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RESEARCH

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Mitigation of water stress by compost and arginine application and its impacts on barley production

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Abstract

Background Water-scarce locations necessitate the deployment of creative and sustainable techniques for managing water for agricultural production. Field experiment was conducted at the Experimental Research Farm of National Research Centre, Nubaria region, Egypt to alleviate the harmful effect of water stress on the yield of Mediterranean barley varieties (Giza 125, Tombari, Ksar Megrine and Tamellat) by compost (0.0, 2.0, 4.0, 6.0-ton fed^{-1}) and arginine application (0.00 and 1000 ppm) under deficit irrigation. The amounts of irrigation water applied were "900 and 450" m^3 fed^{-1} to sufficient irrigation and deficit irrigation, respectively.

Results The greatest and most significant values of the chlorophyll values and relative water content values obtained at the treatment supplied with 6.0-ton compost fed^{-1} and sprayed with Arginine. There was a significant dramatic decrease in proline content with increasing compost application rates and treated barley plants by Arginine for all the studied barley varieties under both studied irrigation treatments. Increasing compost application rate is associated with significant increase in number of spike m^{-2} without or with arginine. Barley Tombari variety received 6.0-ton compost fed^{-1} gained changes to give a greatest significant value of grain (ton fed^{-1}) under sufficient irrigation and Tamellat under deficit irrigation situation. The significant maximum values of the grain yield (1.96- and 2.09-ton fed^{-1}) were attained at Tombari and Tamellat varieties which received 6.0-ton fed^{-1} compost with or without arginine under sufficient irrigation. The increases in compost rate increment changes to incremented grain yield values with arginine application more than untreated one. The greatest and significant grain yield was found at the treatment received 6.0-ton compost fed^{-1} with arginine foliar application.

Conclusion Compost application has an important role in maintaining greatest water use efficiency for plant and arginine application reported to contribute in reduction in destructive effects of a biotic stress thus their importance in increasing the barley production under water stress.

Keywords Water stress, Compost, Arginine, Proline, Grain yield

Background

Drought is an abiotic stress that limits crop production across the world. The coming water scarcity in Egypt poses a serious threat to agricultural growth in general and crop production in particular. It is increasingly crucial to utilize water efficiently in a range of agricultural and human activities due to this threat to the future of the world's rivers (Gebaly et al. 2013). The most significant abiotic stress is drought; according to Barichivich et al. (2019), 20.0% of the world's land area is now

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experiencing moderate to severe drought, and this percentage is expected to rise in the coming years. Drought stress results in comparatively lower biomass production by reducing photosynthesis, stomatal conductance, ATP synthesis, carbohydrate metabolism, and assimilate translocation (Meeks et al. 2019). Furthermore, a restricted water supply during the reproductive stage impairs the function of pollen by reducing the activity of enzymes involved in starch synthesis, downregulating the genes for sucrose synthase and invertase. Reproductive failure results from inadequate pollen tube development caused by the buildup of decreasing starch in the pistils (Hu et al. 2019 and Li et al. 2020). Because barley is more drought- and salinity-tolerant than wheat, it is grown mostly in Egypt's northern coastal region, as well as in the peripheral regions of the Nile Valley and Delta and on recently reclaimed soils. Organic matter influences crop growth and yield directly by providing nutrients and indirectly by changing the physical properties of the soil that can improve the root environment and stimulate plant growth. Compost application plays a significant role in improving the physical and chemical properties of the soil and maintaining greatest water use efficiency for plant growth (Bandyopadhyay et al. 2010).

Consistent with Nguyen et al. (2012), adding compost raised the water content at the permanent wilting point as well as the field capacity. Compost that had been put into drought-stressed plants withered sooner than control plants, while compost that had been mulched lengthened the days until wilting by increasing the availability of water to the plants. According to Abd et al. (2019), using compost seems like a workable way to alleviate the negative impacts of water shortage by improving plant water status, SPAD value, chlorophyll fluorescence, plant development characteristics, and irrigation efficiency. The yield and crop water productivity of sugar beets were then optimized by combining deficit irrigation with compost. Plants treated with amino acids are better able to withstand harsh stress situations and are encouraged to continue growing and developing unhindered. Du Jardin (2015) stated that the most versatile amino acid, arginine is necessary for stress tolerance and is linked to the synthesis of signaling molecules (Hamid et al. 2019). Arginine has been linked to osmotic potential, stomatal activity, and vegetative development. It is also involved in the manufacture of proteins, proline, and polyamines (Nasibi et al. 2011). Plants store and transport organic nitrogen in arginine, which has the largest nitrogen-to-carbon ratio (Winter et al. 2015). One of the most popular methods for boosting the development, chemical composition, and output of barley and other crop plants is foliar spraying with plant growth chemicals like arginine (Akladious and Hanafy 2018). Furthermore, the plant stress response involves both endogenous and exogenous arginine (Matysiak et al. 2020). In keeping with Hussein et al. (2022), arginine supplementation enhanced the synthesis of soluble sugars, proline, free amino acids, phenols, and flavonoids in wheat plants under both normal and stressed circumstances. By applying compost and arginine, the current experiment seeks to lessen the detrimental effects of water stress on the production of Mediterranean barley cultivars.

Methods

Experimental design

Field experiment was conducted during the winter season of 2019/2020 and 2020/2021 to alleviate the harmful effect of water stress on the yield of Mediterranean barley varieties grown under deficit irrigation situation by compost and arginine use in the Nubaria area of Egypt, at the Experimental Research Farm of the National Research Center (latitude 30.87 N, longitude 31.17 E, mean elevation 21 m above sea level). The experimental region was characterized as a parched location, with chilly winters and scorching, dry summers. Throughout the two growth seasons, there was no low intensity or effective rainfall to consider. Data in Table 1 indicated that the soil of experimental site is classified as sandy loam soil. The field capacity and available water of the experimental soil were 17.2 and 11.8 ml 100^{-1} g soil, respectively. Soil pH was 7.91; electrical conductivity 0.96 dS m^{-1} and available N, P and K were 8.65, 2.34 and 16.8 mg 100^{-1} g soil, respectively. Physical and chemical properties of the experimental soil were done according to (George Estefan et al. 2013).

Irrigation treatments

Two drip irrigation rules (sufficient irrigation and deficit irrigation were applied as a percentage of the crop evapotranspiration computed according to Allen et al. (1998). The amounts of irrigation water applied were "900 and 450" m^3 fed to sufficient irrigation (SI) and deficit irrigation (DI), respectively. Irrigation treatments were started after sufficient emergence (after 15 days from the sowing date).

Barley cultivars

The Mediterranean barley selections were used for the field experiment are Egyptian variety (Giza 125), Tunisian variety (Tombari), Algerian variety (Ksar Megrine) and Morocco variety (Tamellat). The seeds of selected varieties obtained from National gene bank of Tunisia. Sowing dates were November 25 2019 and replicated in November 20 2020 winter season, respectively. The soil preparation was prepared as the traditional cultivation.

Table 1 Physical–chemical properties of the experimental soil

pH	EC	OM	$CaCO_3$	Particle size distribution			Texture
(1:2.5)	dS m^{-1}	%	%	Sand %	Silt %	Clay %	Class
7.91	0.96	0.76	1.78	77.3	5.6	17.03	Sandy loam
Cations (me/L)				**Anions (me/L)**			
Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^-	HCO_3^-	Cl^-	SO_4^-
3.54	1.46	3.43	1.38	0.19	2.92	2.96	3.74
Available macronutrients (mg/100 g soil)				**Available micronutrients (mg/kg)**			
N	P	K		Fe	Zn	Mn	Cu
8.65	2.34	16.81		10.31	0.08	4.19	0.013

Fertilization treatment

Arginine (Arg) foliar application [0.00 (Arg−) and 1000 ppm (Arg+)] was applied three times during barley growth at 30, 45 and 60 days after sowing. The analysis of compost was 7.11 pH, 2.12 mS m^{-1} EC in (1:5) extract, 26.2% Organic matter, 20.2 C/N ratio, 0.80% N, 0.18% P and 0.45% K. Compost (complete fermented organic materials) was added into the soil during soil preparation in the dosage (0.0-, 2.0-, 4.0- and 6.0-ton fed^{-1}) accompanied with recommended dose of phosphorus as Calcium Superphosphate P_20_5 (30 kg P_20_5 fed^{-1}). Before the initial irrigation, nitrogen was supplied to the soil in the form of Ammonium Nitrate (33.0% N) at a rate of 20 kg N fed^{-1} as a beginning dosage. Two equal doses of potassium sulfate (48% K_2O) were then applied to the soil at 20 and 40 days following planting. This study employed a split plot design with four replications, with irrigation treatments occupying the main plots and compost rates in the sub-main plot. Throughout the growth season, all additional agronomic (cultural) procedures were carried out as advised by the nearby barley production farmhouses.

Estimation at heading stage

Leaf pigment content

With the use of the Minolta-SPAD Chlorophyll Meter (Minolta Camera Co., Osaka, Japan), the amount of greenery present in a plant was assessed. According to Minolta (1989), the SPAD-502 chlorophyll meter determines the quantity of chlorophyll in a leaf by calculating the absorbance of chlorophyll in the red and near-infrared areas. This results in a numerical number known as the SPAD value.

Relative water content

Castillo (1996) assessed the relative water content (RWC) of leaves throughout each dry episode. Ten fully advanced leaves from five plants each plot (two leaves per plant) that were chosen at the matching heights was measured for their fresh weight (FW). To determine the weight of the submerged leaves, they were submerged in filtered water for a full day under dim illumination. Following the measurement of the turgescence weight (TW), the leaves were dried for 48 h at 75 °C, and their dry weights (D.W.) were determined. The following formula was used to determine RWC: $RWC = (FW-DW)/(TW-DW) \times 100$.

Determination of proline content

After regulating 0.40 g of fresh plant material in 1.5 ml of distilled water, the mixture was incubated for 30 min at 100 °C in a water bath. Following a cooling period to ambient temperature (22 °C), the samples were centrifuged for 10 min at 4000 rpm. After that, 0.5 ml of the supernatant was combined with 1.0 ml of a 1.0% solution of Ninhydrin in 60% acetic acid, and the mixture was incubated at 100 °C for 20 min. Phase separation was achieved by adding 3.0 ml of toluene, shaking the samples, and letting them sit in the dark for 24 h once they had cooled to 22 °C. A cuvette was filled with one milliliter of proline extract, and the absorbance was measured using a spectrophotometer set to measure wavelengths of $\lambda = 520$ nm, according to (Filek Maria et al. 2014).

Yield components estimation

In both years, the entire collected area of each plot was converted to grain yield ton fed^{-1} after potential grain yield (Yp) and stress yield (Ys) per plot were determined. At harvest time, ten distinct plants were arbitrarily chosen from the center of each plot to estimate: Height of plant (cm): The height of ten randomly selected plants per plot is expressed as the separation between the spike points and the culm bases. The average of the data was calculated for each plant. Number of Spikes m^{-2}: It was converted into spikes per square meter by taking a random sample inside each panel. 1000-kernel weight (g):

The weight of 1000 cleaned kernels in grams for every plot was estimated. Biological yield: The total biomass (kg $plot^{-1}$) of the harvested plants, converted to tons per feddan. Grain yield was measured as the weight of the plot's clean grains following threshing and converted to tons per acre. Efficiency of water use: WUE was calculated on a grain basis by dividing the amount of water applied (m^3 fed^{-1}) by the grain yield (kg fed^{-1}). The result was WUE, expressed in (kg m^{-3} of irrigation water), Fed = feddan, ha = hectare, ha = 2.4 fed.

Drought tolerance indices

Stress susceptibility index (SSI), tolerance index (TOL), mean productivity (MP), geometric mean productivity (GMP), and stress tolerance index (STI) are the five drought tolerance indices. Relative yield decreases were computed using grain yield in irrigated (Yp) and drought-stricken (Ys) situations. Drought tolerance indices were calculated by using the equations cited in Table 2.

Statistical analysis

In line with Gomez and Gomez (1984), data from two growth seasons were measurably broken down as a split plot design (RCBD) using estimation of variance (ANOVA). The means of the selections included in this study were comparison using a Fisher test ran by (LSD) at (P = 0.05).

Results

Leaf pigment contents

Data in Table 3 showed the effect of the compost application rates (0.0, 2.0, 4.0; 6.0-ton fed^{-1}) and Arginine application on the pigment content (chlorophyll) reading of the some examined barley varieties (Giza 125, Tombari, Ksar Megrine and Tamellat) under sufficient irrigation (SI) and deficit irrigation (DI). Results revealed that compost application rates treated or not by Arginine significantly increament chlorophyll values under SI and DI treatments. The greatest and significant values of chlorophyll were obtained at 6.0-ton fed^{-1} compost treated by Arginine and it is easy to arrange the studied barley varieties in descending order as follow: Ksar Megrine > Tamellat > Giza 125 > Tombari, under both irrigation water treatments. Also, data cleared that Arginine enhanced chlorophyll under both studied irrigation treatments, while the enhancement under DI was greatest than SI. The increment percent in chlorophyll content with sufficient irrigation ranged from 1.7–9.1%, 0.3–8.0%, 3.8–13.4% and 2.9–8.1% for Giza 125, Tombari, Ksar Megrine and Tamellat, respectively. Meanwhile, the ranges under deficit irrigation were 15.0–27.5%, 14.1–16.2%, 17.3–22.5% and 19.1–26.3% after application of 6.0-ton compost without arginine comparison with control, respectively.

The lowest values of the chlorophyll content were observed at control without Arginine at Ksar Megrine (38.2), Tombari (40.5), Tamellat (40.6) and Giza (41.5) under SI and Ksar Megrine (26.5), Tamellat (28.1), Tombari (30.2) and Giza 125 (31.3) under DI treatment. Also, data cleared that the minimum chlorophyll content was obtained at Ksar Megrine with Arginine and without under SI, while under DI maximum values of chlorophyll were recorded at Tamellat and Giza 125 at 6.0-ton compost in same sequence under DI. Regardless Arginine effect, SI has a positive and significant effect on the chlorophyll content which increament by increasing compost application rates. Also, data pointed out that Tamellat barley variety gained the greatest chlorophyll value under both studied irrigation treatments. The interaction effects between compost and arginine application on chlorophyll content were significant.

Relative water content (RWC)

Results in Table 3 revealed that the lowest values of the RWC were recorded at 2- ton fed^{-1} compost without Arginine treatment and Tamellat gained the lowest value under sufficient irrigation treatment and Giza 125 under DI treatment with or without Arginine, whereas the

Table 2 Stress tolerance indices used for the evaluation of barley genotypes to drought tolerance

Stress tolerance indices	Equation	References
Stress susceptibility index	SSI = 1–(Ys/Yp)/1–(Ŷs/Ŷp)	Fischer and Maurer (1978)
Mean productivity	MP = (Ys + Yp)/2	Rosielle and Hambline (1981)
Stress tolerance	TOL = Yp–Ys	Rosielle and Hambline (1981)
Geometric mean productivity	GMP = (Yp*Ys)1/2	Fernandez (1992)
Stress tolerance index	STI = (Yp*Ys)/(Ŷp)2	Fernandez (1992)
Yield index	YI = Ys/Ŷs	Gavuzzi et al. (1997)
Yield stability index	YSI = Ys/Yp	Bouslama and Schapaugh (1984)
Harmonic means	HM = 2(Ys*Yp)/(Ys + Yp)	Kristin et al. (1997)

Table 3 Chlorophyll and relative water content of barley as affected by arginine (Arg) and irrigation treatments

Varieties	Compost	SPAD chlorophyll				Relative water content (RWC)			
		Sufficient irrigation		Deficit irrigation		Sufficient irrigation		Deficit irrigation	
		Arg (−)	Arg (+)	Arg (−)	Arg (+)	Arg (−)	Arg (+)	Arg (−)	Arg (+)
Giza 125	0.0-ton fed^{-1}	41.50	42.20	31.29	36.00	81.23	82.12	70.25	73.28
	2.0-ton fed^{-1}	42.60	45.40	31.87	38.80	82.20	84.05	71.26	76.11
	4.0-ton fed^{-1}	46.10	50.10	34.45	42.80	83.29	85.98	71.42	79.58
	6.0-ton fed^{-1}	47.30	51.60	35.86	45.70	84.08	88.98	73.60	83.99
Tombari	0.0-ton fed^{-1}	40.50	40.61	30.21	34.46	78.34	80.50	66.62	70.46
	2.0-ton fed^{-1}	41.40	42.00	31.21	35.87	79.91	84.10	69.81	77.84
	4.0-ton fed^{-1}	41.10	43.40	31.70	37.53	82.10	88.19	69.88	80.37
	6.0-ton fed^{-1}	42.40	45.80	36.02	41.85	83.29	90.86	71.54	82.86
	0.0-ton fed^{-1}	38.20	39.64	26.89	31.56	81.02	84.40	70.70	74.30
Ksar	2.0-ton fed^{-1}	41.22	45.10	30.05	35.79	82.27	86.79	73.82	80.26
Megrine	4.0-ton fed^{-1}	45.76	51.90	32.62	38.69	84.10	92.18	74.37	84.12
	6.0-ton fed^{-1}	48.97	55.41	36.52	44.75	86.43	92.52	76.52	87.89
Tamellat	0.0-ton fed^{-1}	40.60	41.77	28.10	33.47	75.34	79.47	71.80	74.09
	2.0-ton fed^{-1}	43.10	44.20	32.29	39.40	81.60	85.18	70.70	79.74
	4.0-ton fed^{-1}	44.30	47.80	33.90	42.80	82.23	87.47	71.63	82.13
	6.0-ton fed^{-1}	50.70	54.80	36.77	44.67	85.14	90.96	73.70	83.09
LSD (0.05)	Varieties	0.36	0.44	0.26	0.53	1.96	1.89	1.92	1.34
	Compost	0.31	0.38	0.22	0.46	0.81	0.87	0.72	0.83
	Interaction	0.63	0.76	0.45	0.91	2.57	2.57	2.45	2.02

greatest and significant values of the RWC were recorded at Ksar Megrine barley variety treated or not by Arginine.

So, it is easy to rank the studied barley varieties in descending order as follow: Ksar Megrine > Tamellat > Tombari > Giza 125 and Ksar Megrine > Giza 125 > Tombari > Tamellat under both studied irrigation treatments, respectively. Regarding to the interaction effect of the compost application rates with or without Arginine on the RWC, data on hand noticed that Arginine significantly enhanced RWC after increment compost rates where the lowest values attained at 0.0 compost and the greatest ones were recorded at 6.0-ton fed^{-1} compost. Respecting to the effect of the interaction between irrigation treatments and the studied barley varieties on the RWC values, data noticed that Ksar Megrine was the superior one where it has got the greatest and significant values under both studied irrigation treatments (86.4, 92.5 and 76.5, 87.9) with and without arginine application, respectively.

Proline content

Data in Table 4 revealed a dramatic decrease in proline content with increasing compost application rates and treated barley plants by Arginine for all the studied barley varieties under both studied irrigation treatments. Also, data cleared that significant values of the proline content under DI were more than SI treatment. The greatest and significant values of the proline content were observed at control under all the studied barley varieties where Tombari scored the greatest value (2.81, 2.57) under SI without Arginine, but Giza 125 (3.85) and Ksar Megrine (3.53) scored the greatest ones under DI without Arginine treatments, respectively. The lowest proline values were observed at Tombari and Tamellat in same sequence. Regarding the negative effect of the Arginine on the proline content, data in Table 4 mentioned that the greatest reduction was occurred at control (zero-ton compost), while the lowest one was observed at 6-ton compost for all the studied barley varieties.

Plant height

Table 4 shows that compost application was associated with increasing plant height under both studied irrigation treatments but the greatest and significant values of plant height were observed under sufficient irrigation comparison to deficit irrigation treatment. Also, data indicated that greatest plant height values were obtained at 6.0-ton fed^{-1} compost plus Arginine under sufficient irrigation and deficit irrigation situation for Tombari barley variety. Whereas, the lowest one values observed at control treatment of the studied

Table 4 Proline and plant height of barley as affected by arginine (Arg) and irrigation regimes

Varieties	Compost	Proline (mg g^{-1} fresh weight)				Plant height (cm)			
		Sufficient irrigation		Deficit irrigation		Sufficient irrigation		Deficit irrigation	
		Arg (−)	Arg (+)	Arg (−)	Arg (+)	Arg (−)	Arg (+)	Arg (−)	Arg (+)
Giza 125	0.0-ton fed^{-1}	2.45	2.21	3.85	2.99	75.30	80.40	61.40	68.30
	2.0-ton fed^{-1}	2.30	2.16	2.84	2.38	85.30	95.60	63.40	73.70
	4.0-ton fed^{-1}	1.55	1.46	2.60	2.21	91.80	104.50	67.30	79.40
	6.0-ton fed^{-1}	1.28	1.24	2.38	2.07	95.00	109.60	71.70	82.20
Tombari	0.0-ton fed^{-1}	2.81	2.57	3.44	2.85	77.80	85.40	60.10	66.30
	2.0-ton fed^{-1}	2.33	2.16	2.74	2.62	86.40	95.40	71.80	80.30
	4.0-ton fed^{-1}	2.06	1.95	2.66	2.57	90.50	103.60	72.20	82.80
	6.0-ton fed^{-1}	2.00	1.87	2.18	2.09	102.70	116.30	75.30	89.00
	0.0-ton fed^{-1}	2.65	2.12	3.53	2.78	65.20	72.40	57.40	66.10
Ksar	2.0-ton fed^{-1}	2.09	1.87	2.74	2.60	80.30	92.10	62.30	74.40
Megrine	4.0-ton fed^{-1}	1.75	1.53	2.65	2.52	90.60	106.60	67.40	82.00
	6.0-ton fed^{-1}	1.48	1.43	2.29	2.20	98.20	113.70	71.20	87.00
Tamellat	0.0-ton fed^{-1}	2.03	1.81	3.91	2.79	71.20	75.40	62.00	69.40
	2.0-ton fed^{-1}	1.67	1.57	2.33	1.97	85.40	95.00	67.90	77.80
	4.0-ton fed^{-1}	1.45	1.36	2.11	1.87	93.60	105.00	70.60	84.30
	6.0-ton fed^{-1}	1.11	1.06	1.54	1.41	100.50	115.00	73.40	88.40
LSD (0.05)	Varieties	0.10	0.06	0.14	0.19	1.92	1.46	1.04	1.27
	Compost	0.07	0.05	0.04	0.25	2.32	1.13	2.08	1.96
	Interaction	0.15	0.11	0.17	0.41	3.86	2.37	2.85	2.95

barley varieties, especially under deficit irrigation at Ksar Megrine. Application of 6.0-ton fed^{-1} compost application with arginine enhanced the plant height under irrigation situation and the greatest increase in plant height was 15.4, 14.5, 17.7 and 14.4% under sufficient irrigation and 18.0, 18.2, 22.2 and 20.4% under deficit irrigation situation for Giza125, Tombari, Ksar Megrine and Tamellat barley varieties with Arginine foliar application, respectively. Regarding to irrigation treatments effect on the plant height of different barley varieties, data indicated that the values of plant height strongly lower under deficit irrigation and the maximum significant values of plant height were found at 6.0-ton fed^{-1} compost for all studied barley varieties but Tamellat barley variety was the superior one under sufficient irrigation and Tombari under deficit irrigation treatment as compare to control of all barley varieties. According to effect of irrigation treatments on the plant height of different barley varieties data indicated that, it is easy to arrange barley varieties in descending order as follow Tombari > Tamellat > Giza125 > Ksar Megrine under sufficient irrigation and deficit irrigation. Data found that the lowest and the greatest reduction caused by deficit irrigation effect were recorded at Tamellat (19.9%) and Giza125 (23.1%), respectively.

Yield parameters

Spike number

Data in Table 5 should the number of Spike m^{-2} as affected by compost application rate and treated by arginine under sufficient irrigation and deficit irrigation, data on hand revealed that number of spike m^{-2} significantly increment by increasing compost application and treated by arginine for all studied barley varieties. The greatest and significant values of the number of Spike m^{-2} were found at 6.0-ton fed^{-1} compost for all studied barley varieties, especially Giza 125 which has the greatest values while the lowest values were observed at control of compost (zero ton) without arginine application under deficit irrigation. The greatest significant increase relative to arginine application could be arranged in descending order as follow: Tombari > Ksar Megrine > Giza > Tamellat at 6.0-ton fed^{-1} compost, except at Tamellat (4.0-ton fed^{-1} compost).

Also, data mention that barley Giza125 was the superior one under sufficient irrigation and deficit irrigation treatments, whereas Ksar Megrine attained the lowest values under both sufficient irrigation and deficit irrigation treatments relative to control. The lowest reduction was observed at Tombari after application 4.0-ton fed^{-1} compost where Ksar Megrine after 4.0- and 6.0-ton fed^{-1} compost increment by 2.9 and 6.0% under

Table 5 Spike number and kernel weight of barley as affected by arginine (Arg) and irrigation regimes

Varieties	Compost	Spike number m^{-2}				1000 kernel weight (g)			
		Sufficient irrigation		Deficit irrigation		Sufficient irrigation		Deficit irrigation	
		Arg (−)	Arg (+)	Arg (−)	Arg (+)	Arg (−)	Arg (+)	Arg (−)	Arg (+)
Giza 125	0.0-ton fed^{-1}	392	420	244	260	25.90	27.22	17.60	18.55
	2.0-ton fed^{-1}	433	476	272	308	28.01	30.32	19.16	21.33
	4.0-ton fed^{-1}	568	628	384	453	28.93	33.08	19.79	22.17
	6.0-ton fed^{-1}	584	673	412	492	30.03	34.21	20.20	22.81
Tombari	0.0-ton fed^{-1}	280	308	252	280	29.11	30.43	16.22	18.08
	2.0-ton fed^{-1}	365	412	260	304	31.15	33.99	18.88	21.58
	4.0-ton fed^{-1}	356	416	336	388	32.79	35.23	19.19	23.49
	6.0-ton fed^{-1}	445	544	345	420	33.25	36.34	19.36	24.34
	0.0-ton fed^{-1}	280	312	232	253	21.76	23.17	15.38	16.55
Ksar	2.0-ton fed^{-1}	344	397	272	316	23.29	25.17	17.46	19.44
Megrine	4.0-ton fed^{-1}	380	460	396	468	25.40	27.86	17.82	20.27
	6.0-ton fed^{-1}	408	480	406	487	26.17	29.12	19.74	22.64
Tamellat	0.0-ton fed^{-1}	296	324	232	244	22.25	23.08	15.57	17.13
	2.0-ton fed^{-1}	376	408	324	364	24.74	25.61	16.60	19.08
	4.0-ton fed^{-1}	472	516	345	403	25.42	26.82	17.59	20.33
	6.0-ton fed^{-1}	496	552	392	452	28.63	31.24	19.33	23.66
LSD (0.05)	Varieties	14.03	11.89	9.04	21.17	0.98	1.04	0.88	0.98
	Compost	21.85	21.67	9.18	21.97	1.09	1.20	0.91	0.99
	Interaction	32.75	30.63	16.64	39.38	1.91	1.81	1.76	1.82

deficit irrigation comparison with control treatment. With respect to the effect of irrigation treatments on the number of Spike m^{-2} of different barley varieties, it is easy to rank studied barley varieties in descending order as follow: Giza125 > Tamellat > Tombari > Ksar Megrine and Ksar Megrine > Giza125 > Tamellat > Tombari under sufficient irrigation and deficit irrigation, respectively.

1000 kernel weight

Data in Table 5 indicated that increasing composted associated with increasing 1000 kernel weight for all studies varieties treated or not by arginine under the sufficient and deficit irrigation. Also, Tombari gained the greatest values of 1000 kernel weight under sufficient irrigation Regarding to the effect of the irrigation treatments on the 1000 kernel weight of the studied barley varieties, data showed the greatest 1000 kernel weight values were observed at Tombari under sufficient irrigation (29.2) and deficit irrigation (21.8), while the opposite was found at Ksar Megrine under sufficient irrigation (22.5) and deficit irrigation (16.0) situation, respectively. With respect to the effect of both compost application and sprayed Arginine, data on hand revealed that significant minimum and maximum values of 1000 kernel weight were recorded at zero- and 6.0-ton fed^{-1} compost under sufficient irrigation followed by deficit irrigation treatment.

Grain and biological yield

Data in Table 6 indicated a relation between compost application rate and sprayed arginine on the grain yield of different barley under different irrigation treatments. The significant maximum values of the grain yield (1.96- and 2.09-ton fed^{-1}) were attained at Tombari and Tamellat varieties which received 6.0-ton fed^{-1} compost with or without arginine under sufficient irrigation on while the lowest values were observed at zero compost without with arginine especially at barley Giza125 under deficit irrigation situation. The greatest increase in grain yield relative to arginine could be arranged in descending order as follow: Tamellat, Ksar Megrine, Giza 125 and Tombari under sufficient irrigation while under deficit irrigation the rank was: Giza 125 > Tombari > Tamellat > Ksar Megrine. While, in the other side the lowest increase was observed at Tamellat (1.5%) under sufficient irrigation and Ksar Megrine (2.8%) without compost application and under deficit irrigation.

According to effect of sufficient irrigation and deficit irrigation on grain yield of barley varieties, data mentioned that barley Tombari gained greatest values under sufficient irrigation and Tamellat under deficit irrigation the greatest and the lowest production percentage were found at Tombari (24.6%) and Tamellat (15.4%). The biological yield values produced under sufficient irrigation

Table 6 Grain and biological yield of barley varieties at as affected by arginine (Arg) and irrigation regimes

Varieties	Compost	Grain yield (ton fed^{-1})				Biological yield (ton fed^{-1})			
		Sufficient irrigation		Deficit irrigation		Sufficient irrigation		Deficit irrigation	
		Arg (−)	Arg (+)	Arg (−)	Arg (+)	Arg (−)	Arg (+)	Arg (−)	Arg (+)
Giza 125	0.0-ton fed^{-1}	1.46	1.51	1.28	1.35	3.41	3.54	2.25	2.30
	2.0-ton fed^{-1}	1.61	1.70	1.32	1.41	4.09	4.31	2.98	3.12
	4.0-ton fed^{-1}	1.86	1.98	1.34	1.44	4.66	5.06	3.35	3.76
	6.0-ton fed^{-1}	1.95	2.12	1.35	1.53	5.04	5.64	4.10	4.66
Tombari	0.0-ton fed^{-1}	1.65	1.69	1.30	1.35	3.02	3.23	2.72	2.87
	2.0-ton fed^{-1}	1.76	1.86	1.32	1.39	3.82	4.09	3.28	3.50
	4.0-ton fed^{-1}	1.84	1.96	1.33	1.47	3.97	4.23	3.49	3.83
	6.0-ton fed^{-1}	1.96	2.09	1.41	1.58	4.78	5.29	3.58	4.03
	0.0-ton fed^{-1}	1.51	1.60	1.29	1.33	2.87	3.01	3.16	3.24
Ksar	2.0-ton fed^{-1}	1.56	1.67	1.26	1.35	3.57	3.82	3.42	3.57
Megrine	4.0-ton fed^{-1}	1.71	1.84	1.32	1.44	4.18	4.42	3.65	3.92
	6.0-ton fed^{-1}	1.77	1.93	1.38	1.53	4.52	4.83	4.38	4.81
Tamellat	0.0-ton fed^{-1}	1.49	1.51	1.36	1.44	3.28	3.40	2.71	2.87
	2.0-ton fed^{-1}	1.64	1.75	1.39	1.50	4.74	5.11	4.46	4.88
	4.0-ton fed^{-1}	1.67	1.81	1.42	1.55	5.03	5.44	5.33	5.95
	6.0-ton fed^{-1}	1.88	2.06	1.43	1.58	5.23	5.77	5.71	6.57
LSD (0.05)	Varieties	0.04	0.05	0.03	0.04	0.17	0.26	0.16	0.15
	Compost	0.06	0.07	0.04	0.05	0.27	0.36	0.17	0.30
	Interaction	0.09	0.10	0.07	0.08	0.41	0.57	0.30	0.41

water were greatest than under deficit irrigation. Also, the increment composted associated with increase in biological yield especially after application of 6-ton fed^{-1} compost. The foliar spray of arginine under both normal irrigation and water stress situations yielded the greatest values of water usage efficiency. The effect of arginine on new growth and nutrient absorption may be responsible for gains in water usage efficiency. These benefits led to beneficial effects on the number of opened bolls per plant and boll weight, which in turn produced increment barley output. According to the effect of compost application rate with and without Arginine, data indicated that the combined application of compost and arginine has a promoting effect on the water use efficiency. The greatest water use efficiency was found at Tamellat received 6.0-ton compost fed^{-1} and the lowest ones were found at Ksar Megrine at zero-ton compost.

Stress tolerance indices

The information in Table 7 demonstrated how foliar arginine treatment and water stress influenced the evaluated barley varieties' stress resistance indicators. The data obtained showed that, except for SSI and YSI for Ksar Megrine and Tamellat, the majority of the greatest values were obtained following compost application for all tested barley types, with the lowest values being seen at control treatments. With respect to the impact of barley varieties on stress tolerance indices, the findings showed that Tamellat obtained the lowest values, with the exception of SSI (Ksar Megrine), while Tombari earned the greatest values, with the exception of SSI (Tamellat) and TOL (Giza 125).

Data indicated that the greatest values were found for control treatments based on the compost rates application on the stress tolerance indices. while the lowest one was obtained at 6.0-ton compost fed^{-1} application (SSI, STI, GMP, YI), TOL and 4.0-ton fed^{-1} compost application (YI, YSI, HM) combined with foliar application of arginine. Simple correlation in Table 8 estimated among the stress tolerance indices and data revealed that STI positively correlated with MP ($P>0.05$, $r=0.954$), GYP ($P>0.05$, $r=0.931$), YI ($P>0.05$, $r=0.886$) and negatively correlated with YSI (−0.683). Also, HM correlated positively with SSI ($P>0.05$, $r=0.663$), STI ($P>0.05$, $r=0.991$), MP ($P>0.05$, $r=0.997$), GMP ($P>0.05$, $r=0.998$); Yi ($P>0.05$, $r=0.900$).

Discussion

Input-intensive agriculture is responsible for land degradation, biodiversity loss, water stress and climate change (Foley et al. 2011). The findings showed that under SI and DI treatments, compost application rates—whether they

Table 7 Drought indices of barley as affected by compost and arginine under deficit irrigation

Varieties	Compost	SSI	STI	MP	GMP	YI	YSI	TOL	HM
Giza 125	0.0-ton fed^{-1}	0.86	0.46	0.37	0.37	0.83	0.74	0.109	0.36
	2.0-ton fed^{-1}	1.00	0.50	0.39	0.38	0.84	0.70	0.134	0.38
	4.0-ton fed^{-1}	1.21	0.61	0.43	0.42	0.89	0.64	0.188	0.41
	6.0-ton fed^{-1}	1.40	0.71	0.47	0.45	0.92	0.59	0.246	0.44
Tombari	0.0-ton fed^{-1}	0.89	0.48	0.38	0.37	0.85	0.74	0.116	0.37
	2.0-ton fed^{-1}	1.06	0.55	0.41	0.40	0.88	0.68	0.153	0.39
	4.0-ton fed^{-1}	1.21	0.63	0.44	0.43	0.90	0.64	0.191	0.42
	6.0-ton fed^{-1}	1.32	0.86	0.52	0.50	1.03	0.61	0.251	0.49
Ksar Megrine	0.0-ton fed^{-1}	1.11	0.57	0.41	0.41	0.87	0.67	0.164	0.40
	2.0-ton fed^{-1}	1.09	0.66	0.45	0.44	0.95	0.68	0.172	0.43
	4.0-ton fed^{-1}	0.75	1.04	0.55	0.55	1.28	0.78	0.139	0.55
	6.0-ton fed^{-1}	0.80	1.17	0.59	0.58	1.34	0.76	0.159	0.58
Tamellat	0.0-ton fed^{-1}	1.09	0.58	0.42	0.41	0.89	0.68	0.162	0.40
	2.0-ton fed^{-1}	0.93	0.67	0.45	0.44	0.99	0.73	0.143	0.44
	4.0-ton fed^{-1}	0.94	0.75	0.47	0.47	1.04	0.72	0.153	0.46
	6.0-ton fed^{-1}	0.85	1.13	0.58	0.57	1.31	0.75	0.167	0.57

Table 8 Correlation between of drought indices as affected by compost and arginine application

	SSI	STI	MP	GMP	YI	YSI	TOL
STI	0.683						
MP	0.710	0.945					
GMP	0.687	0.931	0.999				
YI	0.271	0.886	0.869	0.884			
YSI	− 1.000	− 0.683	− 0.710	− 0.687	− 0.271		
TOL	0.983	0.790	0.812	0.793	0.416	− 0.983	
HM	0.663	0.991	0.997	0.998	0.900	− 0.663	0.771

SSI Stress susceptibility index, *STI* Stress tolerance index, *MP* Mean productivity, *GMP* Geometric mean productivity, *YI* Yield index, *YSI* Yield stability index, *TOL* Tolerance index

were treated with arginine significantly raised chlorophyll levels. The treatment provided with 6.0-ton fed^{-1} compost and sprayed with arginine yielded the greatest values of chlorophyll and relative water content. The locations with the largest DI-induced chlorophyll reductions were Tamellat (23.4%) and Tombari (20.3%), where no compost was used. On the other hand, Tamellat (16.7%) + 4.0-ton fed^{-1} compost and Tombari (11.7%) supplied with 6.0-ton fed^{-1} compost showed the lowest fall in percentage under deficit irrigation. According to the lowest values of the chlorophyll, data showed that they were existed at zero compost under both studied irrigation treatments. According to Taia et al. (2019), using compost seems like a workable way to alleviate the negative impacts of water shortage by improving plant water status, SPAD value, chlorophyll fluorescence, plant development characteristics, and irrigation efficiency. In relation to the arginine effect, data indicated that the untreated arginine produced the lowest chlorophyll levels. It is simple to arrange the barley types under study in increasing order as follows: Giza 125 \ Tamellat ~ Ksar Megrine ~ Tombari at 0% application of compost. At 6.0 tons fed^{-1} of compost, the greatest values showed the same pattern. The greatest increase RWC values were attained at 6.0-ton fed^{-1} compost, Tombari (9.1%) > Ksar Megrine (7.1%) > Tamellat (6.8%) > Giza 125 (5.8%) under SI treatment and Tombari (15.8) > Ksar Megrine (14.9%) > Giza 125 (14.1%) > Tamellat (12.7%), whereas the lowest increase relative to the arginine treatment were recorded at 0.0-ton fed^{-1} compost, Tamellat + 2.0-ton fed^{-1} compost (4.4%), Giza 125 (1.1%) under SI and Tamellat (3.1%) under DI treatment. Arginine's usefulness in boosting barley production under water stress stems from its claimed ability to reduce the damaging effects of biotic and abiotic stressors through the formation of proline, polyamine, and nitric oxide as byproducts. Numerous studies have shown that applying amino acid mixtures topically to plants has positive effects. For instance, Solanum lycopersicum has produced more (Koukounaras et al. 2013), and Vicia faba has accumulated dry matter, starch, and polysaccharides (El-Aal and Eid 2018), as well as chlorophyll (SADAK et al. 2014). According to Hussein et al. (2022), whether wheat plants are stressed or grown normally, arginine supplementation improves the synthesis of proline and free amino acids. Pretreating wheat plants with arginine played a significant influence in mitigating the effects of drought stress by enhancing physiological and metabolic aspects.

Tamellat, which received 6.0 tons of feed compost per day, had the best water usage efficiency, while Ksar Megrine, which received zero tons of compost, had the lowest. Using compost improves the physical and chemical characteristics of the soil and helps plants use water more efficiently. Organic matter influences crop growth and yield in two ways: directly by providing nutrients and indirectly by changing the physical characteristics of the soil, which can enhance the root environment and promote plant growth (Bandyopadhyay et al. 2010). Amendments to compost can change the makeup of the microbial community, which increases microbe competition and/or antagonistic relationships and reduces the activity of plant diseases (Steinberg et al. 2004). For all of the investigated barley types under both investigated irrigation treatments, there was a marked decline in proline concentration with increasing compost application rates and treated barley plants by arginine. Ranking barley types according to the decrease % in descending order is simple and looks like this: Tombari (8.4%) > Giza 125 (9.8%) > Tamellat (10.9%) > Ksar Megrine (19.8%). and under SI and DI treatments, Tamellat (28.7%) > Giza 125 (22.2%) > Ksar Megrine (21.3%) > Tombari (17.2%). According to the lowest reduction in proline content as affected by compost application rates and Arginine treatments, data showed that Giza 125 (3.15%) and Ksar Megrine (3.9%) gained under SI and DI treatments after 6.0-ton fed^{-1} compost application rate, respectively.

Increasing compost application rate associated with increase in number of spike/m^2 without and with arginine. Data on hand revealed that both compost and arginine play an important role in improve spike length under examined compost rates relative to the arginine 7.2, 11.0; 14.1 14.3% for 0.0, 2.0, 4.0; 6.0-ton fed^{-1} compost. Increasing compost rate by 2.0, 4.0; 6.0-ton fed^{-1} increment spike length by 9.0, 16.1, 22.3% and 12.9, 23.5.; 33.3% for 2.0, 4.0; 6.0-ton fed^{-1} compost comparison with control (zero compost) for untreated and treated arginine, respectively. For improving the development, chemical composition, and yield of barley and other crop plants, foliar spraying with plant growth chemicals like arginine is one of the most used methods. Furthermore, foliar spraying arginine can activate enzymes that are important for antioxidation, including as glutathione reductase, ascorbate peroxidase, and superoxide dismutase, which lessen the effects of salt stress (Akladious and Hanafy 2018). Deficit irrigation caused a negative effect on the 1000 kernel weight and reduced their values by about 32.0, 38.6, 26.1 and 28.2% for Giza125, Tombari, Ksar Megrine and Tamellat barley varieties as comparison with sufficient irrigation treatment, respectively.

Barley Tombari variety received 6.0-ton fed^{-1} compost gained greatest values of grain yield under sufficient irrigation and Tamellat under deficit irrigation situation. The increase in compost rate combined with increasing grain yield values after arginine application more than untreated one. The greatest grain yield was found at the treatment received 6.0-ton fed^{-1} compost with arginine foliar application. Deficit irrigation has an effect on the grain yield under different compost application rate and the greatest and lowest reduction were found at 6.0-ton fed^{-1} compost and 6.0-ton fed^{-1} compost (25.1%) and (19.2%), respectively. Applying amino acids carefully is important because they can lower the percentage of dry weight by causing bloated, water-filled tissues because of reduced vegetative development (Abbas et al. 2013). According to the effect of compost application rate with and without Arginine, data indicated that the combined application of compost and arginine has a promote effect on the biological yield. The greatest biological yield was found at Giza 125 received 6.0-ton fed^{-1} compost (10.5%) and the lowest ones was found at Tamellat at zero-ton compost (3.6%). According to Rouphael et al. (2018) and Hellal et al. (2019) and Hellal et al. (2020), barley varieties grown under water stress showed enhanced fresh and dry matter yield along with increment growth behavior when amino acids were used as bio-stimulants, or substances that promote plant growth, improve nutrient availability, and enhance plant quality.

Conclusions

Under water stress, the use of compost together with foliar arginine application produced the greatest values of grain yield and yield components. Following the application of arginine, the rate of composting increment along with the values of grain production. Of the barley types under study, the maximum grain production was recorded when 6-ton compost fed^{-1} was applied to the soil together with arginine foliar spray. Compost and arginine applied together have been shown to stimulate plant development and improve production characteristics in barley cultivars that are irrigated.

Abbreviations

Arg Arginine
SI Sufficient irrigation

DI Deficit irrigation
fed Feddan

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Author contributions
FH analyzed and interpreted the resulted data and has a major contribution in writing the manuscript. SE did the chemical analysis of chlorophyll and proline and relative water and statistical analysis. DM performed the barley cultivation and data collection, HH did the harvesting and collected the yield data. All authors read and approved the final manuscript. This work is a combined effort of all of the authors. All authors read and approved the final manuscript.

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Availability of data and materials
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Declarations

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