Available online: www.notulaebotanicae.ro
Print ISSN 0255-965X; Electronic 1842-4309
Not Bot Horti Agrobo, 2016, 44(1):272-279. DOI:10.15835/nbha4419993

Notulae Botanicae Horti Agrobotanici Cluj-Napoca

Original Article

Quantifying Some Physiological and Productivity Indices of Canola (*Brassica napus* L.) Crop under an Arid Environment

Sibgha NOREEN[1], Shakeela NOOR[1], Shakeel AHMAD[2], Fehmeeda BIBI[3], Mirza HASANUZZAMAN[4]*

[1]Bahauddin Zakariya University, Institute of Pure and Applied Biology, Multan, Pakistan; sibgha.noreen@bzu.edu.pk; shakeelanoor803@yahoo.com
[2]Bahauddin Zakariya University, Faculty of Agricultural Sciences and Technology, Department of Agronomy, Multan, Pakistan; shakeelahmad@bzu.edu.pk
[3]Bahauddin Zakariya University, Faculty of Veterinary Sciences, Multan, Pakistan; fehmida01@gmail.com
[4]Sher-e-Bangla Agriculture University, Faculty of Agriculture, Department of Agronomy, Dhaka, Bangladesh; mhzsauagz@yahoo.com (*corresponding author)

Abstract

Canola (*Brassica napus* L.) crop ranks third after soybean and palm among oilseed crops for production of vegetable oil and meal for human and livestock, respectively around the globe. The cultivars of canola crop vary greatly in their yield potential in response to eco-edaphic factors under different production environments. Therefore, research studies were undertaken to evaluate eight cultivars of canola crop 'Shiralee', 'Dunkled', 'Bulbul-98', 'Ac-Excel', 'Cyclone', 'Rainbow', 'DGL' and 'Faisal Canola' for quantifying some physiological and productivity indices under normal growing conditions. The results showed that various cultivars of canola differed significantly amongst themselves with respect to biological yield, chlorophyll content, protein content, nutrient composition and components of seed yield. Among the cultivars, cvs. 'Bulbal-98' and 'Rainbow' produced maximum biological yield and seed yield, respectively, Furthermore, maximum yield harvested from cv. 'Rainbow' was associated with higher total seed weight plant^{-1}, while cv. 'Faisal Canola' maintained higher chlorophyll content than other ones. Cultivar 'Dunkled' contained higher K^+ nutrient by 21.13 mg g^{-1} in leaf tissues compared to minimum (9.73 mg g^{-1}) in 'DGL' cultivar. The higher amount of Na^+ content (12.16 mg g^{-1}) was determined in cv. 'AC Excel'. Cultivar 'Rainbow' maintained higher photosystem (II) activity and had greater partitioning ability of photo-assimilates in the seed tissues. Of various chlorophyll fluorescence parameters, quantum yield of photosystem II and electron transport performance index could be used as a selection criterion for breeding of canola cultivars.

Keywords: seed yield, shoot length, potassium nutrient, sodium nutrients, chlorophyll content, proteins content, chlorophyll fluorescence

Introduction

Canola (*Brassica napus* L.) belonging to the botanical family of Brassicaceae is one of the most promising oilseed crop (McCaffery *et al.*, 2009). Its production ranks at third position after soybean and palm and contributes to about 15 percent of the total vegetable oil in the world (Banga *et al.*, 2007). In Pakistan, it is most important winter oilseed crop, which shares about 10% towards vegetable oil production (Economic Survey of Pakistan, 2015). It is also grown extensively for production of forage, because of containing low fiber and high protein content (Wiedenhoeft and Bharton, 1994) and seed cake meal for livestock (Bañuelos *et al.*, 2002). The oil is of premium quality in terms of containing low levels of erucic acid (less than 2%) in oil and glucosinolates (less than 30 μmol g^{-1}) in meal for consumption of human and livestock, respectively. The oil contains 62 per cent oleic acid (monounsaturated fatty acids), 20 per cent linoleic acid and 9% linolenic acid (polyunsaturated fatty acids). The meal contains 30-40% protein, and is also being substituted for soybean meal (Muhammad *et al.*, 2007). The presence of higher amount of erucic acid and glucosinolates in the indigenous rapeseed crop is not favored by human and livestock for consumption purpose (Mailer, 2009). Presently, Pakistan is facing deficiency of oil by two-thirds of its total requirement (Government of Pakistan, 2014). The production lacks far behind of requirement due to lower productivity of oilseed crops and further its cultivation on marginal lands (Sahrawat *et al.*, 2011).

The gap between demand and supply is being met mainly through import of palm oil. The country imported a quantity of 2.32 million tons at the cost of PKR 207.66 billion (US $ 2.07 billion) during the year 2012-2013 (Government of Pakistan, 2014). The heavy burden on the country's exchequer could be lessened by growing high yielding cultivars and mass cultivation over a large area. The planting area under canola crop stretched from

Received: 20 June 2015. Received in revised form: 04 Dec 2015. Accepted: 14 Dec 2015. Published online: 14 June 2016.

10,700 ha to 14,700 ha, and its production increased from 9,200 tons to 17,000 tons during the period from the year 2005-2006 and 2012-2013 (Government of Pakistan, 2014). The lower production is mainly attributed to planting on marginal areas, low yielding canola cultivars and more importantly its cultivation in under drought-prone areas and also on saline soils (Stricker *et al.*, 1997). Canola is highly susceptible to drought stress and its yield is reduced to a substantial level during the period from flowering to seed setting stage (Din *et al.*, 2011).

Among the currently grown oilseed crops, canola has potential to bridge the gap between demand and supply, because of its wider adaptability under various production environments (McCaffery *et al.*, 2009; Aminpanah, 2013). The selection of canola crop cultivars is determined primarily by their yield potential capacity and enhanced yield forming processes (Daun, 2006). The components of seed yield are highly variable and influenced greatly by one's genetic background, environmental conditions agronomic practices and resultantly their interactions amongst themselves (Sidlauskas and Berinotas, 2003; Goodwin, 2004). Furthermore, Diepenbrock (2000) reported that biological yield of oilseed rape crops are significantly influenced by their relative crop growth rate and duration of vegetative growth period under the growing conditions. The proportionate quantity of seed yield varies from 28 to 50% of the total biomass, while the remaining 50 to 70% accounts for vegetative biomass (Rathke *et al.*, 2006). Kumar *et al*, (1994) found that photosynthetic capacity, transpiration rate and biological yield are the determinants for seed yield production. The close relationships were found between seed yield and number of pods plant^{-1}, number of seeds pod^{-1} and 1000-seed weight in various canola cultivars (Cantagallo *et al.*, 1997). However, yield potential of canola crop is more of a site-specific characteristic in response to prevailing environmental conditions (Rathke *et al.*, 2006). The negative correlations were observed between protein and seed oil content, i.e, amount of protein content increased with concurrent reduction in oil content in various cultivars of canola crop (Fayyaz-ul- Hassan, 2007; Aminpanah, 2013). The varieties of canola exhibited a great variation in biological yield, seed yield and quality of oil with respect to protein and glucosinolate contents. These were closely related to progressive vegetative growth during the early part of season, higher plant density and reduced shattering of pods at maturity (Snowdon and Friedt, 2004; Rathke *et al.*, 2006). The rapeseed varieties also varied greatly due to one's genetic makeup, integrated nutrients management and differentiation in partitioning of assimilates between reproductive and vegetative plant organs (Zhao and Wang, 2004; Rathke *et al.*, 2006).Various investigators (Kolte *et al.*, 2000; Khoshanazar *et al.*, 2000; Stringam *et al.*, 2000; and Din *et al.*, 2011) studied quantitative traits in various cultivars of canola crop. They found significant variability for various traits related to seed yield and yield determinants, i.e. number of pods plant^{-1}, number of branches plant^{-1} and grain yield plant^{-1}. El-Habbasha and Mostafa (2009) reported non-significant differences between varieties, except for plant height and seed yield. On the other hand, Khehra and Singh (1998) and Paramjit *et al.* (1991) reported significant variability for various seed yield of canola crop. Din *et al.* (2011) reported that productivity of canola is cumulative effects of number of branches plant^{-1}, 100- seed weight and number of pod plant $^{-1}$ in various varieties of canola crop.

Canola crop being a recent introduction in Pakistan, thereby it requires continuing research for screening of advanced genotype/ cultivars, which are highly productive and adaptative under growing environment. This necessitates that the yield potential could be exploited according to agronomic requirements of various cultivars (Tahir *et al.*, 2007). The reason being that productivity of canola varieties is greatly influenced by various eco-edaphic factors, genetic make-up, and quality of planting seed, fertilizer management practices and particularly financial and management resources available to the farmers. Therefore, a research study was carried out to delineate the differences among various cultivars of canola crop with respect to biological yield, biochemical parameters, nutrient assimilation and components of seed yield grown under normal growing conditions.

Materials and Methods

Experimental location

The research study was conducted at the research station of Institute of Pure and Applied Biology, Bahauddin Zakariya University, Multan, Pakistan during the winter crop season 2013-2014. The experiment consisted of eight cultivars, 'Faisal Canola', 'DGL', 'Bulbul-98', 'Shiralee', 'Dunkled', 'Ac-Excel', 'Cyclone' and 'Rainbow' which were planted to quantify their comparative performance under normal growing environments. In Pakistan, Oilseeds Research Institute (ORI), Ayub Agricultural Research Institute, Faisalabad is an institution for research and delivery of oilseed cultivars. Data regarding cultivars used in the study are: 'Faisal Canola' (cross: 'KS-75' × 'Rainbow', origin: ORI, Pakistan); 'DGL' (Dark Green Leaf, origin: ORI, Pakistan); 'Bulbul-98' (introduction, origin: Australia); 'Shiralee' (introduction, origin: Australia); 'Dunkled' (introduction, origin: Australia); 'Ac-Excel' (germplasm, origin: Saskatoon); 'Cyclone' (germplasm, origin, Australia); 'Rainbow' (germplasm, origin: Australia)] The representative soil sample was analyzed for physical and chemical characteristics according to methods of Ryan *et al.* (2001). The soil of growth medium contained soil pHs 8.2; ECe 1.7 d Sm^{-1}; 0.80 percent organic matter, 4.89 mg g^{-1} N; 6.80 mg g^{-1} P; 83.6 mg g^{-1} K and 5.89 percent calcium carbonate content. The textural class of the soil was silty clay loam, having alkaline in reaction and calcareous in nature.

Experimental layout

The treatments involving eight cultivars were arranged in a completely randomized design and each treatment was replicated four times. Ten healthy seed of different canola cultivars, free from any mechanical / diseased infestation were dibbled in each experimental pot during first week of November, 2013. After germination, thinning was done at three leaf stage and four seedlings of uniform in size and development were maintained during the growth period. The moisture content was maintained at field capacity to avoid water stress condition. The pots were kept in a naturally illuminated wire - house to avoid damage from birds and mammals. The plants were sprayed with insecticides to control sucking insect pests during the season.

Collection of data

The quantum of fresh biological yield produced by various cultivars was evaluated by harvesting of plants. The plants were divided into shoots and roots organs. The plant material was dried in an oven at 70 °C till constant weight for estimation of dry biological yield. The chlorophyll content was measured by using portable Chlorophyll Meter (Minolta SPAD-502, Japan). The recent fully expanded 3rd leaf from apex at day 50 after sowing, which coincided pod forming stage was selected to collect data on chlorophyll content. The shoot length was measured on a meter scale. The plant material was processed for chemical analysis of potassium and sodium concentration in leaf tissues according to methods of (Ryan *et al*., 2001). The amounts of total soluble proteins and total amino acids were determined in seeds according to methods of Bradford (1997) and Hamilton and Van Slyke (1943) respectively. Data for seed yield components, number of branches plant $^{-1}$, number of pods plant^{-1} and total weight plant^{-1} were recorded at maturity. Chlorophyll fluorescence measurements were made by employing Flour Pen (FP-100), fixed with an array of six emitting diodes. The diodes were fixed on the leaf (first adapted for 30 minutes) to ensure that all photosystem II reaction centre were in an open state and faceted in the clip on a spot of 4 mm diameter to provide homogeneous elucidation.

Statistical analysis

Data were analysed statistically using analysis of variance (SPSS Verr. 10). The F-value was calculated at the probability level ($p< 0.05$). The significant data were identified by calculating least significant difference (Steel *et al*., 1997).

Results

The statistical analysis of data revealed that cultivars of canola differed significantly ($p<0.05$) in terms of fresh and dry weights of shoot organ (Table 1). Maximum shoot fresh weight of 27.78 g plant^{-1} was produced by cv. 'bulbul-98', while minimal quantity of 16.67 g plant^{-1} was gathered from cv. 'Faisal Canola'. The values of shoot fresh weight ranged from 16.67 to 27.78 g plant^{-1} in various cultivars. Maximum quantity of shoot dry weight (1.57 g plant^{-1}) and minimal value of (0.68 g plant^{-1}) was collected from cv. 'Bulbul-98' and cv. 'Shiralee' respectively. The various cultivars also showed non-significant ($p<0.05$) differences with regard to production of fresh and dry weight of root organ. Maximum quantity of root fresh weight 2.19 g plant^{-1} was obtained from cv. 'Faisal Canola' and minimum production of 1.55 g plant^{-1} was harvested from cv. 'DGL' at maturity. On the other hand, maximum root dry weight of 0.39 g plant^{-1} was gathered from cv. 'Faisal Canola' and minimum quantity of 0.29 g plant^{-1} by cv. 'Dunkled' among various cultivars. Comparatively, various cultivars differed a little in production of fresh and dry weight of root organ. The cultivar 'Bulbul-98' produced maximum quantity of shoot fresh and dry weights. Contrary to it, maximum quantity of root fresh and dry weights was gathered from cv. 'Faisal Canola' (Table 1).

The statistical analysis of data indicated that various cultivars differed statistically non-significant in maintenance of total free amino acids in the seed portion. Maximum content of total free amino acids by 9.04 mg g^{-1} was found in seed of cv. 'Faisal Canola' while its minimal value of 6.07 mg g^{-1} was determined in cv. 'Cyclone'. The cultivars 'Dunkled', 'DGL' and 'Ac-Excel' were statistically at par with each other. Contrarily, the cultivars differed significantly ($p<0.01$) in maintaining total soluble proteins among themselves. Maximum quantity of total soluble proteins by 8.62 mg g^{-1} was obtained in seed tissues of cv. 'Rainbow' while its minimal amount by 1.07 mg g^{-1} was found in seed of cv. 'Faisal Canola'. The maximum quantity of total free amino acid and total soluble proteins were determined in cv. 'Faisal Canola' and cv. 'Rainbow', respectively (Table 1).

The cultivars differed significantly ($p<0.05$) in shoot length. Comparing the cultivars, cv. 'DGL' was the tallest followed by 'Ac-Excel' then 'Shiralee' and 'Dunkled' with values of 95.73, 93.25, 88.38, and 88.00 cm, respectively (Table 2). The statistical analysis of data showed that cultivars differed significantly ($p<0.05$) in maintenance of chlorophyll content in their leaf tissues at day 50 after planting which coincided with pod formation stage. Among various cultivars, maximum SPAD value of 43.25 were recorded in cv. 'Faisal canola' while its minimal value of 38.17 was determined in cv. 'Dunkled'. The cultivars 'Shiralee', 'Cyclone' and 'DGL' were

Table 1. Biological yield and protein content in cultivars of canola

Cultivars	Shoot fresh wt. (g plant^{-1})	Shoot dry wt. (g plant^{-1})	Root fresh wt. (g plant^{-1})	Root dry wt. (g plant^{-1})	Total free Amino acids (mg/g)	Total soluble Proteins (mg/g)
Shiralee	26.09bc	0.68a	2.02bc	0.33a	7.43e	4.37b
Dunkled	22.82bc	1.35b	1.86ab	0.29a	6.48b	6.14c
Bulbul-98	27.78bc	1.57bc	1.84a	0.31a	6.34b	3.12b
Ac-Excel	19.14a	0.75a	1.88ab	0.34a	6.90c	4.23b
Cyclone	20.49a	1.35b	1.79a	0.30a	6.07a	5.90c
Rainbow	23.32bc	1.38bc	1.89ab	0.36a	7.09d	8.62d
DGL	20.17a	1.06b	1.55a	0.35a	7.69f	5.59c
Faisal Canola	16.67a	1.23b	2.19c	0.39b	9.04g	1.07a
LSD	4.62	0.30	0.29	0.08	0.19	1.15

ns = Non significant; **, *** = Significant at ≤0.01 and 0.001, respectively.

Table 2. Chlorophyll content and component of seed yield of canola (*Brassica napus* L.)

Cultivars	SPAD values	No. of branches / plant	No. of pods/ plant	100-seeds wt. (g plant^{-1})	Total seed wt. g plant^{-1}	Plant height (cm)
Shirale	42.12bc	2.75a	118b	0.39a	3.46b	88.38b
Dunkled	38.17a	4.00a	153d	0.48a	0.26a	88.00b
Bulbul-98	40.95abc	4.75b	136c	0.41a	6.18b	85.83b
Ac-Excel	39.82ab	3.25a	129c	0.39a	8.22bc	93.25b
Cyclone	42.70bc	3.50a	199e	0.49a	7.88bc	75.65b
Rainbow	39.17a	3.75a	131c	0.55b	9.26bc	77.80b
DGL	42.87c	4.00a	141c	0.52b	7.60bcd	95.73b
Faisal Canola	43.25c	3.00a	108a	0.37a	5.06b	68.40a
LSD	2.89	1.41	4.99	0.15	2.33	13.40

ns = Non significant; *, ** = Significant at ≤0.05 and 0.01, respectively.

Table 3. Components of nutrients in cultivar of canola (*Brassica napus* L.)

Cultivars	Leaf K^+ ($mg\ g^{-1}$) dry wt.	Root K^+ ($mg\ g^{-1}$) dry wt.	Leaf Na^+ ($mg\ g^{-1}$) dry wt.	Root Na^+ ($mg\ g^{-1}$) dry wt.
Shiralee	11.92a	16.23a	4.38b	4.71a
Dunkled	21.13bcd	24.46b	6.84d	4.87a
Bulbul-98	18.84bc	26.17b	3.88a	5.75a
Ac-Excel	19.39bc	25.57b	3.68a	12.16b
Cyclone	19.98bc	26.02b	6.52bc	5.65b
Rainbow	19.67bc	24.97b	3.99bc	4.89a
DGL	9.73a	26.97b	5.19bc	4.57a
Faisal Canola	17.80bc	24.65b	2.18a	5.55b
LSD	2.42	3.94	1.13	1.01

ns = Non significant; **, *** = Significant at ≤0.01 and 0.001, respectively.

found similar in maintaining chlorophyll content in their leaf tissues at pod formation stage (Table 2).

The seed yield plant^{-1} of canola crop is a cumulative effect of various yield components, i.e. number of branches plant^{-1}, number of pods plant^{-1},100-seed weight and total seed weight plant^{-1}. The statistical analysis revealed that various cultivars differed significantly ($p<0.05$) in the production of number of branches plant^{-1}. The maximum number of branches plant^{-1} by (4.75) were produced by cv. 'Bulbul-98', while minimum number of branches plant^{-1} of (2.75) were recorded in cv. 'Shiralee'. Cultivars 'Dunkled' and 'DGL' produced similar number of branches plant^{-1}. There were statistically significant ($p<0.05$) differences in production of pods plant^{-1} by various cultivars. The maximum (199) and minimum (108) number of pods plant^{-1} were produced by cv. 'Cyclone' and cv. 'Faisal Canola' respectively. Cultivars 'Bulbul-98', 'Rainbow' and 'Ac- Excel' were found similar in production of number of pods plant^{-1}.

The statistically analysis of data indicated that cultivars differed significantly ($p<0.05$) with respect to 100-seed weight. The cultivars 'Rainbow' and 'DGL' had the highest 100 -seed weight and having a little difference between them. While, cv. 'Faisal Canola' had the lowest seed weight (0.37 g) and the highest found in cv. 'Rainbow'. Cultivars 'Shiralee' and 'Ac-Excel' were similar with each other in production of 100 seed weight. The values of 100 seed weight ranged from 0.37 to 0.55 g in various cultivars. Cultivars also differed significantly ($p<0.01$) in production of total seed weight plant^{-1}. Cultivar 'Rainbow' had the highest seed weight plant^{-1} (9.26 g), while 'Cyclone' and 'DGL' cultivars differed non-significantly in total seed weight plant^{-1}. The value of total seed weight plant^{-1} in various cultivars ranged from 0.26 to 9.26 g (Table 2).

The statistical analysis of data revealed that nutrient concentrations of K^+ and Na^+ ions differed in various cultivars (Table 3). There were statistically significant ($p<0.001$) differences in maintenance of K^+ concentration in leaf tissue of various cultivars. Maximum concentration of K^+ nutrient (21.13 mg g^{-1}) was determined in cv. 'Dunkled', while the minimal quantity of 9.73 mg g^{-1} was maintained by cultivar 'DGL'. Cultivar 'Ac- Excel' and 'Cyclone' maintained similar quantity of K^+ content in their leaf tissues. Furthermore, cultivars also differed significantly ($p<0.01$) in maintenance of differential concentration of K^+ nutrients, in their root organ. The maximum quantity of 26.97 mg K^+ g^{-1} was absorbed by cv. 'DGL' while an amount of of 16.23 mg g^{-1} was determined in cv. 'Shiralee'. Cultivars 'Bulbul-98' and 'Cyclone' maintained similar quantity of K^+ nutrient in their root tissue. Data for Na^+ concentration in leaf tissues of various varieties differed significantly ($p<0.001$). Cultivar 'Dunkled' absorbed maximum quantity of 6.84 mg $Na^+ g^{-1}$ compared to cv. 'Faisal Canola' having 2.18 mg Na^+ g^{-1} in the root tissue. Cultivar 'Bulbul-98' and 'Rainbow' had similar quantities of Na^+ content in their root tissues. The statistical analysis of data further showed that cultivars differed significantly ($p<0.01$) in maintenance of differential concentration of Na^+ nutrients in their root tissues. The highest quantity of 12.16 mg Na^+ g^{-1} absorbed by root tissues of 'Ac-Excel' whereas the lowest amount of 4.57 mg Na^+ g^{-1} was determined in 'DGL' cultivar. Cultivars 'Shiralee', 'Dunkeld' and 'Rainbow' maintained 4.71, 4.87 and 4.89 mg Na^+ g^{-1} respectively. Whereas, cvs. 'Bulbul-98', 'DGL' and 'Faisal canola' were also statistically non- significant amongst each other.

Inter varietal-changes in the biophysical parameters derived from the transients curves JIP-test are presented at radar plot (Fig. 1). RC/AOS (density of reaction center) was increased in cv. 'Bulbul-98', while it decreased in cv. 'Ac-Excel' and cv. 'Rainbow'. Data indicated further that maximum photosynthesis was recorded in cv. 'Bulbul-98' and minimum in cvs. 'Ac-Excel' and 'Rainbow'. According to value of performance index, cultivar 'Faisal Canola' showed maximum values, but density of reaction center was greater in cv. 'Bulbul-98'.

Discussion

Various cultivars of canola crop differed to a greater extent in the production of biological yield under the prevailing environments. Maximum and minimum fresh and dry biological yield of shoot organ was harvested from cv. 'Bulbul-98' and cv. 'Shiralee' respectively. On the other hand, maximum and minimum fresh and dry biological yield were harvested from cv. 'Faisal Canola' and cv.'DGL' respectively. The differences in the production of biological yield among eight cultivars are due to differential growth habit, rate of photosynthetic activity and more predominantly by their genetic background. Mukhtar *et al.* (2013) also reported that various varieties of canola crop produced different quantities of biological yield with regard to the shoot and root organ. Several other researches (Wiedenhoeft and Bharton, 1994; Yasari and Patwardhan, 2008; Das, 1998) also found significant difference in the production of biological yield, which were closely correlated with photosynthetic capacity and translocation of photosynthates among different plant parts (Khan *et al.*, 2006a). These results agree with those of Cheema *et al.* (2010) and Ali *et al.* (2011) who found close relationships between total dry matter accumulation and maintenance of phosphosynthatic efficiency by various varieties of canola crop. The canola varieties differed greatly in production of biological yield, because of inherent genetic variability and importantly outcome of genetic× environment interaction (Khan *et al.*, 2006b).

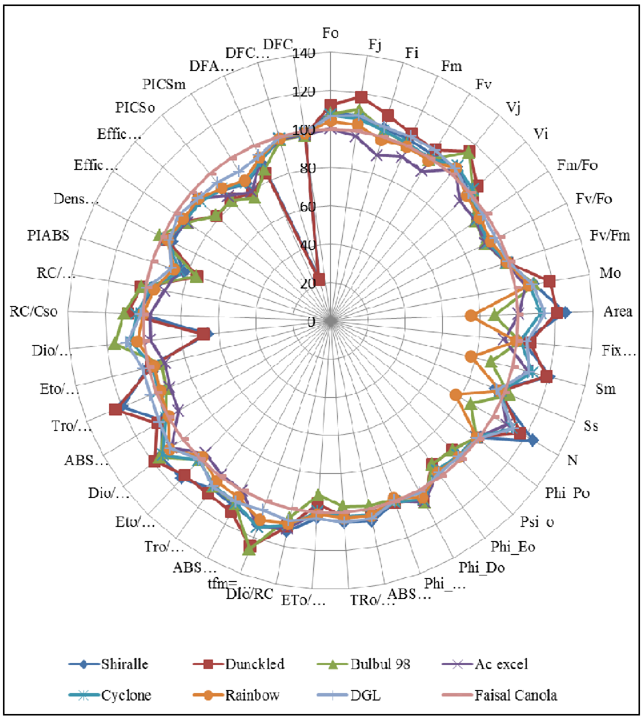

Fig. 1. Radar plot showing the changes in chlorophyll *a* florescence transients parameters in dark adapted cultivars of canola (*Brassica napus* L.)

The cultivars differed appreciably in maintenance of protein contents. Maximum and minimum protein content was recorded in cvs. 'Rainbow' and 'Faisal Canola', respectively. The significant differences in protein contents in cultivars of canola have also been reported by various investigators (Ahmed *et al.*, 2008; Parveen *et al.*, 1996; Padmant *et al.*, 1992). The result of the study agree with those of Sattar *et al.* (2013) and Bengtsson (1988) that Brassica species differed by 9% is their protein content. Analogous to maintenance of total soluble protein, the cultivars also responded deferentially in the maintenance of total free amino acids in the seed tissues. The cv. 'Faisal Canola' was the highest while the lowest in the cv. 'Bulbul-98' in total free amino acid. The results corroborate with those of various investigators (Das, 1998; Gentent *et al.*, 1996; Muhammad *et al.*, 2007) that protein content is mainly attributed to the ability of different canola varieties utilizing natural nitrogen resources and its translocation to different plant parts in the in soil-water-plant continuum. The result of the study pertaining to maintenance of various cultivars of canola are similar to those of Sattar *et al.* (2013) and Bengtsson (1988).

The various cultivars differed significantly in attaining the shoot length. The maximum and minimum shoot length was recorded in cvs. 'DGL' and 'Faisal Canola', respectively. These significant differences among canola cultivars in shoot length might be due to differences in genetic background and genetic×environment interaction effects (El-Nakhlawy and Bakhashwain, 2009; Mirzai *et al.*, 2013). Some cultivars may be sensitive to eco-edaphic factors, while others may be tolerant (Sana *et al.*, 2003).Various investigators (Maestro, 1995; Reddy and Reddy, 1998 also reported that different Brassica varieties differed substantially amongst themselves in attaining shoot length Sana *et al.* (2003) and Chaudhery *et al.* (1987) opined that variation in shoot length in different varieties is mainly attributed to their genetic potential under the specific ecological conditions. The existence of variation in maintaining differential chlorophyll content by various cultivars of canola signified the potential absolute differences in the performance of photosynthetic process. These variation in maintenance of chlorophyll content might be due to specific chlorophyll synthesizing enzymes, such as chlorophllase and peroxidase (Majumadar *et al.*, 1991).These results agree with those of (Taiz and Zeiger, 2006; Din *et al.*, 2011) that there were significant differences among various canola varieties for leaf chlorophyll *a* and *b* content.

The productivity of canola crop is a cumulative effect of different components of yield, i-e., number of branches plant $^{-1}$, number of pods plant^{-1}, 100 seed-weight and total seed weight plant^{-1}. Among these determinants, the number of pods^{-1} is a major contributing component in determining the productivity level of canola crop under certain production ecologies. The maximum and minimum number of pods plant^{-1} was observed in cvs. 'Cyclone' and 'Shiralee', respectively. Khan *et al.* (2006b) also reported significant differences in number of pods per plant in Brassica species. In an earlier study, Chaudhary *et al.* (1987) also found positive and significant correlation between number of pods plant^{-1} and produce of seed yield in different varieties of mustard crop. These results agree with those of other investigators (Sattar *et al.*, 2013; Cheema *et al.*, 2001a, 2012;

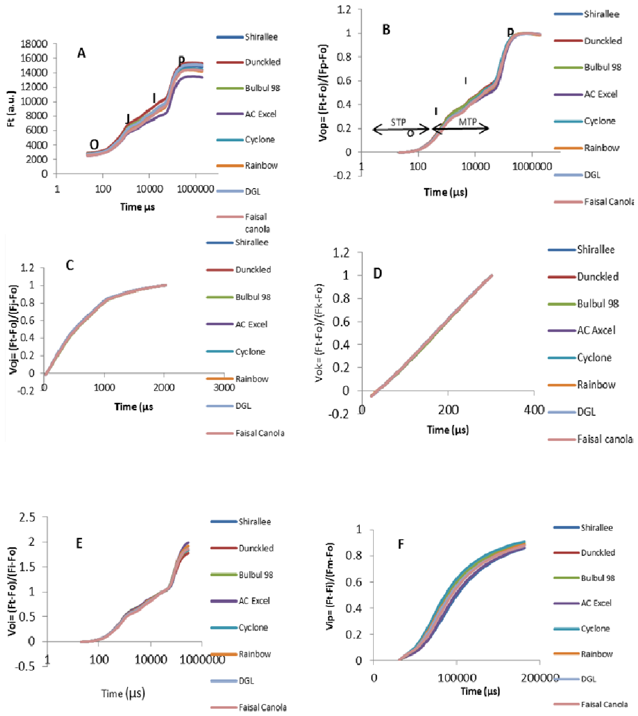

Fig. 2. (A) Chl. *a* florescence transients double normalized between two florescence extremes F_O and F_K phases V_{OK}= (Ft - Fo)/(F_K - Fo); (B) Chl. *a* florescence transients double normalized between two florescence extremes F_O and F_K phases V_{OI} = (Ft - Fo)/(F_I - Fo); (C) Chl. *a* florescence transients double normalized between two florescence extremes F_I and F_P phases V_{IP} = (Ft - F_I)/(F_P - F_I); (D) Kinetic difference of V_{OP} showing OP- bands obtained as line – standard line; (E) Kinetic difference of V_{OJ} showing K- bands obtained as line – standard line; (F) Kinetic difference of V_{OK} showing L- bands obtained as line – standard line.

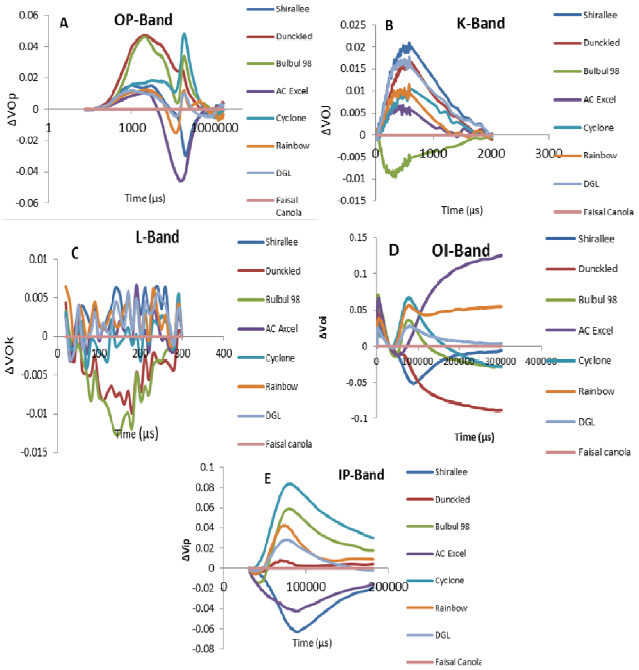

Fig. 3. (A) Kinetic difference of VOP; (B) Kinetic difference of VOJ; (C) Kinetic difference of VOK showing L - bands obtained as Lines – standard Lines; (D) Kinetic difference of VOI (E) Kinetic difference of VIP

Yasari and Patwardhan, 2006, Ec-Kholy *et al*., 2007) who found differences in production of variable number of pods plant^{-1} and attributed this variability to due to genetic make-up and interaction with environment under the production environments. The production of seed yield of canola is greatly contributed by quantum of 100-seed weight. Maximum and minimum 100 seed weight was recorded in cvs. 'Rainbow' and 'Faisal Canola', respectively. The results of this study are in consonance with different researchers, Sattar *et al.* (2013), Cheema *et al.* (2001b, 2012) and Sana *et al.* (2003), who found substantial variation in maintenance of 100 seed weight by various cultivars of *Brassica* species. These results are also in harmony with Kjellström (1993), Mekki (2003) and Khoshanazar *et al.* (2000) who found differences in seed yield among different cultivars. The various yield forming processes resulted in the production of total seed weight per plant. Maximum and minimum total seed weight was recorded in cvs. 'Rainbow' and 'Dunkled', respectively. The result of our study are correlated with those of Mekki (2003), El-Kholly (2007) and Sattar *et al.* (2013), that seed is cumulative interaction of various components of yield processes.

The various cultivars of canola assimilated and translocated differential concentration of K^+ and Na^+ nutrients in their shoot and root organs. Maximum quantities of K^+ nutrient were absorbed by leaf tissues of cvs. 'Dunkled' and 'DGL', respectively. Moreover, cultivars 'Dunkled' and 'Ac-Excel' absorbed maximum quantity of Na^+ nutrient in their leaf and root tissues, respectively. The existence of variation in absorption pattern of nutrients is attributed to inherent capacity of various Brassica species to absorb and ability to retain to by different organs. These results are in harmony with those of Shirazi *et al.* (2011); Yasir *et al.* (2008) that pattern of distribution of nutrients is quite different due to genetic makeup of crop. Plants and interactive effective impacted by external regards of biotic and abiotic stresses. These results are also in agreement with those of Jan *et al.* (2002), Marschner (2011) and Ceccoti (1996).

The chlorophyll '*a*' fluorescence technique revealed alterations in Photosystem II bioenergetics and simultaneously reflecting photosynthetic processes (Fig. 3). The changes in F_o values were attributed to different genetic potential. The O-I part denoted the kinetics proportion for reduction/oxidation of the plastoquinone (PQ) pool (Guha *et al.*, 2013), whereas, the I-P phase revealed changes in the electron flux from reduced plastoquinone (plastoquinol PQ H_2) to the final electron acceptor of PSII (Guha *et al.*, 2013). The appearance of attenuated peaks in the I-P phase of OJIP transients was apparently caused by PSI associated limitations (Guha *et al.*, 2013; Munday *et al.*, 1969; Van Heerden *et al.*, 2007). The structural integrity and stability of PSII were largely maintained as reflected by the L and K bands (Fig. 3) and Δ voj, Δ voi and Δ vjp plots (Guha *et al.*, 2013). Rc/ABC (density of reaction center) was increased in cv. 'Bulbul-98' and decreased in cv. 'AC-Excel'. Data showed that maximum photosynthesis occurred in cv. 'Bulbul-98' and minimum in cv. 'AC-Excel'. According to values of performance index, cv. 'Faisal Canola' showed maximum values, while density of reaction center was greater in cv. 'Bulbul-98' and this cv. had also indicated maximum biomass production.

Conclusion

The present study demonstrated the existence of a wide variation in biological yield, protein content, assimilation of nutrients and components of seed yield in various cultivars of canola crop Maximum seed yield was harvested from cv. 'Rainbow'. The higher photosynthetic (PSII) activity and greater portioning ability of photo-assimilates was determined in cv. Rainbow. The various chlorophyll florescence parameters, quantum yield of photosystem II and electron transport performance index could be used as selection criteria for breeding of highly efficient canola cultivars.

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