Research Article

Field Evaluation of High Yielding Genotypes of Lentil (*Lens Culinaris Medik.*) Developed through Induced Mutagenesis

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Abstract | Induced mutations play paramount role in manipulating the genetic structure of the plants as an indispensable tool for crop improvement. This field study was initiated to evaluate three potential mutant lines of lentil against their parent (M-85) and two check varieties (NIA-Masoor-05 and NIA-Masoor-16). The pooled data of the crop, after two years of evaluation, indicated the earliest maturity in the mutant AEL-40/30 (92.0 days). Plant height was observed to be low in all the studied mutant lines (AEL-40/30, AEL-13/30 and AEL-12/30) against the parent and the control varieties. Important yield contributing traits like number of branches plant^{-1}, seeds pod^{-1} and 1000 seed weight were also seen to be highest in the mutant AEL-40/30 (3.95, 1.91 and 29.11 (g), respectively). Moreover, the same genotype showed an extraordinarily high yield of 1765.1 kg ha^{-1}. The other two mutant lines *viz.* AEL-13/30 and AEL-12/30 produced seed yield of 1628.4 and 1561.9 kg ha^{-1}, respectively. Yield of the check varieties as well as the parent was substantially lower than the evaluated mutants; lowest seed yield was produced by M-85 (1113.5 kg ha^{-1}). Hence, selected mutants indicated improvement in earliness in flowering, maturity, yield and yield contributing traits. Correlation analysis of the agronomic parameters implied that number of branches plant^{-1}, seeds pod^{-1} and 1000 seed weight had highly significant correlation with the seed yield of the lentil. It was concluded that the mutants AEL-40/30 and AEL-12/30 have very high yield potential, and these genotypes can be further evaluated for zonal performance in the Sindh province.

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Introduction

Lentil (*Lens culinaris* Medik) is an important rabi-pulse crop of Pakistan. It is cultivated on 13.6 thousand ha in the country and has an overall production of 6.4 thousand tons (Economic Adviser's Wing, 2018-19). It is mainly grown in rain fed and irrigated areas of the country. Occupying the second position among the major seed legumes, lentil is an important seed legume crop of Pakistan. It is an inexpensive source of protein, calories, and certain vitamins (Nourin et al., 2019). It is also a main source of vegetable proteins in human diet. The protein content of lentil seeds, on average, is around 22-34.6 % while 100 g of dried lentil seeds have 340-346 calories. Moreover, lentil is also a cheap source of fiber, as well as micronutrients (Crook et al., 1999).

The per hectare yield of lentil in Pakistan was about 470 kg ha^{-1} as per 2017-18; which is far less than other lentil cropping countries of the world (Economic Adviser's Wing, 2018-19). The lack of intensive lentil breeding programs can be attributed as the main reason for lower yield potential of lentil varieties in Pakistan (Gupta et al., 2011; Roychowdhury et al., 2012). Various strategies can be adopted for genetic improvement of lentil to develop new promising varieties of the crop. Mutation breeding is one of such strategies. Gamma rays belong to ionizing radiations and are one of the most energetic form of electromagnetic radiations. They are highly penetrating vs. other forms of radiation like alpha and beta rays (Raturi et al., 2015).

For plant improvement, the irradiation of seeds through gamma radiations cause genetic variations which enable breeders to select new genotypes with ameliorated traits e.g. stress tolerance, disease resistance, better quality and higher yields (Ashraf et al., 2003). Like other crops, mutation breeding is one of the major techniques employed for legumes' breeding as well (Gustafsson et al., 1971; Singh et al., 1992; Gupta et al., 2011). Raina et al. (2016) reported that gamma radiations can induce useful genetic changes in crop plants, and can therefore help in improving certain traits. Similarly, Hameed et al. (2008) and Borzouei et al. (2010) proposed that gamma radiations disturb the synthesis of proteins, enzymatic activity, hormonal balance and other characteristics responsible for plants' growth, survival and ultimate yields.

This study assessed three promising mutants of lentil in field conditions against their parent and two control varieties. The said mutants were earlier developed using different doses of gamma radiation, and were selected for further evaluation on the basis of potential characteristics. The study gives an insight into significance of mutation breeding towards crop improvement and highlights the fact that mutation breeding can serve in developing new lentil varieties which would contribute towards socioeconomic development of the country in the long run.

Materials and Methods

The field experiment was conducted at Experimental Farm of Nuclear Institute of Agriculture (NIA), Tando Jam, Sindh, Pakistan. The study evaluated four mutants AEL-12/30, AEL-13/30 and AEL-40/30 against their parent i.e. M-85 and two check varieties (NIA-Masoor-05, and NIA-Masoor-16). The mutants were earlier developed using different doses of gamma radiation and had passed initial stages of field evaluation. AEL-40/30 and AEL-12/30 were developed under 200 Gy of gamma radiation while, AEL-13/30 was developed using 400 Gy of gamma radiation.

The experiment was performed during 2016-17 and 2017-18 using randomized complete block design, replicated three times with net plot size of 5 m x 5 m (25 m^2). The crop was sown in the mid-week of November using single row hand drill. The field was irrigated 15 days before planting and plowed when it was in proper condition. Two plowings followed by planking were employed to make the seed bed for sowing of the crop. Normal cultural practices for lentil including hoeing, plant protection approaches, and proper irrigation were ensured for the crop throughout its growth period. The crop was harvested by the end of March.

The data was collected for various parameters such as days to maturity, plant height (cm), number of seeds pod^{-1}, number of branches $plant^{-1}$, 1000 seed weight (g) and seed yield (kg ha^{-1}). The recorded data were subjected to factorial design of analysis of variance (ANOVA) under linear models of statistics using computer program Student Edition of Statistix (SWX), version 8.1. Further Least Significant Difference (LSD) test was also employed to test the level of significance among different combination means (Gomez and Gomez, 1984).

Results and Discussion

Days to maturity

The statistical analysis of variance indicated that the genotypes' days to maturity exhibited significant variations at 5% level of significance (Tables 1, 2 and 3; Supplementary Tables 1, 2 and 3). For the year 2016-17, early maturity was observed in mutant AEL-40/30 (92.00 days) followed by AEL-12/30 (94.00 days). During season 2017-18, AEL-40/30, again maintained its superiority and recorded the days to maturity values of 92.00 days; however, it was followed by AEL-13/30 in this season (94.00 days). On mean basis, AEL-13/30 showed second best days to maturity values (Table 3). NIA-Masoor-05 and NIA-Masoor-16 both required higher number of days to mature as compared to the evaluated mutant lines

Table 1: *Performance of lentil genotypes under Tando Jam agroclimatic conditions during season 2016-17.*

Genotypes	Days to maturity	Plant height (cm)	Number of branches plant^{-1}	Seeds pod^{-1}	1000 seed weight (g)	Seed yield (kg ha^{-1})
AEL-12/30	94.0 ^{d}	28.73 ^{b}	2.56 ^{d}	1.26^{d}	21.53^{d}	1538.4^{ab}
AEL-13/30	95.66 ^{bc}	27.26^{c}	3.13^{b}	1.53 $^{a-c}$	24.56^{c}	1563.2^{ab}
AEL-40/30	92.0 ^{e}	27.26 ^{c}	3.90 ^{a}	1.73^{a}	28.90 ^{a}	1748.0^{a}
NIA-Masoor-16	97.33 ^{a}	28.70 ^{b}	2.80 ^{c}	1.43^{b-d}	28.43^{a}	1346.9^{bc}
NIA-Masoor-05	95.0 ^{cd}	28.33^{b}	2.30 ^{e}	1.60 ^{ab}	26.93 ^{b}	1260.9^{c}
M-85	97.0 ^{ab}	31.03 ^{a}	2.60 ^{cd}	1.30 ^{cd}	24.23 ^{c}	1150.3^{c}

Means followed by same letters are not significantly different from each other ($p \leq 0.05$).

Table 2: *Performance of lentil genotypes under Tando Jam agroclimatic conditions during season 2017-18.*

Genotypes	Days to maturity	Plant height (cm)	Number of branches Plant^{-1}	Seeds pod^{-1}	1000 seed weight (g)	Seed yield (kg ha^{-1})
AEL-12/30	96.0^{b}	25.0^{b}	3.12^{b}	1.77^{b}	24.03^{b}	1585.4^{b}
AEL-13/30	94.0^{c}	25.6^{b}	3.25^{b}	2.08^{a}	28.26^{a}	1693.6^{a}
AEL-40/30	92.0^{d}	24.6^{b}	4.09^{a}	2.19^{a}	29.33^{a}	1782.2^{a}
NIA-Masoor-16	96.0^{b}	30.7^{a}	2.56^{c}	1.56^{bc}	21.86^{c}	1278.0^{c}
NIA-Masoor-05	98.3^{a}	30.2^{a}	2.38^{c}	1.36^{c}	20.26^{c}	1155.4^{d}
M-85	97.0^{b}	29.6^{a}	2.55^{c}	1.47^{c}	21.70^{c}	1076.8^{d}

Means followed by same letters are not significantly different from each other ($p \leq 0.05$).

Table 3: *Performance of lentil genotypes under Tando Jam agroclimatic conditions (pooled data of crop during seasons 2016-17 and 2017-18).*

Genotypes	Days to maturity	Plant height (cm)	Number of branches Plant^{-1}	Seeds pod^{-1}	1000 seed weight (g)	Seed yield (kg ha^{-1})
AEL-12/30	95.00^{ab}	25.23 ^{c}	3.15^{b}	1.48^{c}	22.76^{c}	1561.9^{b}
AEL-13/30	94.83^{b}	26.43^{bc}	3.16^{b}	1.76^{ab}	26.41^{ab}	1628.4^{ab}
AEL-40/30	92.0^{c}	24.75^{cd}	3.95^{a}	1.91^{a}	29.11^{a}	1765.1^{a}
NIA-Masoor-16	95.0^{ab}	29.45^{ab}	2.65^{c}	1.46^{c}	25.14^{b}	1312.4^{bc}
NIA-Masoor-05	96.0^{a}	28.38^{b}	2.53^{cd}	1.50^{b}	24.31^{bc}	1208.1^{c}
M-85	97.0^{a}	30.11^{a}	2.45^{d}	1.30^{d}	22.24^{d}	1113.5^{d}

Means followed by same letters are not significantly different from each other ($p \leq 0.05$).

Table 4: *Correlation analysis of various traits of lentil.*

Traits	Days to maturity	Plant height (cm)	Number of branches Plant^{-1}	Seeds pod^{-1}	1000 seed weight (g)	Seed yield (kg ha^{-1})
Days to maturity	1					
Plant height (cm)	0.7724	1				
Number of branches plant^{-1}	-0.9411	-0.8945	1			
Seeds pod^{-1}	-0.8885	-0.7641	0.8869	1		
1000 seed weight (g)	-0.8864	-0.5378	0.7820	0.9356	1	
Seed yield	-0.8772	-0.9275	0.9474	0.8808	0.7272	1

(96.00 and 95.00 days, respectively). M-85, the parent, showed the least desired values for the days to maturity (97.0 days). It was evident that the varietal maturity varied from genotype to genotype; from the variations observed in this study it could be expected that early maturing genotypes can be developed through mutation breeding. Similar results have been suggested by Kazmi et al. (2002) and Javed et al. (2000).

Plant height (cm)

Plant height of the genotypes was also evaluated in the study. During the year 2016-17, AEL-13/30 and AEL-40/30 showed the least plant height of 27.26 cm, which was significantly lower than all the other assessed genotypes. For the cropping season 2017-18, it was observed that the plant height varied non-significantly among the mutant lines; however, the plant height for all the mutants was significantly lower than control varieties as well as the parent ($p \leq 0.05$; Tables 1, 2 and 3; Supplementary Tables 1, 2 and 3). As per the pooled data, AEL-40/30 presented shortest plant stature of 24.75 cm, followed by AEL-12/30 (25.23 cm). Check varieties i.e. NIA-Masoor-05, NIA-Masoor-16 and the parent genotype (M-85) showed plant height of 28.38, 29.45, and 30.11 cm, respectively. Although various parameters of lentil, including the plant height, are influenced by both the genetic as well as environmental factors; the changes in genetic architecture seem to the major determinant of plant height. Javed et al. (2000) and Mijic et al. (2006) also suggested a direct effect of mutagenesis on the plant height.

Number of branches plant^{-1}

The number of branches plant^{-1} is an important yield contributing parameter of lentil. This trait was found to be significantly superior in evaluated mutant lines against the parent as well as the control varieties (at $p \leq 0.05$; Tables 1, 2 and 3; Supplementary Tables 1, 2 and 3). The mean values of this attribute for two consecutive years indicated that AEL-40/30 had maximum number of branches plant^{-1}(3.95), followed by AEL-13/30 and AEL-12/30 (3.16 and 3.15 branches plant^{-1}, respectively; Table 3). AEL-40/30 was also seen to maintain its superiority for both cropping seasons regarding this parameter. According to pooled data, check variety NIA-Masoor-05 showed the least number of branches plant^{-1} (*viz.* 2.38 branches) while the parent (M-85) developed 2.55 branches plant^{-1}. The number of branches plant^{-1} hold substantial significance for lentil crop as they play a remarkable role towards the final seed yield of the crop. Rana and Solanki (2015) have also reported similar variations in branching ability of different lentil genotypes.

Number of seeds pod^{-1}

The statistical analysis of variance indicated that the number of seeds pod^{-1} significantly varied among different genotypes evaluated in the study (at 5% level of significance; Tables 1, 2 and 3; Supplementary Tables 1, 2 and 3). Mutant AEL-40/30 produced highest number of seeds pod^{-1} during both years of evaluation (1.73 and 2.19 seeds pod^{-1} for year 2016-17 and 2017-18, respectively). AEL-13/30 ranked second in number of seeds pod^{-1} and yielded 1.76 seeds pod^{-1} as per pooled data for the two years of the evaluation. Worst performance was seen in M-85 which produced 1.30 seeds pod^{-1}. The results were parallel to the report of Jan and Nawabzada et al. (2004).

1000 seed weight (g)

1000 seed weight represents one of the most important parameters related to ultimate crop yields. Significant variation was observed in this trait over the period of evaluation. Two mutants *viz.* AEL-40/30 and AEL-13/30, showed very promising results in terms of 1000 seed weight. 1000 seed weight for both of the genotypes was observed to be 29.11 and 26.41 g, respectively, as per the pooled performance (Table 3). The 1000 seed weight for check varieties was recorded to be 25.14, and 24.31 g for NIA-Masoor-16 and NIA-Masoor-05, respectively. M-85, on the other hand, showed lowest values for 1000 seed weight (22.24 g). 1000 seed weight is an important trait for selection of the potential genotypes. Variations among various genotypes for 1000 seed weight has been reported in earlier studies as well (Chatterjee et al., 2012; Rana and Solanki, 2015).

Seed yield (kg ha^{-1})

The economic benefits of any crop relate to its ultimate yields. Seed yield significantly varied among evaluated genotypes at 5% level of significance. AEL-40/30 showed very promising performance consecutively for two years of evaluation. The highest mean seed yield was observed in AEL-40/30 (1765.0 kg ha^{-1}) followed by the mutant AEL-13/30 (1628.4 kg ha^{-1}; Table 3). The other mutant, AEL-12/30, also produced higher yield than the parent and check varieties (1561.9 kg ha^{-1}). Lowest seed yield was recorded for M-85, the parent of the evaluated mutants (1113.5 kg ha^{-1}). NIA-Masoor-16 and NIA-Masoor-05 produced seed yield of 1278.0 and 1155.4 kg ha^{-1} as per pooled performance of the varieties. Maximum yield potential of 1782.2 kg ha^{-1} was also observed for AEL-40/30 during the cropping season 2017-18. Higher seed yield is the most desired characteristic for selection and advancement of any particular genotype in a breeding program. The increment observed in the seed yield of the mutants against the parent in this study could be attributed to changes in genetic architecture of the mutants because of mutations (Raina et al., 2016). Raturi et al. (2015) also proposed similar variations among the genotypes when they were subjected to field evaluation.

Correlation studies

Correlation analysis of the crop data was also conducted to investigate the relation of various traits towards ultimate yield of the lentil crop (Table 4). It was observed that the most important parameter towards seed yield was the number of branches plant^{-1} (correlation value of 0.9474). Seeds pod^{-1} and 1000 seed weight also had highly significant correlation with the seed yield (0.8808 and 0.7272, respectively). Contrarily, plant height indicated extremely negative correlation with the seed yield (-0.9275). Moreover, days to maturity also had significantly negative correlation with the seed yield (-0.8772). Interestingly, plant height and days to plant maturity were both significantly positively correlated with each other. Correlation of these two parameters to all of the yield contributing characteristics of the crop was negative. Correlation studies provide an insight into interaction of various agronomic parameters of any crop (Khan et al., 2017, 2018, 2019; Seema et al., 2017). Ozer et al. (2003) also proposed a significant correlation between 1000 seed index and the seed yield of lentil, as observed in this study.

Conclusions and Recommendations

It was concluded that mutant AEL-40/30 and AEL-13/30 have very high yield potential, and these genotypes can further be evaluated for zonal performance in the Sindh province. Such promising genotypes can ultimately lead to developing new commercial lentil varieties.

Supplementary Material

There is supplementary material associated with this article. Access the material online at: http://dx.doi.org/10.17582/journal.pjar/2020/33.1.164.169

Author's Contributions

Mohammad Aquil Siddiqui conceived the idea, and conducted the experiment. Muhammad Tahir Khan assisted in conducting the study and writing the manuscript, finalized the references' formatting. Ghulam Shah Nizamani helped in designing the study, improved the manuscript, analyzed the statistical data. Shafquat Yasmeen helped in collecting agronomic traits data of the crop. Imtiaz Ahmed Khan critically reviewed and improved the article. Abdullah Khatri provided the technical input, supervised the work through his feedback. Nighat Seema Soomro conducted the analysis for correlation of the studied traits.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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