*Turk J
Field Crops
2022, 27(2), 276-284
DOI: 10.17557/tjfc.1108917*

EXAMINATION OF AGRO-PHYSIOLOGICAL TRAITS OF DIFFERENT CULTIVARS OF MAIZE (*Zea mays*) WITH LEAF AND EAR TOPPING

Eshagh HOJATIPOUR[1], Hamidreza MIRI[1], Barmak JAFARI HAGHIGHI[1], Hamidreza EBRAHIMI[1], Abdolreza JAFARI[1]*

[1]Islamic Azad University, Faculty of Agriculture, Department of Agronomy, Arsanjan Branch, Arsanjan, IRAN
**Corresponding author: hmiri6@gmail.com*

Received: 25.04.2022

ABSTRACT

The current research aimed to examine the agro-physiological traits of different maize cultivars, with and without topping, in the two crop years of 2017-18 and 2018-19, for which a factorial randomized complete block design (RDBC) in three replications was devised. The research treatments included experimental groups of control samples, samples with topping of half of the ear after pollination, samples with topping of the two upper and lower leaves of the ear after pollination as the first factor, combined with seven maize cultivars of SC704, Consor, Cordona, Karaj 703, Kusha, Fajr and Daniyal 690 as the second factor. In the first and second years after preparing the substrate, the seeds of different cultivars were planted in the plots based on the research treatments. Topping operations were performed after pollination for all samples. The results showed that the highest value of stem height (168.6 cm) was obtained in the control treatment of the Karaj 703 cultivar. The highest weight of one thousand seeds (423.6 g) was obtained in the leaf-topping treatment of Karaj 703, and the highest amount of seed yield (1126 g m^2) was obtained in the leaf-topping treatment Consor cultivar. The highest amount of chlorophyll a (98.46 mg g fresh weight, FW), the highest amount of chlorophyll b (138.7 mg g FW), and the highest amount of carotenoid (74.33 mg g FW) were all obtained in the leaf-topping treatment of SC704 cultivar. The highest amount of catalase enzyme (58.73 mg protein min) was obtained in the control Fajr cultivar. However, the highest amount of peroxidase enzyme (173.4 mg protein min) and the highest activity of polyphenol oxidase enzyme (64.7 mg protein min) was obtained in the control treatments of the Kusha cultivar. The cultivar with optimal topping performance was proven to be the Consor cultivar.

Keywords: Agro-physiological Traits, Maize, Topping of Ear and Leaf

INTRODUCTION

Maize (*Zea mays* L.) is one the most cultivated crops worldwide, which is also of paramount strategic significance given its role in human and livestock nutrition. Being thermophilic, C4 carbon fixation, and efficient water consumption in comparison with other crops, among others, are the very features that have garnered a great deal of academic interest in maize (Imam and Niknejad, 1995). One of the prerequisites for achieving optimal yield is to provide favorable conditions for employing radiation to produce photosynthetic contents (Beheshti et al., 2002). Among the management-related factors, the amount of radiation in the environment is not under the control of the farmer, as it depends on the season, latitude, altitude, and atmospheric composition of the climate within which the plots are situated. However, the amount of radiation absorbed by the plant depends on the leaf area index (LAI), the durability of the leaf surface, and the spatial arrangement of the aerial organs of the plant (Tohidi et al., 2012).

Valentinuz and Tollenar (2004) reported that the rate of leaf senescence during the grain-filling period, while being a genetic trait, is also influenced by the environment and management factors; that is, decreasing temperature leads to a higher duration of the grain-filling period, lower seed growth rate, bigger seeds and, last but not least, more yield, a finding which has been reported by other researchers as well (Tollenar and Wu, 1999; Vargas et al., 2002). Therefore, any environment-induced tension that causes a decrease in plant photosynthesis during the grain filling period accelerates the process of physiological maturity (Emam, 2003). The production period of photosynthetic substances increases by delaying senescence. Cultivars boasting a longer photosynthetic material production period have a greater share of current photosynthetic materials in grain filling (Emam and Seghat al-Eslam, 2003).

Stewart et al. (2003) argued that maintaining LAI until the beginning of seed formation is positively correlated to seed yield. That is, the integral of the leaf area for the period of seed formation is more accurately correlated to grain yield than the maximum leaf area observed at any time. Hence, maintaining optimal LAI is as significant as the initial conditions of the crop year for plant growth. Tetiokago and Gardner (1998) reported that by removing the male inflorescence (corolla) and terminal leaves, the penetration of light into the maize vegetation is improved, and by increasing the amount of photosynthesis in the remaining leaves and ears, grain yield increases. Of course, several leaves are removed from the path of producing photosynthetic materials in this case, so the two reactions will be different determinants of yield. Alison and Watson (1996) reported that the four leaves in the middle of the maize plant (two upper leaves and two lower leaves of the ear) determine 50% of the dry matter of the ear, therefore receiving more light from these leaves may increase the yield of the plant. Therefore, various studies considered the manipulation of plant shading structure, including defoliation, according to these issues.

Allen (1983) examined the effect of topping maize plants and concluded that topping reduced the dormancy of the plants and thus increased the grain yield. Barnett and Pearce (1983) stated that defoliation after tillering reduced non-structural carbohydrates in maize, thereby increasing the use of stem carbohydrates for grain filling and increasing yield.

Considering the waning environmental conditions of the last few years in Iran, leading to country-wide drought, the yield of maize crops is at an all-time low, and it is essential to study it to increase its performance; this plant is one of the plants that have a long history of cultivation in the Shiraz region, and different cultivars of This plant has also been modified and introduced to farmers as a variety. However, based on the research, there has been no test on the growth and performance indicators of different cultivars of this plant in the mentioned area. Therefore, the current research aimed to examine the agro-physiological traits of different maize cultivars with leaf and ear topping.

MATERIALS AND METHODS

The current research was performed in two consecutive crop years, 2017-18 and 2018-19, in the agricultural lands of Shiraz, Iran, at geographical coordinates of 29° 25' N, 52° 35' E, and 1498 meters above sea level. Shiraz city is classified as a temperate semi-arid climate. In order to determine the physical and chemical characteristics of the soil where the research was carried out, soil samples were separately retrieved from five points at depths of 0 to 30 and 30 to 60 centimeters of the ground. After crushing and sieving the soil, the samples were mixed and sent to the laboratory for soil analysis.

In this study, a factorial experiment based on a randomized complete block design was used in 3 replications. The factors of the experiment include the removal of a leaf and a part of the cob in 3 levels: D1 (control), D2 (removal of half of the cob after pollination), and D3 (removal of two leaves at the top and bottom of the ear after pollination) as the first factor and seven maize cultivars of V1 (SC704), V2 (Consor), V3 (Cordona), V4 (Karaj 703), V5 (Kusha), V6 (Fajr), and V7 (Daniyal 690) were the second factors that cultivated in two consecutive crop years at the same site

Tillage and land preparation operations included irrigation before land preparation, a semi-deep plow after harrowing using two perpendicular discs, and leveling, hedging, ditching and plotting. The dimensions of the plots were 12 meters. In the spring of the first year, the fallow land was plowed after irrigation and tillage, and the clods were crushed by two disks perpendicular to each other, after which the land was ploughed. Based on the soil samples results, the required nitrogen fertilizer from the source of urea was weighed for each plot. Half of the nitrogen fertilizer was given to the ground when planting and mixed with the soil by hand rake. The remaining nitrogen fertilizer was also used as a complementary treatment in two stages, 1 and 2 months after cultivation. Phosphorus and potash fertilizers, that is, conventional superphosphate and potassium sulfate, were also spread on the surface of the plots and mixed with the soil before planting. The required seeds of different cultivars were prepared based on seven plants per square meter for the research plots. They were planted by hand in all plots equally in rows at a distance of 75 cm at the same time as the average air temperature reached 12 °C (on May 4 in the first year and May 9 in the second year) after disinfecting the seeds with Carboxin Thiram (Vitawax) fungicide. All treatments were irrigated once 50% of usable water was withdrawn, as determined by a tensiometer. After the completion of the pollination stage, the topping was performed based on the research treatments, during which the leaves and half of the ear were separated using scissors, and the rest of the ear was placed in the pod and closed. After growing and harvesting, the agricultural traits of carotenoid, chlorophyll a, b, catalase (CAT), peroxidase (POD), polyphenol oxidase (PPO) enzymes, stem height, 1000 kernel weight, and seed yield were measured. In the second year, the agricultural operation was repeated similarly. After collecting the required data, the analysis of variance and the comparison of the mean of the data were performed, following by mapping of correlation tables and causality and regression analysis.

In order to measure the concentration of Chl. a and b, carotenoid was measured according to the method Arnon (1975) recommended using a spectrophotometer (Zeletex Zx50) made in Germany. The concentration of Chl. a, b, and carotenoids were obtained according to the following formulas:

Chl. a (mg g FW) = [12.7(D663)-2.59(D645)] × V/1000 × W

Chl. b (mg g FW) = [22.9(D645) - 4.69(D663)] × V/1000 × W

Carotenoids (mg g FW) = [7.6(D480) – 14.9(D510)] × V/1000×W

Where D represents the absorption rate read from the samples at a specific wavelength by the spectrophotometer, V is the final volume of the sample extracted in 80% acetone, and W is the fresh weight of the leaf sample.

The method developed initially by Mac Adam et al. (1992) was used to measure POD enzyme activity, while CAT enzyme was measured using the method of Chance and Maehly (1995). Pyrogallol was used as a reagent to measure the PPO enzyme. Hence, one gram of fresh leaf was weighed and crushed using liquid nitrogen in a porcelain mortar. Three milliliters of the reaction mixture, including 25 mM phosphate buffer with 6.8 acidities and 10 mM Pyrogall,o, were added. Then, enzyme activity was measured at 420 nm wavelength based on the intensity of the orange color of Purpurogallin. The Molar attenuation coefficient for Purpurogallin was 2.47 $mm^{-1}\,cm^{-1}$ (Resende et al., 2002). The height of the stem was also measured using a graduated index from the base to the end of the corolla, and to determine the 1000 kernel weight, the seeds were separated from the ear and then dried and weighed using a digital scale. In order to determine the grain yield, the maize seeds on the harvested and dried ear were measured as grain yield.

Statistical analysis of the experimental data was done using SAS and MSTATC software, and average data comparison was made using Duncan's test (Steel and Torrie, 1980). Bartlett's test was also performed using GenStat software (Shirany Rad and Khany, 2000).

RESULTS AND DISCUSSION

Chlorophyll a

The mixed-design analysis of variance on research data indicated that the effect of year on Chl. a was significant at the statistical level of 1%. The simple and mixed effects of topping and cultivar on the mentioned trait were also significant at the statistical level of 1% (Table 1).

Table 1. Results of mixed ANOVA of agro-physiological traits.

Variable	DoF	Average of squares								
		Chlorophyll a	Chlorophyll b	Carotenoid	stem height	1000 k weight	Seed Yield	Catalase	Peroxidase	Polyphenol oxidase
Year	1	132.5**	1569.93**	718.6**	1.15ns	2498.9**	12686.14ns	99.3*	151.43ns	60.57**
Error (repetition x year)	4	0.11ns	4.54ns	38.93**	579.4**	361.26**	11566.7ns	0.2ns	25.2ns	4.39ns
Topping (D)	2	8735.5**	11983.86**	6143**	21001.8ns	24229.05**	718154.6**	4350.83**	13729.23**	3452.7**
Topping x year	2	0.114ns	38.28ns	1.06ns	8.09ns	0.0003ns	196.6ns	100.9*	227.6**	53.63**
Cultivar (V)	6	346.7**	409.2**	68.8**	281.09*	3052.07**	29102.7**	6.64ns	321.04**	50.6**
Year x cultivar	6	0.11ns	21.69ns	0.54ns	5.83ns	0.001ns	254.08ns	26.8ns	366.36**	34.18*
Topping x cultivar	12	246.7**	268.54**	32.17**	247.49*	3409.12**	45407.7**	100.46**	350.7**	65.5**
Year x topping x cultivar	12	0.11ns	39.36*	0.55ns	3.42ns	0.004ns	227.22ns	112.83**	500.8**	88.9**
Error	80	0.11	15.69	0.51	15.25	3.46	7810.7	13.26	25.17	4.46
Percentage of coefficient of variation		6.45	3.6	10.2	3	8.6	9.7	7.96	9.5	7.82

*: Significant at 1%; **: Significant at 5%; ns: Not significant

The comparison table of the average effect of simple topping on Chl. a showed that the highest amount of Chl. a was obtained in the leaf-topping treatment (88.42 mg g FW), and the lowest amount of Chl. a was witnessed in the control treatment (59.6 mg g FW). Moreover, examining the simple effect of cultivar on chlorophyll revealed that the highest amount of Chl. a was obtained in Daniyal 690 cultivar (80.02 mg g FW) while the lowest amount was witnessed in Fajr cultivar (67.31 mg g FW; Table 2).

Comparing the average mixed effects of topping and cultivar showed that the highest amount of Chl. a was obtained in the leaf-topping treatment of SC704 cultivar (98.46 mg g FW). In contrast, the lowest amount (40.93. mg g FW) was obtained in the control treatment of the Fajr cultivar (Table 3). The comparison table of research data indicated that SC704 and Fajr cultivars generated the highest and lowest reaction to topping treatment, respectively; that is, for all three topping treatment variations, the highest amount of Chl. a was obtained in the SC704 cultivar, while the lowest amount of Chl. a was obtained in all three topping treatment variations of the Fajr cultivar.

The amount of chlorophyll is directly related to the health and vitality of the plant. It is widely deemed as one of the most effective means for studying the effects of various stresses and variable environmental conditions on the physiological processes of plants (Jiang and Huang, 2001). The findings from the mixed-effects table revealed that SC704 and Fajr cultivars demonstrated the highest and lowest sensitivity to chlorophyll changes as the result of topping, respectively. Borras and Otegui (2002) studied maize kernel composition and post-flowering and source-sink ratio. They reported that the removal of the upper leaves of maize led to an increase in light penetration into the canopy and hence an increase in the concentration of chlorophyll. They also reported that defoliation of upper and lower leaves would lead to better chlorophyll performances, consistent with the results of the current study.

Chlorophyll b

The mixed-design analysis of variance on research data indicated that the effect of year on Chl. b was statistically significant at 5%. Furthermore, the simple effects of topping and cultivar and the mixed effect of the mentioned treatments on Chl. b were statistically significant at the 1% level (Table 1).

The results from the comparison table revealed that the highest amount of Chl. b was obtained in the leaf-topping treatment (125.9 mg g FW). The lowest amount of chlorophyll was witnessed in the control treatment (92.3 mg g FW). Moreover, examining the simple effect of cultivar on Chl. b revealed that the highest amount of Chl. b was obtained in the SC704 cultivar (117.6 mg g FW), yet the difference with the Daniyal 690 cultivar was not statistically significant. The lowest Chl. b was obtained in the Kusha cultivar (105.9 mg g FW), which was not significantly different from Fajr, Kordona, and Karaj 703 varieties and were in a single statistical class (Table 2).

Examining the results from comparing the average mixed effects of topping and cultivar showed that the highest amount of Chl. b was obtained in the leaf-topping treatment of SC704 cultivar (138.7 mg g FW), while the lowest amount was obtained in the control treatment of Kusha cultivar (80.6 mg g FW; Table 3). The comparison table of research data indicated that SC704 and Kusha cultivars generated the highest and lowest reaction to topping treatment, respectively.

The performance of any plant is the result of very complex processes that occur throughout growth. Among the factors involved in the performance of plants is the function of chlorophyll, which exhibits enhanced performance under optimal lighting as a result of improved photosynthesis-related function, ultimately leading to better yield (Azadi, 2018).

Amini (2013) showed that in barley genotypes, the rate of reduction of Chl. b under stress conditions is higher than that of Chl. a, which can be attributed to the amount of light-absorbing protein complex in photosystem II decreases drastically. Also, under different stress conditions, as the oxygen radicals in chloroplast are produced at higher rates, chloroplast membranes are degraded at higher rates. Malek Ahmadi et al. (2013) evidenced the significant effect of light on Chl. b, a finding consistent with those of the current study.

Carotenoid

The mixed-design analysis of variance on research data indicated that the effect of year on carotenoids was significant at the statistical level of 1%. The simple effects of topping and cultivar were significant at a 1% level on carotenoid levels. Also, the studies showed that the mixed effect of the treatments above on carotenoids was statistically significant at a 1% level (Table 1).

The results from the comparison table revealed that the highest amount of carotenoid was obtained in the leaf-topping treatment (60.31 mg g FW). The lowest amount of chlorophyll was witnessed in the control treatment (47.27 mg g FW). Moreover, examining the simple effect of cultivar on carotenoid also showed that the highest amount of carotenoid pertained to the SC704 cultivar (61.8 mg g FW). At the same time, the Daniyal 690 cultivar also exhibited statistically similar results. Furthermore, the lowest amount of carotenoid was obtained in the Cordona cultivar (56.7 mg g FW; Table 2).

Examining the results of comparing the average mixed effects of topping and cultivar showed that the highest amount of carotenoid was obtained in the leaf-topping treatment of the SC704 cultivar (74.33 mg g FW). In comparison, the lowest amount (45.35 mg g FW) was obtained in the control treatment of the Fajr cultivar, which did not show significant differences with the control treatment and Karaj 703 and Kusha cultivars (Table 3). The comparison table of research data indicated that SC704 and Fajr cultivars generated the highest and lowest reaction to topping treatment, respectively; that is, for all three topping treatment variations, the highest amount of carotenoid was obtained in the SC704 cultivar, while the lowest amount of carotenoid was obtained in all three topping treatment variations of the Fajr cultivar.

Although the synthesis of carotenoids is perceived to be not directly related to sunlight, it indirectly provides the necessary energy for the ensuing synthesis. Leaves exposed to light have more chloroplasts per unit of leaf area (Jalili-Marandi, 2010), which is more often than not attributed to the increase in the thickness of the tissue between the leaves, and the leaves that have many chloroplasts contain more carotenoids. Carotenoids are tetraterpene compounds responsible for protecting chlorophyll from photooxidation, absorbing light, and transferring energy to chlorophyll (Devlin and Whitman, 2002). They are also considered supporters of non-photosynthetic pigments, which can capture the energy of short wavelengths with increasing light intensity and convert singlet oxygen into triplet oxygen, hence their antioxidant functionality (Chaparzadeh et al., 2012). In the cells of green plants, carotenoids act as light receptors and cause the cell to use different wavelengths. Also, carotenoids protect the chlorophyll pigment contained in the cell from photo-oxidation damage against high radiation (Inze and Montagu, 2000).

Therefore, it can be seen that all the conducted research indicates an increase in the number of pigments due to the intensity of light. In the present research, in the defoliation treatments, the increase in light penetration led to an increase in the number of pigments.

Stem height

The results showed that the effect of year on stem height was insignificant. The simple effect of topping on this trait was insignificant. However, the simple effect of cultivar and the mixed effect of topping treatment and cultivar on stem height were significant at the statistical level of 5% (Table 1).

The comparison of the average effect of topping on stem height revealed that the maximum stem height was observed in the control treatment (159.02 cm), and the minimum stem height was evidenced in the leaf-topping treatment (154.9 cm). Also, the simple effect of cultivar on stem height showed that the highest stem height was obtained in the Consor cultivar (144.83 cm), and the lowest height pertained to Daniyal 690 cultivar (132.84 cm; Table 2).

The average comparison of the mixed effect of topping treatment and cultivar indicated that the highest stem height pertained to the control treatment of Karaj 703 cultivar (168.6 cm), while the lowest value was obtained for the leaf-topping treatment of Daniyal 690 cultivar (105.5 cm; Table 3).

Table 2. Results of the simple effect of treatments on agro-physiological traits.

Treatment		Mean of variables								
		Chlorophyll a (mg g FW)	Chlorophyll b (mg g FW)	Carotenoid (mg g FW)	Stem height (cm)	1000 k weight (g)	Seed Yield (g m^2)	Catalase (mg protein min)	Peroxidase (mg protein min)	Polyphenol oxidase (mg protein min)
Topping (D)	Control	59.6c	92.3c	47.27b	159.02a	302.5c	911.95b	55.09a	159.84a	62.43a
	Topping of half of the ear	75.21b	112.2b	47.3b	157.2a	337.3b	780.51c	47.31b	145.55b	57.22b
	Defoliation of two upper and lower leaves	88.42a	125.9a	60.31a	154.9a	348.6a	1042.04a	34.91c	123.93c	44.8c
Cultivar	SC704	79.32b	117.6a	61.8a	135.7d	330.7c	961.8ab	45.27a	136.5e	53.6cd
	Consor	72.7e	109.16b	58e	144.83a	325.5d	968.6a	46.45a	141.7cd	55.4b
	Cordona	73.12d	107.12bc	56.7f	142.11b	322.8e	909abc	45.8a	147.8a	57.3a
	Karaj 703	75.8c	107.2bc	60.2c	139.5bc	356.7a	901.6bc	45.8a	144bc	56.22ab
	Kusha	72.64e	105.9c	58.5d	138.5c	320.2f	882.7c	46.1a	145.54ab	55.01bc
	Fajr	67.31f	107.6bc	61b	139.82bc	318.5g	857.7c	46.32a	147.2ab	53.6cd
	Daniyal 690	80.02a	116.3a	61.35ab	132.84e	332.03b	899.7bc	44.72a	139.07de	52.54d

Sharifi and Tajbakhsh (2007) have reported that topping and defoliation is common practice in many parts of the world, which is performed for improved vegetative growth and better nutrition of reproductive organs. Topping in maize leads to more absorption and better light distribution inside the vegetation, leading to enhanced photosynthesis. Nakhzari Moghadam et al. (2012) further evidence that defoliation and topping in many crops causes a decrease in vegetative growth and the transfer of more photosynthetic content to the target site, including seeds. Therefore, control treatments often exhibit more growth to access light, owing to the decrease in the amount of light entering the lower canopy

Table 3. Results of the mixed effect of treatments on agro-physiological traits.

Treatment		Mean of variables								
Topping	Cultivar	Chlorophyll a (mg g FW)	Chlorophyll b (mg g FW)	Carotenoid (mg g FW)	Stem height (cm)	1000 k weight (g)	Seed Yield (g m^2)	Catalase (mg protein min)	Peroxidase (mg protein min)	Polyphenol oxidase (mg protein min)
D1	V1	68.16 l	102.1g	49.13j	158.6bcd	315.2h	857.9ej	44.6ef	160cd	55.21b
	V2	64.3n	97.94gh	48.83j	156cd	313.6h	984.6e	56.8ab	156.8cd	63.64a
	V3	63.36o	95.1h	47.63k	156cd	304.6i	857.1ej	54abc	155.2d	63.2a
	V4	58.5p	83.4i	45.87l	168.6a	295.6j	786k	56.03ab	164.4bc	63.71a
	V5	56.5q	80.6i	45.55l	163.6ab	292.4k	639.3m	58.63a	173.4a	64.7a
	V6	40.93r	82.9i	45.35l	159bc	281.8l	636.8m	58.73a	169.2ab	64.2a
	V7	65.6m	104fg	48.57jk	152.6de	314.6h	701.9l	57ab	140fg	62.4a
D2	V1	76.96g	111.9e	64.97e	139.7gh	325.7f	913.5h	52.2bcd	143.7fg	58.2b
	V2	73.96j	110.3ef	61.87f	143.6fg	318.4g	928g	48.1cde	145.5ef	57.2b
	V3	75.6h	111.3e	55.32i	146.5ef	319.8g	906.2h	47.82de	152.1de	57.16b
	V4	74.6i	112.6e	61.98f	152.5de	350.9c	913.2h	46.82de	145.2ef	56.71b
	V5	75.86h	111.1e	58.31g	136.3h	320.6g	920.4g	46.47de	145.9ef	58.3b
	V6	72.86k	114.4de	57.09h	143.4fg	326.7f	881.7i	45.9e	145.4ef	57.14b
	V7	76.76g	113.6de	62.64f	140.5fgh	326.4f	920.6gh	43.92ef	141.2fg	56b
D3	V1	98.46a	138.7a	74.33a	108.8k	351.2c	1019c	39.03fg	123.7hi	47.4cd
	V2	80.93f	119.3cd	68.08d	106.3k	344.5e	1126a	34.47g	122.8hi	45.4de
	V3	84.26e	114.9de	67.07d	125i	344e	1023c	35.62g	119.6hi	50.5c
	V4	94.26c	125.6bc	72.69bc	126.1i	423.6a	1006d	34.5g	122.4hi	43.22e
	V5	85.62d	126b	71.62c	115.5j	347.7d	1008d	33.14g	136.1g	48.24cd
	V6	80.46f	125.5bc	72.63bc	117.1j	347de	963.5f	34.37g	127h	39.42f
	V7	94.96b	131.3b	72.83b	105.5k	355.1b	1069b	33.27g	116.1i	39.3f
LSD%		0.54	6.45	1.16	3.56	3.03	143.8	5.93	8.17	3.44

D1: Control treatment; D2: topping of half of the ear; D3: Defoliation of two upper and lower leaves: V1: SC704; V2: Consor; V3: Cordona; V4: Karaj 703; V5: Kusha; V6: Fajr; V7: Daniyal 690

1000 kernel weight

The mixed-design analysis of variance showed that the effect of year on 1000-k weight was significant at the 1% level. The simple and mixed effects of topping and cultivar were also significant at the statistical level of 1% (Table 1).

The table comparing the average simple effect of topping on the 1000 K weight showed that the highest 1000 K weight was obtained in the leaf-topping treatment (348.6 g), and the lowest was obtained in the control treatment (302.5 g). This research was carried out in the same condition of all sources and production factors except the amount of light, and with other factors being constant, the amount of light had a positive effect on the weight of a thousand seeds. The simple effect of the cultivar on the 1000 K weight also implied that the highest amount of 1000 kernel weight was obtained in the Karaj 703 cultivar (356.7 g), the minimum of which was witnessed in the Fajr cultivar (318. 5 g; Table 2). The findings on the average mixed effect of topping treatment and cultivar for the 1000 K weight showed that the highest 1000 K weight pertained to the leaf-topping treatment of Karaj 703 cultivar (423.6 g) and the lowest 1000 K weight pertained to the control treatment of Fajr cultivar (281.8 g; Table 3).

Sharifi and Tajbakhsh (2007) argue that in topping-less treatments, the canopy-induced competition between plants in absorbing radiation leads to lower seed weights, but since defoliation leads to the increase of light penetration into the cover plants, generating a better light environment and increasing the photosynthetic efficiency of the leaves close to the ear, the weight of the cob seeds increases. Therefore, the results of this research are consistent with the results of the mentioned researchers regarding the thousand seed weight trait.

Seed yield

The results showed that the effect of year on grain yield was not significant, yet simple and mixed effects of topping and cultivar on yield were statistically significant at the 1% level (Table 1). The effect of simple topping on seed yield showed that the highest seed yield related to the leaf-topping treatments (1042.04 g m^2) and the lowest seed yield (780.51 g m^2) pertained to the ear-topping treatment. The simple effect of the cultivar on grain yield also showed that the highest grain yield was obtained in the Consor cultivar (968.6 g m^2). Nevertheless, it was not statistically different from yields of SC704 and Cordona cultivars. The lowest seed yield (857.7 g m^2) was obtained in the Fajr cultivar, yet yields from Karaj 703, Kusha, and Daniyal 690 cultivars were statistically similar (Table 2). The difference in grain yield in the cultivars studied can be attributed to the genetic difference of the cultivars. A comparison of the average mixed effect of topping and cultivar showed that the highest yield was witnessed in the leaf-topping treatment of Consor (1126 g m^2), while the lowest yield pertained to the control treatment of Fajr cultivar (636.8 g m^2; Table 3). The experimental design of the study was such that two leaves from the upper end and lower end of the maize ear were defoliated to increase lighting accessibility to the lower levels canopy, the purpose of which would be to enhance photosynthesis and hence, grain yield.

Given that the authors have exercised due diligence to make the growth conditions constant throughout the research period, any change in the yield can be attributed to those lighting levels. All that being said, topping operations seemed to generate the most significant response in the Consor cultivar regarding grain yield. In contrast, the Fajr cultivar exhibited the lowest value in all three topping treatments, and the sensitivity of these cultivars to topping was higher than other cultivars. Tilahun (1993) showed in various experiments that the yield of maize seeds has a direct relationship with the number of leaves, yet only in case, there is enough light for the leaves at the bottom of the canopy. Otherwise, the maximum reduction in yield occurs when all the leaves are defoliated within a few days after the flowering period. Nevertheless, the evidence from the current research suggests that other variables held constant, particularly those of lighting, defoliation leads to a decrease in yield, yet topping three leaves of the plant has a significant effect on the yield, provided that the penetration of light to the lower layers of the canopy increases.

Catalase

The results from the mixed analysis of variance showed that the effect of year on the average CAT enzyme was significant at the statistical level of 5%. The simple effects of cultivar on this enzyme were insignificant. However, the simple effect of topping and the mixed effect of topping treatment and variety on CAT enzyme were significant at the statistical level of 1% (Table 1).

The results from the table comparing the average effect of simple topping on CAT indicated that the highest amount of CAT pertained to the control treatment (55.09 mg protein min) and the lowest amount of CAT (34.91 mg protein min) pertained to the leaf-topping treatment the treatment of removing the upper and lower leaves of the cob. The simple effect of cultivar on CAT also showed that there is no statistically significant difference between the cultivars for this trait; all cultivars exhibited statistically similar performances (Table 2). Considering the activity of antioxidant enzymes in the plant as a result of different stresses, the change in the level of these enzymes in this research can be attributed to defoliation-related stresses.

The results from the mixed effect table also showed that the highest amount of CAT enzyme was evidenced for the control treatment of the Fajr cultivar (58.73 mg protein min). In comparison, the lowest amount (33.14 mg protein min) pertained to the leaf-defoliation treatment of the Kusha cultivar. Also, there was no significant difference between different cultivars for this trait in the leaf-defoliation treatments (Table 3).

As Neto et al. (2005) stated, this enzyme effectively reduces oxidative damage caused by stress by detoxifying reactive oxygen species (ROS), such as hydrogen peroxide, and its catalysis to water and oxygen. Under specific stresses, some reactive oxygen species (hydrogen peroxide, superoxide, and hydroxyl radicals) accumulate in the plant. Oxygen species create secondary oxidative stress by peroxidation of lipids, destruction of proteins, etc., which leads to severe damage to cellular structures (Sharma and Dubey, 2005). One of the non-enzymatic coping mechanisms for dealing with oxidative stress induced by plant stresses is the accumulation of phenolic compounds. Phenolic compounds act as free radical scavengers and make plants resistant to oxidative stress (Schaller and Kieber, 2002). The results of this research regarding CAT enzyme are consistent with the results of Amini (2008), and Sharma and Dubey (2005).

Peroxidase

The mixed analysis of variance showed that the effect of year on the mean of POD enzyme was insignificant. Nevertheless, the findings indicated that the simple and mixed effects of topping and cultivar on POD enzyme were significant at the statistical level of 1% (Table 1).

The comparison table of the average effect of simple topping on POD showed that the highest amount of POD was obtained in the control treatment (159.84 mg protein min). In comparison, the lowest amount of POD (123.93 mg protein min) was witnessed in the leaf-topping treatment. The simple effect of the cultivar on POD also showed that the highest amount of POD (147.8 mg protein min) was obtained in the Cordona cultivar. At the same time, the Fajr cultivar also exhibited similar performance. As such, the evidence suggests that the capacity of different cultivars to produce the amount of POD enzyme is different, which can be attributed to the genetics of the cultivar. The lowest amount of POD (136.5 mg protein min) was obtained in the SC704 variety, yet the Daniyal 690 cultivar also generated similar results (Table 2).

The results from comparing the mixed effect of topping treatment and cultivar indicated that the highest amount of POD enzyme pertained to the control treatment of Kusha cultivar (173.4 mg protein min) and the lowest amount (116.1 mg protein min) was witnessed in the defoliation treatment of Daniyal 690 cultivar. Furthermore, the findings indicated no significant difference between cultivars under the leaf-topping treatment in terms of POD (Table 3). According to the average comparison table of research data, in all three levels of topping treatment, the highest amount of POD enzyme was obtained in the Kusha cultivar, and this shows the capacity of this variety to produce this enzyme in different topping treatments. In comparison, the lowest amount of POD in all three levels of topping treatment was obtained in Daniyal 690 cultivar.

One of the effects of stress, especially dehydration, is oxidative damage, which is perceived to be administered by ROSs such as hydrogen superoxide radicals and hydroxyl radicals. Plants have different mechanisms for alleviating the harmful effects of reactive oxygen species, among which is the antioxidant defense system. Enzymes that play a role as antioxidants in cleaning the free radicals of the cell include CAT, superoxide dismutase, and ascorbate POD, among others (Amini et al., 2008). Decreased CAT and ascorbate POD activity can lead to the accumulation of hydrogen peroxide and hence decelerate the activity of some Calvin cycle enzymes such as phosphoribulokinase (PRK) and ribulose-1,5-bisphosphate carboxylase (Rubisco). The superoxide dismutase enzyme converts the superoxide radical into hydrogen peroxide, and the decrease in the activity of the superoxide dismutase enzyme leads to the accumulation of the superoxide radical. This radical can combine with hydrogen peroxide and produce hazardous hydroxyl radicals (Srivall and Khanachupra, 2004).

Nevertheless, Sharma and Dubey (2005) argued that the functioning of the POD enzyme indicates the relative abundance of the protein, which is partly owing to the increased expression of the genes encoding the POD enzyme or the stability of the protein molecules of this enzyme against oxidative degradation.

Polyphenol oxidase

The analysis of variance showed that the effect of year on the activity of PPO enzyme was significant at the statistical level of 1%. In addition, the simple and mixed effect of topping and cultivar on the mentioned trait was significant at the statistical level of 1% (Table 1).

The comparison table of the simple effect of topping on PPO showed that the highest amount of PPO was obtained in the control treatment (62.43 mg protein min). In comparison, the lowest amount of PPO was witnessed in the leaf-topping treatment (44.8 mg protein min). It was obtained when removing two upper and lower leaves of the cob. The simple effect of the cultivar on PPO also showed that the highest amount of PPO (57.3 mg protein min) was obtained in the Cordona cultivar, which was statistically similar to that of the Karaj 703 cultivar. The lowest amount of PPO (52.54 mg protein min) was obtained in Daniyal 690 cultivar, yet SC704 and Fajr cultivars revealed similar performances (Table 2).

The results of the comparison of the mixed effect of topping and cultivar showed that the highest amount of PPO enzyme activity pertained to the control treatment of the Kusha cultivar (64.7 mg protein min) and the lowest amount was witnessed in the treatment of leaf topping treatment of the Daniyal 690 cultivar (39.3 mg protein min; Table 3). Based on the average comparison table of research data, for all three levels of topping treatment, the highest amount of PPO enzyme was obtained in the Kusha cultivar, and the lowest amount of PPO was also obtained in all three levels of topping treatment in Daniyal 690 cultivar.

Afsharnia et al. (2012) noted the increased antioxidant enzymes due to light stress. In addition, they reported that intense light led to increased plant growth and zinc absorption in shoots and roots compared to a lesser light. Furthermore, cell defense mechanisms play an essential role in the optimal implementation of cell metabolism and preventing the oxidation of biological materials, and as such, understanding these processes and their behavioral patterns can provide helpful information to crop plant physiologists about the role of leaves with different ages in production and yield physiology.

Correlations of studied variables

Ultimately, the findings of the research indicated that there is a negative and significant relationship between stem height and 1000 kernel weight (r=-0.576), grain yield (r=-0.655), Chl. a (r=-0.859), Chl. b (r=-0.809) and carotenoid (r=-0.869) while having a positive and significant correlation with CAT (r=0.742), POD (r=0.778) and PPO (r=0.793). In addition, 1000 kernel weight has a negative and significant relationship with CAT (r=-0.557), POD (r=-0.485) and PPO (r=-0.541) while bearing a positive and significant relationship with seed yield (r=0.517), Chl. a (r=0.619), Chl. b (r=0.549) and carotenoids (r=0.676). Seed yield, nevertheless, generated a negative and significant relationship with CAT (r=-0.746), POD (r=-0.719) and PPO (r=-0.703) while exhibiting a positive and significant and relationship with Chl. a (r=0.731), Chl. b (r=0.646) and carotenoid (r=0.682). Chl. a demonstrated a positive and significant relationship with Chl. b (r=0.798) and carotenoid (r=0.871) and a negative and significant relationship with CAT (r=-0.745), POD (r=-0.753) and PPO (r=-0.732). Chl. b had a positive and significant relationship with carotenoid (r=0.712) while having a negative and significant correlation with CAT (r= -0.613), POD (r=-0.765) and PPO (r=-0.663). There is a negative and significant relationship between carotenoid and CAT(r=-0.801), POD (r=-0.731), and PPO (r=-0.802). There is a positive and significant correlation between CAT, POD (r=0.791), and PPO (r=0.857). In addition, POD showed a positive and significant relationship with PPO (r=0.870) (Table 4).

Table 4. Matrix of correlation coefficients of traits.

Traits	stem height	1000 k weight	Seed Yield	Chlorophyll a	Chlorophyll b	Carotenoid	Catalase	Peroxidase	Polyphenol oxidase
Stem height	1								
1000 k weight	-.576**	1							
Seed Yield	-.655**	.517**	1						
Chlorophyll a	-.859**	.619**	.731**	1					
Chlorophyll b	-.809**	.549**	.646**	.798**	1				
Carotenoid	-.869**	.676**	.682**	.871**	.712**	1			
Catalase	.742**	-.557**	-.746**	-.745**	-.613**	-.801**	1		
Peroxidase	.778**	-.485**	-.719**	-.753**	-.765**	-.731**	.791**	1	
Polyphenol oxidase	.793**	-.541**	-.703**	-.732**	-.663**	-.802**	.857**	.870**	1

*, ** Significant at 5% and 1% level respectively.

CONCLUSION

The current research aimed to examine the agro-physiological traits of different maize cultivars, with and without topping, in the two crop years of 2017-18 and 2018-19. The results showed that the highest value of stem height (168.6 cm) was obtained in the control treatment of the Karaj 703 cultivar. The highest weight of one thousand seeds (423.6 g) was obtained in the leaf-topping treatment of Karaj 703, and the highest amount of seed yield (1126 g m^2) was obtained in the leaf-topping treatment of the Consor cultivar. The highest amount of Chl. a (98.46 mg g FW), the highest amount of Chl. b (138.7 mg g FW), and the highest amount of carotenoid (74.33 mg g FW) were all obtained in the leaf-topping treatment of SC704 cultivar. The highest amount of CAT enzyme (58.73 mg protein min) was obtained in the control Fajr cultivar. However, the highest amount of POD enzyme (173.4 mg protein min) and the highest activity of PPO enzyme (64.7 mg protein min) was obtained in the control treatments of the Kusha cultivar. The findings further revealed that under various environmental stresses such as drought, salinity, and lack of light, the ensuing increase of oxygen radicals leads to heightened levels of antioxidant enzymes. The correlation matrix between Chl. a, Chl. b, and carotenoid traits were calculated, which indicated that growth had a significant direct correlation with protein, Chl. a, and Chl. b at a 1% significance level.

Furthermore, findings indicated that seed yield has a significant negative relationship with stem height and a significant positive relationship with the weight of 1000 seeds. Thousand seed weight has a significant positive relationship with stem height. In addition, stem height showed a significant positive relationship with the weight of 1000 seeds. The cultivar with optimal topping performance was proven the Consor cultivar.

LITERATURE CITED

Afsharnia, M., A. Asgharzad, R. Haji Boland and Sh. Ostan. 2012. Light intensity, Zn deficiency and the activity of antioxidant enzymes and maize photosynthesis. Iran J. Soil. Res. 27(2):149-158.

Alison, J.C.S. and D.J. Watson. 1996. The production and distribution of dry matter in maiz after flowering. Ann. Bot. 30:365-381.

Allen, R.R. 1983. Topping corn and delaying harvest for field drying. Field Crop Abstract. 36:467.

Amini, S. 2013. The effect of potassium and drought stress on re-transfer of reserves from vegetative organs of barley and its contribution to grain filling. MSc thesis, Islamic Azad University of Ahvaz.

Amini, Z., R. Haddad and F. Moradi. 2008. Effect of water deficit on the activity of antioxidant enzymes in plant reproductive development Barley. Sci. Technol. Agric. Nat. Resour. 12:46-58.

Arnon, D.I. 1975. Copper enzymes increased isolated chloroplast polyphenoxidase increased Beta vulgaris L. Plant Physiol. 45:1-15.

Azadi, A. 2018. The effect of planting date and cultivar yield components and morphological and physiological characteristics of lentils under water stress conditions. PhD Thesis, The Islamic Azad University of Ahvaz.

Barnett, K.H. and R.B. Pearce. 1983. Source sink ratio alteration and its effect on physiologyical parameters in maize. Crop Sci. 23:294-299.

Beheshti, A., A. Koochaki and M. Nassiri Mahallati. 2002. The effect of planting pattern on light interception and radiation use efficiency in canopy of three maize cultivars. Seed Plant. 18(4):417-431.

Borras, L. and D. Otegui. 2002. Maize kernel composition and post flowering and source sink Ratio. Crop Sci. 42:780–790.

Chance, B. and A.C. Maehly. 1995. Assay of catalases and peroxidases. Meth. Enzymol. 11:764-755.

Chaparzadeh, N., L. Rahimpourshefai, M. Dolati and A. Barzegar. 2012. Age-dependent pigment changes in Rosa hybrid leaves. Plant Res. J. (Iran Biol. J.) 26(2):281-289.

Devlin, M.R. and F.H. Withman. 2002. Plant Physiology. CBs publishers and distributers.

Emam, Y. 2003. Graminea Agronomy. Shiraz Daneshgahi Press (In Persian).

Emam, Y. and M.J. Seghateleslami. 2003. Crop yield. Shiraz Daneshgahi Press. (In Persian)

Imam, Y. and M. Niknejad. 1995. An introduction to the physiology of crop plant performance (translation). Shiraz University Press.

Inze, D. and M.V. Montagu. 2000. Oxidative stress in plants. Cornawall Great Britain.

Jalili-Marandi, R. 2010. Physiology of environmental stresses and resistance mechanisms in garden plants. Urmia branch Academic Jihad Publications.

Jiang, Y. and N. Huang. 2001. Drought and heat sress injury to two cool-season turfgrasses in relation to antiaxdant metabolism and lipid peroxidation. Crop Sci. 41:436-442.

Mac-Adam, J.W., C.J. Nelson and R.E. Sharp. 1992. Peroxidase activity in the leaf elongation zone of tall fescue. Plant Physiol. 99:872-878.

Malek Ahmadi, F., M. Kalantari and M. Torkzade. 2013. The effect of waterlogging stress on the induction of oxidative stress and concentration of elements in pepper plant (*Capscicum annum L*). Iran J. Biol. 18(2):111-119.

Nakhzari-Moghadam, A. 2012. The effect of topping and plant density on yield and its components in Barkat bean variety in Gonbad Kavus region. Sci. Agric. Plants Iran. 44(4):703-710.

Neto, A., D. Gomes and E. Filo. 2005. Effect of salt stress on antioxidant and lipid peroxidation in leaves and roots of salt tolerance and salt sensitive maize genotype. Environ. Exp. Bot. 56(1):87-94.

Resende, M.L.V., G.B.A. Nojosa, L.S. Cavalcanti, M.A.G. Aguilar, L.H.C.P. Silva, J.O. Perez, G.C.G. Andrade, G.A. Carvalho and R.M. Castro. 2002. Induction of resistance in cocoa against Crinipellis perniciosaand Verticillium dahliaeby acibenzolar-S-methyl (ASM). Plant Pathol. 51:621-628.

Schaller, G. and J. Kieber. 2002. Ethylene. The American Society of Plant Biologists.

Sharifi, P. and M. Tajbakhsh. 2007. Effect of topping after pollination and plant density on maize yield and its components. Sci. Technol. Agric. Nat. Res. 11(41):237-244.

Sharma, P. and R.S. Dubey. 2005. Drought induces oxidative stress and enhances the activities of antioxidant enzymes in growing rice seedlings. Plant Growth Regul. 46:209-221.

Shirany Rad, A.H. and M. Khany. 2000. Statistical Designs in Agricultural Research. Tehran Dibagaran Artistic and Cultural Institute Publication. (In Persian)

Sinclair, T.R. and R.C. Muchow. 1999. Radiation use efficiency. Adv. Agron. 65:215-265.

Srivall, B. and R. Khanna-Chopra. 2004. The developing reproductive sink induces oxidative stress to mediate nitrogen mobilization during momocarpic senescence in wheat. Biochem. Biophys. Res. Commun. 325:198-202.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of Statistics. McGaw-Hill Book Company, Inc. N.Y.

Stewart, D.W., C. Costa, L.M. Dwyer, R.I. Smith, D.L. Hamilton and B.L. Ma. 2003. Canopy structure, light interception and phothosynthesis in maize. Agron. J. 95:1465-1474.

Tetio Kagho, F. and F.D. Gardner. 1998. Responses of maize to plant population density: reproductive development. Yield adjustment. Agron. J. 72:225-226.

Tilahun, A. 1993. Quantitive and physiological traits in maize (*Zea mays L.*) associated with different levels of moistuer, plant density and leaf defoliation in Ethiopia. Agric. Sci. 11:74-80.

Tohidi, M., A. Nadery, S. Siadat and S. Lak. 2012. Variable productivity of light interception in grain maize hybrids at various amounts of nitrogen. World Appl. Sci. J. 16:86-93.

Tollenar, M. and J. Wu. 1999. Yield improvement in temperate maize is attributable to greater stress tolerance. Crop Sci. 39:1597-1604.

Valentinuz, O. and M. Tollenar. 2004. Vertical profile of leaf area and leaf senescence during the grain- filling period in maize. Crop Sci. 44:827-834.

Vargas, L.A., M.N. Andersen, C.R. Jensen and V.J. Orgenses. 2002. Estimation of leaf area index, light interception and biomass accumulation of Miscanthus sinensis 'Goliath' from radiation measurements. Biomass and Bioenergy 22:1-14.