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RESEARCH ARTICLE

Gamma rays induced variations in some cotton (*Gossypium hirsutum* L.) genotypes and their evaluation in the environment of Bannu.

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Abstract

Pure dry seeds of four cotton genotypes i.e. Gomal-93, Bt-131, Bt-121 and Bt-CIM-602 were irradiated with 10, 15, 20 and 25 kR doses of gamma irradiation from ^{60}Co source of gamma irradiation at Nuclear Institute for Food and Agriculture (NIFA), Tarnab, Peshawar, Pakistan. The treated seed samples along with non-radiated seeds of each genotype were used as control. Field experiment was conducted in randomized complete block design (RCBD) in tri replicates in the green house of the Department of Botany, University of Science and Technology Bannu by planting the seeds during first week of June, 2012. Radiation effects on some agronomic characters like Plant height, Number of branches plant^{-1}, number of bolls plant^{-1}, Fibre Fineness and yield of seed cotton. The analysis of variance (ANOVA) revealed significant differences for radiation treatments, genotypes and interaction for treatments × genotypes regarding plant height, number of branches plant^{-1}, number of bolls plant^{-1} and yield of seed cotton plant^{-1}. Higher gamma rays doses adversely affected most of the parameters. Significant reduction in plant height was observed for all the genotypes under the influence of the gamma rays treatments. Increased radiation doses especially, 20, 25 kR produced adverse effect on number of branches plant^{-1}. However in case of Bt -121, number of branches plant^{-1} was enhanced over the control under certain gamma rays treatments. Some of the radiation doses also produced favourable effect on the number of bolls plant^{-1} in varieties Gomal-93, Bt-131 and Bt -121 under 20 kR dose of radiation. The findings of the present investigations revealed that upland cotton can be successfully grown for commercial purposes in the agro environment of Bannu.

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Introduction

Cotton (*Gossypium hirsutum* L) is allotetraploid with AD genomic group of order Malvales, family Malvaceae and genus Gossypium is naturally a perennial shrub and cultivated as annual crop in agricultural system (Smith, 1995). It is an important source of natural fibre for textile industry and edible oil in tropical and subtropical regions of the world (Smith, 1999). It is a summer crop in Pakistan and India with optimum cultivation time from last May to mid Jun.

Plain areas of Punjab and Sindh provinces are considered as Pakistan cotton belt where the crop is commercially grown for production of best quality fibre which can meet the requirements of existing textile industry. Hence Pakistan ranks 5th in respect of cotton production in the world (Cott. Gr. Rev., ICAC, 2010). Upland cotton as a cash crop plays a vital role in the economy of the country to earn foreign exchange by providing raw materials to the textile industry as fibre and to the oil industry as seed. The agro climate of District Bannu and adjacent areas where the present experiment was conducted is considered out of the range recommended for commercial cultivation of cotton. However, desi cotton (*Gossypium harbacium*) is well adapted to the locality and is grown from the past for fulfilling domestic needs rather than to be utilized as raw material for textile purpose. Until the present research, proper attempts have not been made in order to test the adaptability of upland cotton in the area inorder to introduce the crop to be grown on commercial level.

Though several factors affect the ultimate value of the cotton, yield remains the primary focus in farmer's choice of varieties and in determining the profitability of cotton production (Bridge *et al.*, 2001). Therefore, taking the advantage of the early work of Muller (1927) and Stadler (1929) on mutation induction in crop plants which have now become a well established tool with encouraging results (Irfaq and Nawab, 2003) the present research work was undertaken for creation of artificial genetic variability among the existing cotton genotypes. . The objectives of the present research are to create genetic variability in some cotton genotypes in order to study the adaptability of these mutants in the agro-climatic conditions of District Bannu and compare the performance of newly generated mutants with that of the commercially cultivated cotton varieties. As future strategies for cotton production, the best adaptable cotton mutants may be successfully grown in this new locality thereby by providing a new source of income to the residents of this area in order to uplift the social and economic standard of the people through agro based industries at small scale.

MATERIALS AND METHODS

Seed of four commercial cotton varieties of *Gossypium hirsutum* L. differing in their genetic makeup viz. Gomal-93 (V1), Bt-131(V2), Bt-121(V3) and Bt-CIM-602 (V4) were obtained from Agricultural Research Station Ratha Kulachi, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan. The dry seeds of the genotypes were irradiated with 10, 15, 20 and 25 kR doses of gamma radiation from ^{60}Co source at Nuclear Institute for Food and Agriculture (NIFA), Tarnab, Peshawar, Pakistan. The field experiment was conducted in the green house of the Department of Botany, Faculty of Biological Sciences, University of Science and Technology Bannu (USTB), Khyber Pakhtunkhwa, Pakistan during summer season 2012. The experimental site is situated at latitude 32^{o} 59' N, longitude 71^{o} 36' E and altitude of 371 m AMSL with soil texture of clay to sandy loam. The site is situated at latitude 32^{o} 59' N, longitude 71^{o} 36' E and altitude of 371 m AMSL with soil texture of clay to sandy loam.

The seeds were sown through dibbler in the field on 17th of May, keeping row to row and plant to plant spacing of 75 cm and 30 cm, respectively in a triplicate randomized complete block design (RCBD). Non-radiated seeds of each variety were used as control. Each entry of treatment were planted in a single row (3.3 m long) with 12 plants per row keeping ten plants experimental while two plants, one at each end of the row were left as non experimental. All recommended cultural practices including hoeing, manual weeding, irrigation, fertilizers, etc. and crop protection measures were carried out as usual. The data regarding **Plant height, Number of branches plant^{-1}, number of bolls plant^{-1}, Fibre Fineness and yield of seed cotton** were recorded on 10 randomly selected plants from each plot. The parameters and the detail of the procedure used for data recording and analysis are as follows. The parameters and the detail of the procedure used for data recording and analysis are as follows:

Plant height

On attaining maximum height, lengths of the main stem of the individual plants were measured in centimeters with measuring rod from the base of the plant up to the apex.

Number of Branches plants^{-1}

The total number of branches both of cymose and racemose kinds from the randomly selected plants were counted and recorded to note the correlation with yield components.

Number of bolls plant^{-1}

The total number of bolls from each individual plant was picked at each picking and was recorded correctly. At the end of cropping season when final picking was completed, the pick-wise record was averaged to calculate the total number of bolls per plant for all the plants of individual gamma rays treatments.

Staple Length Plant^{-1} (mm)

Staple length was measured from the representative sample of each plant using tuft method. The lint sample was turned into sliver and passed it through a draw box for several times till it was drafted into a uniform band of parallel fibres. The fibres were then mounted on a set of metallic comb, fixed parallel to each other on a stand. One of the processed samples was aligned with the help of a pair of tweezers and the two tufts were carefully drawn from each sample on a velvet cover tuft board. Two lines were drawn, one on the even end of the tuft just beneath grip mark of the tweezers and second on the opposite of the tuft, where the rate of change of visual density of the fibre was maximum. The distance between the two lines was measured with a scale in millimetres. The average staple length was calculated by taking mean of two readings for the individual plants.

Yield of seed Cotton (g)

A total of three picks of mature bolls at regular interval were taken and weighed on digital balance in grams (g) as yield of seed cotton and calculated the mean of each treatment.

Statistical procedures

The data were statistically analysed (Steel and torrie, 1980) for all the levels of significance. For significant F ratios New Duncan's Multiple Range Test (DMRT) (Leclarg *et al*., 1962).

Results and discussion

1. Plant height (cm):

The analysis of variance for plant height (Table 1**)** reveals significant differences for mean squares due to treatments of different gamma rays doses. Highly significant differences were observed among the mean squares for genotypes as well as due to interaction among the radiation treatments and genotypes. However, the differences for mean squares due to replications were non-significant. As compared to the control (Table 2), significant reduction in plant height was observed for all the varieties under the influence of all the gamma rays doses. Range of mean values for plant height in control plots of all the varieties was recorded 78.33 for Bt-121 to 148.44 cm for Bt-131where as the range for plant height in all the treatments for all the varieties was recorded from 145.38 (Bt-CIM-602 at 15 kR) to 67.97 (Bt-131 on 25 kR). Maximum plant height (146.1 cm) was recorded in Bt-131 at T1 (control). In contrast minimum plant height of 66.9 cm was observed in Bt-131 under the influence of 25 kR dose of radiation. It is prominent from Table 1 that different radiation doses have adverse effect on plant height. Similar results have also been reported by Yue and Zou (2012). They observed that on exposure to radiation doses, the average plant height was reduced in comparison to those of the control in some varieties of cotton. The present results are also in conformity with those of Penic and Jelemic (1963), who observed reduction in plant height of eleven wheat varieties including some wheat breeding lines on exposure to different x-rays doses. In spite of the adverse effects on plant height, variety Bt-121 developed maximum plant height of 135.2 and 111.86 cm under the influence of 20 and 25 kR gamma rays doses, respectively. This indicate that certain genes for controlling height in this variety might have been favorably mutated on 20 and 25 kR gamma doses to promote plant height.

2. Number of Branches plant^{-1}

Increased number of branches plant^{-1} is positively correlated with ultimate yield of seed cotton and fibre production. The analysis of variance for number of branches plant^{-1} (Table 1) revealed highly significant difference in the mean values for branches plant^{-1} due to radiation doses as well as interaction between radiation treatments and cotton genotypes. The differences for mean squares due to genotypes were significant where as these were non-significant for replications (Table 1). It is further evident from Table 2 that all the radiation doses produced adverse effect on number of branches plant^{-1}. Generally, as compared to the respective controls, number of branches plant^{-1} was reduced in all the varieties with an increase in the radiation dose (Table 2). Under the influence of different radiation doses, the range for number of branches plant^{-1} was recorded as 16.33 to 34.0 cm. Maximum reduction in the number of branches plant^{-1} (16.33 cm) was observed for Bt-131 under 25 kR dose of gamma rays. These results are in agreement with those forwarded by Horvat (1961) who observed reduction in the rate of germination and number of tillers plant^{-1} in *Oryza sativa* L under the influence of increase doses of radiation. Contrary to the general fact that radiation has adverse effect on number of branches plant^{-1}, all the doses favorably affected number of branches plant^{-1} in variety Bt-121 (Table 2). In this variety all the doses maximized number of branches plant^{-1}. It is uncertain to say that increase in the number of branches plant^{-1} for this variety has been occurred due to radiation effect. Possibly, it might have been occurred due to increased soil fertility or favorable environmental conditions of the locality in which the experiment was conducted. However, none of the previous investigators have reported that increase in the radiation dose may favor number of branches plan^{-1} in cotton except Yue and

Zou (2012) who advocated that low doses of gamma rays on pollens in cotton may result in the increased coefficient of variation for number of branches per plant.

3. Number of Bolls Plant^{-1}

Number of bolls plant^{-1} is as an important agronomic trait and is directly correlated with both yield of seed cotton and production of fibre. The analysis of variance for number of bolls per plant at first picking illustrates highly significant differences (F ratio calculated > F tabulated at 1% level of probability) due to treatments (radiation doses) as well as due to interaction between treatments and cotton genotypes (Table 1). However, the differences for mean squares of number bolls plat^{-1} due to cotton genotypes were found significant (F ratio calculated > F tabulated at 5% level of probability).

Mean values for number of bolls plant^{-1} (Table 2) reveals that under the effects of different radiation doses number of bolls were decreased in all the genotypes and the increase was inversely correlated with an increase in the radiation dose. However, some of the radiation doses produced favorable effect on the trait and it was observed in case of Gomal-93 under 20 kR and Bt-121 under 10, 20 and 25 kR doses of gamma rays where the number of bolls plat^{-1} have shown apparent increase over their respective controls. Under these radiation doses, number of bolls plant^{-1} was higher than their respective controls i.e. 78.67, 39.00, 60.00 and 40.00, respectively. Maximum increase in the number of bolls plant^{-1} (60.00) was observed in Bt-121 under the influence of 20 kR dose of gamma radiation. The present results regarding the decrease in the number of bolls plant^{-1} in cotton due to exposure to radiation are in agreement with those forwarded by Matsumura (1959) who also observed reduced germination, few tillers, reduced height and less fertility in *Triticum monococum* under the influence of higher doses of gamma rays and beta rays. According to the present investigations, the increase in the number of bolls plant^{-1} under certain gamma rays doses may either be due to favorable environmental conditions or due genetic variability caused by 20 kR radiation dose in Bt-121. The genetic variability for incresead number of bolls under 20 kR can be confirmed in the second mutant generations i.e. M_2 and subsequent advanced generations.

4. Fibre Fineness (Micronair):

Fibre Fineness in cotton is a qualitative trait and may be controlled by single gene. Therefore, there is a chance for induction of positive mutations for fibre strength through radiation. The analysis of variance (Table 1) for illustrates non-significant differences for the mean values of micronair due to genotypes, radiation treatments and interaction between radiation treatments and genotypes. The mean values regarding fibre fineness (micronair) are presented in Table 2. The Table of means for micronair reveals that none of the radiation dose produced significant stimulatory effect on fibre fineness in any of the variety under consideration. However, Bt-121 and Bt-CIM-602 showed a slight increase in fibre strength over their respective control i.e. 4.27 and 4.63 micronair, respectively and was recorded as 6.63 and 4.77 micronair, respectively for the two varieties. Regarding varietal performance Bt-CIM-602 showed maximum mean value of 4.43 micronair while Bt-121 revealed minimum mean value 4.8. Under dose wise mean values across varieties (Table 9) maximum number of micronair was recorded as 4.62 in control while for the treatments, the trait exhibited reduction in all the varieties. As a general conclusion it can be said that on exposure to radiation doses, the micronair is adversely affected in cotton genotypes. Since finesse is negatively correlated with the character like weight of seed cotton, hence the decrease in the trait under consideration may also be due to the negative correlation. The present results coincide with those reported by Bridge (2001), who stated that several factors affect the ultimate value of cotton. Some of these characters have positive while other have negative correlations among them.

5. Yield of seed cotton (g)

Analysis of variance for the mean values of yield of seed cotton (Table 1) shows non-significant differences due to genotypes, radiation doses and interaction between radiation treatments and genotypes. Table 2 presents the mean values for yield of seed cotton of four varieties under the influence of different gamma rays doses. According to the Table, significant increase was observed for variety Bt-CIM-602 under the influence of all the doses. In comparison to its control which was 88.17, the range in the increase was observed from 89.23 to 119.00. Similarly, variety Bt-131 also depicted increase in yield of seed cotton over the control (70.170) in the range of 77.40 to 105.63 under 10, 15 and 20 kR doses except for 25 kR which was recorded as 62.60. For variety Bt-121 the seed cotton yield was higher than that of the control (97.00) and was recorded as 102.20 and 99.27 under 10 kR and 25 kR doses of gamma rays. Form the dose wise mean values, increase (98.65) in seed cotton yield was observed under T4 for all the varieties. However, minimum yield of seed cotton with the mean value of 78.08 was noted under the influence of T5. These observations are reasonably in full conformity with those reported by Muthusamy and Jayabalan, (2012) who stated that some lower doses of both chemical and physical mutagens induce positive mutation for increasing seed yield in cotton. Regarding varietal performance (Bt CIM 602) yielded maximum seed cotton with a mean value of 119.00 g $plant^{-1}$ while Bt 131 produced minimum seed cotton of 70.17 gm $plant^{-1}$ as control.

Table 1: Combined analysis of variance for five different agronomic traits in four cotton genotypes under the influence of four different gamma rays treatments.

Source of variation	**1. Plant height** (CV: 13.54%)				**2. Branches $Plant^{-1}$** (CV: 14.07%)			
	d.f.	SS	MS	F. Ratio	d.f.	SS	MS	F. Ratio
Replication	2	0.44	0.22	0.66	2	65.10	32.55	2.62
Radiation Treatments	4	6.48	1.62	4.83*	4	459.57	114.89	9.26 **
Error	8	2.68	0.33	-	8	99.23	12.44	-
Genotypes	3	7.372	2.46	10.38**	3	150.18	50.06	3.30*
Treatments × genotypes	12	25.72	2.14	9.06**	12	1535.23	127.93	8.45**
Error	30	7.09	0.24	-	30	254.33	15.14	-
Total	59	49.79	-	-	59	2763.65	-	-
	3. Bolls $Plan^{-1}$ (CV: 30.68%)				**4. Fiber Fineness** (CV: 9.77%)			
	d.f.	SS	MS	F. Ratio	d.f.	SS	MS	F. Ratio
Replication	2	109.20	54.600	0.35	2	4.55	2.27	9.23
Radiation Treatments	4	4521.43	1130.35	7.32**	4	2.26	0.56	2.29
Error	8	1235.46	154.43	-	8	1.97	0.24	-
Genotypes	3	1730.73	576.91	3.26*	3	0.17	0.05	0.32
Treatments × genotypes	12	8177.10	681.43	3.86**	12	1.45	0.12	0.67
Error	30	5294.66	176.49	-	30	5.43	0.18	-
Total	59	21068.66	-	-	59	15.84	-	-
	5. Yield of seed cotton (CV: 27.45%)							
	d.f.	SS	MS	F. Ratio				
Replication	2	3991.19	1995.59	2.80	CV	Coefficient of variation		
Radiation Treatments	4	3196.14	854.71	1.20	*	Significant at 5% level of probability		
Error	8	2564.13	712.13	-	**	Significant at 1% level of probability		
Genotypes	3	13489.61	799.03	1.32	df	Degrees of freedom		
Treatments × genotypes	12	23071.05	1124.13	1.85	SS	Sum of squares		
Error	30	46312.12	607.13	-	MS	mean squares		
Total	59	3991.19	6092.72	-				

Table 2: Effects of different doses of gamma radiations on plant height, number of branches per plant, number of bolls per plant, fiber fineness and yield of seed cotton in four cotton genotypes.

Radiation treatments	**6. Plant height (cm)**					**7. Branches $plant^{-1}$**				
	Varieties				Mean	Varieties				Mean
	V1	V2	V3	V4		V1	V2	V3	V4	
T1 (control)	128.02	148.44	78.33	145.38	124.96	32.33	32.33	17.33	44.00	31.50
T2	105.77	101.49	75.28	94.48	94.18	27.00	27.00	27.00	25.33	27.08
T3	96.62	116.74	74.06	145.38	108.20	26.17	20.66	24.67	23.00	23.63
T4	127.11	95.40	135.02	97.53	113.69	25.67	25.67	29.67	34.00	29.75
T5	106.68	67.97	111.86	139.29	106.37	30.67	16.33	31.67	27.00	26.42
Mean	112.78	106.07	94.79	124.35	-	27.27	26.40	26.60	30.33	-
Radiation treatments	**8. Bolls $plan^{-1}$**					**9. Fiber fineness**				
	Varieties				Mean	Varieties				Mean
	V1	V2	V3	V4		V1	V2	V3	V4	
T1 (control)	69.00	61.33	29.67	45.67	51.42	4.70	4.87	4.27	4.63	4.62

T2	50.67	36.33	39.00	26.33	38.08	4.47	4.23	4.63	4.77	4.53
T3	21.00	52.67	27.00	52.67	38.33	4.43	4.30	4.10	4.30	4.28
T4	78.67	39.33	60.00	44.67	55.67	4.00	4.00	4.23	4.03	4.07
T5	42.67	20.67	40.00	28.67	33.00	4.10	4.47	4.20	4.43	4.30
Mean	52.40	42.07	39.13	39.00	-	4.34	4.37	4.28	4.43	-
Radiation treatments	**10. Yield of seed cotton**					Abbreviations:				
	Varieties				Mean	Radiation dose		Genotypes		
	V1	V2	V3	V4		T1: no radiation		V1: Gomal-93		
T1 (control)	130.10	70.17	97.00	88.17	96.35	T2: 10 kR		V2: Bt-131		
T2	71.83	77.40	102.20	100.17	87.90	T3: 15 kR		V3: Bt-121		
T3	90.77	90.50	69.20	100.80	87.82	T4: 20 kR		V4: Bt-CIM-602		
T4	96.63	105.63	73.33	119.00	98.65	T5: 25 kR				
T5	61.70	62.60	99.27	89.23	78.08					
Mean	90.21	81.160	88.200	99.473	-					

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