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Stability and anatomical parameters of irradiated potato cultivars under drought stress

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ABSTRACT

This study was carried out in Desert Research Center and Faculty of Agriculture, Zagazig University, Egypt, under North Sinai conditions during three growing seasons, i.e., summer 2018, fall 2018/2019 and summer 2019 to assess the effect of radiation mutants on leaf histological features and genetic stability of the productivity of some potato cultivars under drought stress conditions. Results reveal that the genotypes can be statistically classified based on regression coefficient (b_i), deviation from regression (S^2_{di}) to 4 groups (with low in S^2_{di} are considered in all groups) as: (i) Genotype with elevated average, $b_i = 1$, it is considered as stable genotype where Cara cultivar (both generations) was included. (ii) Genotype with elevated average, $b_i > 1$ as genotype with average stability where spunta cultivar was involved. (iii) Genotype with low mean, $b_i < 1$ as genotype with low stability where hermes (both primary (M_1) and secondary (M_2) radiated generations) and Caruso (2nd generation) cultivars were involved. (iv) Genotypes including a few b_i values in one generation, as genotype including low stability but are not recommended for use in this generation where Caruso cv in M_1 was included. The results indicated that 20 Gy irradiation exposure revealed that Spunta cultivar produced markedly high mean combined over yield during M_1 (11.771 ton/fed) and M_2 (10.97 ton/fed) generations than other genotypes and ranked first over all environments. It proves that Hermes could be employed as anti-stress genotypes under stress conditions (negative conditions or poor yielding). However, spunta followed by cara cv. represented a good performance in M_2 production yield (10.97 and 8.51 ton/fed, respectively), slight drift from the regression line and coefficient close to 1, therefore, both cultivars were excellent between genotypes in shape of yield stability and is recommended for different conditions. According to anatomical studies, 80 % from field capacity (FC) decreased the thickness of medvein and lamina of potato cv. spunta, also, dimensions of medvein bundle and mean diameter of vessels. In conclusion, plants treated with gamma ray at level 20 and grown under 80 % FC induced prominent increase in all previous characters.

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1. Introduction

Potato (*Solanum tuberosum* L.) belongs to Solanaceae family. It is one of the most serious dicotyledonous tuber crops and represents large global socio-economic impact. Potato is the 5th significant crop globally and it grows on 49 million ha, with productivity of around 377 million tons per year (Zia et al., 2018). The most used potato (*Solanum tuberosum* L.) is an autotetraploid ($2n = 4x = 48$) that displays tetrasomic inheritance (Muthoni et al., 2015). The potato represents highly heterozygous individuals which suffer

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inbreeding depression upon selfing. Due to their tetrasomic inheritance and high degree of heterozygosity, tetraploid potatoes can be very productive and stable in different conditions compared with their diploid counterparts (Muthoni et al, 2015). The aim of the plant breeding is to change and improve the genetic feature of plants to meet human demands. Success in breeding new potato cultivars, utilizing these resources, has been slow, mainly because the difficulty of hybridization and highly heterozygous (Bado et al., 2016). Most of the researchers are still working on variant aspects of mutation breeding such as salt tolerance, drought tolerance, heat tolerance and for quality amelioration of potatoes and most of them have succeeded in obtaining the wanted properties (Zia et al., 2018).

The morphology, physiology and biochemistry of plants are differentially affected by low-dose gamma ionizing radiation that is associated with the tolerance of plant species under biotic/abiotic stress. In study of Beyaz, (2020) on the Impact of gamma irradiation pretreatment on the growth of common vetch (*Vicia sativa* L.) seedlings grown under salt and drought stress. The author clearly show that exposure to gamma irradiation pretreatment (100 Gy), alone or in combination with salt stress and drought stress, led to significant increases ($p < .01$) in dry matter accumulation, CAT, SOD and APX activities, proline contents and decreases in relative water content.

Potato (*Solanum tuberosum* L.) is a drought sensitive crop and its continuous production is threatened because of drought episodes. There are different trials aiming to know the physiological, biochemical and genetic basis of drought tolerance in potato as a basis for amelioration productivity under drought circumstances (Obidiegw, et al., 2015). A Successful cultivar must have good and reliable yield over the variety of ecosystem. The base of differences in stability between cultivars is a wide occurrence of genotype by environmental interactions ($G \times E$). Cultivars are determined neither by their genes nor their environment; they are the interaction of genes and environment, (Raja., et al. 2018). The aim of this work was to evaluate differential responses of potato cultivars treated using gamma rays under environmental stress factors.

2. Materials and methods

2.1. Experimental conditions

This experiment was adopted in the Experimental Farm of Baloza station, Desert Research Center, North Sinai Governorate Egypt and Horticulture Dept., Fac. Agric., Zagazig Univ., during three growing seasons, i.e., summer 2018, fall 2018/2019 and summer 2019 to assess the effect of radiation mutants on leaf histological features and genetic stability of the productivity of some potato cultivars exposed to drought stress. The physiochemical characteristics of the tested soil as well as chemical analyses of the irrigation water are presented in Table 1.

Climate and reference evapotranspiration data of Baloza region were obtained from the Center Laboratory for Agricultural Climate (CLAC), A.R.C., Egypt during growing seasons of summer 2018, fall 2018/2019 and summer 2019 were observed in Fig. 1.

2.2. Plant materials

Dry tubers of four potato cultivars (*Solanum tuberosum* L.), i.e., spunta, cara, caruso and hermes (Table 2) were exposed to gamma rays and were sown immediately after irradiation in the open field under full irrigation on 11th February 2018 to obtain M_1 generation seeds.

2.3. Gamma irradiation treatment

Dry tubers of all cultivars were exposed to three levels gamma rays, i.e., 20, 30 and 40 Gy in Egyptian Atomic Energy Authority (EAEA).

2.4. Field experiment

2.4.1. M_1 Generation (fall season of 2018/2019)

The irradiated and non-irradiated (control) tubers (M_0) were sown under drought stress (100, 80, and 60 % from field capacity) on 1st October 2018. The trial involved 48 treatments, which were the mixing between four irradiation doses, 3 irrigation levels and 4 potato cultivars using Split-split plot arranged in a randomized complete block design including 3 replications. The main plots were randomly assigned to the irrigation levels, cultivars and gamma-irradiation treatments were arranged over the sub- and sub-sub plot, respectively. In harvest, three tubers were taken from each M_1 plant for sowing of the following M_2 generation.

2.4.1.1. M_2 Generation. Tubers of M_1 generation were sown on 3rd March 2019. Split-split plot design with 3 replications was used as in previous generation and all cultural practices were used as recommended.

The trial unit area was 12.6 m². Each plot includes three dripper lines 6 m length each and 0.70 m distance between the two dripper lines. One line was used to evaluate the leaf histological features and the rest 2 lines were used for yield estimation. Plus, one row was left between them as guard area to exclude the overlapping infiltration of irrigation water. Farmyard manure (FYM) at 30 m³/feddan were used during soil handling. All treatments received N₁₂₀, P₈₀, K₁₀₀ as ammonium sulfate (20.6 % N), calcium super phosphate (15.5 % P₂O₅) and potassium sulfate (48–52 % K₂O), respectively. One third of both N and K₂O as well as all P₂O₅ doses were supplied during soil preparation with FYM. The rest of N and K₂O (two thirds) were supplied as fertigation at 4 days interval starting 30 days after planting. All the agricultural practices were adopted following the district of this investigation.

2.5. Data collection

At maturity stage of both M_1 and M_2 generations, the samples were collected from each treatment to analyze the total yield/fed (Desoky et al., 2020a, 2020b), and the relative increases in total yield/fed. over control.

2.6. Anatomical evaluation

A comparative microscopically testing was adopted on plant material for treatment which revealed significant response. In addition to the control, tested material the lamina of the terminal leaflet of the corresponding structure leaf growth on the center portion of the main stem of potato. Specimens were taken throughout the fall growing season of 2018/2019 at the age of 55 days from sowing date. Samples from control and selected treatment were fixed for at least 48 hrs. in F.A.A. (10 ml formalin, 5 ml glacial acetic acid and 85 ml ethyl alcohol 70%). The chosen substances were washed in 50% ethyl alcohol, dehydrated in a normal butyl alcohol series, soaked in paraffin wax of melting point 56 °C, divided to 20 μm (μm) thickness, double stained with safranin and fast green, cleared in xylene and mounted in Canada balsam (Nassar and El-Sahhar, 1998). Sections were investigated to detected histological changes of the selected treatments and photomicrography made.

Table 1
Some soil physical and both soil and water chemical characteristics.

Physical characteristics			Chemical analysis for both soil and irrigation water		
Content		Soil	Content	Soil	Water
Particle size distribution (%)	Sand	87.91	pH	8.15	7.15
	Silt	7.13	EC (ds/m)	4.62	1.21
	Clay	4.96	CaCO ₃ %	5.39	–
Texture			CEC meq /100 g	7.51	–
	OM (%)	Sandy	SAR*	–	3.19
ρ _b (g/cm ³)		0.25	Soluble cations, meq/l	Na ⁺	19.34
K _s (cm/h)		1.54		K ⁺	2.79
FC (%)		11.12		Ca ⁺⁺	13.42
WP (%)		10.68		Mg ⁺⁺	10.65
AW (%)		6.93	Soluble anions, meq/l	Cl ⁻	19.49
				HCO ₃ ⁻	2.95
				CO ₃ ⁻	–
				SO ₄ ⁻	23.76
					4.97

* Sodium Adsorption Ratio.

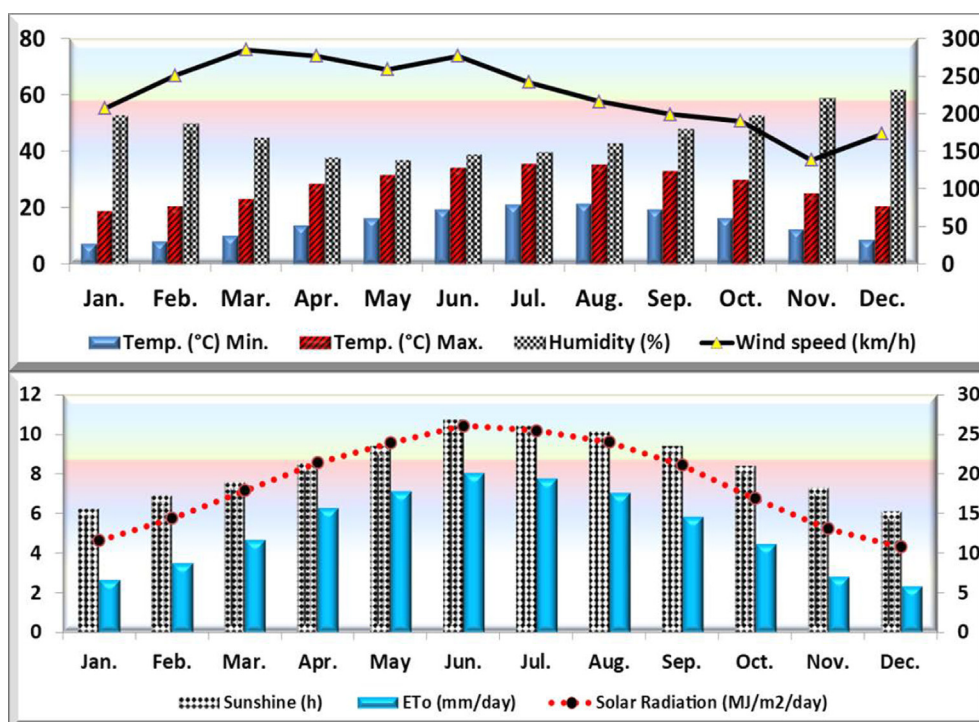


Fig. 1. Climate and reference evapotranspiration data of Baloza area.

Table 2
Pedigree of tested potato cultivars.

Potato cultivar	Code	Origin	Imported by	Objective	Maturity date
Spunta	G1	Holland	Daltex Co.*	Table	Medium Early
Cara	G2	England	UPEHC**	Table	Late
Caruso	G3	Germany	Daltex Co.	Processing	Late
Hermes	G4	Scotland	Daltex Co.	Processing	Med. Early to Med. Late

* Daltex Co.: 42 Wadi Al Nile, Gazirat Mit Oqbah, Agouza, Giza Governorate.

** UPEHC: Union Producers and Exporters of Horticultural Crops: 7 Nady El Seid St., Dokki – Giza – Egypt.

2.7. Stability studies:

To examine the magnitude of genotype-environment interactions, the yield trial of four cultivars were studied over 12 different environments. These environments (Env) were **Env₁**: 100% FC × Zero Gy, **Env₂**: 100% FC × 20 Gy, **Env₃**: 100% FC × 30 Gy, **Env₄**: 100% FC × 40 Gy, **Env₅**: 80% FC × Zero Gy, **Env₆**: 80% FC × 20 Gy, **Env₇**: 80% FC × 30 Gy, **Env₈**: 80% FC × 40 Gy,

Env₉: 60% FC × Zero Gy, **Env₁₀**: 60% FC × 20 Gy, **Env₁₁**: 60% FC × 30 Gy, **Env₁₂**: 60% FC × 40 Gy (Table 3).

2.8. Statistical analyses

To show the genotype by environmental response impacts, a combined estimation of variance was used across the 12 different circumstances as mentioned by Steel et al., (1997) using SAS soft-

Table 3
Environmental Means over all studied potato cultivars during 1st (M_1) and 2nd (M_2) mutant generations.

Environment	Water level	Gamma rays	M_1	M_2
Env-1	100-FC%	Zero (control)	9.035	7.785
Env-2		20 Gy	9.315	8.534
Env-3		30 Gy	8.024	7.333
Env-4		40 Gy	8.196	7.347
Env-5	80 FC%	Zero (control)	7.6022	8.098
Env-6		20 Gy	7.699	8.295
Env-7		30 Gy	7.086	7.248
Env-8		40 Gy	7.241	6.981
Env-9	60 FC%	Zero (control)	8.991	8.940
Env-10		20 Gy	10.118	10.995
Env-11		30 Gy	7.934	9.127
Env-12		40 Gy	8.649	7.363

ware Version 9.1. LSD (0.05) were used to comparison between the means value of four potato cultivars under two levels of irrigation (80 and 60% from field capacity) compare with control (100 % from field capacity) and four doses of gamma rays (control, 20,30 and 40 Gy). The method of Eberhart and Russell (1966) used to estimate the regression coefficient (b_i), deviation from regression (S^2d_i). It is calculated by regressing mean tuber yield of individual genotypes genotypic index.

3. Results

3.1. Mean performance of all environments

The data in Tables 3 and 4 showed that, tested potato cultivars responded differently under twelve environmental factors, suggesting the significance of cultivars evaluation under variable conditions (twelve environments) during two mutants to identify the best genetic make up for yield per feddan for each environment.

The current data showed that, the average of yield per feddan was stimulated for plants grown under 80% FC interacted with 20 Gy irradiation exposure (Environment six, Env-6) compared with the other environments. Moreover, combined results (Table 6) revealed that Spunta cultivar produced markedly high mean combined over yield during M_1 (11.771 ton/fed) and M_2 (10.97 ton/fed) generations than other genotypes and ranked first over all environments.

Pooled analysis of variance over all environments (water levels and doses of gamma rays) displayed highly significant differences between genotypes and environment relative to yield/fed (Table 4) as well as genotypes \times environment interactions, showed that genotypes interacted with different conditions which is variable between the cultivar's behavior. Furthermore, the $G \times E$ interaction was significant, with the deviation from linear response accounting for a large part of it.

3.2. Stability parameters

Findings in Table 5 show the linear response of environments of both mutant generations was highly important for yield. Thus, the regression coefficient (b_i) and deviation from regression (S^2d)

Table 4
Mean squares of combined analysis of variance for yield/fed across 12 different environments of the two mutant generations (M_1 and M_2).

Source of variance	d.f.	Mean squares	
		M_1	M_2
Genotypes (G)	3	221.40**	164.92**
Environments (E)	11	9.90**	15.53**
$G \times E$	33	2.01**	2.21**
Error	97	0.002	0.007

** Significant and highly significant at 0.01 level of probability.

pooled over the twelve different circumstances were estimated for every genotype as found in Table 6.

The significant mean squares due to $E + (G \times E)$ response represented that genotype response with the twelve different circumstances factors. A large portion of these responses owing to E (linear) contents. On the other hand, non-significance of pooled deviation means squares in both generations suggesting non-deviation mean squares for individual genotypes (Table 5).

Based on Table 6, the genotypes can be divided into four groups: I Where the Cara cultivar (both generations) was adopted, genotypes with a high mean, $b_i = 1$, and no marked change in S^2d_i are appropriate for extensive accommodation and are stable genotypes. (ii) When the Spunta cultivar was engaged, genotypes with a high mean, $b_i > 1$, and no marked difference in S^2d_i were genotypes with average stability and suggested for preferable conditions. (iii) Genotypes with low mean, $b_i < 1$ with no marked difference in S^2d_i are of low stability where Hermes (both generations) and Caruso (2nd generation) cultivars in downing order, were involved. (iv) Genotypes with a few b_i values in one generation are with reduced stability but are not recommended for use in this generation where Caruso cv in M_1 was involved.

For appropriate settings, genotypes with significant yield and average yield stability are suitable. According to the findings, genotypes Spunta and Cara revealed significant value of harvest, but their stability was different. The potato genotypes Spunta and Cara not only showed high tubers yield over the mean, the two types considered more stable, particularly after M_2 generations. Accordingly, it is evident that stability analysis revealed a high difference between genotypes; some genotypes revealed marked adaptation, while other revealed adaptation with different environmental factors. In Table 6, the high yielding genotype Spunta produced the highest mean yield (10.97 ton/fed), in 2nd mutant generation over different environments and had regression coefficient (b_i) 1.268 and deviation from regression (S^2d_i) not significantly from zero subsequent by Cara, Hermes and Caruso. The value of " b_i " approached nearly unity in Cara cultivar for yield, indicating moderate interaction with un-stable environment. Hermes, on the other hand, generated a medium yield across a wide range of conditions, resulting in a lower regression coefficient (b_i) and non-significant departure from regression (S^2d) in both generations, indicating adaptation of this genotype to adverse environments. Our results reveal that the abovementioned cvs under studied environments might be of prime importance for traditional agricultural procedures for high yield and/or some of its important components.

Table 7 shows data on the three-stability metrics of mean performance (\bar{x}_i), regression coefficient (b_i), and deviation from regression (S^2d_i) under various scenarios. The regression coefficient (b_i) for yield/fed was marked in Spunta and caruso cultivars in M_1 generation whereas genotype Cara revealed approximately a unit regression in both generations. Also, all studied genotypes showed insignificant regression coefficient (b_i) in 2nd mutant gen-

Table 5
Regression analysis of variance over twelve environments of four potato genotypes tested for yield/feddan during mutants generations (M₁ and M₂).

SOV	d.f.	M ₁		M ₂	
		S.S	M.S	S.S	M.S
Total	47	279.82	–	246.23	–
Genotypes	3	221.39	73.80**	164.92	54.97**
Env. + (G. × Env.)	44	58.42	1.33	81.31	1.85
Env. (linear)	1	36.27	36.28	56.95	56.95
Genotyp × Env. (linear)	3	6.84	2.28*	4.16	1.39*
Pooled deviation	40	15.30	0.38	11.20	0.28
Pooled error	97	0.074	0.001	0.225	0.002

** Highly significant at 0.01 level of probability.

Table 6
Mean values of 12 environments for mutant generations (M₁ and M₂) and stability parameters of the potato genotypes for yield/feddan.

Genotype	Yield/feddan					
	M1			M2		
	Mean	Bi	S ² di	Mean	bi	S ² di
Spunta	11.771	1.652**	0.7186	10.97	1.268	2.277
Cara	8.360	1.089	1.6341	8.51	1.064	1.225
Caruso	6.103	0.476*	0.9958	5.99	0.936	1.070
Hermes	7.047	0.783	0.5840	7.14	0.732	0.969
Mean	8.320	–	–	8.153	–	–
S.E.	0.187	0.205	–	0.226	0.197	–

*** Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.

eration and deviation from regression (S²d_i) in both mutant generations. When the regression coefficient (bi) was close to unity and the deviation from regression was diminished, genotype Cara and Hermes demonstrated yield stability in both generations, while genotype Spunta and Caruso revealed yield stability in just the second generation (non-significant, S²d). As a result, the M₂ mutant generation of Spunta, Cara, Caruso, and Hermes, in that order, were good and strongly recommended for planting in numerous ecological studies at the investigated sites. The genotype Spunta followed by Cara presented an elevated productivity in M₂ yielded (10.97 and 8.51 ton/fed, respectively), lower deviation from the regression line (non-significant S²d) and the regression coefficient (b_i) nearby 1, so that two cultivars were excellent among other genotypes.

3.3. Leaf anatomy

The blade of the terminal leaflet of the compound leaf growth on the median portion of the main stem of both hermes and spunta potato cvs plants developed under felid capacity of control (100 % FC) and drought stress (80 % FC) as well as drought stress at 80 % FC

plus 20 Gy radiation exposure are assessed in transverse sections via the blade of the terminal leaflet of the compound leaf growth on the median portion of the main stem of both hermes and spunta potato cvs plants developed under (Figs. 1–7).

3.4. Leaf of Hermes cv.

It is realized in Table 7 and Figs. 1, 2 and 3 that, 80 % FC (non-radiated cvs) lowered the thickness of both medvein and lamina by 15 and 36.4% lower than control ones, respectively. The decrease in lamina was due to the small thickness of both epidermis and mesophyll tissues. The decrements below the control were 50, 25, 26 and 38.51 % for the thickness of upper epidermis, lower epidermis, palisade, and spongy tissues, respectively. Such treatment decreased dimensions of med-vein bundle below the control by 20 % in length and by 16.3 in width. Number of vessels/med-vein bundle decreased less than the control by 18.2 %. Moreover, the mean diameter of Xylem vessels decreased by 11.1 % less than the control (Fig. 2). On the other hand, Plants treated with gamma ray at 20 Gy and grown under 80 % FC induced a prominent

Table 7
Leaf histological features of both Hermes and Spunta potato cvs at 55 days after sowing as affected by drought stress (80 %FC) and 20-GY radiation exposure during fall growing season (2018/2019).

haracters of leaf anatomy		Hermes cv			Spunta cv		
		100 %FC	80% FC	20 GY radiated genotype	100 %FC	80% FC	20 GY radiated genotype
Name	Symbol	Control	Non-radiated	20 GY radiated genotype	Control	Non-radiated	20 GY radiated genotype
Midvein thickness (μ)	Mid-v T	990	841.5	1257.3	1168.2	990.9	1207.8
Lamina thickness (μ)	L T	237.7	151	282.5	304.6	250.8	349.8
Upper epidermis (μ)	UE	19.8	9.9	23.1	26.4	19.8	26.4
Lower epidermis (μ)	LE	13.2	9.9	16.5	13.2	9.9	9.9
Palisade tissue (μ)	P T	75.9	56.1	102.2	95.4	92.4	115.5
Spongy tissue (μ)	S T	128.7	79.2	140.7	207.9	128.7	151.8
Midvein bundle length (μ)	Mid-v BL	148.5	118.8	168.3	158.4	138.6	168.3
Midvein bundle width (μ)	Mid-v BW	425.7	356.4	574.2	346.5	445.5	465.3
No vessels/medvein bundle	Nves/medvB	11	9	13	8	8	10
Xylem vessels diameters (μ)	Xy.VesD	29.7	26.4	36.3	26.4	23.1	33

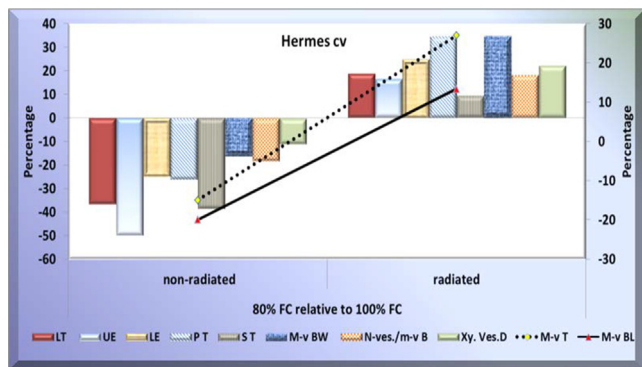


Fig. 2. Radiated and nonradiated Hermes cv under drought stress (80 %FC) relative to control (100% FC).

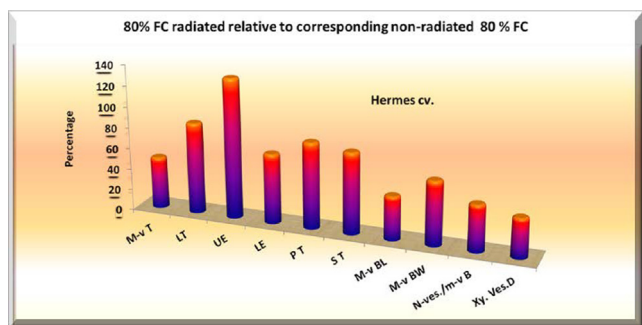


Fig. 3. Radiated Hermes plants under drought stress (80 %FC) relative to nonradiated 80 % FC.

increase in med-vein and lamina thickness by 27 and 18.8 %, respectively. The increase in lamina thickness which was observed in leaflet blade could be attributed mainly to the increase in thickness of upper and reduced epidermis, thickness of palisade and spongy tissues (Fig. 2). The increments over those of control plants were 16.6, 25, 34.6 and 9.3%; respectively.

Also, the med-vein bundle showed a prominent increase in length by 13.3 and 41.7 % and in width by 34.8 and 61.1% comparing with control (100% FS) and un-radiated drought stress (80% FS) treatments, respectively (Figs. 3, 4). Number of vessels/med-vein bundle increased over the control by 18.1 and Diameter Xylem vessels showed an increase by 22.2 and 37.5 % compared with control (100% FS) and un-radiated drought stress (80% FS) treatments, respectively (Figs. 3, 4).

3.5. Leaf of Spunta cv.

It is realized in Table 7 and Figs. 5, 6 and 7 that 80 % FC (non-radiated cvs) decreased thickness of both medvein and lamina by 15.2 and 17.7 % less than those of control ones, respectively and decreased thickness of lamina by 17.80 % less than those of control ones. As the above discussion in Herm’s leaf, the decrease in lamina is due to reduce in thickness of both epidermis and mesophyll tissues. The decrements below the control were 25, 25, 3.1, and 38.1 % for the thickness of upper epidermis, lower epidermis, palisade and spongy tissues, respectively. Such treatment decreased med-vein bundle length by 12.5 % below the control. On contrary, med-vein bundle width elevated by 28.5 % over the control and Number of vessels/ med-vein bundle not affected. Moreover, the mean diameter of vessels decreased by 12.5 % less than the control. On the other hand, plants treated with gamma ray at 20 Gy and

grown under 80 % FC induced a prominent increase in med-vein and lamina thickness by 13.3 and 14.8 %, respectively.

The higher lamina thickness which was detected in leaflet blade could be due to the elevation in thickness of palisade cells by 21.1 over control plants. While thickness of reduce epidermis lowered by 25 % below the control. Also, dimensions of medvein bundle improve in length by 6.3 % and in width by 34.3 % over the control. Vessels with bundle number and diameter vessels showed increments by 25 % compared with control plants.

4. Discussion

Previously recorded by Asfour and Zayed (2010) who found that some legume and potato genotypes had significant ecosystem impacts on their yielding capabilities. The examined genotypes changed regularly in producing ability between different conditions, demonstrating a substantial magnitude of GxE interaction (Zayed et al., 1999). Again, the differences in both linear 7 non-linear trends relative to yield/fed was significant, as recorded by Kulkarni et al., (2000). Eberhart and Russell (1966) emphasized the necessity of considering both the linear and non-linear trend when estimating yield and/or other measures of genotypic stability. Eberhart and Russell (1966) suggested that if the results were accompanied by improved yield performance, genotype selection based just on yield would be effective.

Gamma radiation is the most preferred physical mutagen by plant breeders. The impact of radiation is mainly related to the species, cultivar, and plant age, physiology, morphology and genetic organization. Ionizing radiation causes structural and functional changes in DNA molecule, which have role at cellular and systemic levels. Gamma-treated Santana plantlets were more tolerant to salinity as compared to other cultivars. It showed a significant increment of fresh weight (250% over the untreated). Gamma-treated plantlets of Lady Rosetta, Diamante, and Gold showed higher activity of peroxidase (POD) and polyphenol oxidase (PPO). Isoenzymes analysis showed an absence of POD 3, 4, and 5 in Gold plantlets. The dye of most PODs and PPOs bands were denser (more active) in gamma-treated plantlets of Santana as compared to other cultivars. Both gamma-treated and untreated plantlets showed the absence of PPO1 in Lady Rosetta and Diamante, and PPO 3, 4, and 5 in gold plantlets (Mohamed et al, 2021).

The findings are in concur with Badran (2015) who found that, the stability of tested cultivars is significant to assess the differential results for bulb weight per plant under various environments factors, this stability can be also achieved by using nanomaterials (El-Saadony et al., 2021a, 2021b). In the same way, Badran (2020) talked about how to make an objective evaluation of genotypes in different settings to help plant breeders figure out which genotypes are the most suited and stable for yield given the environmental factors (Hassanin et al., 2020). In general, preferred genotypes show lower GE variance, elevated mean yield under various conditions, and lower deviation from the desired response in a certain ecosystem (Lin and Binns 1988). Which explains its elevated productivity, which is related to its maximal adaptability and consistency of performance under varying conditions. Also, Eberhart and Russell (1966), found that genotypes with “b_i” value < 1.0 and over S_d² than zero are considered particularly accommodate to bad circumstances, while genotypes having elevated “b_i” value are particularly accommodate to good circumstances and elevated productivity. It is suggested that this genotype could be handled as stress tolerant genotypes under bad conditions by using natural compounds (Saad et al., 2015, 2021a, 2021b). Zayed et al. (2005) in pea, Asfour and Zayed (2010) in potato, and Hussein and El-Hady, 2015 in cowpea, found ideal genotypes that grow under worse conditions. On the other hand, Spunta could provoke the ele-

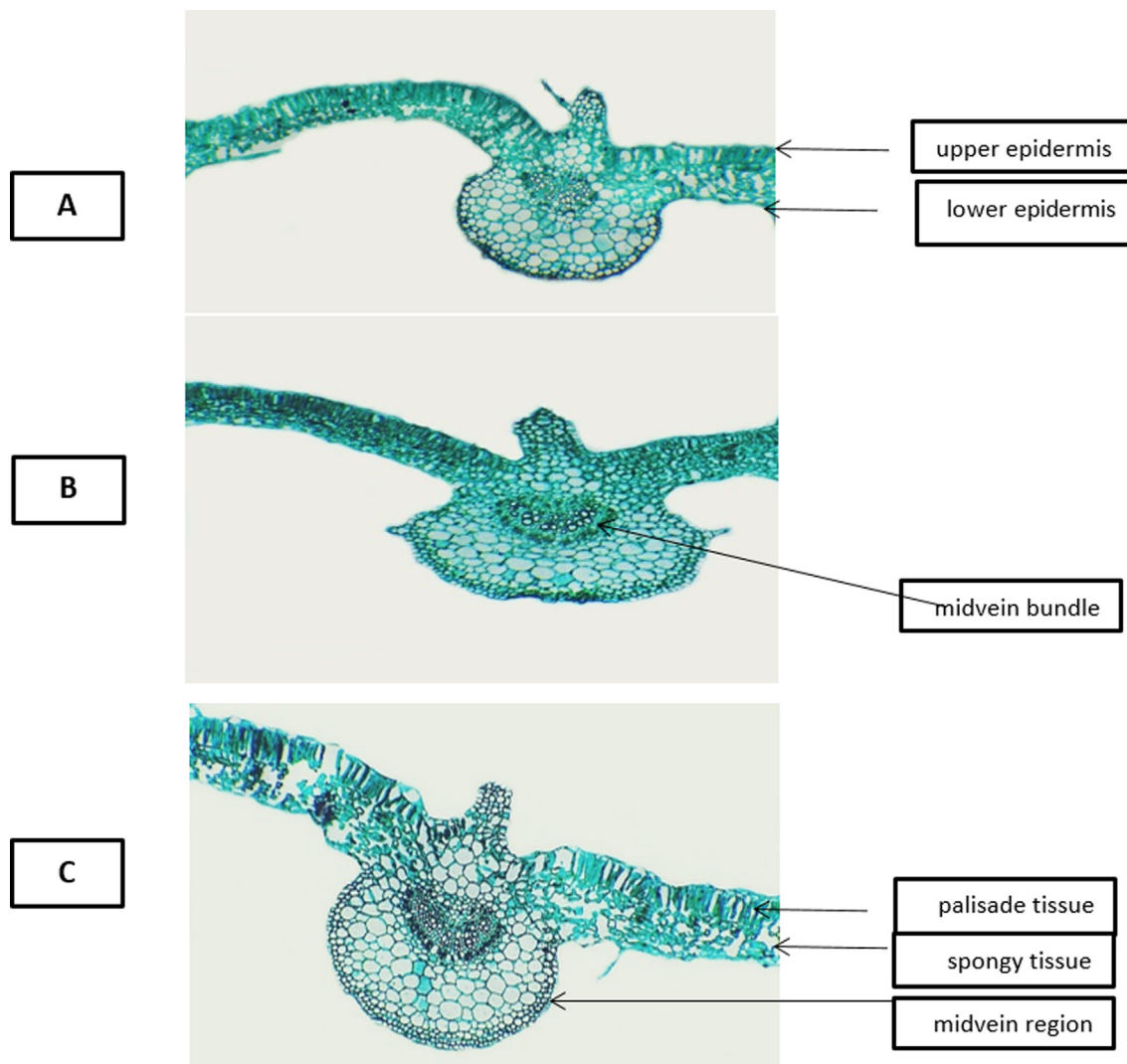


Fig. 4. Transverse sections (X = 100) through apical leaf developed on the median portion of Herms potato main stem at 55 days after sowing as affected by radiation treatments. Where: (A): control (Non-radiated plant grown under 100 % FC) (B): Non-radiated plant grown under 80 % FC (C): 20 GY Radiated plant grown under 80% FC.

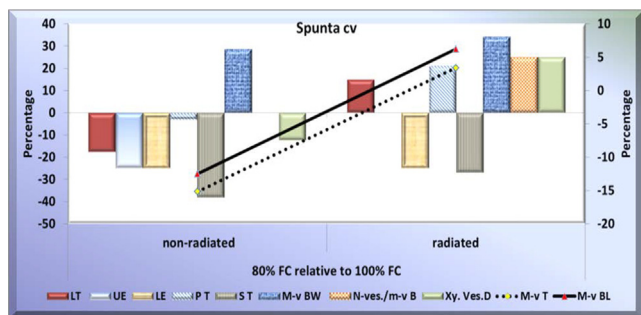


Fig. 5. Radiated and nonradiated Spunta cv under drought stress (80 %FC) relative to control (100% FC).

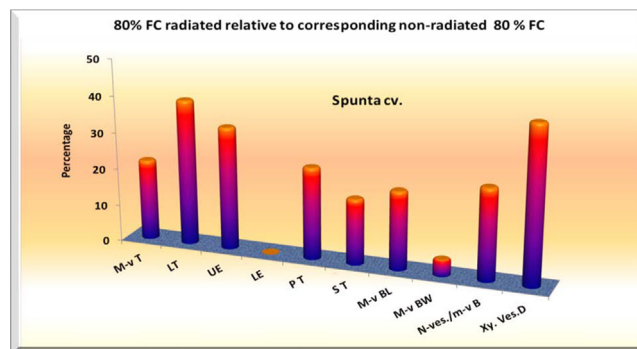


Fig. 6. Radiated Spunta plants under drought stress (80 %FC) relative to nonradiated 80 % FC.

ated yield at good circumstances. On contrary, regression coefficient was lower than 1 ($b_1 < 1$) for both Hermes and Caruso cultivars for yield. Therefore, both cultivars are higher productive under bad conditions. Zayed et al. (2005) found some genotypes as ideal cultivars for growth under poor circumstances. The water deficiency can be handled by virus applications to plant leaves such as nanoparticles (El-Saadony et al., 2021c; Saad et al., 2021c), polyphenols rich

materials (El-Saadony et al., 2020; Saad et al., 2021d). Although, Selim and El-Nady (2011) found that a water deficit of 60 and 40% FC reduced the thickness of the lamina, palisade tissue, spongy tissue, and vascular bundle in tomato plant leaves. Similar, when wheat plants were irrigated with standard tap water at 50% FC, the leaves were thinner because the midvein and lamina thicknesses were

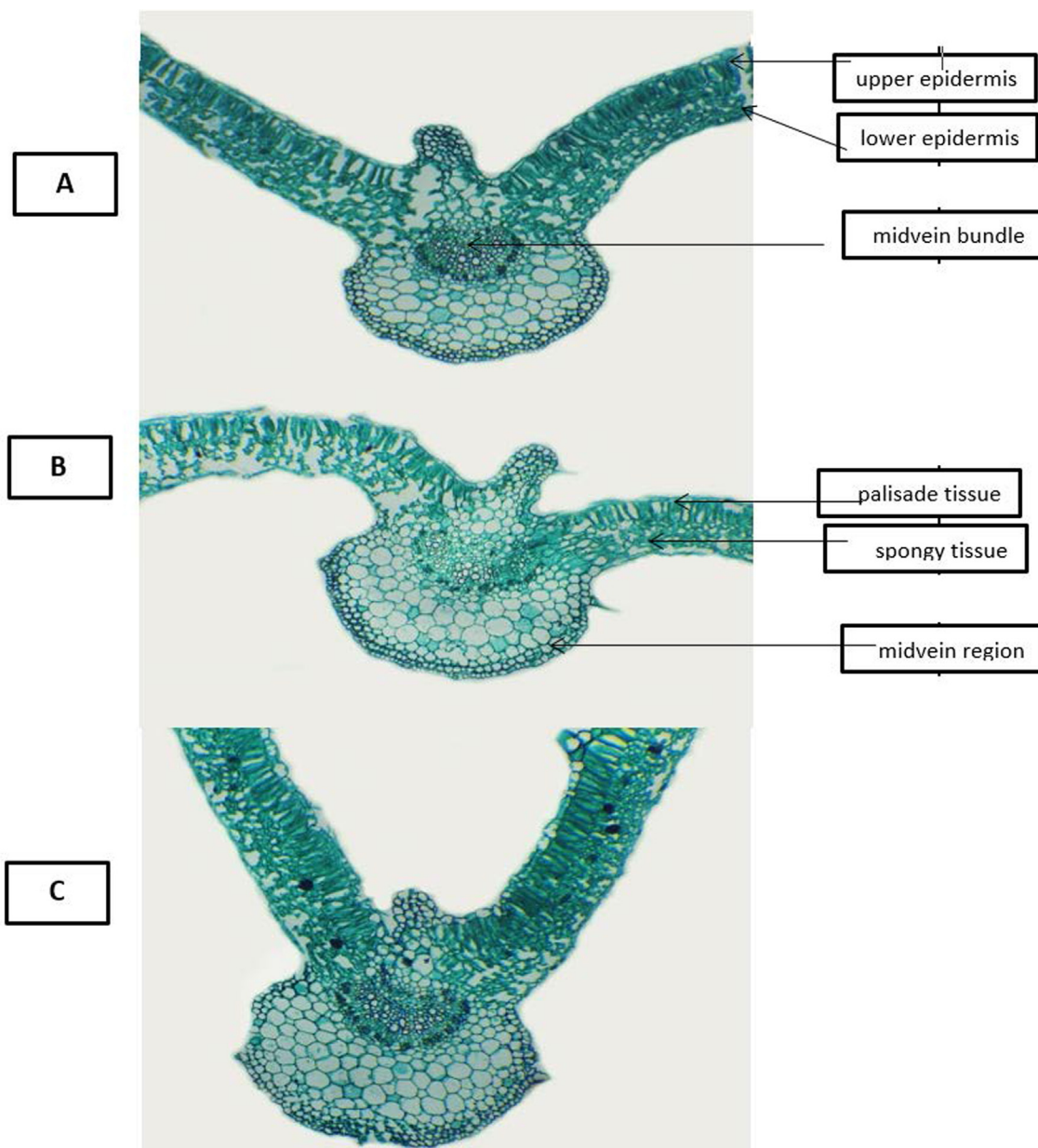


Fig. 7. Transverse sections (X = 100) through apical leaf developed on the median portion of Spunta potato main stem at 55 days after sowing as affected by radiation treatments. Where: (A): Control (Non-radiated plant grown under 100 % FC) (B): Non-radiated plant grown under 80 % FC (C): 20 GY Radiated plant grown under 80% FC.

reduced by 13 and 10%, respectively, compared to the control. In addition, the midvein bundle's length and width decreased by 15% and 13%, respectively. The diameter of the metaxylem channel and the thickness of phloem tissue were also reduced by 17 and 10%, respectively (Selim et al.,2019).

5. Conclusion

Hermes could be employed as anti-stress genotypes under stress conditions (negative conditions or poor yielding). However, Spunta followed by Cara cv represented a good performance in M2 production yield (10.97 and 8.51 ton/fed, respectively), slight drift from the regression line and coefficient close to 1, therefore, both cultivars were excellent between genotypes in shape of yield stability and is recommended for different conditions. According to anatomical studies, 80 % from field capacity (FC) decreased the

thickness of medvein and lamina of potato cv. spunta and herms plants and thickness of mesophyll tissues also, dimensions of medvein bundle and mean diameter of vessels. Plants treated with gamma ray at level 20 and grown under 80 % FC induced prominent increase in all previous characters.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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