



Original article

Performance of some elite potato cultivars under abiotic stress at North Sinai



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ABSTRACT

The current experiment was adopted during the summer 2018, fall 2018/2019 and summer 2019 respectively at the Experimental Farm of Balozza station, Desert Research Center, North Sinai Governorate, Egypt to study the effect of different doses of irradiation (0, 20, 30 and 40 Gy), three irrigation levels (100, 80 and 60% field capacity) on growth, yield and its quality of some potato cultivars (Spunta, Cara, Caruso and Hermes). Treated Spunta cultivar pre planting with 20 (Gy) and irrigated with 80% field capacity was the best treatment for increasing number of aerial stem/plants, leaf area, total chlorophyll in leaves, average tuber weight, and total yield/fed. Hermes cultivar with 20 (Gy) and irrigation level of 80% was the best for increasing dry matter content in tuber in both mutagenic generations.

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1. Introduction

Potato (*Solanum tuberosum* L.) is a major food crop in Egypt subsequent to wheat, rice & maize. It is an important vegetable for billion people (Hussain, 2016). Its annual production of over 368 million tonnes ranks fourth after maize, rice and wheat (Albiski et al., 2012). The cultivated area with Potato in Egypt, have enormously increased through the last decades reaching about 381.379 fed., producing about 4.265.178 tons, with average 11,184 tons/fed., (FAO, 2020). Induced mutations by gamma ray irradiation can increase genetic variation of economically important traits in germplasm. It can enhance conventional breeding by directly improving genotypes for specific traits or providing valuable material for further breeding work (Songsri et al., 2019). Mutation induction in potato has produced mutants for diverse

traits such as modified starch biosynthesis (Muth et al., 2008), increased growth and yield (Al-Safadi et al., 2000; Li et al., 2005; Cheng, et al., 2010).

Agriculture in Egypt is almost entirely dependent on irrigation from River Nile, although there are minor contributions from groundwater. The average consumption of water for agriculture is about 58 billion m³year⁻¹ (Burak, and Margat, 2016). Agriculture has major disadvantages over other water-consumed activities (industry, domestic and tourism, etc.) due to a large percentage of irrecoverable losses because of high rates of evaporation and evapotranspiration (Desoky et al., 2020a,b; Fouda et al., 2022).

In order to mitigate such this difficulty, agriculture has to come up with innovative ideas with respect to both cropping and irrigation water management to improve water productivity and to accomplish agriculture sustainability concepts. Foliar spraying of natural compounds may lead to manage water requirements i.e., essential oils and herbal extracts (Saad et al., 2021a,b; El-Tarabily et al., 2021), chitosan and amino acids (Fouda et al., 2022; El-Sobki et al., 2021), biological nanoparticles (Saad et al., 2021c; Abd El-Hack et al., 2021), and bioactive peptides (Saad et al., 2021d; El-Saadony et al., 2021a,b). Excessive permeability, water deficiency, and nutrient availability are the major problems in soils (Suganya and Sivasamy, 2006). Hence, managing irrigation water

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

Soil 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		Sandy	CEC meq/100 g	7.51	–
OM (%)		0.25	SAR*	–	3.19
ρ_b (g/cm³)		1.54	Soluble cations, meq/l	Na ⁺	19.34
K_s (cm/h)		11.12		K ⁺	2.79
FC (%)		10.68		Ca ⁺⁺	13.42
WP (%)		3.75		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.

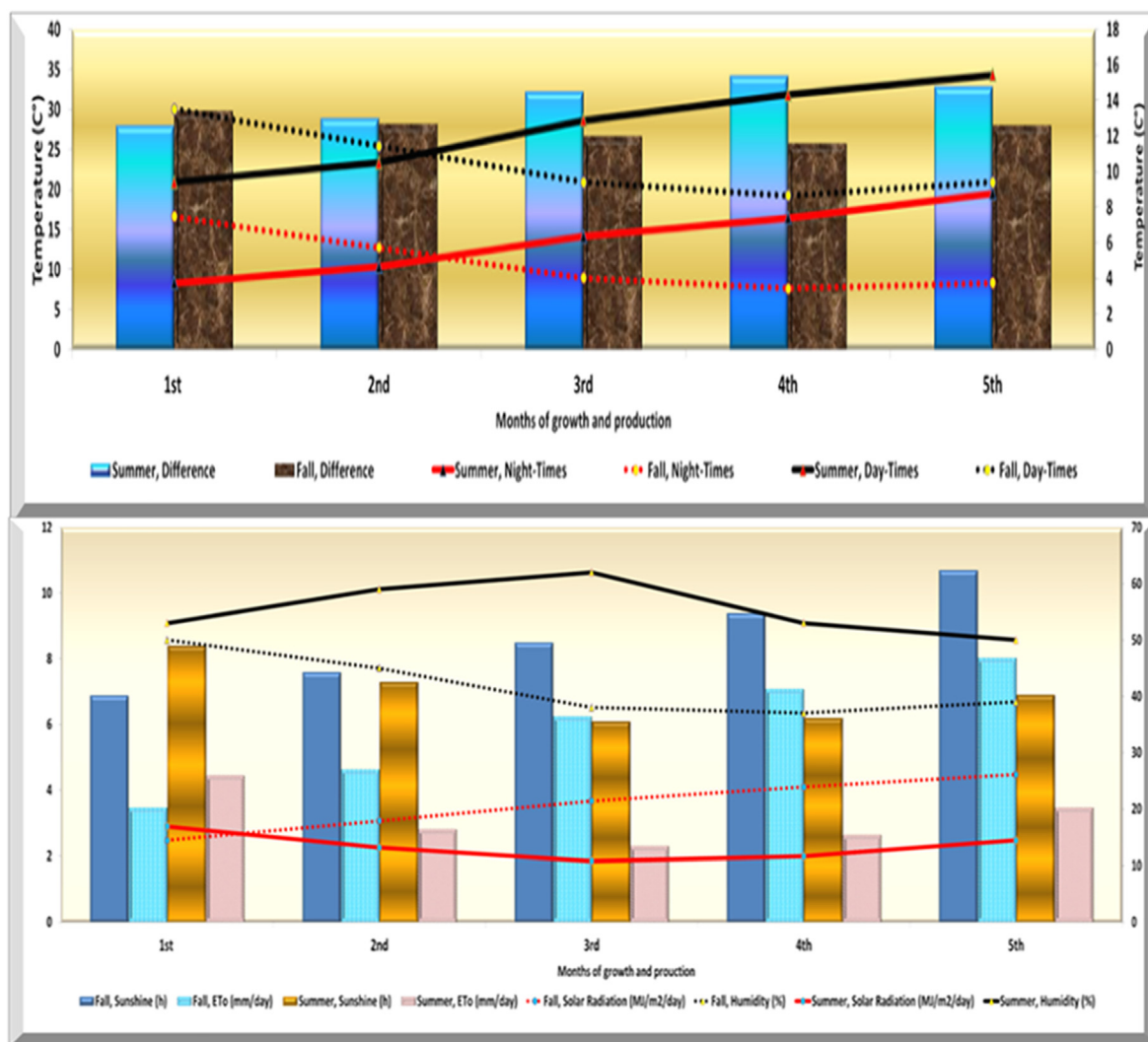


Fig. 1. Climate and reference evapotranspiration data of Baloza area as average of both generations.

and plant nutrients are the major challenge of soil amelioration efforts. Since, insufficient irrigation water results of high soil moisture tension, which fall plant under stress and, in turn, reduce its yield. While, excess irrigation water may reduce crop yield due

to leaching of applied nutrients, increased disease incidence and/or failure to stimulate growth of the commercially valuable parts of the plant (Solomon, 1993). Several studies reported that increasing irrigation water quantities improving growth, yield and its

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.

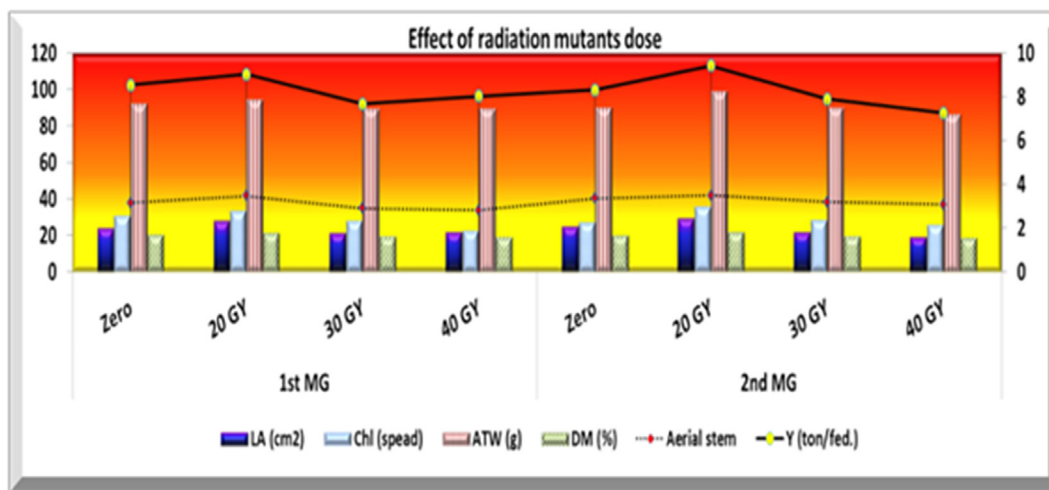


Fig. 2. Effect of radiation mutants doses (Gy) on potato traits during two mutagenic generations (MG).

components and enhanced tuber quality of potato. In this regard, Abubaker et al. (2014), Farrag et al. (2016), Adhikari and Rana (2017), Dash et al. (2018), Mahmoud et al. (2019) and Eid et al. (2020) found that number of stems/plant, leaf area, total chlorophyll, average tuber weight, total yield and dry matter contents in tubers were increased with increasing water applied. Screening and selection of cultivars/varieties or genotypes which can be cultivated for profitable yield under drought situations represent eternal as well as complementary resolution in order to curtail consequence of drought. Besides, improving the crop yield under water stress is dependent on selection which is one of significant aspect of plant breeding (Ashraf et al., 2010). There were marked differences among cultivars especially in plant development, yield & tuber feature (Hamideldin and Hussien, 2013; Jatav et al., 2017; Youssef et al., 2017; Tsegaye et al., 2018; Banjade et al., 2019).

Therefore, this study was undertaken to investigate the effect of different irradiation doses and amount of irrigation water on plant growth, yield characteristics and tuber quality of some potato cultivars under North Sinai Governorate, Egypt at growing seasons of summer 2018, fall 2018/2019 and summer 2019.

2. Material and methods

2.1. Experimental conditions:

This study was adopted in summer season 2018, fall 2018/2019 and summer 2019 at the Experimental Farm of Baloza station, Desert Res. Center, North Sinai Governorate, Egypt to study the effect of different doses of irradiation and irrigation water levels on growth, yield, and quality of some potato cultivars. Physical

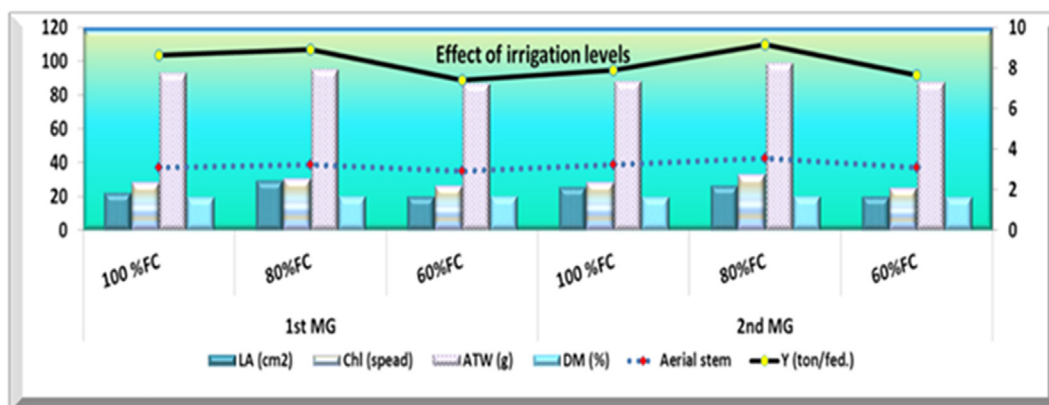


Fig. 3. Effect of irrigation levels on potato traits during two mutagenic generations (MG) FC = field capacity.

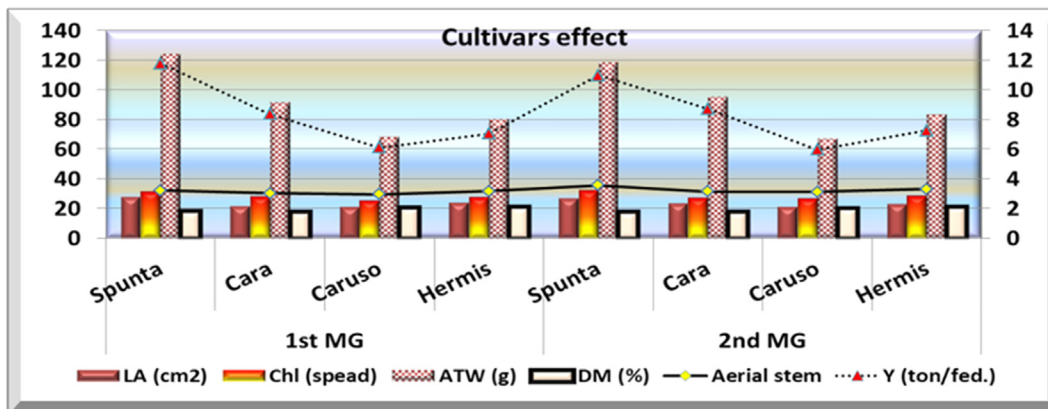


Fig. 4. Effect of potato cultivars on potato traits during two mutagenic generations (MG).

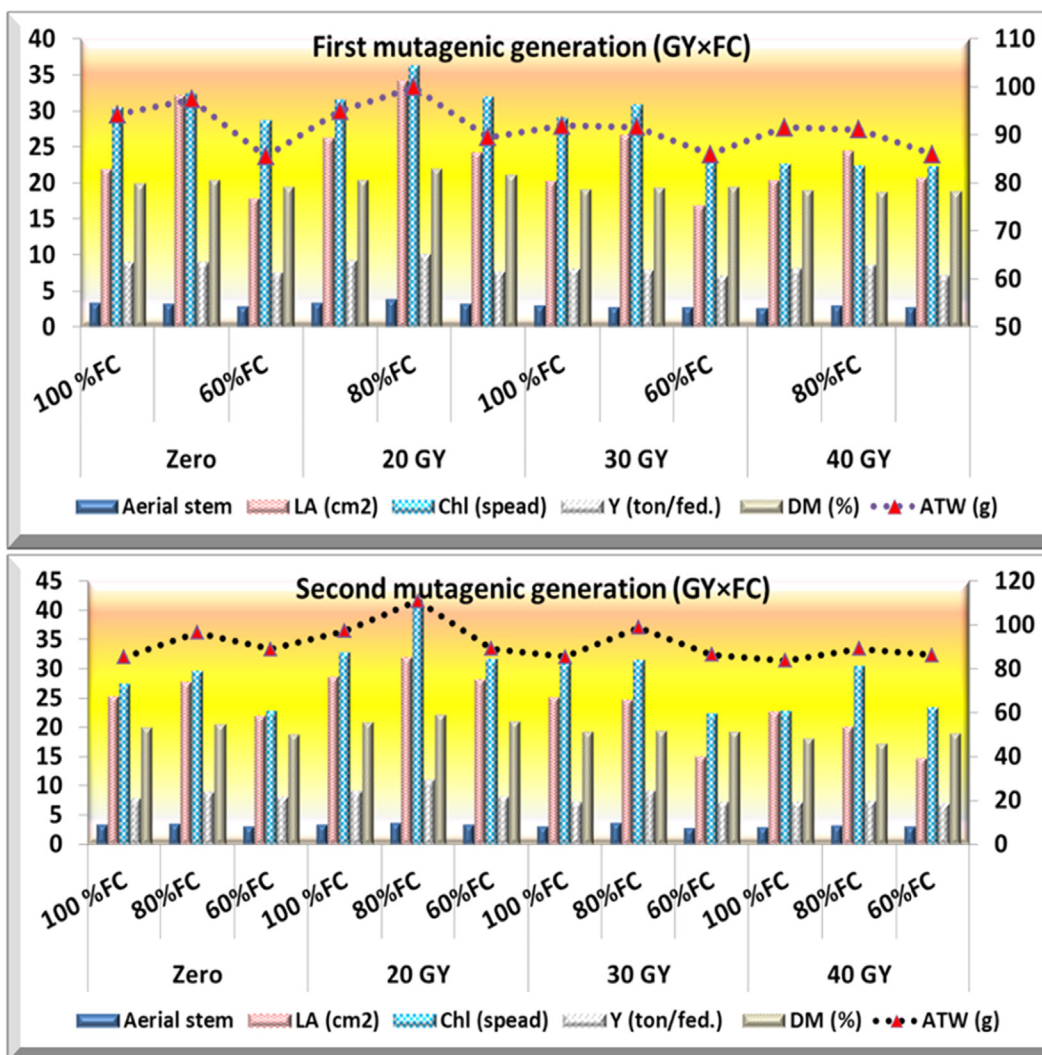


Fig. 5. Effect of interaction between radiation doses (Gy) and irrigation levels (FC) on potato traits at 1st (Upper) and 2nd (Down) mutagenic generations. FC = field capacity.

and chemical features of the experimental soil as well as chemical analyses of the irrigation are presented in Table 1. Climate and reference evapotranspiration data of Balzoza region were presented in

Fig. 1 and obtained from Center Laboratory for Agricultural Climate (CLAC), agricultural research center (A.R.C.), Egypt during growing seasons.

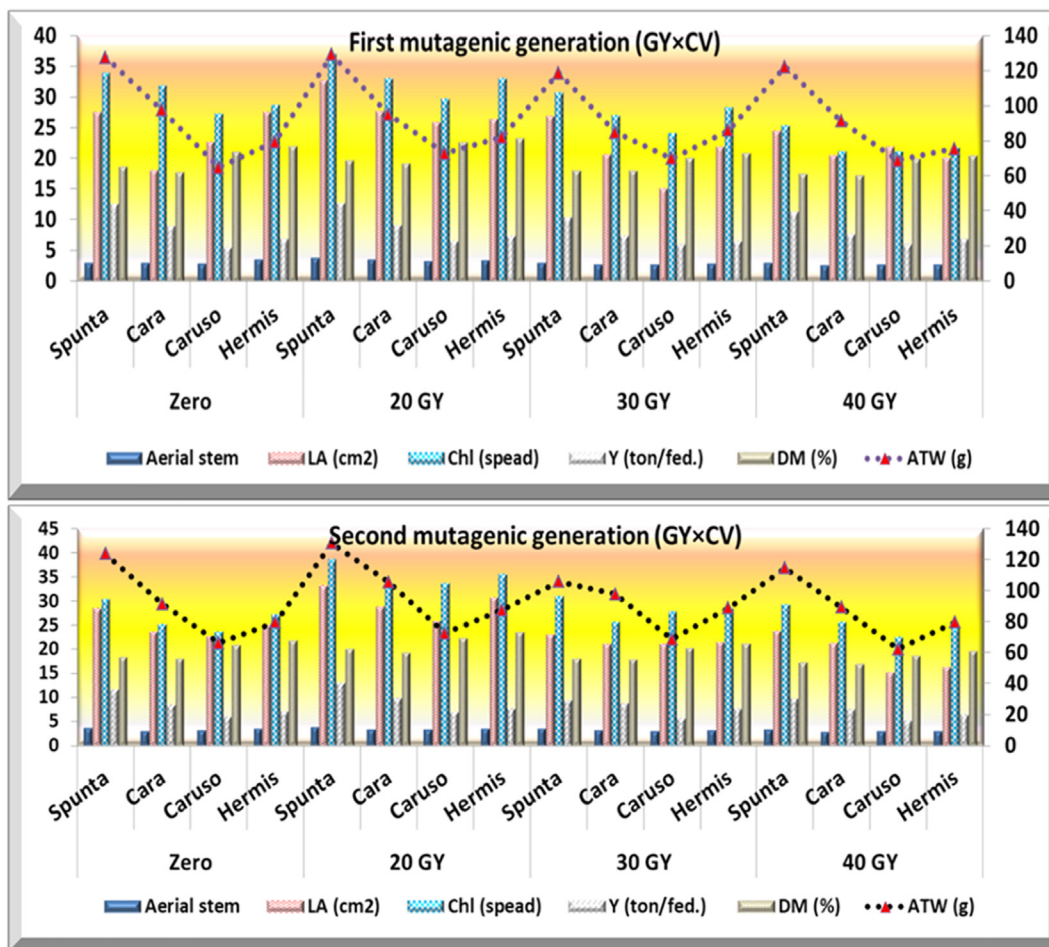


Fig. 6. Effect of interaction between radiation dose (Gy) and cultivars (CV) on potato traits during 1st (Upper) and 2nd (Down) mutagenic generations.

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 M₁ generation seeds.

2.3. Gamma irradiation treatment

Dry tubers of all cultivar 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. M₁ generation (fall season of 2018/2019)

The irradiated and non-irradiated (control) tubers (M₀) were sown under drought stress (100, 80, and 60% from field capacity) on 1st October 2018. The experiment included 48 treatments, which were the combinations among four irradiation doses, three irrigation levels and four potato cultivars. Split-split plot design in a randomized complete block design with three replications was used. 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 M₁ plant for sowing of the following M₂ generation.

2.4.2. M₂ generation

Tubers of M₁ generation were sown on 3rd March 2019. Split-split plot design with 3 replications was exploited as in previous generation & all cultural practices were used as recommended.

The experimental unit area was 12.6 m². Each plot involves three dripper lines 6 m length each & 0.70 m distance between the two drippers lines. One line was used to estimate the morphological & physiological traits and the other two lines were used for yield assessment. In addition, one row was left between each two experimental units as guard area to exclude infiltration mix of irrigation water. Farmyard manure (FYM) at 30 m³/feddan was used during soil elaboration. All processing received N₁₂₀, P₈₀, K₁₀₀ as ammonium sulfate (20.6% N), calcium super phosphate (15.5% P₂O₅) & potassium sulfate (48–52% K₂O), respectively. One third of both N and K₂O as well as all P₂O₅ doses were added during soil elaboration with FYM. The rest of N and K₂O (two thirds) were supplied as fertigation at 4 days interval starting one month after planting. The normal agricultural practices were adopted as usually followed in the district of this investigation.

2.5. Data collection:

A randomized sample of 5 plants were taken from each experimental unit after 90 days from planting in the two mutant generations of study to determine number of main (aerial) stems/plant, leaf area (cm²), total chlorophyll in leaves (model Minolta chlorophyll meter SPAD -501, China) in both generations. At maturity stage of both M₁ and M₂ generations, all plants were taken from

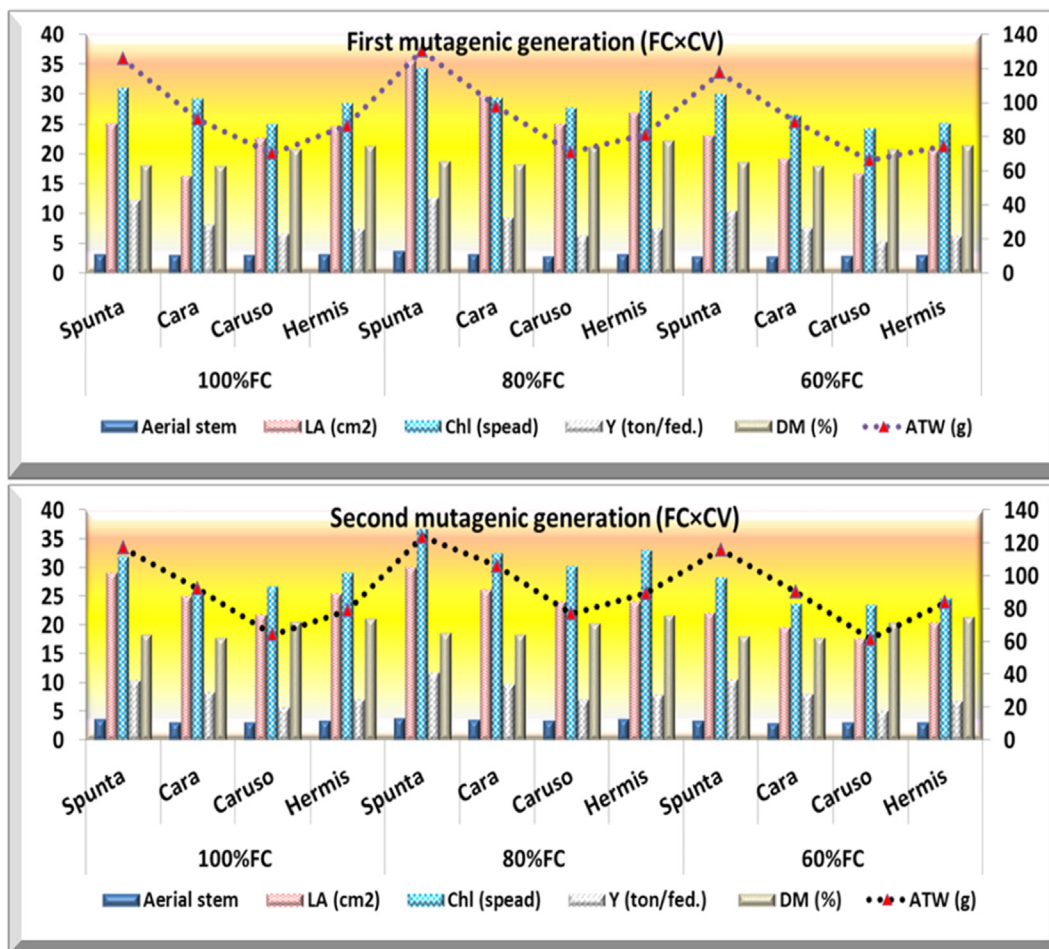


Fig. 7. Effect of interaction between irrigation levels (FC) and cultivars (CV) on potato traits during 1st (Upper) and 2nd (Down) mutagenic generations. FC = field capacity.

each treatment to record average tuber weight (g) total yield (ton/fed.) as well as dry matter (%)

2.6. Statistical Analysis:

Recorded data were statistical analyzed of variance following [Snedecor and Cochran \(1980\)](#), and means were compared with LSD at 5% level.

3. Results

The present study aimed to assess the effect of radiation mutant doses under different irrigation levels on the development, productivity and characteristic of some potato cultivars under North Sinai Governorate.

3.1. Radiation mutant doses:

Results showed that, there were significant differences between radiation mutant doses on growth parameters, total chlorophyll, average tuber weight, total yield and tuber dry matter in two mutagenic generations (Fig. 2). Radiation tubers of potato pre sowing at 20 Gy exhibited the highest significantly increases for number of aerial stem/plant, leaf area, total chlorophyll in leaves (spad), average tuber weight, total yield/fed and dry matter in tubers followed by control tubers (0 Gy) in both mutagenic generation with no significant differences between this treatment and control in average tuber weight at 1st mutant generation. The increment per-

centage of total yield/fed due to 20 Gy was about 5.79 and 13.42% over control treatment in the 1st and 2nd mutagenic generations, respectively. On the contrary, treated tubers of potato with 40 Gy gave the lowest values of all above-mentioned parameters in both mutagenic generations with no significant differences between 30 and 40 Gy treatments in number of aerial stem/plants, average tuber weight and dry matter at 1st mutant generation. As for the yield reduction caused by 30 Gy and 40 Gy treatments was about 10.05 and 6.02% in 1st generation and 4.92 and 12.73% in 2nd mutagenic generation less than the corresponding control.

3.2. Effect of irrigation levels

Data in Fig. 3 indicated that irrigation treatments had significant on number of aerial stem/plants, leaf area (LA), and total chlorophyll (Chl) in leaves, yield (Y) and dry matter (DM) of potato in two mutagenic generation. The medium levels of irrigation (80% from filed capacity, FC) was the best levels for increasing all vegetative growth traits, total chlorophyll, average tuber weight, total yield/fed and tuber dry matter contents in both mutagenic generations followed by the control plants (100% FC) with no significant differences between them for aerial stem/plant in 1st generation. The lowest values were recorded for all studied traits under 60% FC drought stress in the 1st and 2nd mutagenic generations. However, the increases in total yield/fed due to plants irrigated at 80% from FC were about 3.25 and 16.01% than irrigation with 100% from FC in the 1st and 2nd mutagenic generations. While the decreases in total yield were about 14.27 and 3.20 due to irrigation

Table 3
Potato traits as affected by the triple interaction (FC × Gy × CV) during 1st mutagenic generation.

Item			Number of aerial stem/plant	Leaf area (cm ²)	Total chlorophyll (spad)	Average tuber weight (g)	Total yield (ton/fed)	Dry matter (%)
RD	IL	Cvs	1st mutagenic generation					
Zero	100%	Spunta	2.96	19.93	34.66	124.80	12.897	17.90
	FC	Cara	3.03	18.56	33.10	104.40	10.191	18.11
		Caruso	3.16	28.38	26.00	63.87	5.507	21.55
		Hermis	4.23	31.08	28.33	83.93	7.506	22.03
	80%FC	Spunta	3.50	42.10	35.33	139.73	13.645	19.18
		Cara	3.20	26.92	31.00	101.03	9.026	18.54
		Caruso	2.76	27.20	31.33	67.90	6.063	21.57
		Hermis	3.43	32.61	32.00	80.87	7.229	22.53
	60%FC	Spunta	2.63	20.91	32.00	118.47	11.174	19.07
		Cara	3.00	18.97	32.00	87.37	7.843	16.86
		Caruso	2.93	12.65	25.00	62.80	5.299	20.49
		Hermis	3.10	19.31	26.00	73.37	6.093	21.60
20	100%	Spunta	3.80	29.62	34.00	130.90	13.767	19.03
	FC	Cara	3.76	21.92	33.00	95.33	9.170	18.96
		Caruso	3.26	29.48	27.00	70.47	7.009	21.77
		Hermis	2.76	24.11	32.33	83.13	7.277	22.15
	80%FC	Spunta	4.70	42.09	42.93	138.53	14.559	20.11
		Cara	3.93	35.43	34.66	101.90	10.389	19.30
		Caruso	3.13	27.08	31.33	73.80	6.745	23.83
		Hermis	3.60	32.18	36.00	85.60	8.741	24.72
	60%FC	Spunta	2.76	26.53	34.33	118.27	10.054	19.93
		Cara	2.83	25.78	31.66	88.17	7.889	19.35
		Caruso	3.50	21.39	31.00	74.03	6.238	22.31
		Hermis	3.76	23.32	31.00	77.43	6.579	23.02
30	100%	Spunta	3.20	27.70	31.66	118.93	11.023	17.74
	FC	Cara	3.10	18.23	28.33	72.80	6.277	17.01
		Caruso	3.00	12.89	25.33	70.97	7.018	20.76
		Hermis	3.00	22.21	31.00	104.87	7.779	20.81
	80%FC	Spunta	2.93	32.56	33.33	120.77	10.262	18.32
		Cara	2.70	29.21	31.00	92.90	8.862	18.55
		Caruso	2.66	19.35	27.00	73.73	6.124	19.23
		Hermis	2.86	25.42	32.33	79.27	6.489	21.36
	60%FC	Spunta	3.10	20.67	27.40	116.73	10.064	18.18
		Cara	2.76	14.86	22.00	89.00	7.512	18.61
		Caruso	2.76	13.76	20.33	64.70	5.040	20.29
		Hermis	2.73	18.32	22.00	73.50	5.729	20.66
40	100%	Spunta	2.76	23.52	24.00	127.80	11.584	18.09
	FC	Cara	2.43	16.65	22.66	88.90	7.220	18.20
		Caruso	2.73	20.37	21.66	75.57	6.815	19.45
		Hermis	2.66	21.03	22.33	73.93	7.164	20.42
	80%FC	Spunta	3.50	25.98	26.00	122.57	11.853	17.33
		Cara	2.93	27.32	21.00	94.97	8.784	16.89
		Caruso	2.76	26.78	21.33	68.07	6.383	20.25
		Hermis	2.96	17.78	21.66	78.60	7.536	20.38
	60%FC	Spunta	2.76	24.37	26.33	116.77	10.374	17.34
		Cara	2.73	17.78	20.33	90.30	7.156	17.05
		Caruso	2.76	18.93	21.00	62.93	4.993	20.31
		Hermis	2.83	21.91	21.66	73.70	6.443	20.82
LSD at 0.05 level			0.97	1.02	2.93	10.73	0.608	1.35

RD = Radiation dose, IL = irrigation levels, cvs = cultivars, FC = field capacity.

with 60% from FC than irrigation with 100% from FC in the 1st and 2nd mutagenic generations.

3.3. Effect of cultivars:

Results presented in Fig. 4 revealed that there were significant differences among all potato cultivars in vegetative development parameters, total leaf chlorophyll, average tuber weight (ATW), yield and DM in both mutagenic generations. Spunta cultivar exhibited the highest values of number of aerial stem/plants, leaf area, total chlorophyll, average tuber weight and total yield/fed followed by Hermis cultivar which gave the highest value of dry matter contents in tuber in both mutagenic generations. On the contrary, Caruso cultivar was recorded the lowest values of plant growth, leaf total chlorophyll and yield components in two mutagenic generations with no significant differences between Cara and

Caruso cvs in number of aerial stem and between Cara and Hermis in total chlorophyll at 1st generation.

It is clearly from the data that the effects of the Gy × FC interaction was significant in vegetative growth, total chlorophyll in leaves, yield and its components as well as tuber dry matter during two mutagenic generations. 20 Gy × 80% FC (Irradiated tubers with 20 Gy and Irrigated with the moderate levels of 80% FC) exhibited the highest values of all studied traits as compared to other interaction treatments in both mutagenic generations (Fig. 5), while the lowest values of all plant growth parameters and yield and its components were recorded with the interaction between tuber seeds irradiated with 30 or 40 Gy and 60%FC stressed plants for most traits in both mutagenic generations.

The elevation in total yield/fed were about 12.01 & 41.23% for the interaction between irradiation of seeds with 20 Gy and irrigation plants at 80% FC over the interaction between irradiation of

Table 4
Potato traits as affected by the triple interaction (FC × Gy × CV) during 2nd mutagenic generation.

Item			Number of aerial stem/plant	Leaf area (cm ²)	Total chlorophyll (spad)	Average tuber weight (g)	Total yield (ton/fed)	Dry matter (%)	
RD Zero	100% FC	Cvs Spunta	3.76	29.45	32.00	125.73	11.244	18.22	
		Cara	3.10	23.84	25.00	84.17	7.482	18.06	
		Caruso	3.03	22.56	24.00	60.20	5.683	21.63	
	80%FC	Hermis	3.76	25.44	29.00	71.33	6.730	22.07	
		Spunta	3.93	31.55	32.93	128.73	12.324	19.28	
		Cara	3.20	27.55	29.33	99.50	9.530	18.68	
	60%FC	Caruso	3.43	25.62	26.00	73.77	6.680	21.91	
		Hermis	3.70	26.58	30.66	83.93	7.607	22.24	
		Spunta	3.43	24.81	26.33	117.10	11.353	17.64	
	20	100% FC	Cara	2.86	19.86	21.66	90.60	8.544	17.47
			Caruso	3.10	20.31	21.00	64.60	5.449	19.05
			Hermis	3.13	23.25	22.33	83.53	7.046	21.22
80%FC		Spunta	3.76	32.14	36.66	130.13	12.043	20.13	
		Cara	3.36	29.53	30.00	100.67	9.442	18.87	
		Caruso	3.20	23.87	31.66	73.53	7.135	21.67	
60%FC		Hermis	3.43	29.32	33.33	84.67	7.681	22.71	
		Spunta	3.93	36.17	45.33	138.03	14.666	20.91	
		Cara	3.70	30.29	39.00	123.90	11.766	19.80	
30		100% FC	Caruso	3.43	28.20	38.33	84.10	8.166	23.21
			Hermis	3.76	33.56	42.00	97.87	9.382	24.67
			Spunta	3.66	31.29	34.33	123.83	12.397	19.35
	80%FC	Cara	3.03	26.80	30.00	92.20	8.590	19.05	
		Caruso	3.26	25.69	31.00	60.23	5.503	22.00	
		Hermis	3.46	29.42	31.66	80.63	6.291	23.41	
	60%FC	Spunta	3.50	26.84	33.33	105.03	8.780	17.84	
		Cara	2.86	24.24	27.00	92.27	8.256	17.17	
		Caruso	2.86	24.73	31.00	62.30	5.324	20.84	
	40	100% FC	Hermis	3.10	25.24	32.33	82.67	6.964	21.39
			Spunta	3.86	26.07	34.00	104.57	10.230	18.56
			Cara	3.86	22.85	29.00	113.90	10.178	18.90
80%FC		Caruso	3.36	26.39	31.33	83.23	7.556	19.04	
		Hermis	3.70	24.00	31.66	93.83	8.505	21.16	
		Spunta	2.90	16.46	26.00	107.83	9.145	17.64	
60%FC		Cara	2.86	16.32	21.00	87.30	7.921	17.70	
		Caruso	2.73	12.35	21.33	60.63	4.341	20.85	
		Hermis	2.80	15.33	21.66	90.37	7.586	20.95	
LSD at 0.05 level		100% FC	Spunta	3.36	28.44	26.33	106.57	9.611	17.71
			Cara	2.86	23.27	21.66	91.20	8.143	17.21
			Caruso	2.86	16.81	21.00	60.57	4.728	18.50
	80%FC	Hermis	2.93	22.22	22.33	76.80	6.867	18.94	
		Spunta	3.53	26.96	34.66	123.10	10.363	16.20	
		Cara	2.93	24.72	33.10	86.53	7.349	16.54	
	60%FC	Caruso	3.26	16.44	26.00	65.97	5.770	17.29	
		Hermis	3.13	12.39	28.33	81.27	6.240	19.19	
		Spunta	3.26	16.25	27.00	114.03	9.476	17.81	
	LSD at 0.05 level	Cara	3.03	16.10	22.33	90.13	7.186	17.10	
		Caruso	2.86	12.59	21.00	60.27	5.083	20.10	
		Hermis	2.93	14.25	23.33	80.60	6.178	20.73	

RD = Radiation dose, IL = irrigation levels, cvs = cultivars, FC = field capacity.

seeds with 0 Gy and irrigation plants at 100% FC in the 1st and 2nd mutagenic generations, respectively.

The results in Fig. 6 show that the interaction between radiation doses and potato cultivars had significant effect on all studied traits of potato during the two mutagenic generations. Irradiated Spunta cultivar with 20 Gy were the best interaction for increasing number of aerial stem/plant, leaf area, total chlorophyll in leaves, average tuber weight, and total yield/fed in two mutagenic generations. On the opposite, 40 Gy dose × Caruso cultivar showed the lowest values of the most traits. As for tuber dry matter content, the highest value was recorded with the interaction between irradiated Hermis cultivar with 20 Gy (23.29 and 23.59%) in both mutagenic generations. Accordingly, treated Spunta cultivar with 20 Gy gave the highest total yield/fed, i.e., 12.793 and 13.035 ton/fed in the 1st and 2nd mutagenic generations, respectively, while the lowest total yield/fed (5.623 and 6.061 ton) was obtained

with both zero Gy × Caruso cv (5.623 ton) and 30 Gy × Caruso cv (6.064 ton) interactions with no significant differences between them in the 1st generation and 40 Gy × Caruso cv (5.194 ton/fed) in the 2nd mutagenic generation.

Data in Fig. 7 revealed that the interaction between irrigation levels and cultivars reflected a significant effect on in all potato studied traits during both mutagenic generations. The results showed that irrigation of Spunta cultivar with the moderate levels of water (80%FC) recorded the highest values of aerial stem number/plant, leaf area, and total chlorophyll in leaves, average tuber weight and total yield/fed in both mutagenic generations. In opposite, the lowest values of most vegetative growth parameters, total chlorophyll in leaves and total yield were recorded with the interaction between irrigation at 60% FC and Caruso cultivar in both mutagenic generations. Concerning dry matter contents in tubers, the best result was recorded with the interaction between irriga-

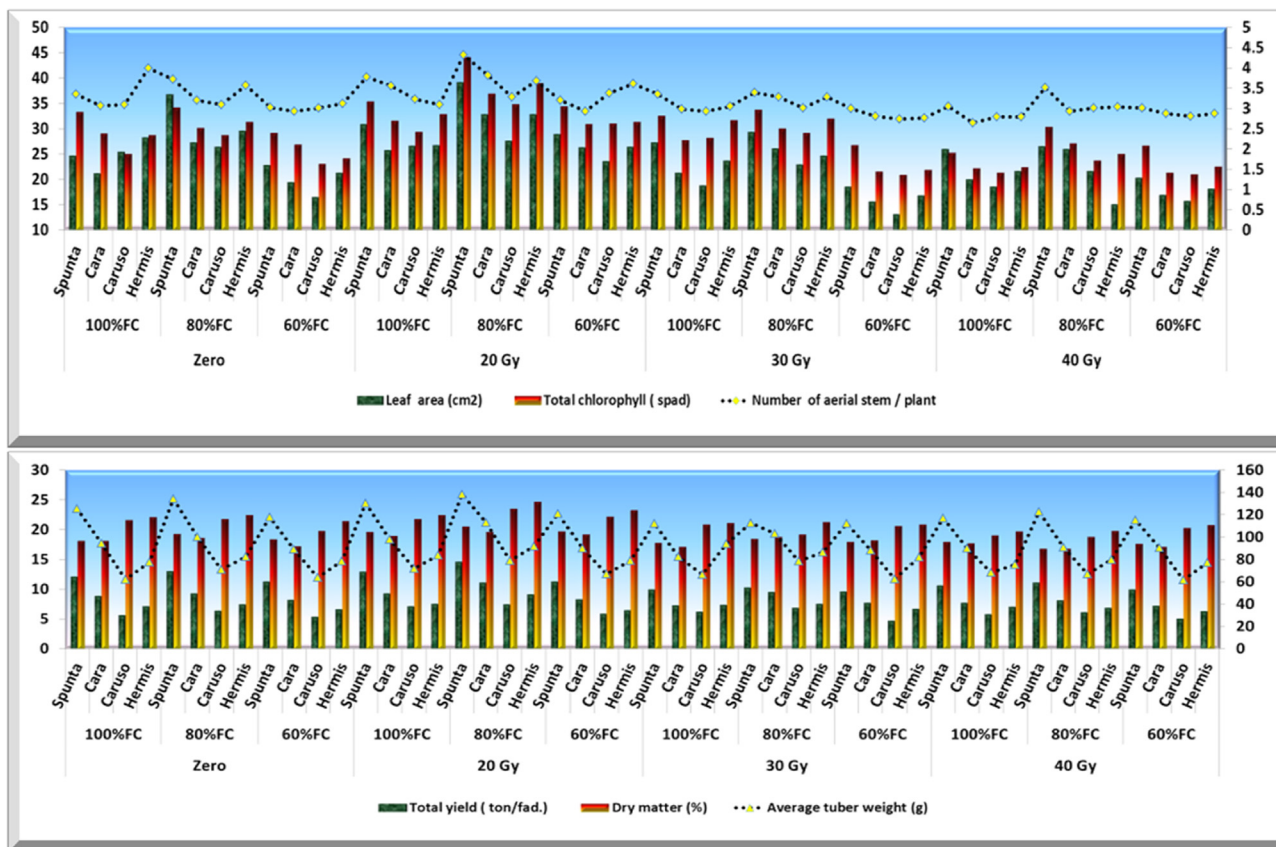


Fig. 8. Potato traits as affected by the triple interaction (FC × Gy × CV) as average of both studied mutagenic generations.

tion at 80% FC and Hermis cultivar (22.24 and 21.81%) in both mutagenic generations. Accordingly, the interaction between irrigation at 80% FC and spunta cultivar recorded the highest total yield/fed (12.580 and 11.896 ton/fed), while the interaction between irrigation at 60% of FC with Caruso cultivar recorded the lowest total yield/fed (5.393 & 5.094 ton/fed) in the first & second mutagenic generations, respectively.

Obtained results in Tables 3 and 4 and Fig. 8 showed that, there were significant differences between the triple interaction treatments on vegetative growth parameters, total chlorophyll in leaves, average tuber weight, total yield and tuber dry matter content in both generations. Number of aerial stem/plant, leaf area, total chlorophyll in leaves, average tuber weight and total yield/fed significantly increased with the interaction among irradiation at 20 Gy, irrigation level at 80% from FC and Spunta potato cultivar (80% FC × Spunta × 20 Gy) in the two mutagenic generations. On the contrary, irradiated Caruso with 30 Gy under water stress (60% FC) recorded the lowest values of most studied traits in average of both mutagenic generations (Fig. 8). Regarding tuber dry matter content, the maximum value was recorded with the triple interaction among treated Hermus cultivar with 20 (Gy) and irrigated with 80% from FC (24.72, 24.67% and 24.695% in 1st, 2nd and average of both generations, respectively). Accordingly, treated tubers of spunta cultivar with 20 Gy and irrigated with 80% from FC recorded the highest total yield/fed (14.559, 14.666 and 14.613 ton/fed in 1st, 2nd and average of both generations, respectively), while treated Caruso cultivar tubers with 30 Gy or 40 Gy exhibited the lowest total yield/fed (4.691 or 5.038 ton, respectively) as average of both generations (Fig. 8) under drought stress of 60% from FC treatment.

4. Discussion

Radiation of plants with a high dose of gamma rays disturbs the hormone balance and enzyme activity which inhibit the rate of cell elongation and result in a reduction in plant growth such as leaf area (Stoeva, 2002; Kiong et al., 2008). However, low dose of gamma ray may increase the enzymatic activation which stimulates the rate of cell division and result in promotion of plant growth. Tuber yield increased with low gamma dose and this could be due to increasing enzyme activation which stimulates the rate of cell division along with plant growth such as leaf area and plant height and ultimately increase tuber yield (Ali et al., 2016). These results are in concur with Al-Safadi et al. (2000), and Li et al. (2005) and Cheng et al. (2010) and Bado et al. (2016).

The improvement in total yield of potato plant might be because of the positive effect of moderate quantities of irrigation water on plant development & total chlorophyll which, resulted in an increase the potato yield. Primarily irrigation increase leaves development which in turn elevates net assimilation of organic nutrients & subsequently plant development and yield. Low water content lowers root development & suppress leaf elongation rate with elevation the concentration of ABA in the leaves (Smith and Dale, 1988) & lower CYT synthesis & export (Atkin et al., 1973) and this reflect on the development & potato yield. Drip irrigation regime of 80% FC might be enhanced the regular growth of the shoots, stolon formation, tuber initiation, early stage of tuber bulking, and tuber ripening, which are considered to be sensitive stages to water deficit stress in potatoes (Ierna and Mauromicale, 2012). The increasing tuber yield by increasing irrigation level might be due to the increase of total chlorophyll content. In addition, it

might be due to the increment of leaf transpiration, which correlate with the increasing water supply. Consequently, this might have a positive effect on yield via the enhancing gases exchange and photosynthesis process (Foti et al. 1995). Thus, to achieve high yielding of tubers, the soil water content should be no lower than 50% of the maximum available water in the root zone, particularly during tuber formation (Harris, 1978). Results are harmony with those obtained by Abubaker et al. (2014), Farrag et al. (2016), Adhikari and Rana, (2017), Dash et al. (2018), Mahmoud et al. (2019) and Eid et al. (2020). They showed that elevating irrigation water amount markedly improved the development and productivity of potato.

Yield quaintly affected by total chlorophyll content and These results are in agreement with those obtained by Hussein and Hamideldin (2014), Youssef et al. (2017), Tsegaye et al. (2018) and Banjade et al. (2019). All found that there were significant differences among potato cultivars for growth, yield and tuber quality.

5. Conclusion

Radiating potato cultivars pre planting with 20 (Gy) lead to reduce the water capacity by 20% without affecting the yield quality and quantity where, increasing number of aerial stem/plants, leaf area, total chlorophyll in leaves, average tuber weight, total yield/fed. Hermes cultivar with 20 (Gy) and irrigation with the same level of irrigation was the best for increasing dry matter content in tuber in both mutagenic generations.

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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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