study no stimulatory effect of gamma irradiation has been found in the oil-rich Indian variety Mukta of Linum usitatissimum except in the third week growth stage under 25 krad treatment. D'Amato (1957) in his studies on the effect of chronic gamma irradiation in flax has also could not find any growth stimulation. Bari (1971) found in acute irradiation studies on flax that the plant height at maturity decreases with the increasing intensity of doses. In the present study also the variety Mukta has been found to undergo reduction in height growth with the increasing level of gamma-ray treatments.
The information on the effect of ionizing radiation on cotyledonary leaf expansion is very meagre in literature. Rudolph and Miksche (1970) have reported various degrees of radiosensitivity in cotyledonary expansion for nine species of Pinus. During a recent investigation, it has been found that the cotyledonary leaf expansion does not get materially affected by gamma-ray treatment in linum (Abidi, 1981). Chauhan (1969 & 1976) and Chopra (1972) have, however, reported an adverse effect of gamma radiation on cotyledons of Carthamus tinctorius and Guizotia abyssinica respectively. In the present study it has been found that the size of cotyledon in the gamma-ray treated plants is significantly greater under 50, 75 and 100 krad level of doses, while under 125 and 150 krad level, it is reduced to a significant level compared to control.

It has further been found during the present investigation that the fresh weight of cotyledons is significantly higher than in control plants which were treated with gamma ray doses having 75 krad and above. Similarly, the dry weight of cotyledons also recorded high in higher level doses than the control, while the lower doses yield lower values both in terms of fresh as well as dry weight per cotyledon. In the recent studies on flax, Abidi (1981) has found that the ratio of fresh and dry weight of cotyledons to be higher in gamma ray treated plants compared to the
untreated ones. Abidi (1981) attributed this high ratio to a temporary change induced by gamma ray treatment leading to water holding quality of the treated plants. In the present investigation, it has been found that the water content of cotyledons in the treated plants to be considerably higher than the control.

In the present investigation, the shoot and root biomass has been found significantly lower in the treated progenies at all levels of growth indicating the adverse effect of radiation on biomass production. These findings go in accordance with those of Abidi (1981) on another variety of linseed crop. Nath (1974) has also observed a significant decrease in the dry weight of seedlings of *Sesamum indicum* due to gamma ray treatment. The work of Uzorin and Demina (1965) also shows that the dry matter accumulation to be affected in tomato under the influence of gamma-ray doses including the low level doses as has been found in the present investigation. Saric et al. (1961) however found that in the growing seedlings of wheat, the dry matter content increases in doses above 10,000 R due to decrease rate of respiration. Hell and Silveira (1976) observed the loss in fresh weight of *Phaseolus vulgaris* to be more than the dry weight. In the present study also the fresh weight has been noted to be more radiosensitive than the dry mass. Further the water holding capacity of plants of *M₄* generation increases under the influence of higher
gamma-ray doses than the control. However this water holding capacity comes down below the normal under low level doses of gamma rays.

Flowering: The initiation of flowering has been found delayed in the treated progenies of $M_1$ generation especially under high doses. In normal cases, the flowering initiates after 60 days of sowing seeds, as well as in lower doses like 25 and 50 krad treatments, while with high doses, it is delayed by a month. Further, there is a considerable reduction in the number of flowers in the treated progenies compared to control. Delayed and reduced flowering has often been found as an effect of ionizing radiation by Johnson (1936b). Negative effects of gamma radiation on flowering has also been reported in potato tubers by Fischnic et al. (1961) in *Crocos* by Mitsukuri and Shinohara (1961) and in *Linum usitatissimum* L. var. *K2* by Nath (1981). Gunckel (1965) has also observed retarding effect of gamma rays on flowering. Bari (1971) has observed delayed flowering in *Linum* with increased rate of gamma ray exposure by a month. In his recent studies on *Linum usitatissimum* L. var. Neelum, Abidi (1981) has observed that both flowering and number of flowers per plant to be affected adversely by high intensity doses of gamma rays. Chauhan (1978) has however, noted that the irradiated plants of *Solanum khasianum* to flower simultaneously with the control. Contrary to the above, there are
also few reports expressing stimulatory effect of gamma irradiation on flowering. Stimulated flowering has been noted in case of *Nicotiana rustica* by Sparrow and Singleton (1953) and Gunckel and Sparrow (1954), *Impatiens sultanii* by Gunckel (1957) and *Tradescantia paludosa* by Gunckel et al. (1953 a), inter-specific hybrid of *Nicotiana glauca* × *N. longsdorfii* (Sparrow and Gunckel, 1956) and on flax (Bari, 1971). Johnson (1948) has also reported early flowering in a group of irradiated *Kalanchoe* plants while Haskins and Moore (1935) reported premature flowering in *Citrus* grown from X-rayed seeds.

In the present study reduced flowering has been observed in all the three generations to a significant level in the majority of doses and, therefore, it is believed that irradiation treatment has brought about on the flowering trait of the variety studied, a permanent change in its genetic constitution.

In the present study, it is further noticed that the number of capsules per plant, number of seeds per capsule, number of seeds per plant and the yield per plot to show decreasing trend with increasing gamma ray doses to the extent of significance at five per cent level. The significant reduction in yield in the M₁ generation has been brought about both by reduced number of capsules per plant and number of seeds per capsule. Nath (1981) has also observed a significant loss in the yield of linseed crop variety.
studied by him. The loss in yield in the present study has found to persist in the subsequent generations of $M_2$ and $M_3$. However Abidi (1981) in another oil rich Indian variety of flax, Neelum, failed to find continued loss in flowering and yield in the $M_2$ generation of gamma-ray irradiated progenies, while the 3rd generation was not studied by him. Abidi (1981) has rather noted a slight increase in yield under 25 krad treatment over that of control. In the present study also a slight improvement in yield has been noted in the $M_2$ and $M_3$ progenies, although the overall loss in yield persisted to a significant level even in the $M_3$ generation compared to control. A similar improvement in yield and in the yield-contributing characters have been reported by a number of earlier workers (Breslavets et al., 1960; Borojevic, 1965 & 1966; De, Nettancourt and Contant, 1966; De, Nettancourt and Ecochard, 1968; Bari, 1971; Sparrow et al. 1971; Flowler and Macqueen, 1972; Shamsi and Sofajy, 1980; Nayar, 1982). Chauhan (1978), on the other hand, has noted reduced yield in case of gamma irradiation Solanum khasianum. Seetharam (1976) found the yield to decline in linseed as a result of gamma irradiation. Subhash et al. (1977) have observed 25% decrease in yield due to X-radiation in Capsicum annum. Nath (1981) has found gamma irradiation to affect adversely the seed setting and yield in Linum usitatissimum L. var. K$_2$. Labana et al. (1976) and Nath and Singh (1981) have also reported loss in yield in the form of oil content in Brassica and Sesamum.
respectively. However Culbertson and Kommedahl (1956), Barnes et al. (1960), Bari (1971), Nath (1981) and Abidi (1981) have found the possibility of improving the yield of Linum through gamma irradiation both by improving the quality as well as the quantity of oil content.

In the present study the reproductive capacity of the variety Mukta has been found affected adversely by gamma-ray irradiation under all doses in all the three generations studied, although a slight improvement in the reproductive capacity has been noticed in subsequent generations ($M_2$ and $M_3$). It is worth noting here that in $M_1$ generation, reproductive capacity of the plants has been reduced to a mere 18.0 under 100 krad treatment and even lesser under higher doses like 125 and 150 krad, against an index of 578.98 of the control.

**Variation**

A number of morphological variations have been met within $M_1$ generation. Induction of dichotomy, development of adventitious branches all over the plant axis, fasciation, conversion of shoot apices into leaf like or needle like structures, curving and twisting of shoot axis, condensation of apex and fusion of two or three leaves into one compound structure are some of the many abnormalities noted in the present study in the irradiated progenies have also been recorded by a number of earlier workers.
Flattening of the shoot axis as found in the present study has also been reported by Chauhan (1969) and Rai (1971). Johnson (1926, 1931) has described the reduction in leaf blade size, twisting of leaflets and fusion of leaf parts as common in irradiated tomato seedlings as well as in Helianthus.

Fasciation and condensation of floral axis have been frequently met within M₁ generation of the irradiated plants in the present case. Similar reports are made in case of sunflower by Johnson (1926), flax by D'Amato (1957) and Abidi (1981) and in Snapdragon (Gunckel and Sparrow 1954). Gunckel et al. (1953b) have noted in Tradescantia paludosa that those received 20-24 R per day for 8 weeks to proliferate into a globose head by the formation of leaf like structure and modified flowers. Reduction in the size of flowers and floral parts, variation in number and colour of petals have also been observed in the present study as reported by earlier workers in a number of species (Moore and Haskins, 1935; Sagawa and Mehlquist, 1957; Abidi, 1981).

**Pollen fertility:** The irradiation treatments undertaken in the present study has been found to affect the male fertility of linseed crop seriously and damage the viability of pollen grains to
a considerable extent. The fertility of pollen has fallen to 2 per cent under heavy doses of irradiation. Similar such heavy loss in pollen fertility has been noted in the past by a number of workers in linseed as well as in other crops, (Mikaelsen and Aastveit, 1957; Singh and Gunckel, 1965; Siddiqui et al., 1976; Abidi et al., 1978a; Ghouse and Kazmi, 1979 and Ghouse et al., (1981). In the present study it is further noted that the damage caused by irradiation treatments does not last long and recovery from the damage in pollen fertility is quick in the subsequent generations. A similar observation of quick recovery from the damage caused by irradiation treatments in male fertility has also been made by earlier workers (Bari, 1971; Chopra, 1972; Nath, 1974; Abidi et al., 1978; Gangwar, 1980; Ghouse et al., 1982). The quick recovery in M₂ and M₃ generations from the serious damage inflicted by irradiation may in all probability be due to the altered physiology of the pollen mother cells rather than the geneti­

atic change.

Anatomical variations: A number of anatomical variations have been noted in the present study in plants raised out of irradiated seeds with different doses of gamma rays. Some of the changes were quite apparent but qualitative, while others happen to be quanti­

tative. In general, the ground tissue has been found to prolife­
orate in the irradiated plants while the secondary xylem development
is hampered to a considerably extent. As a result of this unequal development of tissue system in the shoot axis the proportion of cortex and xylem cylinder and pith has been found to vary to different degrees under different doses, depending on the intensity of gamma rays. In general, the cortical area showed an increase when the xylem cylinder decreased in diameter. A similar situation in the shoot anatomy has been reported by D'Amato (1957). On one of the cultivars of the Linum, Abidi et al. (1978b) has also come across a similar situation in relation to gamma irradiation and reported proliferation of pith and cortical cells. In the other recent reports Ghouse et al. 1979, 1980 and 1981) have noted a number of anatomical aberrations caused by gamma irradiation in the shoot axis of Linum and hampering of cambial activity. In the present study it has been further recorded that the xylem rays undergo widening as well as multiplications due to gamma irradiation, as has been reported by Ghouse et al. (1980, 1981) in addition to thickening of cell walls.

The irradiated plants has been found to have developed a high water holding capacity by developing gelatinous wall in secondary xylem. This quality has given the plants to hold 85.67 per cent more water in the 125 krad treatment than the control. This indicates the probability of improving the stock of linseed crop, through radiation treatments against drought conditions. All the above aberrations noted in the M₁ generation have been found
to undergo modifications towards normalisation of the stem anatomy in the subsequent generations, but the ray structure as well as its system appeared to be disturbed both from that of normal as well as from the M₁ generation. In the M₂ and M₃ generations, the heterogenous ray of the normal and the M₁ generation change into a homogenous system in having either only procumbent cells or only upright cells. In most of the cases in M₂ and M₃ generations the ray cells undergo vertical elongation and probably develop vertical polarity too instead of lateral. This aspect needs further exploration to give any satisfactory explanation.

In the abnormal xylem developing in the 1st generation after irradiation number of wider pores become progressively narrow with the increasing dose level. In other words the vessel members grow slim and their density increases per unit area. The measurements made in the macerated mass of xylem it has been found that the tracheary elements (vessels and fibres) undergo considerable reduction in dimension. Such damaging effect of irradiation treatment has also been noted in the anatomical studies carried out by earlier workers like Foard and Haber (1961), Ghous et al. (1978); Abidi et al. (1979) and Abidi (1981).