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Yield and Quality of Soybean and Associated Weeds In Relation To Irrigation Intervals and Weed Management

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Abstract

A field study was conducted at Shandaweel Agricultural Research Station, Sohag, Egypt in 2020 and 2021 to evaluate the effects of irrigation interval (10, 15 and 20 day) and some weed managements on soybean yield and associated weeds. The results revealed that all measured soybean traits and associated weeds were significantly affected by irrigation interval and weeding treatments as well as their interactions. Irrigation at 15-day interval produced the highest values of soybean yield and its attributes; seed protein and oil contents. Also, it gave a satisfy result in reducing the weeds biomass. Hand hoeing twice followed by pendimethalin pre + one hoeing at 30 days after sowing (DAS) were the best treatments in controlling weeds and improving soybean yield, its components and seed quality. The highest seed yield of 2.04 t fedan^{-1} (fed^{-1}) (average of the two seasons), with best quality of soybean (cv. Giza 111) could be achieved from the combined treatment of 15-day interval with hand hoeing twice or with pendimethalin (pre) + one hoeing at 30 DAS. This conclusion could be recommended for soybean production in similar agro-ecosystems.

Keywords: Soybean yield, quality, irrigation intervals, integrated weed management.

INTRODUCTION

Increasing soybean [Glycine max (L.) Merrill] production can contribute much to improving the Egyptian food security because of its high quality vegetable oil and protein. It is used for production of edible oil and for the manufacture of feed for livestock and poultry. Besides, it contributes as a legume crop in agricultural sustainability and it is environmentally-friendly. Globally, soybean has become the main source of vegetable oil and protein. Its seeds contain about 40 % of protein and 20 % of oil and represented 61% of the world's oilseed production (ASA, 2022). Despite the importance of soybean for supporting of Egyptian food security, the domestic production just represented 1.5% (63 000 t) of the available for use (4 309 000 t), according to B.F.B.S.E. (2022). At present, Egypt imports most of soybean consumption needs which adds an economic load on the balance of payments. Expanding the harvested area of soybean, moving up the yield of both units of area and irrigation water and reducing yield losses (5%, B.F.B.S.E., 2022) are the major tools within the integrated strategy to improve the self-sufficiency of soybeans. Recently, the Egyptian government has turned to a "Contract Farming" policy that guarantees a profitable price for soybeans to encourage farmers to continue producing the crop. As a benefit of such policy, the soybean harvested area has increased to 150 117 fed in 2023 (K.M. Ahmad, 2023, Pers. Comm.) compared with 30 043 fed with average yield of 1.2 t fed^{-1} in 2020 (B.A.S.E., 2020). As a result of global warming phenomenon, drought will be more prevalent in arid and semi-arid regions similar to conditions of Upper Egypt particularly in summer season. Drought may cause yield losses of soybeans ranging from 25-50% (Zou et al., 2020). In contrast, using excess water supply leads to exposure soybeans to root rot diseases, wilting and leaching of nutrients as well as urges spreading of weeds. Soybean requires a sufficient water supply during its growth process to achieve high yields (Buezo et al., 2019). Thus, both drought stress and excess irrigation water should be avoided to produce high yield with good quality of soybeans. Weeds strongly compete with soybean plants for moisture, light, nutrients, and space that limit the crop yield, increase production costs paid for irrigation, harvesting and weed controlling thus reduce the net profitability. Uncontrolled weeds can reduce crop yields 37-52% in soybean even with advanced technology applied as in USA (Soltani et al., 2017); but in India, weeds cause 31% yield loss in soybean (Gharde et al., 2018). Weeds consume more water than many crops and many weeds are known as "water wasters". Some weeds use up to three times as much water as do the crops to produce the same unit of dry matter. This weed characteristic is more obvious under stress condition (Abouziena et al., 2014). The crop-weed competition occurs in the early growth stage of crop development and soybean fields should be kept free from weeds for the first 30-40 DAS. Early post emergent control treatments recorded significantly lower weed count, dry weight and highest weed control efficiency; but yielded less due to the phytotoxicity on soybean crop (Emmiganur and Hosmath, 2020). Integrated use of herbicides with different mode of action efficiently controlled weeds and gave better seed yield than their individual application (Peer et al., 2013; Vázquez-García et al., 2020). The previous studies revealed that the higher soybean seed yield was obtained by hand hoeing twice (Galal, 2004) or by pendimethalin pre + one hoeing (Metwally et al., 2009). Thus, supplying soybean with sufficient amount of irrigation water at the right time besides application of the correct weeding program are among the important factors that enhancing yield and quality of soybean. Therefore, this study amid to evaluate the effects of irrigation intervals and weed control treatments on the yield of soybean and associated weeds.

MATERIALS AND METHODS

A 2-year field experiment was conducted at Shandaweel Agricultural Research Station (26° 33´ N and 31° 41´ E), Sohag, Egypt in 2020 and 2021 seasons to evaluate the effects of irrigation intervals and some weed managements on soybean yield and associated weeds. The top soil (0-30 cm) of the experimental farm was clay loam with pH 7.7, EC 0.5 dS m^{-1} and having 0.64% organic matter. The experiment included 18 treatments which were the combinations of three intervals (10, 15 and 20 days) and six weeding treatments as follows:

1- Pendimethalin applied as pre-emergence (pre-em) at rate of 1.5 L fed^{-1}.
2- Bentazone applied as post-emergence (post-em) at rate of 0.75 L fed^{-1} followed by Clethodim applied as (post-em) at rate of 0.25 L fed^{-1}.
3- Pendimethalin applied as (pre-em) at rate of 1.5 L fed^{-1}followed by hand hoeing at 30 day after sowing (DAS).
4- Hand hoeing once at 18 (DAS).
5- Hand hoeing twice at 18 and 30 (DAS).
6- Unweeded check.

The experimental plots were irrigated using a furrow irrigation method. The experimental design was RCBD in a split-plots arrangement with three replicates. The main plots were assigned to the irrigation intervals, while weeding treatments were in subplots. The area of each subplot was 10.5 m^2; each subplot contained 5 ridges, 60-cm wide (3 m width) and 3.5 m long. Soybean variety Giza 111 was sown at a rate of 30 kg seeds fed^{-1} on 27th of May and 16th of June in 1st and 2nd seasons, respectively. The wet sowing method was followed in which the soil had sufficient moisture content ensuring good germination. The remained seedlings after thinning were 140 000 seedling fed^{-1}.

Weed survey and measurements:

Weeds were hand-removed from one m^2 chosen randomly in each subplot at 60 DAS. Fresh weight of weeds was measured and then air dried, then oven dried at 70 ºC until a constant weight to measure the dry weight of total weeds. Efficacy coefficient (EC%) of weeding treatments was calculated according to Sawant and Jadav (1985) as shown in the following equation: $EC\ \% = (Pc-Pt)/ Pc *100$, where:

Pc = average dry weight of weeds m^{-2} for the unweeded plots.

Pt = average dry weight of weeds m^{-2} for the treated plots.

Soybean yield and its components:

At harvest, the following measurements were recorded for an average of 10 randomly chosen plants as follows:

1. Number of survival (remained till harvest) plants m^{-2}.
2. Number of pods $plant^{-1}$.
3. Number of seeds pod^{-1}
4. Weight of 100 seeds (g), average of three replicates.
5. Seed yield (t fed^{-1}): measured from 2 middle ridges, 2 x 0.6 m width * 3 m long.
6. Biological yield (t fed^{-1}): measured from the same area of seed yield.

Quality traits of soybean seeds:

Seed protein content was estimated according to Lowry et al. (1951), while seed oil content was determined by using Soxhlet apparatus and petroleum ether as a solvent according to AOAC (1975).

Statistical Analysis:

The collected data of soybean traits and dry weight of the associated weeds were statically analyzed according to analysis of variance of the split plot technique (SAS ver. 9.2, SAS Institute, 2008). LSD test at 0.05 level was used for separation of treatment means according to Gomez and Gomez (1984). Analysis of Pearson correlation coefficient among some traits of soybean and associated weeds with its significance ($p < 0.01$) was performed using PC software of SAS ver. 9.2 (SAS Institute, 2008).

RESULTS AND DISCUSSION

The predominant broadleaf weed species associated with soybean crop plots in both seasons of the Experiment were *Ipomoea eriocarpa*, *Xanthium strumarium* L, *Tribulus terrestris* L, *Euphorbia genicualata* Ortega, *Datura stramonium* L, *Corchorus olitorius* L, *Trianthema portulacastrum* L. While, the prevailing narrowleaf weed species were: *Echinochloa colonum* (L.) Link and *Digitaria sanguinalis*.

Weeds dry weight at 60 DAS:

Irrigation at 20 or 15 days interval significantly reduced the dry weight of total weeds as compared with 10-day interval in 1st season (Table 1). Whilst, the 2nd season's result displays that the effect of the 15-day interval surpassed the impact of 20-day interval. This result might be due to the dominance of some different broadleaf weed species in the two seasons. Khaffagy, et al. (2022) reported similar results on the effects of amounts of irrigation water on dry weight of total weeds. Mechanical weed control by W5 followed by W2 or W3 were better than W1 and W4 in reducing the dry weight of total weeds or increasing the efficacy control in both seasons (Table 1). These results are in consistent with those reported by Galal (2004) and Dawood (2017). It was observed that the interaction between 15-day intervals combined with W5 resulted in the least values for dry matter of total weeds in both seasons. Yet, the 10-day interval associated with W1 was the worst treatment in controlling the total weeds in both seasons. Ferdous et al. (2017) reported similar results.

Table 1. Influence of irrigation intervals, weed control treatments and their interactions on dry weight of total weeds (g m-2) as well as the impact of weed control treatments on the efficacy coefficient (EC%) of weeding treatments at 60 DAS in 2020 and 2021 seasons.

Weed control treatment (W)	2020 season					2021 season				
	Irrigation interval (day) (I)			Mean	EC%	Irrigation interval (day) (I)			Mean	EC%
	10	15	20			10	15	20		
W1: Pendimethalin (pre*)	350	189	165	**234.6 b¶**	**31**	172	51	104	**109.0 b**	**50**
W2: Bentazone (post) + Clethodim (post)**	43	22	19	**28.0 d**	**92**	57	42	41	**46.9 d**	**79**
W3: Pendimethalin (pre)+1 hoeing (30 d.)	40	23	31	**31.2 d**	**91**	42	20	35	**32.6 e**	**85**
W4: Hoeing once (18 d.)	122	96	76	**98.0 c**	**71**	107	44	51	**67.1 c**	**69**
W5: Hoeing twice (18 & 30 d.)	10	10	11	**10.3 e**	**97**	28	13	31	**24.1 e**	**89**
W6: Control (without weeding)	473	283	266	**340.7 a**	**--**	245	184	227	**219.0 a**	**--**
Mean	**173.0 a¶**	**103.8 b**	**94.6 b**			**108.7 a**	**59.2 c**	**81.5 b**		
L.S.D. (0.05):										
I		**17.26**						**8.22**		
W		**11.50**						**12.45**		
I x W		**19.91**						**21.56**		

*Applied as pre-emergence
**applied as post emergence
¶ Means in each season in columns or in rows followed by the same letter (s) are not significantly different at the 0.05 level.
EC% = Efficacy coefficient (%) of weed control treatments compared to unweeded plots.

Number of survival plants:

The number of remained prolific plants at harvest is considered one of the main components of seed yield of soybean. Results in Table 2 reveal highly significant effects on survival plants as influenced by irrigation interval, weeding treatments and their interaction in both seasons of study. Irrigation at 15-day interval produced the highest number of survival plants in both seasons. This result might be due to the well-known role of water in plant growth and development, and this effect partially disappeared in case of 10-day interval treatment because of weed prevalence. W5 followed by W2 and W3 in 1st season and followed by W3 and W2 in 2nd season produced the higher number of remained soybean plants. The favorable weed-free conditions around soybean crop caused by these treatments might be the reason for such good result. Yet, W1 followed by W4 were the worst after the unweeded check in this respect. These results are in line with those reported by Galal (2004) and Akter et al. (2016). It is expected from previous individual results of each of irrigation intervals and weeding treatments, the combined treatment of 15-day interval and W5 was the best for remaining more survival plants in both seasons.

Table 2. Influence of irrigation intervals, weed control treatments and their interactions on number of soybean survival plants m^{-2} at harvest in 2020 and 2021 seasons.

Weed control treatment (W)	2020 season				2021 season			
	Irrigation interval (day) (I)			Mean	Irrigation interval (day) (I)			Mean
	10	15	20		10	15	20	
W1: Pendimethalin (pre*)	17	20	18	**18.4 e¶**	22	26	24	**23.9 d**
W2: Bentazone (post) + Clethodim (post)**	25	29	27	**27.0 b**	25	31	27	**27.3 b**
W3: Pendimethalin (pre)+1 hoeing (30 d.)	24	27	26	**25.7 c**	27	32	29	**29.2 a**
W4: Hoeing once (18 d.)	22	24	23	**22.9 d**	23	28	26	**25.8 c**
W5: Hoeing twice (18 & 30 d.)	27	30	29	**28.7 a**	28	33	31	**30.4 a**
W6: Control (without weeding)	15	17	16	**16.0 f**	15	21	20	**19.0 e**
Mean	**21.7 c¶**	**24.4 a**	**23.2 b**		**23.3 c**	**28.4 a**	**26.2 b**	
L.S.D. (0.05):								
I		**0.84**				**0.98**		
W		**1.22**				**1.41**		
I x W		**2.12**				**2.44**		

*Applied as pre-emergence

**Applied as post emergence

¶ Means in each season in columns or in rows followed by the same letter (s) are not significantly different at the 0.05 level.

Number of pods plant^{-1}:

Significant impacts on number of pods plant^{-1} as affected by irrigation interval, weeding control and their interactions in both seasons of study are shown in Table 3. Irrigation at 15-day interval gave the highest number of pods plant^{-1}, while the lowest value was resulted from the 10-day interval in both seasons. This result indicates evidently that the 15-day of irrigation interval was favorable in stimulating soybean plants to produce more pods plant^{-1} because of adequate water supply associated with this treatment. These results are partially in line with those reported by Mahmoud et al.(2013). W5 resulted in the greatest number of pods plant^{-1} followed by W2 in 1st season or W3 in 2nd season. However, the fewer number of pods plant^{-1} was obtained from W1 followed W4 in both seasons. These results are in harmony with those obtained by Megawer and El-Ysazl (2008). The irrigation at 15-day interval with W5 gave the greatest number of pods plant^{-1} in both seasons, whilst the smallest number of pods was resulted from 10-day interval combined with W1. This result was true in both seasons.

Number of seeds pod^{-1}:

Significant effects of irrigation interval, weeding treatments and their interactions on number of seeds pod^{-1} in both seasons were observed in Table 4. Treatment of 15-day interval stills the proper for producing seeds pod^{-1} among other irrigation intervals with significant differences in both seasons; yet, the 10-day interval resulted in the smallest number of seeds pod^{-1} in both seasons with no significant difference between its effect and the 20-day effect in 2nd season. The 15-day interval seems to stimulate photosynthesis and accumulate more nutrients that reflect the increased seeds number pod^{-1} compared with other treatments. Ibrahim and Kandil (2007) reported similar results. W5 followed by W2 and W3 in 1st season and followed by W3 or W2 in 2nd season produced the highest number of seeds pod^{-1}. Yet, the fewer number of seeds was resulted from W1 and W4 in both seasons. Metwally et al. (2009) reported similar results. The irrigation at 15-day interval combined with W5 achieved the highest number of seeds pod^{-1}, but the least value of seeds pod^{-1} was obtained from the effect of 10-day interval and W1 in both seasons.

Weight of 100 seeds:

Results in Table 5 show significant impact of irrigation interval, weed control and their interactions on weight of 100 seeds in both seasons. Irrigation at 15-day interval recorded the heaviest weight of 100 seeds, while smallest 100-seed weight was obtained from 10-day interval in both seasons. The good result of 15-days interval would be due to the conditions associated with this treatment in providing sufficient water supply and reducing weeds infestation as compared with 20- and 10-day intervals, respectively.

Table 3. Influence of irrigation intervals, weed control treatments and their interactions on number of pods plant^{-1} at harvest in 2020 and 2021 seasons.

Weed control treatment (W)	2020 season				2021 season			
	Irrigation interval (day) (I)			Mean	Irrigation interval (day) (I)			Mean
	10	15	20		10	15	20	
W1: Pendimethalin (pre*)	47	61	60	**56 d¶**	58	71	64	**64 e**
W2: Bentazone (post**) + Clethodim (post)	92	115	108	**105 b**	100	127	118	**115 c**
W3: Pendimethalin (pre)+1 hoeing (30 d.)	89	112	106	**103 b**	105	129	120	**118 b**
W4: Hoeing once (18 d.)	83	91	89	**87 c**	93	97	94	**95 d**
W5: Hoeing twice (18 & 30 d.)	98	122	119	**113 a**	112	136	125	**124 a**
W6: Control (without weeding)	29	56	50	**45 e**	44	62	51	**52 f**
Mean	**73 c¶**	**93 a**	**89 b**		**85 c**	**104 a**	**95 b**	
L.S.D. (0.05):								
I		**2.0**				**3.0**		
W		**3.3**				**1.9**		
I x W		**5.7**				**3.4**		

*Applied as pre-emergence
**Applied as post emergence
¶ Means in each season in columns or in rows followed by the same letter (s) are not significantly different at the 0.05 level.

Table 4. Influence of irrigation intervals, weed control treatments and their interactions on number of seeds Pod^{-1} at harvest in 2020 and 2021 seasons.

Weed control treatment (W)	2020 season				2021 season			
	Irrigation interval (day) (I)			Mean	Irrigation interval (day) (I)			Mean
	10	15	20		10	15	20	
W1: Pendimethalin (pre*)	2.07	2.27	2.20	**2.18 e¶**	2.27	2.43	2.33	**2.34 d**
W2: Bentazone (post**) + Clethodim (post)	2.67	2.93	2.83	**2.81 b**	2.77	3.10	2.90	**2.92 bc**
W3: Pendimethalin (pre)+1 hoeing (30 d.)	2.57	2.73	2.70	2.67 c	2.90	3.23	3.00	**3.04 b**
W4: Hoeing once (18 d.)	2.50	2.53	2.43	**2.49 d**	2.73	2.93	2.73	**2.80 c**
W5: Hoeing twice (18 & 30 d.)	2.87	3.30	3.17	**3.11 a**	2.93	3.63	3.03	**3.20 a**
W6: Control (without weeding)	1.73	1.90	1.83	**1.83 f**	1.80	2.00	1.93	**1.91 e**
Mean	**2.40 c¶**	**2.61 a**	**2.53 b**		**2.57 b**	**2.89 a**	**2.66 b**	
L.S.D. (0.05):								
I		**0.083**				**0.139**		
W		**0.144**				**0.128**		
I x W		**0.249**				**0.221**		

*Applied as pre-emergence
**Applied as post emergence
¶ Means in each season in columns or in rows followed by the same letter (s) are not significantly different at the 0.05 level.

Ibrahim and Kandil (2007) and Ali (2021) found similar results. W5 recorded the highest weight of 100 seeds; however, the W1 resulted in the lowest value of weeding methods in both seasons. This result was expected since W5 and W1 were the 1st and the last, respectively in controlling weeds in both seasons. Khlifa and Fakkar (2020) reported similar results. The interaction between 15-day regime and W5 recorded the highest weight of 100 seeds in both seasons. Meanwhile the lowest 100-seed weight was obtained from 10-day interval and W1 in both seasons. Similar results were recorded by Megawer and El-Ysazl (2008).

Table 5. Influence of irrigation intervals, weed control treatments and their interactions on 100-Seed weight (g) at harvest in 2020 and 2021 seasons.

Weed control treatment (W)	2020 season				2021 season			
	Irrigation interval (day) (I)			Mean	Irrigation interval (day) (I)			Mean
	10	15	20		10	15	20	
W1: Pendimethalin (pre*)	14	16	15	**14.9 d¶**	14	18	16	**16.1 e**
W2: Bentazone (post) + Clethodim (post)**	23	29	26	**25.9 ab**	21	28	27	**25.1 c**
W3: Pendimethalin (pre)+1 hoeing (30 d.)	22	27	26	**24.8 b**	22	30	27	**26.6 b**
W4: Hoeing once (18 d.)	18	24	23	**21.8 c**	21	26	24	**23.3 d**
W5: Hoeing twice (18 & 30 d.)	23	30	29	**27.0 a**	24	31	30	**28.4 a**
W6: Control (without weeding)	9	11	10	**9.9 e**	10	12	11	**11.0 f**
Mean	**18.0 c¶**	**22.7 a**	**21.5 b**		**18.6 c**	**24.1 a**	**22.6 b**	
L.S.D. (0.05):								
I		**0.80**				**1.38**		
W		**1.61**				**1.30**		
I x W		**2.79**				**2.25**		

*Applied as pre-emergence
**Applied as post emergence
¶ Means in each season in columns or in rows followed by the same letter (s) are not significantly different at the 0.05 level.

Seed yield (t fed^{-1}):

Results in Table 6 exhibit significant effects of irrigation interval, weeding control and their interactions on seed yield in both seasons. The 15-day interval regime significantly surpassed either 20- or 10-day intervals in both seasons. The 15-day interval increased the seed yield with 60 and 440 kg fed^{-1} as compared to 20- and 10-day intervals, respectively in 1st season, yet these increases were 90 and 480 kg fed^{-1} in 2nd season. The superior effect of the 15-day interval on seed yield might be due to the accumulated good effects of this treatment on the vegetative and yield attributes of soybean crop. Similar results were reported by Masoumi et al. (2011), Ali (2021). Since the W5 followed by W2 and W3 in 1st season or followed by W3 and W2 in 2nd season were the best treatments in enhancing the previously mentioned yield components of soybean, it was expected for these treatments to improve the seed yield in both seasons. The weeding treatments of W5, W3, W2, W4 and W1 increased the seed yield with 1355, 1210, 1205, 490 and 180 kg fed^{-1}, respectively as compared to the check as an average of the two seasons. This means, in other words, that if weeds left uncontrolled as in the check treatment they could cause a reduction percentage (loss %) in seed yield estimated to 78, 76 and 76% (average of the two seasons) as compared to W5, W3 and W2, respectively. Galal (2004), Singh and Jolly (2004), Metwally et al. (2009) and Dawood (2017) reported similar results. The interaction between irrigation interval and weeding managements affected significantly seed yield of soybean in both seasons. The treatment of 15-day interval combined with W5 produced the highest seed yield (2.04 t fed^{-1}) as average of the two seasons. However, lowest seed yield value (0.45 t fed^{-1}) was obtained by the 10-day interval and pendimethalin (pre). Similar results were reported by Khaffagy et al. (2022).

Table 6. Influence of irrigation intervals, weed control treatments and their interactions on seed yield (t fed^{-1}) in 2020 and 2021 seasons.

Weed control treatment (W)	2020 season				2021 season			
	Irrigation interval (day) (I)			Mean	Irrigation interval (day) (I)			Mean
	10	15	20		10	15	20	
W1: Pendimethalin (pre*)	0.41	0.62	0.60	**0.54 e¶**	0.49	0.64	0.62	**0.59 e**
W2: Bentazone (post) + Clethodim (post)**	1.19	1.83	1.73	**1.59 b**	1.09	1.89	1.80	**1.59 c**
W3: Pendimethalin (pre)+1 hoeing (30 d.)	1.06	1.79	1.72	**1.52 c**	1.16	1.95	1.89	**1.67 b**
W4: Hoeing once (18 d.)	0.72	0.94	0.90	**0.85 d**	0.80	0.99	0.91	**0.90 d**
W5: Hoeing twice (18 & 30 d.)	1.27	1.89	1.83	**1.66 a**	1.33	2.18	1.95	**1.82 a**
W6: Control (without weeding)	0.24	0.45	0.38	**0.36 f**	0.35	0.48	0.41	**0.41 f**
Mean	**0.81 c¶**	**1.25 a**	**1.19 b**		**0.87 c**	**1.35 a**	**1.26 b**	
L.S.D. (0.05):								
I		**0.033**				**0.046**		
W		**0.027**				**0.047**		
I x W		**0.046**				**0.081**		

*Applied as pre-emergence
**Applied as post emergence
¶ Means in each season in columns or in rows followed by the same letter (s) are not significantly different at the 0.05 level.

Biological yield (t fed^{-1}):

Significant effects were observed for irrigation interval, weeding treatments and their interactions on biological yield in both seasons (Table 7). Irrigation at 15-day interval produced the higher biological yield as averaged over the two seasons; yet, the lowest dry matter was associated with the 10-day interval. These results are in line with those obtained previously on the impact of these treatments on number of remained plants, pods number plant^{-1} , 100 seed weight and seed yield fed^{-1}. Ibrahim and Kandil (2007) and Masoumi et al. (2011) reported similar findings. Meanwhile, W5 resulted in the highest biological yield fed^{-1}, however the lowest dry matter was obtained from W1 treatment in both seasons. While W2, W3 and W4, respectively were in-between W5 and W1 on the rank of biological yield. These results are in consistent with those reported by Akter et al. (2016) and Weber et al. (2016). The combination of 15-day interval and W5 gave the highest biological yield as an average of the two seasons; yet, the lowest biomass was resulted from 10-day interval combined with W1 treatment. Results obtained by Khaffagy et al. (2022) support this result.

Seed protein content (SPC) (%):

Results in Table 8 show significant effects of irrigation interval, weeding control and their interactions on SPC in both seasons. The highest SPC was achieved with irrigation at 15-day interval; however the 10-day interval resulted in the lowest SPC in both seasons. Because the 15-day interval gave satisfied results with factors leading to assimilate more N and other nutrients might be the reason for this result. Ibrahim and Kandil (2007) reported similar results. As an average of the two seasons, the mean value of SPC as affected by the W5 was the highest among weeding treatments, followed by W3, and W2.

Table 7. Influence of irrigation intervals, weed control treatments and their interactions on biological yield (t fed^{-1}) in 2020 and 2021 seasons.

Weed control treatment (W)	2020 season				2021 season			
	Irrigation interval (day) (I)			Mean	Irrigation interval (day) (I)			Mean
	10	15	20		10	15	20	
W1: Pendimethalin (pre*)	3.06	3.23	3.18	**3.16 e¶**	2.73	2.90	2.77	**2.80 d**
W2: Bentazone (post) + Clethodim (post)**	3.67	3.91	3.96	**3.85 b**	3.40	4.03	4.18	**3.87 b**
W3: Pendimethalin (pre)+1 hoeing (30 d.)	3.58	3.89	3.96	**3.81 c**	3.38	4.08	4.23	**3.90 b**
W4: Hoeing once (18 d.)	3.38	3.55	3.54	**3.49 d**	2.97	3.28	3.13	**3.13 c**
W5: Hoeing twice (18 & 30 d.)	3.73	3.94	3.95	**3.88 a**	3.74	4.42	4.15	**4.10 a**
W6: Control (without weeding)	2.89	3.03	2.99	**2.97 f**	2.64	2.84	2.71	**2.73 d**
Mean	**3.38 b¶**	**3.59 a**	**3.60 a**		**3.14 b**	**3.59 a**	**3.53 a**	
L.S.D. (0.05):								
I		**0.034**				**0.116**		
W		**0.028**				**0.077**		
I x W		**0.049**				**0.133**		

*Applied as pre-emergence
**Applied as post emergence
¶ Means in each season in columns or in rows followed by the same letter (s) are not significantly different at the 0.05 level.

The effective action of W5, W3 and W2 in controlling the total weeds within soybean plants that made them accumulating more N and other nutrients this might be the reason for such result. These results are partially agreed with those obtained by Peer et al. (2013), Morsy and Tantawy (2018). The 15-day irrigation interval combined with W5 achieved the highest protein content in seeds, whilst 10-day interval combined with W1 resulted in the lowest SPC in both seasons.

Table 8. Influence of irrigation intervals, weed control treatments and their interactions on seed protein content (%) in 2020 and 2021 seasons.

Weed control treatment (W)	2020 season				2021 season			
	Irrigation interval (day) (I)			Mean	Irrigation interval (day) (I)			Mean
	10	15	20		10	15	20	
W1: Pendimethalin (pre*)	29.3	32.2	30.2	**30.6 d¶**	31.3	33.5	32.3	**32.3 e**
W2: Bentazone (post) + Clethodim (post)**	38.1	41.5	39.5	**39.7 b**	38.5	43.4	41.2	**41.0 c**
W3: Pendimethalin (pre)+1 hoeing (30 d.)	37.2	40.9	39.0	**39.0 b**	40.0	44.5	42.3	**42.3 b**
W4: Hoeing once (18 d.)	32.2	32.8	33.1	**32.7 c**	32.5	38.1	35.8	**35.4 d**
W5: Hoeing twice (18 & 30 d.)	39.7	42.2	41.3	**41.1 a**	43.3	45.4	43.5	**44.1 a**
W6: Control (without weeding)	22.0	23.8	23.3	**23.0 e**	23.5	26.3	24.7	**24.8 f**
Mean	**33.1 c¶**	**35.6 a**	**34.4 b**		**34.9 c**	**38.5 a**	**36.6 b**	
L.S.D. (0.05):								
I		**0.89**				**0.79**		
W		**1.03**				**1.00**		
I x W		**1.78**				**1.73**		

*Applied as pre-emergence
**Applied as post emergence
¶ Means in each season in columns or in rows followed by the same letter (s) are not significantly different at the 0.05 level.

Seed oil content (SOC) (%):

Results in Table 9 exhibit significant effects of irrigation interval, weeding control and their interaction on SOC in both seasons. The highest SOC value (22.1%) was produced from 15-day interval; yet, the lowest value (21.1%) was resulted from 10-day interval as an average of the two seasons. These results to some extent are in line with those reported by Morsy et al. (2018). All weeding treatments increased significantly the SOC versus the check treatment in both seasons, where the SOC values were 24.3, 22.4, 22.2, 21.1, 20.1 and 19.2 % for W5, W3, W2, W4, W1 and W6, respectively as an average of the two seasons. Metwally et al. (2009), Eldabaa et al.(2012) and Khlifa and Fakkar (2020) reported similar results. The highest value of SOC was recorded with 15-day interval combined with W5 in both seasons. Meanwhile, the 10-day interval interacted with W1 gave the least SOC in both seasons. Khaffagy et al. (2022) reported similar results.

Table 9. Influence of irrigation intervals, weed control treatments and their interactions on seed oil content (%) in 2020 and 2021 seasons.

Weed control treatment (W)	2020 season				2021 season			
	Irrigation interval (day) (I)			Mean	Irrigation interval (day) (I)			Mean
	10	15	20		10	15	20	
W1: Pendimethalin (pre*)	19.4	20.2	19.9	**19.8 d¶**	20.0	21.0	20.4	**20.4 e**
W2: Bentazone (post) + Clethodim (post)**	21.0	22.9	22.5	**22.1 b**	21.7	22.7	22.6	**22.3 c**
W3: Pendimethalin (pre)+1 hoeing (30 d.)	21.6	22.3	21.9	**21.9 b**	23.1	24.7	23.9	**23.9 b**
W4: Hoeing once (18 d.)	20.4	21.1	20.7	**20.8 c**	20.9	21.6	21.4	**21.3 d**
W5: Hoeing twice (18 & 30 d.)	22.9	24.5	23.7	**23.7 a**	24.2	25.6	24.7	**24.8 a**
W6: Control (without weeding)	19.2	19.0	19.4	**19.2 e**	18.7	19.7	19.2	**19.2 f**
Mean	**20.7 b¶**	**21.7 a**	**21.4 a**		**21.4 b**	**22.5 a**	**22.0 a**	
L.S.D. (0.05):								
I		**0.38**				**0.54**		
W		**0.59**				**0.81**		
I x W		**1.02**				**1.41**		

*Applied as pre-emergence
**Applied as post emergence
¶ Means in each season in columns or in rows followed by the same letter (s) are not significantly different at the 0.05 level.

Coefficients of simple correlation among some measured traits of soybean and associated weeds in 2020 and 2021 seasons:

Coefficients of simple correlation among some selected traits of soybean and associated weeds in 1st and 2nd seasons are presented in Tables 10 & 11. It is evident that all measured traits on soybean yield traits (T2 – T7) were highly significantly, negatively and strongly correlated with the dry weight of total weeds in both seasons. These results were expected since the infestation of total weeds that left uncontrolled affected significantly, strongly and negatively on all measured soybean traits (Tables 2 - 7). This observation might be due to the noticed strong competition impact of weeds with soybean plants. Similar results were reported by Singh and Jolly (2004). All correlations among each of the chosen yield components and others on one side and soybean yields on the other side were highly significant, positive and strong in both seasons.

Table 10. Correlation coefficients and their significance among some measured traits (T) of soybean and associated weeds in the first season, 2020.

Measured traits of soybean and associated weeds	T1	T2	T3	T4	T5	T6	T7
Dry weight of total weeds, (**T1**)	1						
Remained plants no., (**T2**)	-0.892**	1					
Pods no. plant^{-1}, (**T3**)	-0.931**	0.964**	1				
Seeds no. pod^{-1}, (**T4**)	-0.858**	0.947**	0.916**	1			
100-seeds weight (seed index), (**T5**)	-0.882**	0.948**	0.952**	0.902**	1		
Seed yield, (**T6**)	-0.848**	0.933**	0.952**	0.894**	0.927**	1	
Biological yield, (**T7**)	-0.913**	0.949**	0.972**	0.905**	0.957**	0.975**	1

** Highly significant (P value < 0.01).

Table 11. Correlation coefficients and their significance among some measured traits (T) of soybean and associated weeds in the second season, 2021.

Measured traits of soybean and associated weeds.	T1	T2	T3	T4	T5	T6	T7
Dry weight of total weeds, (**T1)**	1						
Remained plants no**., (T2)**	-0.868**	1					
Pods no. plant-1, **(T3)**	-0.871**	0.889**	1				
Seeds no. pod-1, **(T4)**	-0.880**	0.875**	0.931**	1			
100-seeds weight (seed index), **(T5)**	-0.879**	0.912**	0.958**	0.934**	1		
Seed yield, **(T6)**	-0.776**	0.857**	0.953**	0.871**	0.920**	1	
Biological yield, **(T7)**	-0.758**	0.831**	0.939**	0.846**	0.902**	0.986**	1

** Highly significant (P value < 0.01).

CONCLUSION

The highest seed yield (2.04 t fed^{-1}, average of the two seasons) with best quality of soybean (cv. Giza 111) could be achieved from the associated treatment of 15-day interval with hand hoeing twice or with pendimethalin (pre) plus one hoeing at 30 DAS. This conclusion would be recommended for soybean production in similar agro-ecosystems.

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محصول فول الصويا وجودته والحشائش المصاحبة وعلاقتها بفترات الرى ومكافحة الحشائش

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أجريت تجربة حقلية بمحطة شندويل للبحوث الزراعية، سوهاج، مصر في موسمى 2020 و 2021 لتقييم تأثير فترات الري (10 و 15 و 20 يومًا) ومعاملات مكافحة الحشائش على محصول فول الصويا والحشائش المصاحبة له. أظهرت النتائج أن جميع صفات فول الصويا والحشائش المرتبطة بها تأثرت معنوياً بفترات الري ومعاملات مكافحة الحشائش والتفاعل بينهما. أدى الري كل 15 يوم إلى اعلى إنتاجية من فول الصويا ومحتوى البذور من البروتين والزيت. كما أنها أعطت نتيجة جيدة في تقليل الوزن الجاف للحشائش وكان العزيق اليدوي مرتين ثم البنديميثالين قبل الزراعة + عزقة واحدة عند 30 يوماً من الزراعة هي أفضل المعاملات في مكافحة الحشائش وتحسين إنتاجية فول الصويا وجودته. وامكن تحقيق أعلى إنتاجية من البذور (2.04 طن للفدان) مع أفضل جودة لفول الصويا (صنف جيزة 111) من المعاملة المشتركة بين الرى كل 15 يوم مع العزيق اليدوي مرتين أو مع البنديميثالين + عزقة واحدة عند 30 يوم. و يمكن التوصية بهذه النتيجة لإنتاج فول الصويا تحت الظروف البيئية المماثلة.

الكلمات المفتاحية: فول الصويا وجودته، فترات الري، المكافحة المتكاملة للحشائش.