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RESEARCH ARTICLE

MAXIMIZING WATER PRODUCTIVITY FOR IRRADIATED COWPEA

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ABSTRACT

Using water regime and biophysical applications on expansion agricultural area are very obligatory to achieve self sufficiency of crops. Pretreated cowpea seeds by four γ- doses (G) 0, 15, 25 and 35 Krad., were grown till maturity to determined their response under three water deficit percentage (W) 100, 85, 70%. (G) in conjunction with (W) results, were evaluated in terms of seed and yield indexes "SI","YI", biological and economical yields "BY" and"EY", harvest index "HI", water use efficiency "WUE", irrigation water productivity "IWP" and seed crude protein "CP", using split plot design. Results affirmed that all parameters had direct relations with studied treatments. Whereas, (W) has constrictive and significantly effects on all parameters except, EY and CP. So, irrigation regimes might not be increased more than 15%. In contrast, γ- irradiation – till 15 krad- has stimulatory and significantly ($P \leq 0.05$) effects on SI, YI, EY, HI, WUE, and IWP. On the other hand, exposed seeds by γ- ray with more than 15 krad., had a grave effect on shoots on this cultivar. Moreover, interaction between W×G had insignificant effect on parameters except YI. Eventually, W has been a positive exponential correlation with all parameters at all treatments except SI.

INTRODUCTION

Egypt looks for to increase cultivated area, in order to achieve self sufficiency of crops, through ambitious projects after revolution e.g., reclamation project 630,000ha. However, the limited water resources, and expose Egypt's historical rights in Nile river to risks, as a result of infringement in international agreements by Nile basin countries (construction Nahda dam in Ethiopia), or climatic conditions, (Egypt's occurrence in dray or semi arid region – move the rain belt to the south as a result of climate change, which reduce the amount of rain falling on Nile river source), represents real obstacles to achieving these goals. Meanwhile, horizontal expansion on sandy soil, bide several problems like, scarce and costly water supplies, poor ability for water conservation and reduction of fertility [1]. To overcome these problems, it must be recall new ideas, methods, and techniques. Water deficit (or regulated deficit) is technique in a package of applications aimed to reducing water consumption, maximizing water use efficiency and water productivity [2]. Although, there is a direct relation between reducing applied water and yield parameters, i.e., growth criteria, indexes of seed and harvest, biological and seed yield, and water use efficiency "WUE" on wheat and okra plants. Where, max. seed yield and greater "WUE" were achieved when irrigating to 100%., of field capacity [3, 4 and 5]. Meanwhile, there were insignificant differences for applied water between 100 to 80 or 75%., of field capacity on wheat and faba bean parameters [6 and 7]. Gamma radiation is ionizing radiation, had more ability of penetration, with low linear energy transfer, causing changes in physiological and structural on plants [8]. Gamma radiation increased growth and yield of plants [9].Noteworthy, the morphological and functional changes depended on power and duration of γ.dose of exposure. Where, a very low frequency of γ-rays could be detrimental to reducing germination, growth rate, and vigor [10]. Over and above, high doses disturb the protein synthesis, and enzyme activity [11]. In addition, γ-dose enhanced differ among plant species. For example, with 600 Gy ≈ 60 krad ., of γ-rays tend to stimulatory effects on plant height, branches no., root length, fresh and dry weight of leaves, stems and roots for okra and roselle [12]. Meanwhile, wheat and soybeans had the stimulatory effects with much lower doses [13 and 14]. Cowpea (*Vigna unguiculata* L. Walp.), is withstand salinity, and drought resistant crops, and considered as one of the most important warm season legume in newly cultivated land. It improves and restores soil fertility by crop rotation with fixing atmospheric nitrogen through root nodulation by the bacterium Rhizobium leguminosarum [15, 16, 17, and 18]. Where, it is an essential crop in developing countries, dray and semi-arid region. Also, it is a sustainable source of protein (23-25%) as food and fodder, good source of carbohydrate, vitamins, minerals and carotene.

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Table 1. Physical and chemical analysis of experimental soil.

Property	Sand (%)		Silt (%)	Clay (%)	Texture	FC (%)	PWP (%)	OM (%)	ρ (g cm^{-3})
Physical	Coarse	Fine							
	11.5	29.5	40.6	18.4	Silt	17	8	0.3	1.21
Chemical	pH	ECe dS m^{-1}				Meq l^{-1}			
			Cations				Anions		
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO^{-3}	SO^{-4}
	7.75	0.6	2.2	1.71	1.83	0.27	1.35	2.09	2.57

Furthermore, a source of cash income So, it is consumed as dry seeds - boiled alone or in combination with other foods-fresh green pods or leaves [19, 20, 21, and 22]. The experiment seeks to investigate the efficacy of water deficit and different doses of gamma ray on some metric traits, i.e., seed index, yield index, biological and economical yield, harvest index, water use efficiency, irrigation water productivity and seed crude protein for cowpea plants.

MATERIALS AND METHODS

Cowpea dry seeds [*Vigna unguiculata* (L.)], cultivar Kafr El–Shiekh supplied by private company (Mecca Trade), were allowed to grow till maturity, at Agricultural Engineering Research Institute (AEnRI), Giza governorate. Experiment carried out during Nile season (18/6 to 18/9/2017), in polyethylene pots (30 and 35 cm for diameter and long), which filled about 21.38 kg., of the soil for 25 cm., height. Pots placed in plastic dish to collect the flash water. Seeds irradiated with different doses of gamma ray (0. 15, 25, and 35 krad), using a gamma source ^{60}Co., through Egypt's Mega Gamma-1, of the type J-6500 supplied by the Atomic Energy of Canada limited. Where, irradiation process performed at the National Center for Radiation Research and Technology (NCRRT), Cairo, Egypt. Before sowing, experimental soil, physical analyses, chemical properties, permanent wilting point (PWP) and field capacity (FC) were carried out according to [23, 24 and 25] table (1). At the same day, after irradiation process, seeds inoculated by Bradyrhizobium sp. Vignae, with rate of 5g/kg., seed, prior to planting using arabic gum solution (16%) as an adhesive agent. Then, left to dry in the shade for minutes before planting. Six seeds were sown in each pot. Later than, germination by 15 days, the plants were thinned to 3 plants/Pot.

Water deficit (WD) was applied after thinning. The three water deficit "W" (as a percent of soil moisture content at field capacity) were 5962.16 cm^3., for control treatment "W_1" (100%), 5067.83 cm^3., for "W_2"(85%) and 4173.5 cm^3., for "W_3" (70%)., every 21days. Water with "EC"., of 0.5 dS m^{-1}., was applied at 18:00 Greenwich Mean Time "GMT"., by graduated beaker with 1000 ml., capacity. Weeds controlled by handing remove, while plants were sprayed three times with Malthion life 57%., Ec., (chemical name= O,O-dimethyl phosphorodithoate of diethyl mercaptosuccinate) at 1cm / l of water, to control insect's pests. Calcium super phosphate (15.5% P_2O_5), added, and mixed with the soil at the rate of 50 kg fed^{-1}., "Before planting" for hollow amount of experimental soil. After 21 days from planting Ammonia sulphate (20% N) as N., fertilizer, potassium sulphate (48% K_2O), and calcium super phosphate (15.5% P_2O_5), were applied at rate of 50 kg fed^{-1}. Plants harvested after 90 days, as 95% from matured pods on the vine were dry. They were uprooted carefully from pots, and sun dried for one week, as well as, dried in hot air oven at 70°C ±10., until a constant weight.

Metric traits, i.e., seed index "SI" (g), yield index "YI", biological yield "BY" (kg fed^{-1}), economical yield (seed grain yield) "EY" (kg fed^{-1}), and harvest index "HI", were estimated as dry matter. As well as, crude protein "CP" in seeds (g/100g) was determined according [26]. While, water use efficiency “WUE” (Kg m^{-3}) and irrigation water productivity “IWP” (Kg m^{-3}) were calculated according to the following eqs.

$$\text{“WUE”}(kg\ m^{-3}) = \frac{\text{Biological yield " BY"(Kg fed}^{-1})}{Total\ applied\ water\ \text{" TAW"(m}^3\ \text{fed}^{-1})} \quad (1)$$

$$\text{IWP”(Kg m}^{-3}) = \frac{\text{Economical yield "EY" (kg fed}^{-1})}{\text{Total applied water "TAW" (m}^3\ \text{fed}^{-1})} \quad (2)$$

Pots experimental included 12 treatments, the combination of three applied water quantities (W) × four levels of gamma ray dose (G), with eight replications. Experimental design was split plot design. The main plots assigned to apply water quantities (W), while subplots were different levels of gamma ray dose (G). All data obtained were subjected to statistical analysis of variance (ANOVA), according to the procedures outlined by [27], followed by the least significant difference test (LSD-test), with significance level 95%.

RESULTS

Noteworthy, there were not exist for any shoots derived from seeds exposed to doses more than 15 krad ≈150Gy. Results presented in (Fig.1), show clearly that water deficit "W" from W_3 to W_1 or W_2, significantly increased cowpea seed index "SI" (g), by 294.69 and 280.1% at control seeds (C)., and about 255.26 and 182.33 at G_1 (15 krad). Where, the plants grown under the condition of W_1 was significant higher "SI" (12.2 and 18.2g) compared with plants at W_3 which produce lightest "SI" (4.14 and 7.13g) for C and G_1 (15krad). Meanwhile, the difference between W_1 and W_2 did not reach to a significant level. For γ dose "G" data showed that a significant difference between C and G_1 treatments. Where, expose seeds by 15 krad., lead to increase "SI" about 149.18, 112.07, and 172.23%., at W_1, W_2, and W_3., respectively. By contrast, the interaction between W and G, had insignificant effect on this character. That may due to the independent and inconsistent effect of them. Yield index "YI" is product indicator, include; pods no/plant, pod length (cm), seeds no/pod, and "SI" (g). With regard to obtained results demonstrated at (Fig.1) reveled that "YI" was significantly decreasing with the W. The reduction of "YI" reached to 31.34 and 25.35% from W_1 or W_2 to W_3. As "SI" results, WD did not affect on "YI" significantly from W_1 to W_2. Where, reduction applied water more than 85%.,(W_2) leads to deterioration "YI". With references to γ-dose results showed that "YI" was significantly affected by γ-dose. It obvious from irradiation that, exposing seeds by 15 krad., had a constructive impact on

"YI" about 11.03, 9.5, and 6.7% at W_1, W_2, and W_3 respectively.

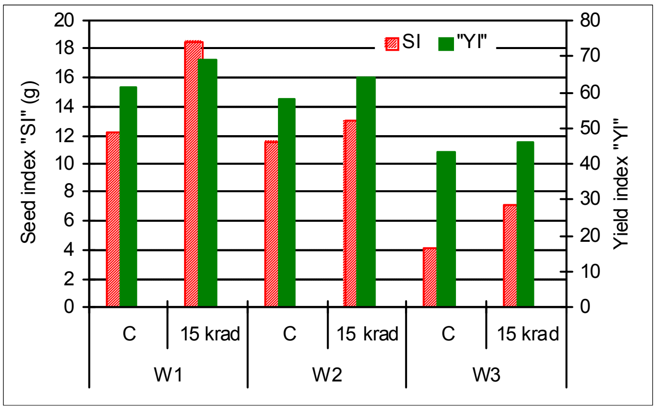

Fig. 1. Histograms illustrating effects of water deficit "W" and γ-dose "G" on seed index "SI" (g) and yield index "YI"

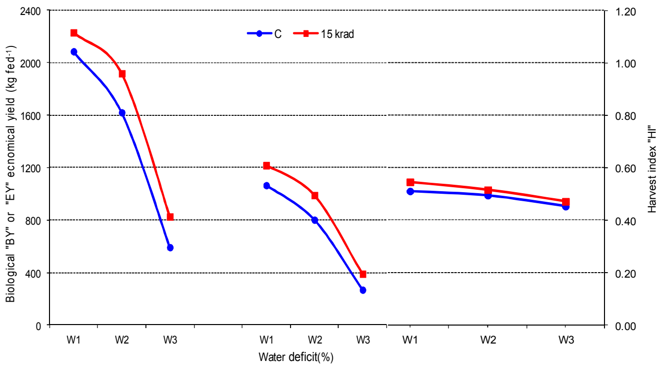

Fig. 2. Biological "BY", economical "EY" yield (kg fed-1) and harvest index "HI" Vs. applied water quantities "W" at different γ-dose irradiation "G"

The interaction between "W" and "G" was significant. However, $W_1\times G_1$ treatment had the highest value of "YI", while, $W_3 \times C$ resulted the lowest value of "YI". Biological "BY" or economical "EY" yield (kg fed^{-1}) Vs. W at different G, are presented in Fig.2. The highest biological (biomass) or economical (grain seed) yield were observed with fully irrigation (W_1) while, the lowest were with W_3 treatment. Where, water stress has reduced both of them. "BY" and "EY" directly decreased with decrease "W", in all treatments. Where, BY= -746.97 W + 2926.9, with R ≈0.97., at "C" treatment, as well,= -702.16 W + 3062.8, with R ≈ 0.95., at G_1, treatment. Meanwhile, EY = -398.52 W +1508.8 = - 413.87 W + 1693.3., at C and G_1 treatments with $R^2 \approx 0.96$, and 0.94. Eventually, harvest index "HI" values ranged from 0.45 to 055. Max. values of "HI" (0.55 and 0.51), were obtained with W_1 at C and G_1 treatments, meanwhile, min. values (0.45, and 0.47) were scored with W_3 at C and G_1 treatments. Exposing seeds by 15 krad., lead to increase "HI" about 106.25%. Meanwhile, enhanced W from W_3 to W_1 lead to increase "HI" about 113.04%. (Fig.2). Increasing WD percentage resulted in progressively lower WUE. Where, at W_1 treatment, WUE was 1.48 and 1.58 kg m^{-3}., while it reduced to 0.54 and 0.76 kg m^{-3}., as WD percent increased from W_1 to W_3 for C and 15 krad., treatments. Conversely, decreasing WD percentage, consequence gradually higher IWP. Where, IWP increased about 118.75 and 108.86%., by decrease deficit percentage from 15 to 0% at C and 15 krad., treatments. Concerning, WUE and IWP data presented in (Table. 2) revealed that, there had negative direct proportions with "W" at all treatments. As well as, "W" significantly affected on WUE and IWP from W_1 or W_2 to W_3, but the difference did not approach to significant level from W_1 to W_2. Where, WUE decreased about 57.51 and 54.23 %., as well, IWP decreased about 61.73 and 56.95%. Contrary to the former relations, there were a positive proportional between them and γ-dose. Therefore, irradiated seeds by 15 krad., both WUE and IWP were enhanced at all W treatments. WUE and IWP as affected by γ-dose, results show that irradiated seed by 15 krad., was significantly higher than control by 16.21 and 21.82%. The interaction between "W" and "G" was insignificant on those indicators. It could be due to independent and inconsistent effect of γ dose and applied water on data of "WUE" and "IWP".

Table 2. Effect of W, G and their interaction on WUE and IWP

	"WUE"			"IWP"		
G	C	15 krad	Mean	C	15 krad	Mean
W						
W_1	1.48	1.58	1.53	0.76	0.86	0.81
W_2	1.30	1.53	1.42	0.64	0.79	0.72
W_3	0.54	0.76	0.65	0.25	0.36	0.31
Mean	1.11	1.29	1.2	0.55	0.67	0.61
LSD Date 0.05						
W		*			*	
G		*			*	
W × G		NS			NS	

Water deficit "W" insignificantly ($P \leq 0.05$) affected the total crude protein "CP" (g/ 100g of dry weight) on grain seed. CP decreased with decreasing W. Max. CP value on grain seed (38.12g /100g) was scored under W_1C treatment. Meanwhile, the min. CP value (34.62 g/100g) was scored under W_3G_1 treatment. γ- dose as well, had insignificant effect on CP. Exposing seeds by 15 krad., (G_1) tended to decrease CP about 5.2% (Fig.3).

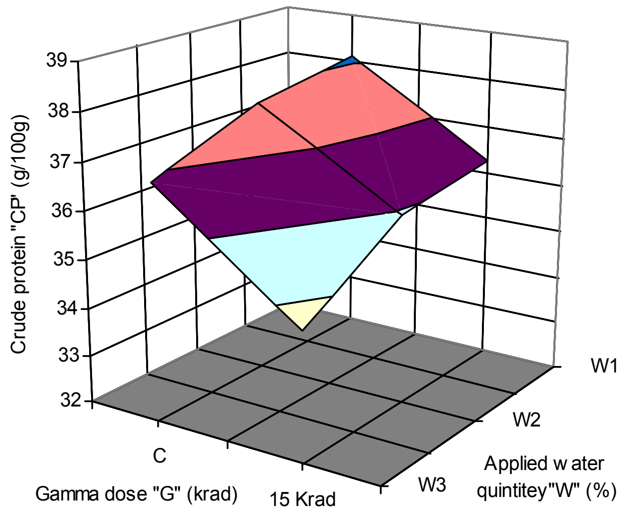

Fig. 3. Effects of studied parameters on crude protein "CP" (g/100g)

Of these results, W has been a positive exponential correlation with metric traits at C treatment. Where, $W= 0.5981e^{0.04(SI)}= 0.326\ e^{0.02(YI)}= 0.6045\ e^{0.0002(BY)}= 0.617e^{0.0004(EY)}= 0.0513e^{5.79(HI)}= 0.5755e^{0.34(WUE)}= 0.5884e^{0.65(IWP)}= 5 \times 10^{-4} e^{0.27(CP)}$. At the same manner, with G_1 treatment W also has been a positive exponential correlation with all parameter studied except SI. Whereas, it has been a positive linear correlation with SI. Where, W = 0.0262 (SI) + 0.5127 = $0.3569e^{0.01\ (YI)}$ = $0.5705e^{0.0002\ (BY)}$ = $0.5904e^{0.0004(EY)}$ = $0.0879e^{4.4(HI)}$ = $0.543e^{0.34(WUE)}$ = $0.5547e^{0.62\ (IWP)}$ = $0.0002e^{0.23(CP)}$ (Data not shown).

DISCUSSION

The foregoing results showed that all cowpea parameters under current studied, were affected negatively following 100, 85 and 70%., (W_1, W_2 and W_3). Where WD presumably, modifies inner structure of chloroplasts and reduced their size, causes internal chloroplast membranes degradation [28]. Therefore, reduce total chlorophy ll, about 12%., inhibiting photosynthesis activity about 42%., by harms the photosynthetic apparatus [29]. In addition, it reduce plant leaves relative water content [30], and modifies some enzymes activity and sugars and proteins accumulation in the plant [31]. In contrast of WD, studied parameter had affected positively by gamma irradiation. Where, exposing cowpea seeds by 15 krad., caused affirmative effect on criteria of vegetative growth, plant biomass, and YI index. A stimulatory, effect of low dose of gamma irradiation – till 15 krad – is associated with increase mitotic activity in the roots, promote cell respiration, enzyme activation, and accelerated development the metric traits of plants. These results advocated by [32 and 33]. On the other hand, inconsistent effect of W and G varies in chloroplasts originated from water deficit, plants pretreated with γ- ray were not as drastic as those behold for plants under water deficit only [34]. Where, low dose irradiation and water deficit will encourage the vegetative growth stimulation by changing the hormonal signaling network in plant cells [35].
Of late results, no plants outgrowth from exposed seeds to ≥ 15 krad ≈150 Gy. Similar results were demonstrated by [36 and 37]. Where, a high dose of gamma rays disturbs the hormone balance, protein synthesis, and enzyme activity [38]. These results were also supported previously on wheat and maize grain yield by [36, 39, 40, and 41]. In addition, [42], observed that with increasing dosage, frequency of chromosomal damage may be accountable for reduction in plant survival. On the other hand, this remark was conflict with [9 and 43].

The most probable explanation of "SI" results, is that WD during pod filling stage reduce assimilate for grain filling and retains location of stored assimilates to the grain which in turn led to reduction in grain size [44]. Reduction on cowpea YI from 100 or 85 to 70%., is associated with water deficit action [45]. While, increasing pods no./plant^{-1} and seeds no./pod, were more pronounced and significant effect at 15 krad. Those results advocated by [46]. Water deficit during plants flowering and pod filling exhibit fewer elongated vines resulted in lower plant growth, and reduction on BY, EY, and HI [4, 47 and 48]. In addition, [49, 50, 51, 52 and 53], explicated the lowest values of biological yield, components under the condition of less moisture on wheat, furthermore, reduction in yield components. Over and above, pretreated seeds with gamma dose before planting tended to increase in criteria of vegetative growth (shoot length and dray weight, leaf length and area, terminal leaflet length and width), therefore, increasing plants biomass. These results advocated by [43 and 54]. Most reduction in WUE and IWP due to decrease total water applied according to the deficit percent and therefore due to the decreasing in seed yields [45]. Apparently, crude protein decreased by exposing seeds to gamma irradiation [55 and 56]. Of these results have been dissimilar than which reported by [46, 57, 58 and 59], they declared that the seeds irradiated with gamma rays increase and promote crude protein content. Similar observation had been marked by [42], they reported that low dose of gamma irradiation enhanced protein synthesis in *Citrus sinensis*. Whereas, [60], clarified that content of crude protein "CP" not significantly affected by γ- irradiation at both 5 and 10 kGy., other than, these results were differed considerably with [61].

Conclusion

In general, all parameters under current studied had a direct proportion with "W" & "G". Where, response of studied parameters were obviously decreased by withholding water, and enhanced by increasing γ- dose till 15 krad. Where, there were positive exponential correlations between parameters and studied treatments, except "SI" have an linear correlation with "W", at 15krad. Further, yield and yield components, "WUE", "IWP" and "CP", could be predicted from "W" value using the following equation; W= $0.5981e^{0.04\ (SI)}$ = $0.326\ e^{0.02(YI)}$ = $0.6045\ e^{0.0002(BY)}$ = $0.617e^{0.0004(EY)}$= $0.0513e^{5.79(HI)}$ = $0.5755e^{0.34\ (WUE)}$ = $0.5884e^{0.65\ (IWP)}$ = $5\times10^{-4}\ e^{0.2736(CP)}$., at control seeds. As well as, W = 0.0262 (SI) + 0.5127 = $0.3569e^{0.01(YI)}$= $0.5705e^{0.0002\ (BY)}$ = $0.5904\ e^{0.0004(EY)}$ = $0.0879\ e^{4.4(HI)}$=$0.543e^{0.34(WUE)}$= $0.5547e^{0.62(IWP)}$ = $0.0002\ e^{0.23(CP)}$., with seeds exposed to 15 krad., of gamma ray. The results concluded that, the deficit percent and γ- dose might not be increased more than 15%., and 15 krad., on this cowpea cultivar in order to achieve higher water use efficiencies.

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