FACULTY OF AGRICULTURE

Minia J. of Agric. Res. & Develop.
Vol. (43), No.4, pp. 789 - 818 , 2023

EVALUATION OF GROWTH YIELD AND ITS ATTRIBUTES OF SOME SOYBEAN CULTIVARS AS AFFECTED BY IRRIGATION INTERVALS AND PLANTING METHODS.

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Received : 11 Dec. 2023 Accepted: 20 Dec. 2023

ABSTRACT

The present study was carried out at the Experimental Farm of Faculty of Agriculture, Minia University, Egypt during two seasons of 2020 and 2021 to study the response of three soybean cultivars to irrigation intervals and planting methods. Irrigation intervals, planting methods, cultivars in addition first and second order of interactions among them had significant effect on most of growth, yield attributes and water relations in both growing seasons. Seed yield feddan^{-1} was gradually decreased with prolonging irrigation interval from 14 to 28 days in both seasons. The reduction percentages in seed yield feddan^{-1} as the mean of the two seasons were 23.05 and 49.40% with irrigation by interval of 21 and 28 days compared to interval of 14 days, respectively. The heaviest seed yield feddan^{-1} was obtained for the planting on ridges compared to terraces. The increase percentages of seed yield due to Giza 111 and Giza 22 almost were 8.00% compared to Crawford in first and second seasons, respectively. About the effect of irrigation intervals x planting methods interaction on seed yield/fed. in both seasons. It could be recommended that irrigation by interval of 14 days with planting on ridges can achieve the heaviest seed yield feddan^{-1}.

Keywords: Soybean, cultivars, irrigation intervals, planting methods, seed yield.

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is the most important crops for obtaining oil and protein worldwide. Its seeds have the highest protein content among leguminous crops **(Sinclair *et al.* 2014)**. Its oil is used either directly in the human consumption or indirectly in the many manufactured valuable materials. Indeed, soybean seeds has many uses such as human food, animal feed. However, soybean plants foliage can be used as hay, pasture, cover and green manure crop **(Essa and Al-Ani, 2001).**

The increase of soybean acreage as a summer crop to face the great demand for edible oil and poultry feed is very difficult because of competition with other strategic crops as cotton, corn and rice. High yield of soybean per unit area is the aim of agronomists and farmers under the limited area and water resources. Therefore, it is necessary to increase the productivity per unit area of soybean and/or horizontal expansion in newly reclaimed lands. Irrigation management is very important nowadays owing to shortage in irrigation water because of the increase of human and agricultural consumption especially in the newly reclaimed lands. Therefore, it is necessary to determine the optimum water requirements and planning the best irrigation regime for obtaining maximum yield. More attention was paid to maintain the water resources by minimizing the losses, decreasing the water consumption and indicating the best schedule soybean irrigation for farmers.

Irrigation from the critical factors affecting growth, yield, and its attributes of soybean. Exposing soybean to soil moisture stress might cause harmful effect on growth, yield, and its components especially during pod development and seed fill **(Kranz *et al.*, 1998).** The growth and yield components significantly affected in clay loam soil in Egypt by irrigation intervals. Irrigation every 14 days gave the greatest values for plant height, dry matter plant^{-1}, seeds plant^{-1} and yield fed^{-1} in comparison with irrigation every 7 and 21 days **(Ibrahim and Kandil, 2007**).

The effect of irrigation every 2 and 3 weeks on growth and yield attributes of soybean plants was studied by **Hussein *et al.* (2019**) who, showed significant effect for irrigation intervals on plant height, branches plant^{-1}, leaf area index LAI, pods plant^{-1} and dry weight plant^{-1}. Days to flowering and maturity, plant height, branches and pods plant^{-1}, seeds/pod, seed index, seed yield feddan^{-1} and water consumptive use were significantly increased with each increase in available soil moisture ASM% before irrigation from 20 to 50% in both seasons. The maximum values for water use efficiency WUE were recorded for plots irrigated at 35% of ASM followed with significant differences by that irrigated at 50% of ASM (**El-Karamity, 1998). Ali** and **Abdel Aal (2021)** found significantly decreased in leaf area, plant height and dry matter plant^{-1}, pods plant^{-1}, no. and weight of seeds pod^{-1}, 100-seed weight and seed yield plant^{-1} and fed$^{-1.}$ As a result, prolonging irrigation interval to 20 days. It could be save water amounted by 18.62% with irrigation every 16 days and 27.82% with irrigation every 20 days compared to 12 days. Irrigation after 16 days correlated with hydrogel produced the greatest values of WUE meaning it’s more effective on consumption productivity of water. Soil moisture content lower than 75% field capacity decreased the net assimilation rate, LAI and 100-seed weight. Seed filling stage is more sensitive to water shortages than the vegetative or flowering stages. At all growth stages, a high level of drought equals a high reduction in the growth and yield of soybean **(Aziez and Prasetyo, 2022).**

The planting methods on ridges and terraces have a great importance in productivity and saving irrigation water compared to flat cultivation. In addition to save in the quantity of seeds, speed of germination (**Madhana *et al.*, 2022)**, the regular appearance of plants and the homogeneity of the distance between plants (**Kang *et al.,* 2012)** as well as ease of performing all service operations, such as irrigation, fertilization and weeds control to increase crop productivity, and the planting method on terraces could be save the amount of added water compared to planting on ridges or flat cultivation (**Jayapaul *et al*., 1995** and **Jain and Dubey, 1998).**

Seed yield plant^{-1} of ridges and furrows planting was superior over the flatbed sowing method by 9.79% (**Madhana *et al.,* 2022).** The planting on furrow and ridge achieved the highest values for growth attributes, straw and seed yield compared to soybean planting on normal flatbed (**Dhakad *et al*., 2015).**

There are wide variations among soybean cultivars in seed yield and yield components. Therefore, the main factor affecting soybean production is selecting the suitable soybean cultivar. **Hassan *et al*. (2002)** indicated that Giza 22 cultivar surpassed all tested cultivars in no. of pods and seeds and seeds weight/plant. However, Giza 111 gave the heaviest seed index then Giza 22 then Crawford. **Mehasen and Saeed (2005)** found that significantly high values for traits pods and weight seeds plant^{-1}, seed index and seed yield fed^{-1} for CV. Giza 22 compared to CV. Giza 111. **Shaheen (2010)** indicated that the two cultivars Crawford and Giza22 had the tallest plants compared to the Toano cultivar. **Shairef *et al.* (2010)** found that Crawford yielded the highest straw yield (t/fed). **Mostafa (2011)** and **El-Karamity *et al*. (2015)** showed that Giza 22 cultivar gave highest values for plant height and branches plant^{-1}. **Kandil *et al.* (2012)** observed that Giza 22 surpassed Giza 111 in plant height, pods and seeds plant^{-1} and seed yield (ton/fed) in both seasons.

The present study aimed to investigate the effect of irrigation intervals and planting methods on growth, seed yield and its attributes and water relations of some soybean cultivars under water stress conditions.

MATERIALS AND METHODS

The current investigation was conducted at the Experimental Farm of Fac. Agric., Minia Univ., El Minia Governorate, Egypt, during the two seasons of 2020 and 2021 to investigate the response of three soybean cultivars to irrigation intervals and planting methods. The experiment was conducted in silty clay loam soil. The soil analysis is presented in Table (1).

Table 1. Mean in both seasons. mechanical and chemical analyses of the soil

Mechanical analysis	**Clay %**	**Silt %**	**Sand %**	**Texture**
	54.74	35.34	9.92	Clay loam
Chemical analysis	**pH**	**N%**	**P mg / 100 g**	**K ppm**
	7.96	0.88	12.87	16.00

Source, Soil and Water Lab., Fac. Agric., Minia Univ.

In both seasons, the experiment included 18 treatments which the combinations of three irrigation intervals, two planting methods and three soybean cultivars. The experimental design was randomized complete blocks (RCBD) in split-split-plot arrangement with three replicates. The main plots occupied three irrigation intervals as 14, 21 and 28 days. The sub-plots comprised the two planting methods on ridges, the experimental plot consisted of 6 ridges (4 m long and 60 cm width) and on terraces, the experimental plot consisted of 3 terraces (4 m long and 120 cm width). The sub-sub plots comprised to three soybean cultivars Giza 111, Giza 22 and Crawford (Table 2).

Table 2. Maturity group, growth habit and pedigree of soybean cultivars

Cultivars	Maturity group	Growth habit	Pedigree	Days to maturity
Giza111	IV	Indeterminate	Crawford × Celest	115-120
Giza 22	IV	Indeterminate	Crawford × Forrest	115-120
Crawford	IV	Indeterminate	Williams × Columbus	120-125

The preceding previous crop was wheat in both seasons. The experimental field was prepared by fertilization with phosphorus at rate of 30 kg P_2O_5/Fadden in of calcium superphosphate (15.5% P_2O_5). A starter dose of 15 kg N/feddan in urea form (46.5% N) added at sowing. Seeds were inoculated with the specific *Brady Rhizobium japonicum*, 15 minutes prior sowing. The commonly known Afir method of sowing was used on 25th and 27th of May in the first and second seasons, respectively. Seeds were sown in hills of 20 cm apart on both sides of the ridge and 4 lines on the terrace.

Irrigation was done immediately after planting. Thinning of seedlings was to 2 plants/hill, two weeks after sowing to attain the desired plant population density of 140000 plants /fed. Plots were kept free weeds throughout the growing seasons. Other recommended agricultural practices were conduct for El-Minia province.

The following studied characters were recorded:

- **Phenological traits:** Days to 50% flowering and Days to 95% maturity.
- **Growth measurements:** Its were recorded according to **(Gardner *et al.* 1985)** at 45, 60 and 75 days after sowing (DAS) on 5 randomly guarded plants taken from the sampling row of each plot. Plant fraction were separated and oven dried at 70° C to constant weight as follows: Dry weight plant^{-1} (g), leaf area index LAI = plant leaf area cm^2 / plant ground area cm^2 and net assimilation rate NAR (mg/cm^2/day) = $[(W_2\text{-}W_1)(\text{Ln } A_2 - \text{Ln } A_1)]/[(T_2\text{-}T_1)(A_2\text{-}A_1)]$ Where, W_1 and W_2 refer to dry weight, A_1 and A_2 refer to leaf area of at first t_1 and second t_2 time in days.
- **Yield components:** 10 guarded plants were chosen randomly from the three

middle ridges of each sub-sub plot to record the following yield components; plant height (cm) (PH), number of branches plant^{-1} (NB/P), number of pods plant^{-1} (NP/P), number of seeds pod^{-1} (NS/Pod) and 100-seed weight (g) (seed index) (SI).

- **Yield per unit area:** Seed yield feddan^{-1} (ton) (SY) and straw yield feddan^{-1} (ton) (StY) were estimated on the basis of the three middle ridges or the middle terraces of each experimental unit.

-**Water relations measurements:** estimated for each irrigation interval during the two seasons as follows:

1- Water consumptive use (WCU) (m^3/fed).

The depleted soil moisture was detected after each irrigation and the water consumptive use WCU = D × Bd × (e_2–e_1) / 100 **(Israelsen and Hansen, 1962):** Where: WCU = Water consumptive use (ET) in mm., D = Soil depth (cm), Bd = Bulk density in g/cm^3, e_1, e_2 = Soil moisture content before e_1 and after e_2 each irrigation. Soil samples were taken from 0-20, 20-40 and 40-60 cm depth with a regular auger from planting time to harvest time before and 48 hours after each irrigation to determine soil moisture content (Table 3).

Table 3. Soil moisture contents of the experimental site.

Soil depth(cm)	**Bulk density g/cm^3**	**Field capacity%**	Wilting point
0-20	1.25	34.70	16.40
20-40	1.31	31.55	15.52
40-60	1.36	24.65	14.11

2- Water use efficiency (WUE) in Kg/m^3 = seed yield in Kg fed.$^{-1}$ / WCU in m^3 fed.$^{-1}$ **(Pierre *et al*. 1965).**

Data statistical analysis

All obtained data in both seasons were subjected to proper statistical analysis according to procedures outlined by **Steel and Torrie (1980)** and the difference among treatment means were compared using Least Significant Difference test (L.S.D) at 5% level of probability.

RESULTS AND DISCUSSION

Phenological characters

Days to 50% flowering and 95% maturity were significantly affected by irrigation intervals and planting methods in the two seasons except the maturity in 1st season. Prolonging irrigation intervals from to 14 to 28 days decreased gradually days to 50% flowering and 95% maturity. The earliest plants in flowering and maturity were recorded for irrigation of 28 days, while the latest ones were achieved from irrigation every 14 days (Table 4).

The earliest plants in flowering in 2nd season and maturity in the two seasons were recorded for sowing on terrace.

Soybean cultivars were significantly differed for their maturity in the two seasons; however, soybean cultivar did no show significant difference in 50% flowering in the two seasons. Concerning the maturity, the earliest cultivar was Crawford in both seasons. The earliest plants in flowering were obtained for Giza 22 and Crawford sown on terraces and irrigated every 28 day in 2020 and 2021 seasons, respectively (Fig. 1).

The interactions among planting methods, irrigation intervals and cultivars and each other possessed significant effect on days to 95% maturity in 2nd season (Fig. 2).

The earliest plants in maturity were recorded for plots sown on terrace and irrigated by interval of 28 day, while the latest one were recorded for plots planted on ridges and irrigated every 14 days. Moreover, the earliest plants in maturity were recorded for Crawford irrigated by interval of 28 day. In addition the earliest plants in maturity were recorded for plots planted with Crawford sown on terrace. Absolutely, the earliest plants in maturity were recorded for Giza 111 sown on the terraces irrigated by interval of 28 day (Fig. 2).

Table 4. Effect of irrigation intervals, planting methods and soybean cultivars on days to 50% flowering and 95% maturity in 2020 and 2021 seasons.

Treatments	**Days to 50% flowering**		**Days to 95% maturity**	
	2020	**2021**	**2020**	**2021**
Irrigation intervals (days)				
14 days	34.61	34.99	116.89	119.72
21 days	33.01	32.84	114.39	115.61
28 days	31.66	30.30	108.39	109.49
LSD 5%	0.64	0.67	2.98	2.08
Planting methods				
Ridges	33.40	33.73	114.63	116.29
Terraces	33.73	31.69	112.56	113.59
F-test	*	*	NS	*
Cultivars				
Giza 111	33.24	32.50	115.17	115.50
Giza 22	32.81	32.80	113.83	114.94
Crawford	33.23	32.82	111.78	114.38
LSD 5%	NS	NS	1.38	0.60

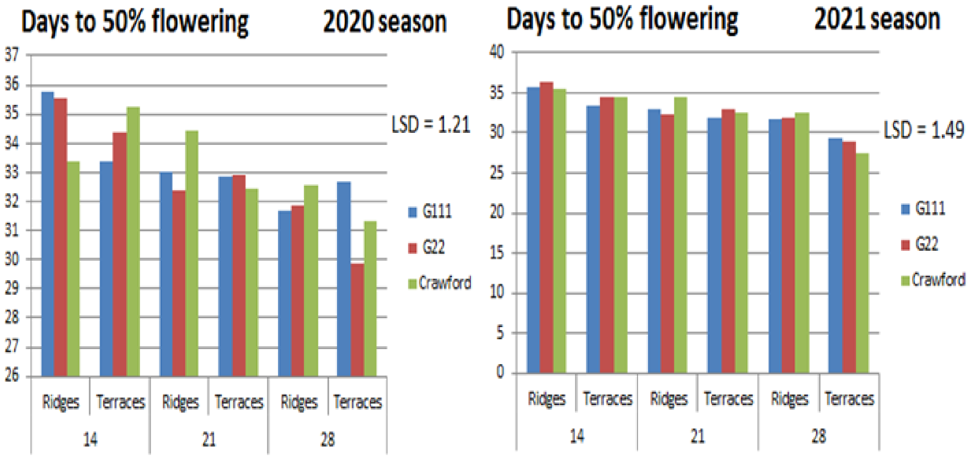

Fig. 1. Effect of irrigation intervals x planting methods x cultivars interaction on days to 50% flowering in 2020 and 2021 seasons.

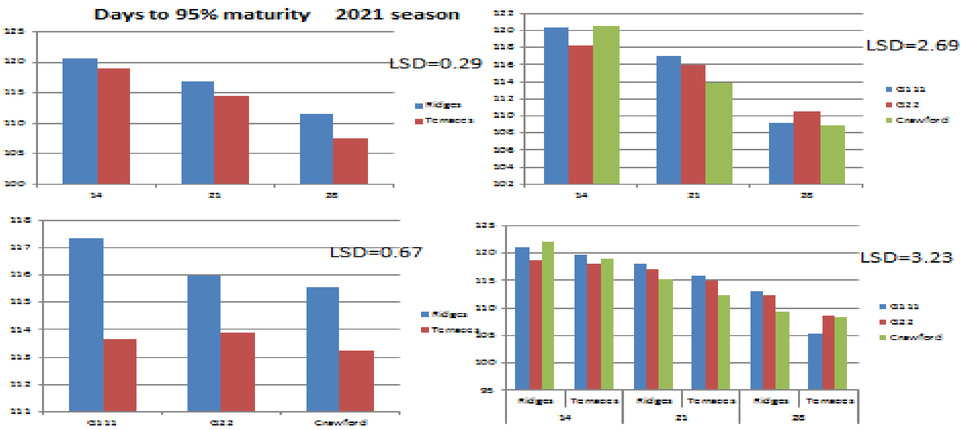

Fig. 2. Effect of the interactions among irrigation intervals, planting methods and cultivars and each other on days to 95% maturity in 2021 season.

Growth parameters:

Irrigation intervals, planting methods and cultivars exhibited significant effect on dry matter/plant (Table 5) and LAI (Table 6) at three different ages of 45, 60 and 75 DAS in the two seasons except cultivars effect at 45 DAS in 1st season. Concerning interactions, irrigation intervals x planting methods interaction revealed significant effect on dry matter plant^{-1} (Table 5) at 45 and 60 DAS in 2nd season and LAI (Table 6) at 45 and 60 DAS in the two seasons. Irrigation intervals x cultivars interaction had significant effect on dry matter plant^{-1} at 60 and 75 DAS of 2nd and 1st seasons, respectively (Table 5) and on LAI at 60 DAS of 1st season and the three ages of 2nd season (Table 6). Planting methods x cultivars interaction detected significant effect on dry matter plant^{-1} at 60 and 75 DAS in 1st season and at 45 DAS in 2nd season (Table 5) and on LAI at three ages of two seasons (Table 6). Irrigation intervals x planting methods x cultivars interaction had significant effect on dry matter plant^{-1} at 60 and 75 DAS in 1st season (Table 5) and on LAI at three ages in the two seasons (Table 6). The heaviest dry matter plant^{-1} and LAI was recorded for plants irrigated by interval of 14 days followed by those irrigated every 21 days at different ages in the two seasons. The decrease in dry matter plant^{-1} may be attributed to the effect of irrigation water deficit via prolonging irrigation interval (water stress) which reflect on physiological and metabolites processes, therefore an reduction in metabolites could be expected, consequently plant dry matter. These results are in agreement with those reported by **El-Shafey (2017) and Ali and Abdel Aal (2021).**

Concerning to the effect of planting methods, the maximum values of dry matter plant^{-1} (Table 5) and LAI (Table 6) were recorded for the planting on ridges at three ages in both seasons. While, the contrast was recorded for planting on terraces. This may be exposing terraces planting to water stress which negatively effect on metabolites formation, consequently, plant dry matter. These results were are agreement with those reported by **Gajic *et al.* (2018), Basediya *et al.* (2020) and Keerthana *et al.* (2021).** The differences in LAI with different water supply is mainly due to the variation in total leaf area/plant. These results are in agreement with those reported by **Abdel Reheem *et al.* (2018), Khattab *et al.* (2019) and Ali and Abdel Aal (2021).**

The heaviest dry matter plant^{-1} was recorded for Giza 111 cultivar at 60 and 75 DAS in both seasons (Table 5). These results may be attributed to genetic construction of studied cultivars and its interaction with environment condition prevailed during growth seasons. Giza 22 gave the greatest values for LAI at 45 DAS age in both seasons in addition to 60 DAS age in the 2nd season. However, Giza 111 surpassed all studied cultivars at 60 DAS in the 1st season and at 75 DAS in both seasons (Table 6). The present findings may be due to the differences in total leaf area per plant among the studied genotypes. These results are in agreement with those reported by **Ibrahim (2014), Khattab *et al.* (2019) and Saad *et al.* (2023) .**

Concerning interaction, it is worthy to note that the greatest dry matter plant^{-1}

and LAI was achieved with irrigation by interval of 14 days with planting on ridges at three ages in both seasons (Tables 5 and 6). With regard to irrigation intervals x cultivars interaction, the highest values of dry matter plant^{-1} were recorded for Giza 111 irrigated every 14 days at 60 DAS and Crawford at 75 DAS in 2020 season.

The highest values for LAI were recorded for irrigation every 14 days with planting Giza 22 at 45 DAS in 1st season and Giza 111 at 75 DAS in 2nd season. However, the highest LAI was recorded for Giza 22 and Giza 111 irrigated every 14 days at 60 DAS in the 1st and 2nd seasons, respectively (Table 6).

With regard to planting methods x cultivars interaction effect, the maximum values of dry matter plant^{-1} were recorded for Giza 111 planted on ridges at 60 and 75 DAS in 1st season (Table 5). The highest values of LAI were recorded for planting on ridges for each of Crawford and Giza 22 at 45 DAS in 1st and 2nd seasons, respectively, Giza 111 at 75 DAS in both seasons and Giza 111 and Giza 22 at 60 DAS in 1st and 2nd seasons, respectively (Table 6).

For the 2nd order of interaction, the highest values of dry matter plant^{-1} was recorded for irrigation every 14 days and planting on ridges for each of Giza 22 at 45 DAS in 2nd season and at 60 DAS in 1st season and Crawford at 75 DAS in 1st season (Table 5). The highest values of LAI were recorded for irrigation by interval 14 days and planting on ridges for each of Crawford and Giza 22 at 45 DAS in 1st and 2nd seasons, respectively. In addition to Giza 111 and Giza 22 at 60 DAS in 1st and 2nd seasons, respectively. However, Giza 111 irrigated every 14 days planted on ridges gave the highest LAI at 75 DAS in two seasons (Table 6).

Irrigation intervals had significant effect on net assimilation rate NAR at the two periods of (45-60) and (60-75) DAS in both seasons in addition to cultivars at two periods of 2nd season and planting methods at (60-75) DAS in 2nd season (Table 7).

Irrigation intervals x cultivars interaction had significant effect on NAR at 1st period in both seasons and at 2nd period of 2nd season (Table 7).

The 2nd order effect of interaction had significant effect on NAR at two periods in the 2nd season, in addition to at the 2nd period in the 2nd season (Table 7).

The heaviest values of NAR (mg/g/cm^2) were recorded for plants irrigated by interval of 14 days compared to 21 and 28 days. The present findings may be due to the effect of water deficit on dry matter accumulation during growth cycle of plant, in addition to the variation in total leaf area / plant. These results are in agreement with those reported by **Gajic *et al.* (2018), Ali and Abdel Aal (2021) and Saad *et al.* (2023).**

The maximum values of NAR were recorded for the planting on ridges at the 2nd period in 2nd season compared to terraces (Table 7). These results are in agreement with those reported by **Basediya *et al.* (2020) and Keerthana *et al.* (2021**).

Table 5. Means of dry matter plant^{-1} (g) of soybean cultivars (C) as affected by irrigation intervals (A), planting methods (B), and their interactions at (45, 60 and 75) days after sowing in 2020 and 2021 seasons

Irri. Int. (A)	Planting method (B)	2020 season Soybean cultivars (C) G111	G22	Crawford	Mean	2021 season Soybean cultivars (C) G111	G22	Crawford	Mean
45 DAS									
14 days	**Ridges**	16.28	15.71	16.54	**16.18**	13.05	13.13	12.07	**12.75**
	Terraces	14.27	17.19	15.37	**15.61**	12.57	11.88	11.95	**12.13**
	Mean	**15.27**	**16.45**	**15.95**	**15.89**	**12.81**	**12.51**	**12.01**	**12.44**
21 days	**Ridges**	15.43	14.16	13.48	**14.36**	11.8	11.32	11.22	**11.45**
	Terraces	13.1	13.10	11.95	**12.72**	10.96	10.82	10.09	**10.63**
	Mean	**14.27**	**13.63**	**12.72**	**13.54**	**11.38**	**11.07**	**10.66**	**11.04**
28 days	**Ridges**	9.10	9.51	9.51	**9.67**	9.05	8.89	8.44	**8.79**
	Terraces	9.73	9.50	9.28	**9.50**	7.75	7.63	6.57	**7.32**
	Mean	**9.86**	**9.51**	**9.40**	**9.59**	**8.40**	**8.26**	**7.51**	**8.06**
Mean B	**Ridges**	13.90	13.13	13.18	**13.40**	11.3	11.76	10.58	**11.21**
	Terraces	12.37	13.26	12.20	**12.61**	10.43	10.11	9.54	**10.02**
Mean C		**13.13**	**13.19**	**12.69**	**13.01**	**10.86**	**10.93**	**10.06**	**10.62**
	Season	**A**	**C**	**AB**	**AC**	**BC**	**ABC**		**B**
LSD 5%	**2020**	0.31	NS	NS	NS	NS	NS	**F-test**	*
	2021	0.28	0.13	1.08	NS	NS	0.67		*
60 DAS									
14 days	**Ridges**	29.25	29.75	27.40	**28.80**	27.53	25.86	25.82	**26.40**
	Terraces	27.40	25.70	27.50	**26.87**	24.69	23.58	23.42	**23.90**
	Mean	**28.33**	**27.73**	**27.45**	**27.83**	**26.11**	**24.72**	**24.62**	**25.15**
21 days	**Ridges**	23.20	23.05	20.37	**22.21**	20.42	21.28	19.76	**20.48**
	Terraces	20.60	21.10	21.25	**20.98**	19.85	19.43	18.80	**19.36**
	Mean	**21.90**	**22.08**	**20.81**	**21.59**	**20.14**	**20.36**	**19.28**	**19.92**
28 days	**Ridges**	15.20	13.28	14.30	**14.26**	13.13	13.27	12.72	**13.04**
	Terraces	14.25	12.50	11.70	**12.82**	11.61	11.57	10.89	**11.36**
	Mean	**14.73**	**12.88**	**13.00**	**13.54**	**12.37**	**12.42**	**11.81**	**12.20**
Mean (B)	**Ridges**	22.55	22.02	20.69	**21.75**	20.36	20.13	19.43	**19.98**
	Terraces	20.75	19.77	20.15	**20.22**	18.72	18.20	17.70	**18.21**
Mean C		**21.65**	**20.90**	**20.42**	**20.99**	**19.54**	**19.17**	**18.57**	**19.09**
	Season	**A**	**C**	**AB**	**AC**	**BC**	**ABC**		**B**
LSD 5%	**2020**	0.79	0.59	NS	NS	0.87	1.63	**F-test**	*
	2021	0.56	0.26	2.13	0.66	NS	NS		*
75 DAS									
14 days	**Ridges**	54.02	57.88	59.30	**57.07**	52.26	51.55	48.65	**50.82**
	Terraces	54.68	51.47	52.30	**52.82**	49.38	46.55	45.52	**47.15**
	Mean	**54.35**	**54.68**	**55.80**	**54.94**	**54.35**	**50.82**	**49.05**	**47.09**
21 days	**Ridges**	48.2	38.64	37.00	**41.28**	44.47	40.69	39.97	**41.71**
	Terraces	37.25	37.30	36.66	**37.07**	36.15	36.70	34.61	**35.82**
	Mean	**42.72**	**37.96**	**36.83**	**39.18**	**42.73**	**40.31**	**38.70**	**37.29**
28 days	**Ridges**	23.55	22.10	23.50	**23.05**	23.05	22.10	22.00	**22.38**
	Terraces	22.64	18.76	18.50	**19.97**	18.73	18.76	17.97	**18.49**
	Mean	**23.09**	**20.43**	**21.50**	**21.51**	**23.10**	**20.89**	**20.43**	**19.98**
Mean (B)	**Ridges**	41.92	39.54	39.93	**40.47**	39.93	38.11	36.87	**38.30**
	Terraces	38.19	35.84	35.82	**36.62**	34.75	34.00	32.70	**33.82**
Mean C		**40.06**	**37.69**	**37.88**	**38.54**	**40.06**	**37.34**	**36.06**	**34.79**
	Season	**A**	**C**	**AB**	**AC**	**BC**	**ABC**		**B**
LSD 5%	**2020**	2.28	1.82	NS	0.86	1.83	4.27	**F-test**	*
	2021	3.07	1.33	NS	NS	NS	NS		*

Table 6. Means of leaf area index of soybean cultivars (C) as affected by irrigation intervals (A), planting methods (B), and their interactions at (45, 60 and 75) days after sowing in 2020 and 2021 seasons.

Irri. Int. (A)	Planting method (B)	2020 season				2021 season			
		Soybean cultivars (C)				Soybean cultivars (C)			
		G111	G22	Crawford	Mean	G111	G22	Crawford	Mean
45 DAS									
14 days	Ridges	1.63	1.60	1.70	**1.64**	1.85	1.95	1.78	**1.86**
	Terraces	1.49	1.63	1.44	**1.52**	1.74	1.82	1.68	**1.75**
	Mean	**1.56**	**1.61**	**1.57**	**1.58**	**1.80**	**1.88**	**1.73**	**1.80**
21 days	Ridges	1.48	1.42	1.44	**1.45**	1.52	1.59	1.50	**1.54**
	Terraces	1.40	1.43	1.43	**1.42**	1.45	1.43	1.41	**1.43**
	Mean	**1.44**	**1.43**	**1.43**	**1.43**	**1.48**	**1.51**	**1.45**	**1.48**
28 days	Ridges	1.21	1.16	1.21	**1.19**	1.21	1.16	1.08	**1.15**
	Terraces	1.15	1.14	1.10	**1.13**	1.06	1.05	1.02	**1.04**
	Mean	**1.18**	**1.15**	**1.16**	**1.16**	**1.13**	**1.10**	**1.05**	**1.10**
Mean (B)	Ridges	1.44	1.39	1.45	**1.43**	1.52	1.57	1.45	**1.51**
	Terraces	1.35	1.40	1.32	**1.36**	1.42	1.43	1.37	**1.41**
Mean C		**1.39**	**1.40**	**1.39**	**1.39**	**1.47**	**1.50**	**1.41**	**1.46**
	Season	A	C	AB	AC	BC	ABC		B
LSD 5%	2020	0.05	NS	0.19	NS	0.03	0.07	F-test	*
	2021	0.02	0.02	0.08	0.04	0.03	0.06		*
60 DAS									
14 days	Ridges	3.24	2.99	3.11	**3.11**	4.11	4.30	3.71	**4.04**
	Terraces	2.68	2.68	2.45	**2.60**	3.77	3.73	3.24	**3.58**
	Mean	**2.96**	**2.84**	**2.78**	**2.86**	**3.94**	**4.01**	**3.48**	**3.81**
21 days	Ridges	2.26	2.21	2.17	**2.21**	2.96	2.89	2.72	**2.86**
	Terraces	2.26	2.12	2.24	**2.21**	2.74	2.75	2.69	**2.73**
	Mean	**2.26**	**2.17**	**2.21**	**2.21**	**2.85**	**2.82**	**2.71**	**2.79**
28 days	Ridges	1.59	1.55	1.61	**1.58**	2.22	2.16	2.10	**2.16**
	Terraces	1.58	1.61	1.50	**1.56**	2.05	2.06	2.03	**2.05**
	Mean	**1.58**	**1.58**	**1.55**	**1.57**	**2.13**	**2.11**	**2.06**	**2.10**
Mean (B)	Ridges	2.36	2.25	2.30	**2.30**	3.09	3.12	2.84	**3.02**
	Terraces	2.17	2.14	2.06	**2.12**	2.85	2.85	2.65	**2.78**
Mean C		**2.27**	**2.19**	**2.18**	**2.21**	**2.97**	**2.98**	**2.75**	**2.90**
	Season	A	C	AB	AC	BC	ABC		B
LSD 5%	2020	0.03	0.03	0.12	0.06	0.04	0.1	F-test	*
	2021	0.04	0.02	0.16	0.05	0.03	0.08		*
75 DAS									
14 days	Ridges	4.79	4.47	4.38	**4.55**	5.50	5.19	5.06	**5.25**
	Terraces	4.50	4.36	4.41	**4.42**	5.07	5.10	5.02	**5.06**
	Mean	**4.64**	**4.42**	**4.39**	**4.48**	**5.29**	**5.15**	**5.04**	**5.16**
21 days	Ridges	3.68	3.94	3.46	**3.69**	4.76	4.79	4.72	**4.76**
	Terraces	3.60	3.22	3.23	**3.35**	4.57	4.54	4.38	**4.50**
	Mean	**3.64**	**3.58**	**3.34**	**3.52**	**4.67**	**4.66**	**4.55**	**4.63**
28 days	Ridges	2.53	2.45	2.63	**2.54**	3.94	3.92	3.69	**3.85**
	Terraces	2.48	2.46	2.25	**2.40**	3.57	3.75	3.22	**3.51**
	Mean	**2.51**	**2.45**	**2.44**	**2.47**	**3.75**	**3.83**	**3.46**	**3.68**
Mean (B)	Ridges	3.67	3.62	3.49	**3.59**	4.73	4.63	4.49	**4.62**
	Terraces	3.53	3.35	3.30	**3.39**	4.40	4.46	4.21	**4.36**
Mean C		**3.60**	**3.48**	**3.39**	**3.49**	**4.57**	**4.55**	**4.35**	**4.49**
	Season	A	C	AB	AC	BC	ABC		B
LSD 5%	2020	0.04	0.11	NS	NS	0.14	0.4	F-test	*
	2021	0.29	0.04	NS	0.07	0.07	0.15		*

The maximum values of NAR were recorded for Giza 111 cultivar at the two periods in the 1st season beside the 2nd period in 2nd season. However, the heaviest NAR was recorded for Crawford cultivar in the 1st period of the 2nd season (Table 7). The present findings of the 1st season may be due to these cultivars belong to the same maturity group. The present findings are in agreement with those reported by **El-Karamity (1996), Khattab *et al*. (2019) and Saad *et al.* (2023).**

For the effect of irrigation intervals x cultivars interaction on NAR, the greatest values of NAR were recorded for irrigation every 14 days for each of Giza 111 and Crawford cultivars at 1st period in 2020 and 2021 seasons, respectively, in addition to Giza 22 at the 2nd period in 2nd season. For the effect of the 2nd order interaction, irrigation intervals x planting methods x cultivars, the greatest values of NAR were recorded for Crawford at 1st period irrigated by interval 14 days and planted on ridges in 1st season. In 2nd period of 1st season planting on ridges for each Crawford irrigated after 14 days and Giza 111 irrigated after 21 days recorded the highest NAR without significant difference between them by 1.92 $mg/g/cm^2$. In addition Giza 111 at 2nd period of 2nd season irrigated by interval 21 days and planted on ridges achieved highest NAR by 1.41 $mg/g/cm^2$. Meaning that these cultivars Giza 111 and Crawford save half of water amount and achieve highest NAR (Table 7).

Yield components:

Irrigation intervals, planting methods and soybean cultivars possessed significant effect on plant height, no. of branches plant^{-1} no. of pods plant^{-1}, no. of seeds pod^{-1} and seed index in both seasons except soybean cultivars on plant height in 1st season (Table 8). Irrigation intervals x planting methods interaction had significant effect on pods plant^{-1} in the 2nd season (Fig. 5) and on branches plant^{-1}and seed index in both seasons (Fig. 4 and 7) in addition seeds pod^{-1} in 1st season (Fig. 6). Irrigation intervals x cultivars interaction showed significant effect on plant height and pods plant^{-1} in both seasons (Fig. 3 and 5) in addition seeds pod^{-1} in 2nd season (Fig. 6). Planting method x cultivars interaction exhibited significant effect on seeds pod^{-1} and seed index in 1st season (Fig. 6 and 7). Irrigation intervals x planting methods x cultivars interaction exerted significant effect on seed index in the two seasons (Fig. 7) and plant height and pods plant^{-1} in the 2nd season (Fig. 3 and 5).

Concerning irrigation intervals effect, the maximum values for PH, NB/P, NP/P, NS/Pod and SI were recorded for plants irrigated by interval of 14 days in both seasons compared to those irrigated every 21 and 28 days in both seasons (Table 8). The reduction in these traits due to shortage of water may be attributed to the harmful effect of inadequate water supply on different physiological processes, in addition shortage of water depressed translocation of metabolites from source to sink which reflect on cell division and elongation. The reduction in number seeds per pod by exposing soybean plants to medium or high water shortage might be attributed to the fact that the development of pod was accompanied by some of physiological processes that are affected by moisture stress at the early stage of developing flowers primordial till ovules fertilization which would lead to the reduction in number of seeds per pod. Subjecting the plants to high water deficit via irrigation by interval of 28 days gave the lightest 100-seed weight. It is well known that translocated metabolites from source to different organs of soybean plant to the developing seeds during pod formation stage was depressed with exposing soybean plants to water deficit which might account much more reduction of its weight throughout minimizing the amounts of translocated metabolites. In this connection, these results are in acceptance with those reported by **El-Karamity and Hammad (1997), El-Karamity (1998), El-Shafey (2017), Khattab, *et al*. (2019)** and **Ali and Abdel Aal (2021).**

Regarding planting methods, the highest values for PH, NB/P, NP/P, NS/Pod and SI were recorded for the plots planted on ridges compared to terraces in both seasons (Table 8). The differences in plant height according to terraces method may be due to the shortage of irrigation water which cause harmful effect on different physiological processes, consequently cell division and elongation. These results may be due to the abortion of some flowers for terraces planting as a result of the relationship between soil moisture stress and different physiological processes which occurs inside plant. The increase in number of pods per plant for planting on ridges might be attributed to the more availability of minerals from the soil to the root hairs owing to increase soil moisture which in turn enhancing vegetative growth and branching capacity, consequently number of pods per plant. These results are in accordance with those obtained by **Gupta *et al.* (2017), Gajic *et al.* (2018), Basediya *et al.* (2020) and Madhana *et al.* (2022)**

For the soybean cultivars effect, Giza 22 cultivar gave the highest values for plant height, no. of seeds pod^{-1} and seed index followed by Giza 111 with significant differences between them in both seasons. Giza 22 and Giza 111 cultivar gave the greatest number of branches per plant in 1st and 2nd seasons, respectively (Table 8). Giza 111 and Giza 22 gave the greatest number of pods per plant in 1st and 2nd seasons, respectively (Table 8). The differences in plant height among genotypes might be attributed to the growth habit of each cultivar which is governed by genetical factors and its interaction with environmental conditions as discussed previously. The present findings are in agreement with those reported by **El-Haggan (2014), Khattab *et al.* (2019) and Saad *et al.* (2023).**

Concerning the interaction between irrigation interval x planting methods, irrigation after 14 days with planting on ridges achieved highest values for each of NB/P and SI in both seasons (Fig. 4 and 7), NP/P in 2nd season (Fig. 5), NS/Pod in 1st season (Fig. 6).

For irrigation interval x cultivars interaction, irrigation by interval 14 days gave maximum values for PH with planting Crawford in 1st season and Giza 22 in 2nd season (Fig. 3), highest NP/P with planting Giza 22 in both seasons (Fig. 5) and highest NS/Pod with planting Giza 22 in 2nd season (Fig. 6).

The effect of interaction between planting methods and cultivars, planting on ridges gave the maximum values for each of number of seeds pod^{-1} for Giza 22 in 2020 season (Fig. 6) and seed index for Giza 111 in 1st season (Fig. 7).

Concerning to the effect of second order interaction, irrigation by interval

14 days with planting Giza 22 on ridges was achieved the highest values for each of PH and NP/P in 2nd season (Fig. 3 and 5) and SI in both seasons (Fig. 7).

Table 7. Means of Net Assimilation Rate (NAR) (mg/g/cm^2) of soybean cultivars (C) as affected by irrigation intervals (A), planting methods (B) and their interactions at (45-60) and (60-75) DAS in 2020 and 2021 seasons.

Irri. Int. (A)	Planting method (B)	2020 season				2021 season			
		Soybean cultivars (C)				Soybean cultivars (C)			
		G_{111}	G_{22}	Crawford	Mean	G_{111}	G_{22}	Crawford	Mean
(45-60) DAS									
14 days	Ridges	1.32	1.26	1.14	**1.24**	1.14	0.95	1.16	**1.08**
	Terraces	1.33	0.87	1.33	**1.18**	1.03	1.03	1.07	**1.04**
	Mean	**1.33**	**1.07**	**1.24**	**1.21**	**1.08**	**0.99**	**1.12**	**1.06**
21 days	Ridges	0.90	1.15	0.90	**0.98**	0.89	1.02	0.93	**0.94**
	Terraces	0.88	1.09	1.01	**0.99**	0.97	0.95	0.98	**0.97**
	Mean	**0.89**	**1.12**	**0.95**	**0.99**	**0.93**	**0.98**	**0.95**	**0.96**
28 days	Ridges	0.81	0.62	0.76	**0.73**	0.55	0.61	0.62	**0.59**
	Terraces	0.71	0.43	0.44	**0.53**	0.57	0.58	0.65	**0.60**
	Mean	**0.76**	**0.53**	**0.60**	**0.63**	**0.56**	**0.60**	**0.64**	**0.60**
Mean (B)	Ridges	1.01	1.01	0.93	**0.99**	0.86	0.86	0.90	**0.87**
	Terraces	0.97	0.80	0.93	**0.90**	0.86	0.85	0.90	**0.86**
Mean C		**0.99**	**0.90**	**0.93**	**0.94**	**0.86**	**0.86**	**0.90**	**0.87**
	Season	A	C	AB	AC	BC	ABC		B
LSD 5%	2020	0.13	NS	NS	0.05	NS	NS	F-test	NS
	2021	0.04	0.03	NS	0.01	NS	0.08		NS
(60-75) DAS									
14 days	Ridges	1.39	1.67	1.92	**1.66**	1.15	1.29	1.17	**1.20**
	Terraces	1.73	1.65	1.67	**1.68**	1.25	1.17	1.14	**1.19**
	Mean	**1.56**	**1.66**	**1.79**	**1.67**	**1.20**	**1.23**	**1.15**	**1.19**
21 days	Ridges	1.92	1.17	1.34	**1.47**	1.41	1.03	1.10	**1.18**
	Terraces	1.30	1.48	1.53	**1.43**	0.97	1.06	1.01	**1.01**
	Mean	**1.61**	**1.32**	**1.43**	**1.45**	**1.19**	**1.05**	**1.06**	**1.10**
28 days	Ridges	1.20	1.36	0.94	**1.17**	0.73	0.67	0.73	**0.71**
	Terraces	0.89	0.50	1.02	**0.80**	0.57	0.58	0.61	**0.59**
	Mean	**1.05**	**0.93**	**0.98**	**0.99**	**0.65**	**0.62**	**0.67**	**0.65**
Mean (B)	Ridges	1.50	1.40	1.40	**1.43**	1.10	1.00	1.00	**1.03**
	Terraces	1.30	1.21	1.41	**1.31**	0.93	0.94	0.92	**0.93**
Mean C		**1.40**	**1.31**	**1.40**	**1.37**	**1.01**	**0.97**	**0.96**	**0.98**
	Season	A	C	AB	AC	BC	ABC		B
LSD 5%	2020	0.25	NS	NS	NS	NS	0.41	F-test	NS
	2021	0.08	0.04	NS	0.02	NS	0.12		0.05

Table 8. Effect of irrigation intervals, planting methods and soybean cultivars on plant height, no. of branches plant^{-1}, no. of pods plant^{-1}, no. of seeds pod^{-1} and seed index in 2020 and 2021 seasons.

Treatments	PH		NB/P		NP/P		NS/Pod		SI	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Irrigation intervals (days)										
14 days	86.90	92.97	3.16	2.61	69.45	74.40	2.68	2.63	16.89	16.78
21 days	79.31	80.57	2.67	2.23	58.07	63.82	2.32	2.37	15.42	14.96
28 days	71.24	68.87	1.73	1.52	38.13	41.37	1.69	1.78	13.52	13.40
LSD 5%	5.40	2.68	0.20	0.10	3.32	0.65	0.05	0.07	0.37	0.21
Planting methods										
Ridges	80.63	83.79	2.62	2.22	58.81	63.16	2.43	2.36	15.65	15.39
Terraces	77.67	77.82	2.43	2.01	51.63	56.57	2.22	2.16	14.90	14.70
F-test	*	*	*	*	*	*	*	*	*	*
Cultivars										
Giza 111	78.37	79.15	2.55	2.19	63.37	61.62	2.34	2.30	15.32	15.17
Giza 22	80.42	80.84	2.63	2.18	62.16	63.14	2.40	2.38	15.48	15.39
Crawford	78.66	83.65	2.38	1.99	55.22	54.83	2.23	2.11	15.03	14.58
LSD 5%	NS	0.88	0.09	0.06	1.67	1.42	0.04	0.04	0.22	0.17

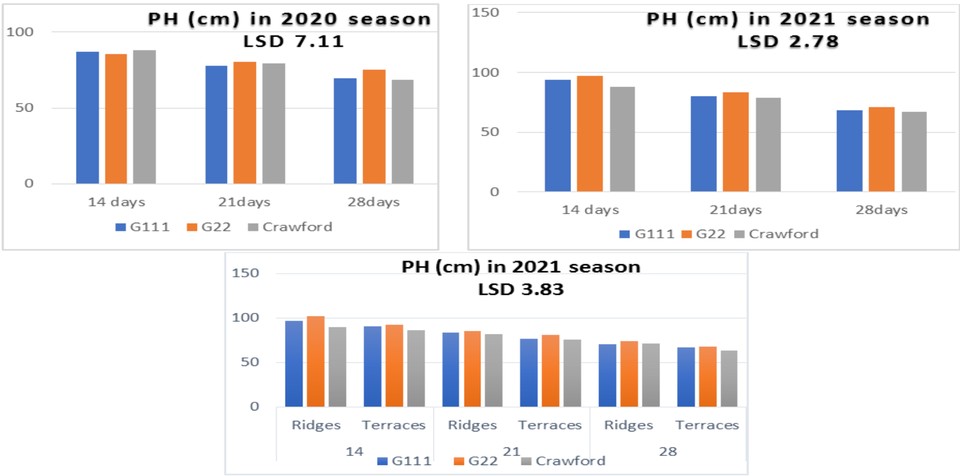

Fig. 3. Effect of the interactions between irrigation intervals, planting methods and cultivars on plant height in 2020 and 2021 seasons.

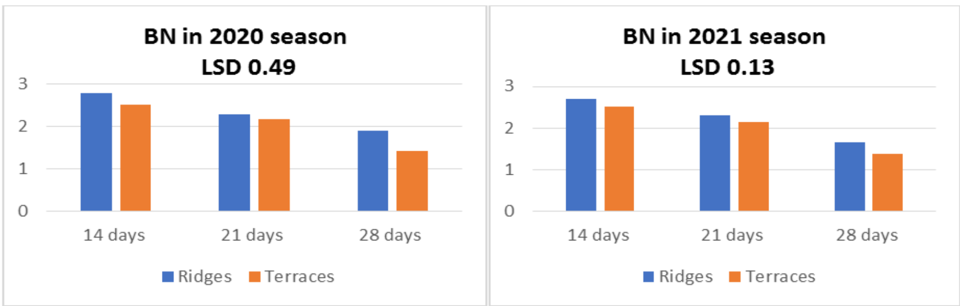

Fig. 4. Effect of the interactions between irrigation intervals and planting methods on number of branch plant^{-1} in 2020 and 2021 seasons.

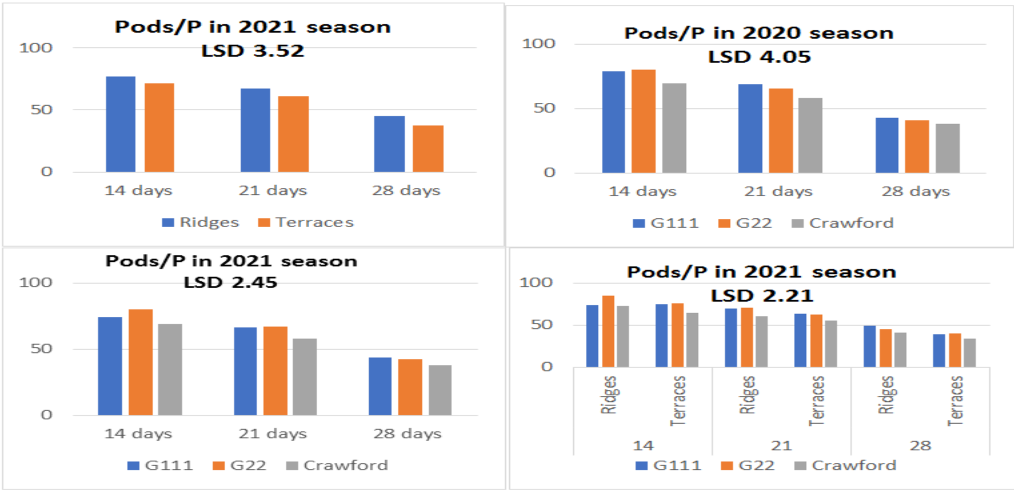

Fig. 5. Effect of the interactions between irrigation intervals, planting methods and cultivar on number of pods plant^{-1} in 2020 and 2021 seasons.

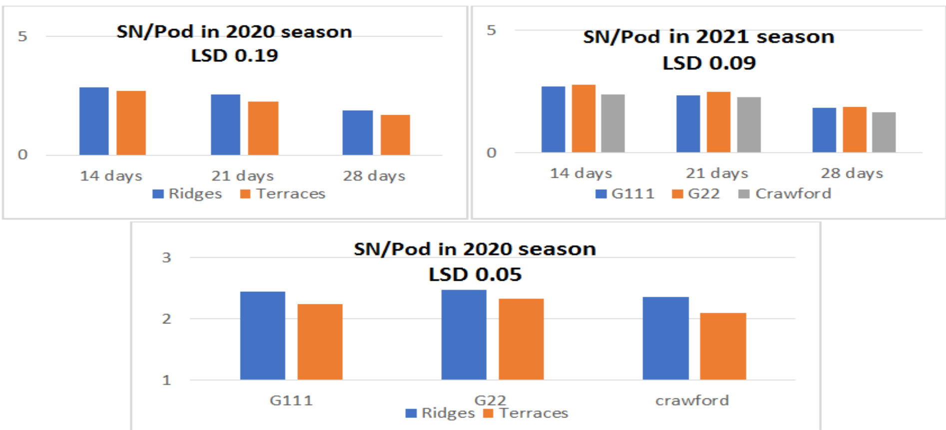

Fig. 6. Effect of the interactions between irrigation intervals, planting methods and cultivar on number of seeds pod^{-1} in 2020 and 2021 seasons.

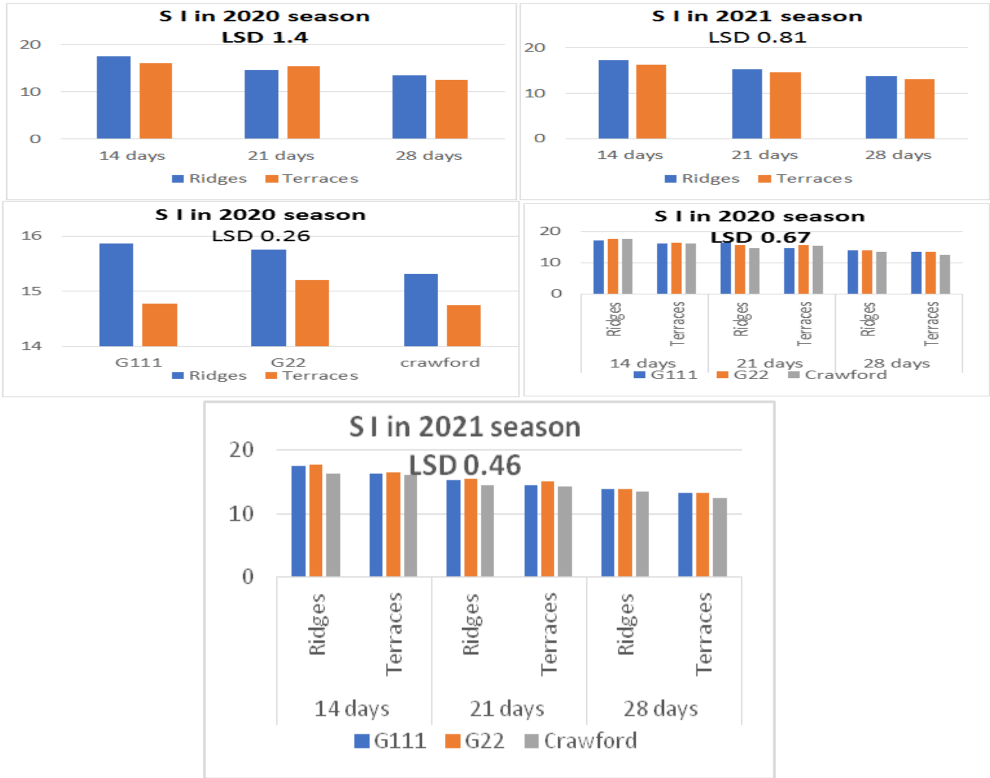

Fig. 7. Effect of the interactions between irrigation intervals, planting methods and cultivar on seeds index in 2020 and 2021 seasons.

Seed and straw yield feddan^{-1}:

Irrigation intervals, planting methods, soybean cultivars and irrigation intervals x planting methods interaction possessed significant effect on seed and straw yields feddan^{-1} in both seasons except planting effect on straw yield in 1st season (Table 9). Irrigation intervals x cultivars and planting methods x cultivars interactions had significant impact on seed and straw yields feddan^{-1} in 2nd season. The 2nd order interaction, irrigation intervals x planting method x cultivars had significant effect on straw yield feddan^{-1} in 2nd season (Table 9).

Seed and straw yields feddan^{-1} were gradually decreased with prolonging irrigation interval from 14 to 28 days in both seasons (Table 9).

The heaviest seed and straw yields feddan^{-1} was produced for plants irrigated by 14 days interval, while frequent irrigation by interval of 28 days gave the lightest seed and straw yields feddan^{-1} in both seasons (Table 9). It is important to note that the reduction percentages in seed yield / feddan were 23.35 and 49.10 % in 1st season and 22.75 and 49.7% in 2nd season with irrigation by interval of 21 and 28 days compared to interval of 14 days, respectively (Table 9). The reduction in seed yield with exposing soybean plants to water deficit via prolonging irrigation interval might be directly attributed to the reduction in dry mater accumulation and yield components i.e., number of branches, pods and seeds per plant, number of seeds per pod and seed index as discussed previously. It is obvious that straw yield is a function of plant height, branches/plant, leaf area/plant and total dry matter accumulation. All these characters should be increased under non stress conditions, consequently maximum straw yield could be expected with irrigating by interval of 14 days. These results are in harmony with those reported by **El-Karamity (1998), Hussein *et al*. (2019**), **Khattab *et al*. (2019) and Ali and Abdel Aal (2021).**

Concerning the effect of planting methods, it is worthy to notice that the heaviest seed and straw yields feddan^{-1} were obtained for the planting on ridges compared to terraces in both seasons (Table 9). The reduction percentages in seed yield feddan^{-1} due to planting on terraces were 11.85% in the two seasons compared to planting on ridges. These results may be due to water deficit in planting on terraces tended to decrease the potential of plants in using environmental conditions related to metabolic processes which in turn on dry matter formation, the reduction in dry mater accumulation and yield components i.e., number of branches, pods and seeds per plant, number of seed per pod and seed index, consequently produced smaller seed yield and lighter in their mass. These results are in accordance with those obtained by **Basediya *et al.* (2020) and Madhana *et al.* (2022).**

Concerning the effect of soybean cultivars, Giza 111 and Giza 22 cultivars gave the heaviest seed yield in 1st and 2nd seasons, respectively. The increase percentages of seed yield due to Giza 111 were 0.78% and 7.44% compared to Giza 22 and Crawford in the first season, respectively. In the second season, these increases due to Giza 22 were 8.26% and 1.55% compared to Crawford and Giza 111 cultivars, respectively (Table 9). The differences in seed yield due to studied cultivars may be attributed to their potentiality in producing more yield attributes i.e., number of branches, pods and seeds per plant which reflect on seed yield. These results are in agreement with those reported by **Khattab *et al*. (2019) and Saad *et al.* (2023).**

Crawford and Giza 22 cultivars gave the heaviest straw yield in 2020 and 2021 seasons, respectively (Table 9). These results may be due to the genetical differences among studied genotypes which reflect on growth habit, consequently growth characters responsible for straw yield i.e., plant height, number of branches and leaves / plant. These results are in agreement with those reported by **El-Haggan (2014), Khattab *et al*. (2019) and Saad *et al.* (2023).**

About the effect of irrigation interval x planting methods interaction, the heaviest seed and straw yields feddan^{-1} were obtained for plots irrigated by interval of 14 days planted on ridges in both seasons. (Fig. 8 and 9).

With regard to the effect of irrigation intervals x cultivars interaction, in the 2nd season, the greatest seed yield feddan^{-1} and straw yield feddan^{-1} were recorded for Giza 22 cultivar irrigated by interval of 14 days (Fig. 8 and 9).

For the planting methods x cultivars interaction effect, irrigation by interval

14 days was achieved the greatest seed and straw yields feddan^{-1} with planting Giza 22 cultivar on ridges in 2nd season (Fig. 8 and 9).

The effect of the 2nd order of interaction, it is could be detected that the for Giza 22 cultivar planted on terraces and irrigated every 14 days in 2nd season recorded heaviest straw yield feddan^{-1} (Fig. 9).

Table 9. Means of seed yield and straw yield (ton) feddan^{-1} of soybean cultivars (C) as affected by irrigation interval (A), planting methods (B) and their interactions in 2020 and 2021 seasons.

Irri. Int. (A) (Days)	Planting method (B)	2020 season				2021 season			
		Soybean cultivars (C)				Soybean cultivars (C)			
		G111	**G22**	**Crawford**	**Mean**	**G111**	**G22**	**Crawford**	**Mean**
Seed yield (ton) per feddan									
14 days	**Ridges**	1.75	1.75	1.66	**1.72**	1.74	1.77	1.69	**1.73**
	Terraces	1.64	1.64	1.57	**1.62**	1.62	1.64	1.57	**1.61**
	Mean	**1.70**	**1.70**	**1.62**	**1.67**	**1.68**	**1.71**	**1.63**	**1.67**
21 days	**Ridges**	1.50	1.51	1.28	**1.43**	1.49	1.50	1.27	**1.42**
	Terraces	1.18	1.13	1.09	**1.13**	1.20	1.20	1.10	**1.17**
	Mean	**1.34**	**1.32**	**1.19**	**1.28**	**1.35**	**1.35**	**1.18**	**1.29**
28 days	**Ridges**	0.87	0.93	0.86	**0.89**	0.91	0.93	0.86	**0.90**
	Terraces	0.86	0.80	0.77	**0.81**	0.78	0.80	0.76	**0.78**
	Mean	**0.87**	**0.86**	**0.81**	**0.85**	**0.84**	**0.86**	**0.81**	**0.84**
Mean (B)	**Ridges**	1.37	1.40	1.27	**1.35**	1.38	1.40	1.27	**1.35**
	Terraces	1.23	1.19	1.14	**1.19**	1.20	1.21	1.15	**1.19**
Mean C		**1.30**	**1.29**	**1.21**	**1.27**	**1.29**	**1.31**	**1.21**	**1.27**
	Season	**A**	**C**	**AB**	**AC**	**BC**	**ABC**		**B**
LSD 5%	**2020**	0.06	0.04	0.22	NS	NS	NS	**F-test**	*
	2021	0.03	0.02	0.11	0.04	0.03	NS		*
Straw yield (ton) per feddan									
14 days	**Ridges**	3.14	2.94	2.94	**3.01**	2.41	2.41	2.40	**2.41**
	Terrace	2.93	2.9	2.89	**2.92**	2.41	2.46	2.37	**2.41**

	s		5						
	Mean	**3.04**	**2.95**	**2.92**	**2.97**	**2.41**	**2.44**	**2.39**	**2.41**
21 days	**Ridges**	2.62	2.89	3.06	**2.86**	2.32	2.33	2.32	**2.32**
	Terraces	2.93	3.05	2.99	**2.99**	2.30	2.41	2.04	**2.25**
	Mean	**2.78**	**2.97**	**3.03**	**2.92**	**2.31**	**2.37**	**2.18**	**2.29**
28 days	**Ridges**	2.92	2.59	3.02	**2.84**	1.92	1.92	1.71	**1.85**
	Terraces	2.79	2.71	2.49	**2.66**	1.67	1.77	1.49	**1.65**
	Mean	**2.86**	**2.65**	**2.75**	**2.75**	**1.80**	**1.85**	**1.60**	**1.75**
Mean (B)	**Ridges**	2.90	2.81	3.01	**2.90**	2.22	2.22	2.14	**2.19**
	Terraces	2.88	2.90	2.79	**2.86**	2.13	2.21	1.97	**2.10**
Mean C		**2.89**	**2.85**	**2.90**	**2.88**	**2.17**	**2.22**	**2.06**	**2.15**
	Season	**A**	**C**	**AB**	**AC**	**BC**	**AB**		**B**
LSD 5%	**2020**	0.06	0.04	0.22	NS	NS	NS	F-test	NS
	2021	0.07	0.04	0.25	0.1	0.06	0.14		*

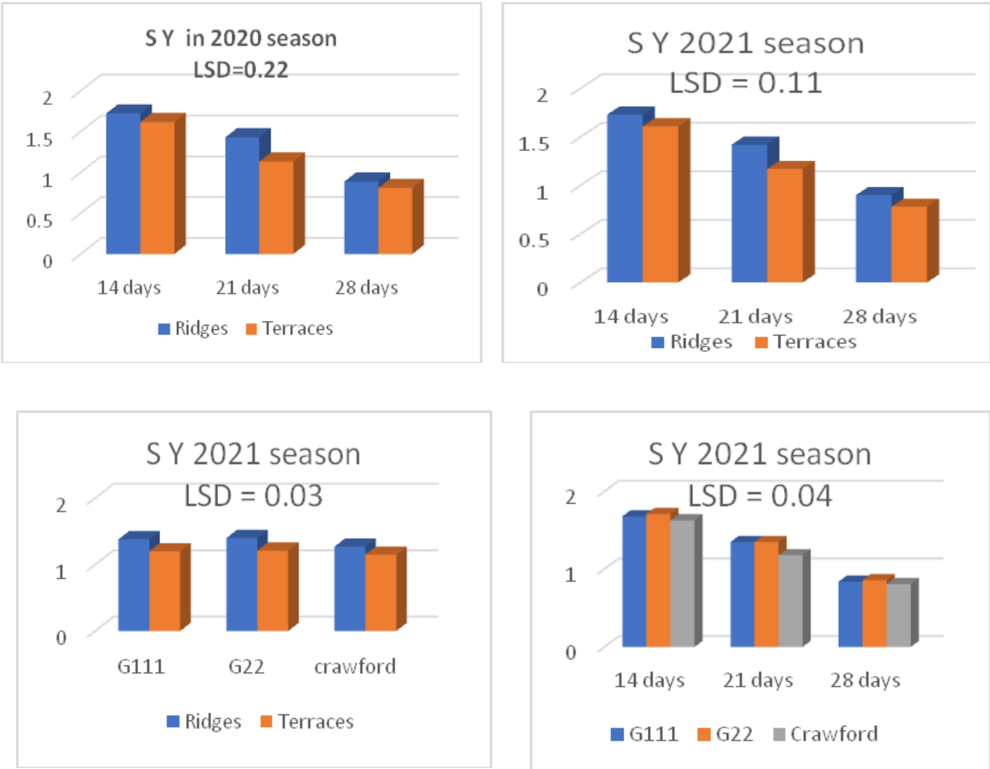

Fig. 8. Effect of the interactions between irrigation intervals, planting methods and cultivar on seed yield feddan^{-1} in 2020 and 2021 seasons.

Fig. 9. Effect of the interactions between irrigation intervals, planting methods and cultivar on straw yield feddan^{-1} in 2020 and 2021 seasons.

Water relations measurements

Irrigation intervals, planting methods, soybean cultivars and irrigation intervals x planting methods interaction had significant effect on water consumptive use WCU and water use efficiency WUE in both seasons except planting methods in 1st season. Planting methods x cultivars interaction had significant impact concerning WCU in 2020 season. Irrigation intervals x cultivars interaction had significant influence on WUE both seasons. Irrigation intervals x planting methods x cultivars interaction had significant effect on WCU in 2nd season (Table 10).

The highest values of WCU and WUE were recorded for plants irrigated by interval of 14 days. The irrigation by interval of 21 days decreased water consumptive use by 565.65 and 617.22 m^3 / fed. which led to save 21.30% and 23.34% of irrigation water compared to irrigation every 14 days in 2020 and 2021 seasons, respectively. However, the respective values for irrigation every 28 days were 847.79 and 984.91 m^3/fed. which led to save 35.73% and 43.26% in 1st and 2nd seasons, respectively (Table 10). The reduction in WUE may be due to decreased on seed yield compered to WCU. These results are in harmony with those reported by **Abdel Reheem *et al.* (2018), Hussein *et al*. (2019**) **and Ali and Abdel Aal (2021).**

Concerning to the effect of planting methods, the highest values of WCU and WUE were obtained for the planting on ridges compared to planting on terraces in both seasons. The planting on terraces decreased WCU by 138.89 m^3/fed which led to save which represent 5.22% irrigation water compared to planting on ridges in 2nd season (Table 10). These results may be due to the differences between the added irrigation water in addition to result for losses from the transpiration processes in the plant and evaporation for the soil surface. These results are in accordance with those obtained by **Gajic *et al.* (2018*),* Basediya *et al.* (2020) and Madhana *et al.* (2022).**

Concerning the effect of soybean varietal differences, Giza111 cultivar consumed the greatest values of WCU in both seasons and Giza 22 cultivar gave the greatest values of WUE in both seasons (Table 10). These results may be due to the differences among studied genotypes in growth habit and response of each one to environmental conditions prevailed during the growing season which controlled by genetical factors. These results are in agreement with those reported by **Khattab *et al.* (2019), Ali and Abdel Aal (2021) and Saad *et al.* (2023).**

For the effect of irrigation interval x planting methods interaction, plots planted on ridges gave highest WCU when irrigated by interval of 14 days in both seasons (Fig 10) and highest WUE with irrigation every 21 days in both seasons and irrigated every 14 days in 2nd season (Fig 11).

Irrigation intervals x cultivars interaction, the highest values of WUE were recorded for Giza 22 cultivar irrigated by 14 days interval in both seasons.

About that the planting methods x cultivars interaction, the maximum of WCU were recorded for Giza 111 cultivar planted on ridges in 2nd season.

Irrigation intervals x planting methods x cultivars interaction, the maximum WCU was recorded for Giza 111 cultivar planted on ridges irrigated by interval 14 days in 2021 season.

Table 10. Means of water consumptive use (WCU) and water use efficiency (WUE) of soybean cultivars (C) as affected by irrigation intervals (A), planting methods (B) and their interactions in 2020 and 2021 seasons

Irri. Int. (A) (Days)	Planting method (B)	2020 season Soybean cultivars (C)				2021 season Soybean cultivars (C)			
		G111	G22	Crawford	Mean	G111	G22	Crawford	Mean
Water Consumptive Use WCU (m^3/fed)									
14 days	Ridges	3270.32	3265.55	3134.34	**3223.40**	3426.99	3331.68	3267.67	**3342.11**
	Terraces	3292.98	3130.16	3233.34	**3218.83**	3192.98	3183.50	3166.67	**3181.05**
	Mean	**3281.65**	**3197.86**	**3183.84**	**3221.12**	**3309.98**	**3257.50**	**3217.17**	**3261.58**
21 days	Ridges	2690.62	2669.15	2656.26	**2672.01**	2690.62	2669.10	2656.26	**2672.01**
	Terraces	2633.36	2627.40	2656.03	**2638.93**	2633.36	2627.40	2589.36	**2616.71**
	Mean	**2661.99**	**2648.27**	**2656.15**	**2655.47**	**2661.99**	**2648.27**	**2622.81**	**2644.36**
28 days	Ridges	2417.47	2380.49	2312.50	**2370.15**	2417.47	2380.49	2332.50	**2376.82**
	Terraces	2361.40	2424.62	2343.51	**2376.51**	2261.40	2124.62	2143.51	**2176.51**
	Mean	**2389.44**	**2402.56**	**2328.01**	**2373.33**	**2339.44**	**2252.56**	**2238.01**	**2276.67**
Mean (B)	Ridges	2792.80	2771.73	2701.03	**2755.19**	2845.02	2793.77	2752.14	**2796.98**
	Terraces	2762.58	2727.40	2744.29	**2744.76**	2695.91	2645.17	2633.18	**2658.09**
Mean C		**2777.69**	**2749.56**	**2722.66**	**2749.97**	**2770.47**	**2719.47**	**2692.66**	**2727.54**
	Season	A	C	AB	AC	BC	ABC		B
LSD 5%	2020	60.15	25.57	225.82	NS	30.09	NS	F-test	NS
	2021	21.91	24.3	83.53	NS	NS	49.27		*
Water Use Efficiency WUE (kg/m^3) per feddan									
14 days	Ridges	0.51	0.53	0.52	**0.52**	0.53	0.53	0.53	**0.53**
	Terraces	0.51	0.51	0.50	**0.51**	0.50	0.53	0.49	**0.50**
	Mean	**0.51**	**0.52**	**0.51**	**0.51**	**0.52**	**0.53**	**0.51**	**0.52**
21 days	Ridges	0.55	0.56	0.48	**0.53**	0.56	0.57	0.48	**0.53**
	Terraces	0.46	0.46	0.43	**0.45**	0.45	0.43	0.41	**0.43**
	Mean	**0.51**	**0.51**	**0.45**	**0.49**	**0.50**	**0.50**	**0.44**	**0.48**
28 days	Ridges	0.38	0.39	0.37	**0.38**	0.36	0.39	0.37	**0.37**
	Terraces	0.35	0.38	0.36	**0.36**	0.37	0.33	0.33	**0.34**
	Mean	**0.36**	**0.38**	**0.36**	**0.37**	**0.36**	**0.36**	**0.35**	**0.36**
Mean (B)	Ridges	0.48	0.49	0.45	**0.48**	0.48	0.50	0.46	**0.48**
	Terraces	0.44	0.45	0.43	**0.44**	0.44	0.43	0.41	**0.42**
Mean C		**0.46**	**0.47**	**0.44**	**0.46**	**0.46**	**0.46**	**0.43**	**0.45**
	Season	A	C	AB	AC	BC	ABC		B
LSD 5%	2020	0.03	0.02	0.11	0.04	NS	NS	F-test	NS
	2021	0.02	0.01	0.08	0.03	NS	NS		*

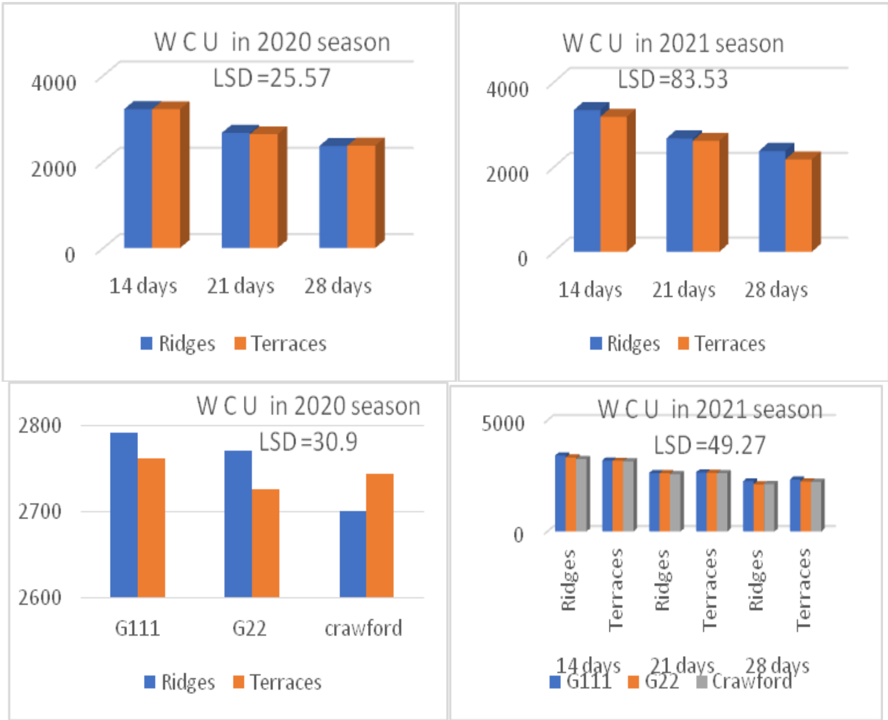

Fig. 10. Effect of the interactions between irrigation intervals, planting methods and cultivar on water consumptive use (WCU) in 2020 and 2021 seasons.

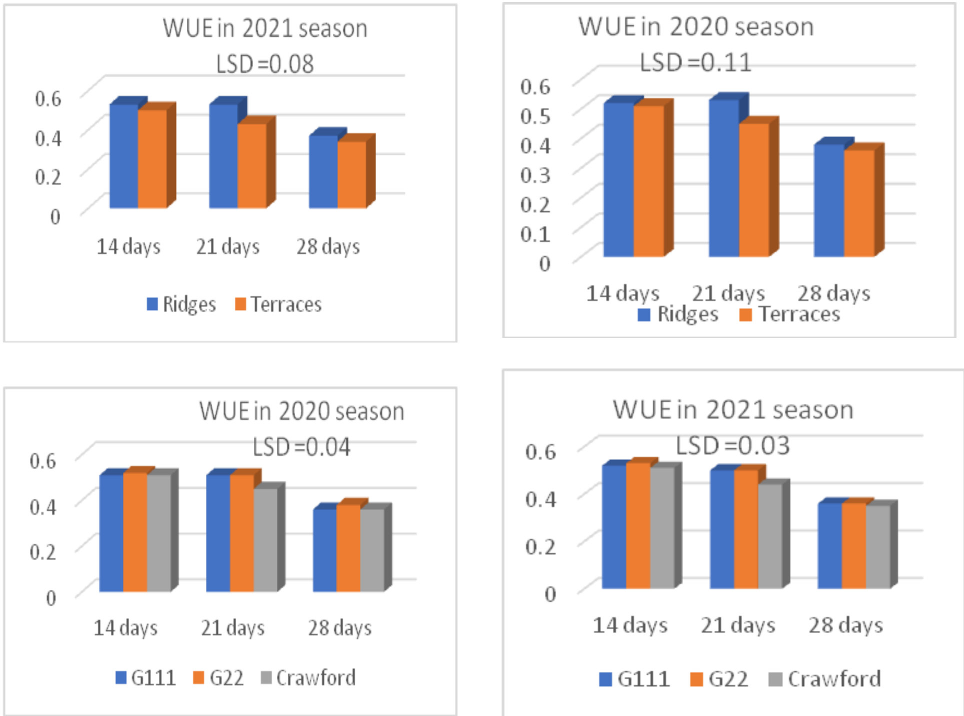

Fig. 11. Effect of the interactions between irrigation intervals, planting methods and cultivar on water use efficiency (WUE) in 2020 and 2021 seasons.

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الملخص العربي

تقييم تأثر صفات النمو والمحصول ومكوناته لبعض اصناف فول الصويا بفترات الري وطرق الزراعة

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أجريت الدراسة في مزرعة التجارب بكلية الزراعة – جامعة المنيا – مصر خلال موسمين 2020 و 2021 لدراسة استجابة ثلاثة أصناف من فول الصويا لفترات الري وطرق الزراعة ، ووجدت تأثيرات معنوية لفترات الري وطرق الزراعة والأصناف بالإضافة إلى تفاعلات الدرجة الأولي والثانية بينهم على معظم صفات النمو والمحصول والعلاقات المائية في كلا الموسمين ، وأظهرت النتائج حدوث نقص تدريجي في محصول البذور للفدان مع إطالة فترة الري من 14 يوم إلى 28 يوم في كلا الموسمين ، وكانت نسب الانخفاض في محصول البذور للفدان كمتوسط للموسمين 23.05 و 49.40% مع الري بفترات 21 و 28 يوم مقارنة بفترة الري 14 يوم على الترتيب ، وأدت الزراعة على خطوط إلى الحصول على أعلى وزن لمحصول البذور للفدان مقارنة بالزراعة على المصاطب ، وسجلت زيادة في محصول البذور للفدان تقريباً بنسبة 8.00% بزراعة الصنفين جيزة 111 وجيزة 22 مقارنة بالصنف كراوفورد في الموسم الأول والثاني على الترتيب ، ويمكن التوصية بأن الري بفاصل 14 يوم مع الزراعة على الخطوط يمكن أن يحقق أعلى إنتاجية من البذور للفدان.