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CLIMATIC VARIATION EFFECTS ON CANOLA (*BRASSICA NAPUS*) GENOTYPES

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Abstract

Canola (*Brassica napus*) is an important quality edible oil crop. An increase in the production of canola can significantly reduce the import of edible oil. With climate change, production of canola is expected to suffer due to water availability issues. Keeping this fact in mind, this study was planned to evaluate the performance of various canola genotypes under diverse agro-ecological regions of Pakistan having different rainfall. The experiment was planned in a randomized complete block design with three replications. Ten canola genotypes viz. Bulbul-98, Zafar-2000, Abaseen, Rainbow, Shiralee, Con-I, Dunkeld, 19-H, Westar and Con-II were grown at three experimental sites (Haripur, Rawalpindi, Layyah) for two years. The results indicated that the chlorophyll contents index, seasonal crop growth rate, seed yield, oil yield, protein contents and the water productivity was the highest at Haripur site and the lowest at Layyah site. However, the oil contents were the maximum at Layyah site during the second year. Among the canola genotypes, the genotype 'Zafar-2000' had the highest chlorophyll content index, seasonal crop growth rate, net assimilation rate, seed/oil yield and water productivity than other canola genotypes. However, during the second year, the highest chlorophyll content index, seasonal crop growth rate, seed/oil yield and water productivity were noted in genotype '19-H'. This study indicated that the high rainfall areas (e.g. Haripur, Rawalpindi) must be exploited to grow the canola crop to lessen the import of oil from foreign markets. In low rainfall areas (e.g. Layyah), the canal and tube well irrigation facilities are available and the water shortage can be accomplished through irrigation with minimum reliance on rainfall.

Key words: Agro-ecological regions, Canola genotypes, Oil contents, water productivity, oil imports

Introduction

Edible oil is basic component of every diet. Production of edible oil in Pakistan is quite low and Pakistan imported the edible oil worth of Rs. 269.412 billion (US$ 2.663 billion) during 2014-15. Canola is one of the top two oil producing crops in Pakistan and can be successfully grown in many regions of Pakistan. However, its production is highly affected by climatic variations. In two separate studies, Kutcher *et al*. (2010) and Khan *et al*. (2014) reported the negative impacts of variations in temperature and rainfall on the yield of canola. However, above average rainfall was very useful was improving the performance of canola irrespective of temperature. In another study, Ahmadi & Barhani (2009) reported that supplying sufficient water to rapeseed crop, particularly at flowering and pod formation significantly improved yield and quality of the crop. Qaderi *et al*. (2006) studied the effect of climate change on physiological traits of canola and reported that high CO_2 concentration, temperature and drought affects the crop growth by interrupting the physiological processes like abscisic acid production. Naderikharaji *et al*. (2008) reported significant effect of water stress on chlorophyll contents, leaf area, net assimilation rate and yield of canola.

Apart from this, its production is also affected by poor agronomic practices and use of low yielding varieties as farmers grow canola mostly on marginal lands (Ahmed *et al.,* 2016; Sharma *et al.,* 2016; Kumar, 2016; Ul-Allah *et al.,* 2014). With proper management and improved varieties yield of this crop can be improved significantly. For example, Dutta (2014) reported 18-38% increase in yield of rapeseed mustard by adopting different agronomic and management practices

The effects of water deficit and temperature on morphological and yield related traits has been well-reported; however, the information is lacking on the impacts of variable climatic conditions on the growth, stay green, seed yield and oil quality of various canola genotypes. Keeping in view the constraints and facts, the present study was conducted to investigate the effect of variable climatic conditions on the growth, stay green, seed yield and oil quality of various canola genotypes.

Materials and Methods

Ten canola genotypes *viz*; Bulbul-98, Zafar-2000, Abaseen, Rainbow, Shiralee, Con-I, Dunkeld, 19-H, Westar and Con-II were grown at three sites *viz.* (1) University Research Farm, PMAS- Arid Agriculture University, Rawalpindi (AAUR), (2) University of Haripur (UOH), Haripur and (3) Agronomic Farm Area Hafizabad, Bahauddin Zakariya University (BZU), Bahadur Sub Campus, Layyah, Pakistan. These stations are selected on the bases of annual rainfall. The annual rainfall at Haripur, Rawalpindi and Layyah site is 1000-1200 mm/annum (high), 650-850 mm/annum (medium) and 450-550 mm/annum (low), respectively. The weather data recorded during the experimental period at all three sites during the both years (Table 1). The experiment was conducted at all three sites for two consecutive years (2012-13 & 2013-14) during the winter season. The composite soil samples from all the three experimental sites were taken from a depth of 0.20 m to determine those for various physico-chemical characteristics (Table 2). The experimental treatments were quadruplicate and were arranged in a randomized complete block design.

Table 1: Weather data during the experimental period at three experimental sites (average of two years)

		October	November	December	January	February	March	April
Rawalpindi	Rainfall	20	10	40	40	40	30	30
	Max. Temperature	30	23	18	16	20	25	31
	Min. Temperature	15	8	5	3	5	9	16
Layyah	Rainfall	2	2	6	0.1	97.1	25.1	15
	Max. Temperature	35.5	28.6	23.4	21.3	24.5	28.7	35.2
	Min. Temperature	18.5	9.5	3.5	3.6	9.3	12.1	18.7
Haripur	Rainfall	22	15	38	63	69	78	58
	Max. Temperature	30.8	24.8	19.5	17.2	18.7	23.9	28.8
	Min. Temperature	14.8	8.9	4.8	3.1	5.8	10.3	14.5

Table 2: Soil physico–chemical characteristics of the experimental locations during both experimental years

Parameter	Rawalpindi		Haripur		Layyah	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Soil texture	Clay loam	Clay loam	Silt loam	Silt loam	Sandy loam	Sandy loam
pH	7.1	7.2	7.9	7.8	7.8	7.9
EC (dS m^{-1})	0.83	0.87	0.22	0.24	0.85	0.89
Organic matter (g kg^{-1})	3.8	3.7	9.5	9.7	4.6	4.8
Total N (g kg^{-1})	0.76	0.74	1.90	1.95	0.92	0.96
Extractable P (mg kg^{-1})	6.6	6.3	2.6	3.0	6.8	7.0
Extractable K (mg kg^{-1})	110	110	105	106	116	118

EC= electrical conductivity; N= nitrogen; P= phosphorous; K= potassium

At all sites, the soil was cultivated with the help of a tractor mounted cultivator (upto 0.30 m depth) four times followed by two plankings with the help of a wooden planker. Deep ploughing with the help of mould board plough was also done at each site to preserve the soil moisture for sowing of canola crop. The seeds of all the canola genotypes were sown with manual operated hand drill in 45 cm apart rows at each site using a seed rate of 5 kg ha^{-1}. The plant to plant distance was maintained at 5 cm by thinning the plants after uniform germination. The fertilizer was applied at the rate of 80-40 kg NP ha^{-1}, respectively at the time of land preparation, using the diammonium phosphate and urea as sources of phosphorous and nitrogen at each site. No irrigation was applied to canola crop at either site and the whole crop cycle of the crop was only dependent on rainfall during both years of experimentation. Weeding was done manually in the experimental plots at each site in both years. No insect pest and disease attack was detected at any canola genotype at either site, so no pesticide was used at all.

For determination of relative water contents, the fresh fully expanded leaves were collected at peak vegetative stage just before flowering from each treatment. Fresh weight was determined with the help of portable digital balance (CS-3000, YMC Japan) just after sample collection. Leaves were made fully turgid by keeping in distilled water for 48 hours and turgid weight was recorded with same digital balance after surface drying with a blotting paper. To record the dry weight of the samples, these were oven dried until constant weight (approximately 48 hours) at 70°C. Relative water contents were calculated using following formula given by Kumar *et al.,* (1984).

$$\text{RWC} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

The chlorophyll content index was estimated using a chlorophyll meter (CCM-200 plus; Opti-Sciences, Inc. NH 03051 USA). The seasonal crop growth rate and net assimilation rate was calculated following the standard formulas as detailed by Hunt (1978).

The canola plants harvested from central two rows of each plot and were threshed manually after sun drying. After threshing, the data on seed yield, seed oil content (by near infrared spectroscopy system), oil yield (by multiplying oil contents with the yield), and the protein contents were recorded following the standard procedures. The concentration of nitrogen in seeds was estimated by Kjeldahl method. After this, the protein contents were estimated by multiplying the concentration of nitrogen with 6.25. The data on water productivity was calculated as the ratio between the canola seed yield harvested per unit of water used (i.e. rainfall) (Molden, 1997).

The data collected on all parameters were analyzed by standard statistical procedures as described by Gomez and Gomez (1984). SNK test was used to evaluate the significance of differences between the genotypes and locations at $p \leq 0.05$. Data were analyzed using statistical package STATISTICA 9.0 (Stat-Soft, Inc., USA).

Results

Relative water content (%): The relative water contents were significantly different among various experimental locations during the both years. The canola genotypes also differed significantly for relative water contents during both years. The interaction of experimental locations with canola genotypes was also significant for the relative water contents during the both years of experimentation. The maximum relative water contents of 77.1 and 83.2% during the first and the second year, respectively were observed at Haripur site, and they were the lowest at Layyah site during both years. Among the canola genotypes, the highest relative water contents of 79.1 and 85.3% during the first and second year, respectively were recorded in the genotype 'Abaseen' (Table 3).

Chlorophyll contents index: Chlorophyll contents is an important indicator of stay green of a crop. This study indicated that the chlorophyll content index was significantly different among various experimental locations during both years. Various canola genotypes also differed significantly for chlorophyll content index during the both years. The interaction of experimental locations with canola genotypes was also significant during the both years of experimentation. Among the experimental locations, the highest chlorophyll content index of 40.4 and 52.1 during the first and second year, respectively was recorded in the canola crop grown at Haripur site, and it was the lowest at Layyah site during the both years. Among the canola genotypes, the highest chlorophyll content index was recorded in the genotype 'Zafar-2000' (48.8) during the first year, and in the genotype '19-H' (49.5) during the second year of experimentation (Table 3).

Seasonal crop growth rate (g m^{-2} day^{-1}): In this study, the seasonal crop growth rate was significantly different among various experimental locations during the both years. Various canola genotypes also differed significantly for seasonal crop growth rate during the both years. The interaction of experimental locations with canola genotypes was also significant during the both years for seasonal crop growth rate. Among the experimental locations, the highest seasonal crop growth rate of 11.3 and 13.5 g m^{-2} day^{-1}, during first and second year respectively, was recorded at Haripur site, and it was the lowest at Layyah site during both years. Among the canola genotypes, the highest seasonal crop growth rate was recorded in the genotype 'Zafar-2000' (12.9 g m^{-2} day^{-1}) during the first year, and in the genotype '19-H' (11.9 g m^{-2} day^{-1}), and 'Bulbul-98' (11.7 g m^{-2} day^{-1}) during the second year of experimentation (Table 3).

Net assimilation rate (g m^{-2} day^{-1}): The net assimilation rate was not significantly different among various experimental locations during both years. The canola genotypes differed significantly for net assimilation rate only during the first year of experimentation; results being non-significant during the second year. The interaction of experimental locations with the canola genotypes was also significant during the first year of experimentation. Among the canola genotypes, the highest net assimilation rate of 0.90 g m^{-2} day^{-1} was recorded in genotype 'Zafar-2000, and it was the lowest in genotype 'Dunkeld' (0.83 g m^{-2} day^{-1}) during the first year of experimentation (Table 3).

Seed yield (Mg ha^{-1}): The seed yield was significantly different among various experimental locations during the both years. Various canola genotypes also differed significantly for seed yield during the both years. The interaction of experimental locations with canola genotypes was also significant during the both years for seed yield. Among the experimental locations, the maximum seed yield of 1897 and 2368 Mg ha^{-1}, during the first and second year respectively was observed at Haripur site. On the other hand, the Layyah site had the lowest seed yield of canola during both years. The seed yield at Haripur site was 25-47% higher than the Layyah site during the both experimental years. Amongst canola genotypes, the genotype 'Zafar-2000' and '19-H' produced the maximum seed yield of 2271 and 2310 Mg ha^{-1} during 2012-13 and 2013-14, respectively, than the other canola genotypes (Table 3).

Oil content (%): The oil contents were significantly different among various experimental locations during the second year of experimentation; with maximum oil contents of 49.7% recorded at Layyah site. The differences among canola genotypes, and the interaction of experimental locations with canola genotypes was non-significant during the both experimental years for the oil contents (Table 4).

Oil yield (Mg ha^{-1}): The oil yield was significantly different among various experimental locations during the both years. Various canola genotypes also differed significantly for oil yield during the both years of experimentation. The interaction of experimental locations with canola genotypes was also significant during the both years for oil yield. Maximum oil yield of 907 and 1111 Mg ha^{-1} was recorded at Haripur site during the first and second year, respectively; while the minimum oil yield was recorded at Layyah site during the both years. Among the canola genotypes, the maximum oil yield of 1079 and 1086 Mg ha^{-1} was observed in 'Zafar-2000' and '19-H' during 2012-13 and 2013-14, respectively than the other canola genotypes (Table 4).

Protein contents (%): The protein contents were significantly different among various experimental locations during both years. Various canola genotypes also differed significantly for protein contents during the both years. The interaction of experimental locations with canola genotypes was also significant during both years for protein contents. Among the experimental locations, the highest protein contents of 24.9 and 27.8 %, during first and second year respectively were recorded at Haripur site, and that was statistically similar with the protein contents recorded at Rawalpindi site during the first year of experimentation. The protein contents were the lowest at Layyah site during the both years. Among the canola genotypes, the highest protein contents were recorded in the genotype 'Rainbow' (27.3%) during the first year, and in the genotype 'Dunkeld', 'Con-I' and 'Bulbul-98' during the second year of experimentation (Table 4).

Table 3: Relative water contents, chlorophyll content index, seasonal crop growth rate, net assimilation rate and seed yield of various canola genotypes grown at different locations during both experimental years

Treatments	Relative water content (%)		Chlorophyll contents index		Seasonal crop growth rate ($g/m^2/day$)		Net assimilation rate ()		Seed yield (Kg ha^{-1})	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Locations (L)										
Rawalpindi	76.5 A	81.8 A	38.76B	45.8B	10.7B	11.07B	0.86	0.86	1822 B	2087 B
Layyah	72.3 B	76.6 B	33.55C	32.5C	8.2C	5.43C	0.85	0.87	1517 C	1606 C
Haripur	77.1 A	83.2 A	40.44A	52.1A	11.3A	13.49A	0.86	0.86	1897 A	2368 A
LSD ($p \leq 0.05$)	*1.2*	*2.0*	*0.66*	*0.69*	*0.44*	*0.76*	*0.035 ns*	*0.029 ns*	*16.7*	*15.7*
Genotypes (G)										
Bulbul-98	77.3 ABC	82.3 ABC	36.6D	48.3B	9.84D	11.65 A	0.87AB	0.86	1743 D	2035 E
Zafar-2000	75.1 DE	81.6 A-D	48.8A	39.8H	12.91A	8.98 DE	0.90A	0.89	2271 A	2182 C
Abaseen	79.1 A	85.2 A	32.2H	38.7I	8.50E	8.64DE	0.87AB	0.85	1586 G	1844 G
Rainbow	77.8 AB	76.1 E	32.7H	47.3 C	8.65E	10.72 B	0.85AB	0.85	1637 F	1708 I
Shiralee	73.4 EF	78.6 DE	37.2D	44.4 E	10.59C	10.26 BC	0.85AB	0.85	1728 D	2212 B
Con-I	75.2 CDE	76.2 E	35.7E	42.0 F	10.16CD	9.41 CD	0.86AB	0.86	2032 B	2142 D
Dunkeld	72.1 F	78.7 CDE	41.6C	40.6 G	11.45B	9.59CD	0.83B	0.85	1525 H	1769 H
19-H	71.9 F	80.9 BCD	33.5G	49.5A	8.97E	11.89 A	0.86AB	0.87	1958 C	2310 A
Westar	74.6 DE	81.1 BCD	34.3F	37.3 J	8.65E	8.08 E	0.85AB	0.86	1551 H	1819 G
Con-II	76.5 BCD	84.5 AB	42.8B	46.6 D	11.18B	10.78 B	0.85AB	0.86	1637 F	1927 F
LSD ($p \leq 0.05$)	*2.1*	*3.6*	*0.42*	*0.44*	*0.28*	*0.48*	*0.02*	*0.01*	*30.5*	*28.7*
G × L	<0.001*	<0.001*	000***	0000***	0000***	0000***	0000***	0.11ns	<0.001*	<0.001*
C.V. (%)	3.5	5.6	5.19	4.98	5.40	9.39	5.05	4.19	12.1	11.2

ns= non-significant; *= significant at $p \leq 0.05$; **= significant at $p \leq 0.01$; Different letters indicate statistically significant-difference among the values in each column and individual factors (SNK test; $p \leq 0.05$

Table 4: Oil contents, oil yield, protein contents and water use efficiency of various canola genotypes grown ate different locations during both experimental years

Treatments	Oil contents (%)		Oil yield (Mg ha^{-1})		Protein contents (%)		Water use efficiency (kg mm^{-1} ha^{-1})	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Locations (L)								
Rawalpindi	48.7	47.5 B	881.6 A	989.9 B	24.7A	26.09 B	6.96 B	12.2 B
Layyah	47.5	49.7 A	763.8 B	755.1 C	22.9B	22.99 C	4.32 C	6.6 C
Haripur	47.9	47.0 B	906.6 A	1111.4 A	24.9A	27.76 A	7.52 A	14.4 A
LSD ($p \leq 0.05$)	*0.534 ns*	*1.8*	*34.9*	*34.1*	*1.24*	*1.12*	*0.35*	*0.61*
Genotypes (G)								
Bulbul-98	48.6	48.1	847.0 CD	978.2 CD	24.05CD	26.82 A	7.17 BC	11.2 BC
Zafar-2000	46.8	46.5	1079.2 A	1013.3 BC	23.19CD	24.47 D	7.83 A	11.2 BC
Abaseen	46.9	48.2	746.2 F	887.7 EF	23.35CD	24.05 D	5.53 EF	11.2 BC
Rainbow	47.2	49.1	773.2 EF	840.1 F	27.32A	26.39 AB	4.78 G	9.5 D
Shiralee	48.5	47.3	834.3 DE	1038.9 ABC	24.16CD	25.99 ABC	6.13 DE	12.4 A
Con-I	48.3	49.1	975.1 B	1046.8 AB	23.51CD	25.15 BCD	6.62 CD	11.4 AB
Dunkeld	50.5	47.7	769.2 F	841.7 F	24.75BC	27.52 A	5.13 FG	10.2 CD
19-H	46.2	48.1	902.2 C	1086.1 A	22.55D	24.72 CD	7.38 AB	12.4 A
Westar	49.5	48.2	771.9 EF	869.5 EF	22.97CD	24.07 D	5.23 FG	10.3 BCD
Con-II	48.1	47.9	808.8 DEF	919.1 DE	25.96B	26.96 A	6.87 BC	10.4 BCD
LSD ($p \leq 0.05$)	*0.460 ns*	*0.917 ns*	*63.7*	*62.3*	*0.78*	*0.70*	*0.64*	*1.12*
G × L	0.559 ns	1.00 ns	<0.001*	<0.001*	0000***	0000***	<0.001*	<0.001*
C.V. (%)	9.7	8.6	9.2	8.1	6.35	5.39	12.6	12.6

ns= non-significant; *= significant at $p \leq 0.05$; **= significant at $p \leq 0.01$; Different letters indicate statistically significant-difference among the values in each column and individual factors (SNK test; $p \leq 0.05$)

Water productivity (kg mm^{-1} ha^{-1}): Water productivity is production per unit area with per unit of water use. The water productivity was significantly different among various experimental locations during both years. Various canola genotypes also differed significantly for water productivity during the both years. The interaction of experimental locations with canola genotypes was also significant during both years for water productivity. Among the experimental locations, the highest water productivity of 7.5 and 14.4 kg mm^{-1} ha^{-1} during the first and second year respectively was recorded at Haripur site, and that was the lowest at Layyah site during the both years. Among the canola genotypes, the highest water productivity of 7.8 and 12.4 kg mm^{-1} ha^{-1} was recorded in genotype 'Zafar-2002' and 'Shiralee'/'19-H' during 2012-13 and 2013-14, respectively. The lowest values of water productivity were observed in genotype 'Rainbow' during the both years (Table 4).

Discussion

Relative water content (RWC) of leaves is an important traits used to assess the crop performance under limited water resources (Arjenaki *et al.,* 2012; Farahani *et al.,* 2013). Momentous pattern of divergence were observed in RWC among the diverse genotypes under various agro-ecological conditions. The variation in RWC was due to the differences in agro-ecological condition of the location and difference in climatic conditions like temperature, humidity and rainfall (Table 1). High rainfall led to more RWC (i.e. Haripur site) whereas low rainfall with high temperature (i.e. Layyah site) reduced the RWC of leaves. In another study, Wang *et al*. (2010) and Bouthiba *et al*. (2008) reported that high rainfall increases the soil water contents which maintain water balance in leaves and make plants more water efficient. In present study, the canola genotypes performed differently under same climatic conditions and variable climatic conditions which was due to differences in the genetic potential of these genotypes (El-Soda *et al.,* 2014; Kant *et al.,* 2014; Kumar *et al.,* 2013 and Tahir *et al.* 2007). Geographical locations also influenced the growth characteristics (e.g. seasonal crop growth rate and net assimilation rate), plant physiological traits (e.g. relative water contents, chlorophyll content index), due to variation in soil characteristics, humidity, light intensity, rainfall and temperature (Tables 1, 2; Kumar *et al.,* 2013; Sadeghi-Shoae *et al.,* 2014; Siddiqui *et al.,* 2008).

Water productivity is an important agronomic trait that describes actual water yield (Ul-Allah *et al.,* 2015). Acclimatization of any crop, in the area with limited water resources, mainly depends on its water productivity (Ponton *et al.,* 2002). Highly significant genotypic differences ($P\leq0.05$) for water productivity in this study were due to different in the genetic potential of genotypes under varying climatic conditions. These results are supported by the findings of Kant *et al.* (2014) and Kirkegaard (2015) who worked on canola and related *Brassica* species and reported genotypic differences for water productivity. The water productivity could be enhanced under restricted water by increasing transpiration and evaporation rate and by improving harvest index. It may be possible to improve the water productivity by efficient utilization of the available water resources (Tanner and Sinclair, 2009; Ul-Allah *et al.,* 2015).

The oil contents were significantly affected by the various locations, as well differed among various canola cultivars. This variation in oil contents may be due to variation in rainfall at different location as availability of more water boosted the yield (Moosavi *et al.,* 2014) and also improved the oil contents (Pahlavani *et al.,* 2007). From results, it is clear that oil contents were lower ($P\leq0.05$) at Haripur and Rawalpindi location which are cooler and received more rainfall than at comparatively hotter and dry location of Layyah. Higher contents in dry regions may be due to effect of temperature on biochemical processes which lead to production of oil. Higher oil contents of canola in dry regions have also been reported by Cheema *et al.* (2012 & 2001) and Masarovicová & Král'ová (2011) who compared the performance of canola cultivars under different geographical location based on temperature and rainfall. Oil contents may be lower in the soils with high soil moisture due to possible concentration of more water contents in the seed. As different cultivars has variable potential of seed oil contents and grain yield (Ahmed *et al.,* 2016; El-Soda *et al.,* 2014; Masarovicová & Král'ová, 2011; Siddiqui *et al.,* 2008; Cheema *et al.,* 2012& 2001), these were also observed in present study where genotypes differ significantly ($P\leq0.05$) from each other for grain yield, oil contents and ultimately oil yield.

Among the canola genotypes, the highest seed yield was recorded in the genotype 'Zafar-2000'. This highest seed yield may be attributed to better chlorophyll contents, higher seasonal crop growth rate and net assimilation rate which resulted in better photosynthesis and growth of this canola genotype resulting in higher seed yield. Higher seed yield in this cultivar led towards higher oil yield and the maximum water productivity than the other canola genotypes.

Conclusions

The genotype 'Zafar-2000' showed maximum performance with respect to stay green, crop growth rate which resulted in higher water productivity, seed yield and oil yield than the other canola genotypes. All the parameters were highest with availability of more water (high rainfall e.g. at Rawalpindi and Haripur site) except oil contents that were higher at dry location (i.e. Layyah site). The cultivation of genotype 'Zafar-2000' is recommended for arid and semi-arid regions with subtropical climate to boost the oil yield in Pakistan with low reliance on oil imports.

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