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SYNERGISTIC IMPACT OF SOIL MULCHING AND KAOLIN CONCENTRATION ON *Zinnia elegans* PLANTS GROWN UNDER DIFFERENT IRRIGATION LEVELS

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ABSTRACT

The present investigation was carried out during 2016 and 2017 seasons in the Horticulture Research Station at El-Kassasin, Ismailia Governorate, Egypt, to examine the performance of *Zinnia elegans*, Jacq. (mixed colour) plants grown under different irrigation levels (60%, 80% or 100% of field capacity) and soil surface organic mulching with clover hay as well as spraying with kaolin as anti-transpirant at different concentrations. Mulching was more effective in most cases than non-mulching treatments. Increasing kaolin concentration increased most of the studied traits with the exception of root length, chlorophylls and proline contents. Regarding the interaction treatments, the highest level of irrigation water (100% f.c.) + mulching with clover hay + kaolin at 5% resulted in the highest values of most of the studied traits except number of branches/plant, root length and proline contents. However, other combined treatments minimized the harmful effects of reducing irrigation water, *i.e*. irrigation water at 80% f.c. + mulching with clover hay + kaolin at 3%. Also, irrigation water at 60% f.c. + mulching with clover hay + kaolin at 3 or 5% could be applied with quality reduction. It might be recommended to irrigate at 80% f.c. + mulching with clover hay + spraying with kaolin at 3% to give sufficient growth quality of *Zinnia elegans*, Jacq.

Key words: *Zinnia elegans, Jacq., irrigation levels, mulching, kaolin, vegetative growth, flowering, chemical composition.*

1. INTRODUCTION

Expansion of green areas cultivation coinciding with expansion of urban communities will in turn lead to increase water consumption. Saving clean water for human uses has a great priority. Agriculture accounts for about 70% of global water withdrawals, the vast majority of which is used for irrigation (WWDR, 2018). Searching for an effective method to reduce water consumption *via* irrigation may be a solution to save clean water for human uses especially under water scarcity conditions.

It is well known that 25% of water is lost through transpiration. Transpiration facilitates the movement of water and nutrients (Brown, 2002). Reduction of transpiration by application of waterproof coatings or of materials that cause closure of stomata would enable plants to survive with minimal injury. Substances intended to reduce transpiration commonly are termed antitranspirants (Pallardy, 2008). There are three general types of antitranspirants: (1) film-forming, (2) stomatal-regulating, and (3) reflective compounds (Brooks, 1970).

Particle film technology has long been used to limit the impact of water and heat stress on crops. Kaolin may be effective in this regard (Azizi *et al.*, 2013). Abou-Khaled *et al.* (1970) reported that a white leaf coating of kaolinite reduced leaf temperatures 3 to 4 °C, resulting in transpiration reductions of 22 to 28% for several species. Kaolin spray was found to decrease leaf temperature by increasing leaf reflectance and reducing transpiration rate in many plant species grown at high solar radiation levels (Nakano and Uehara, 1996). Kaolin is a white nonabrasive fine-grained aluminosilicate mineral ($Al_4 Si_4O_{10}[OH]_8$) that has been purified and sized so that it easily disperses in water and acts as an anti-transpirant, reducing drought stress on plants (Puterka *et al.*, 2000).

Another technique that can be used to reduce

water loss via evaporation is soil surface mulching. Mulch could be defined as a material that are applied to, or grow upon the soil surface (Brunetti, 2014). Li *et al*. (2018) divided the materials applied as mulches into three main types: organic mulching (crop straw, leaves, geotextiles, etc.), inorganic mulching (pure plastic film, degradable film, etc.) and mixed mulching (plastic, straw, grass, gravel, etc.). Potential benefits could be gained by using organic mulches which buffer soil temperature by keeping the ground cooler in the daytime and warmer at night, keeping the soil temperature warmer in winter than that of uncovered soil (Harrison 1998). They also add organic matter to the soil and do not have to be removed at the end of the growing season or before tilling. Løes *et al*. (2000) reported that mulch application with chopped clover (*Trifolium pratense*) increased the yield levels of both red beet [beetroots] and Dutch white cabbage crops.

Zinnia elegans, Jacq. (Fam. Asteraceae) is one of summer flowering annuals native to Mexico. It is upright, annual bushy plant bearing lightly hairy, ovate to lance-shaped leaves, to 8 cm long. Daisy-like, broad-petaled flowering heads (4.5 cm across), are produced in summer. It grows fairly rapidly to 60-75 cm in height and to 30 cm in width. Zinnias are cultivated for their solitary, long-stemmed, daisy-like, terminal flowering heads in a wide range of colors. In some, the flowering heads resemble formal decorative dahlias (referred to as "dahlia-flowered"); others resemble cactus-flowered dahlias (referred to as "cactus-flowered"). Use in an annual or mixed border, and as cut flower. Smaller cultivars are suitable for edging, and for window boxes or other containers. (Brickell, 1997 and Mills-Hicks, 2007).

The present study was carried out to investigate the effect of different irrigation levels, organic mulching with clover hay and spraying with kaolin at different concentrations on growth, flowering and chemical composition of *Zinnia elegans* plant.

2. MATERIALS AND METHODS

An open field experiment was carried out during 2016 and 2017 seasons in the Horticulture Research Station at El-Kassasin, Ismailia Governorate, Egypt to figure out the performance of *Zinnia elegans*, Jacq. (mixed colour) plants grown under different irrigation levels and soil surface organic mulching with clover hay as well as spraying with Kaolin (as anti-transpirant) at different concentrations.

2.1. Plant materials

Seeds of *Zinnia elegans*, Jacq. (mixed colour) were obtained from Fac. Agric., Moshtohor, Benha Univ., Egypt. On the 12^{th} and the 11^{th}, April, 2016 and 2017 seasons, respectively. The seeds were sown in plastic trays at the nursery. Vigorous seedlings were established and transplanted into the open field on 60 cm apart rows, while the plants at 30 cm in between. Physical and chemical properties of the soil are presented in Table (1). Different irrigation levels, mulching and spraying with kaolin treatments were applied after 2 weeks from planting.

2.2. Irrigation levels

Drip irrigation system was applied in this experiment; only one dripper (4 l/h) was installed beside each plant. Three irrigation levels were applied, 60, 80 and 100% of the soil field capacity. In this regard, each pipe represented one level of these three irrigation levels.

2.3. Mulching treatment

After planting and installing drip irrigation system, mulching treatment was applied. In this regard, the experimental plot was divided into two sections; the first one had been left without mulching, while the other one was mulched with Egyptian clover hay (*Trifolium alexandrinum*) by covering the soil and irrigation pipes with about 3.0 cm thickness (at the rate of 2.128 kg/m^2). Some chemical properties of Egyptian clover hay are shown in Table (2) according to Abdel-Azeam (2014).

2.4. Kaolin foliar spraying

Kaolin ("aluminum silicate" $Al_4Si_4O_{10}[OH]_8$) manufactured by Loba Chemie, India, was brought from a local company. Kaolin was dispensed in tape water to prepare three concentrations (1.0%, 3.0% and 5.0%). The plants were sprayed with each concentration till run off, control plants were sprayed with water only. Three applications with kaolin were applied; the first one was done after one month from transplanting, while the second and third were applied at one month intervals.

2.5. Experimental layout

This experiment was designed as a randomized complete block design in a split-split plot arrangement with three factors (Gomez and Gomez, 1984). Irrigation three levels represented main plot (A). Mulching two treatments represented sub-plot (B). Kaolin 4 concentrations represented sub sub-plot (C).

Table (1): Some physical and chemical properties of the used soils.

Sand %	89.92	**Macro elements**	
Silt %	4.00	Nitrogen	8.10
Clay %	6.08	Phosphorus	23.00
Soil texture	Sand	Potassium	108.00
F.C. %	11.20		
W.P.	2.20	**Micro elements**	
Organic matter %	0.42	Fe	2.00
pH (1 soil : 2.5 water)	8.10	Cu	--
EC (mmohs/cm) (1 soil : 5 water)	0.21	Zn	0.26
$CaCO_3$	2.60	Mn	0.80
Soluble ions (meq/l)			
Ca^{++}	1.00		
Mg^{++}	0.40		
Na^{+}	0.76		
K^{+}	0.31		
HCO_3^{-}	1.00		
Cl^{-}	0.50		
SO_4^{--}	0.97		

Table (2): Some chemical properties of Egyptian clover hay.

Moisture %	10.00
Dry matter (DM%)	90.00
Organic matter (OM%)	91.20
Crude protein (CP%)	12.00
Ether extract (EE%)	2.10
Nitrogen free extract (NFE%)	47.10
Ash%	8.80
Crude fiber (CF%)	30.00
Neutral detergent fiber (NDF%)	56.00
Acid detergent fiber (ADF%)	40.00
Hemicellulose %	16.00
DE (kcal/kg)	1780

Total number of treatments was 24 (3×2×4) with three replicates per treatment and 5 plants/replicate.

2.6. Data recorded

2.6.1. Morphological characteristics

At the end of each season the following data were recorded:

2.6.1.1. Vegetative growth and root parameters: plant height (cm), number of branches/plant, vegetative growth fresh weight/plant (g), vegetative growth dry weight/plant (g), root length (cm), roots fresh weight (g) and roots dry weight (g).

2.6.1.2. Flowering characteristics: number of flowering heads/plant, flowering head diameter (cm), flowering heads fresh weight (g) and flowering heads dry weight (g).

2.6.2. Chemical constituents

At the end of the second season, the following chemical tests were done:

2.6.2.1. Chlorophylls (a and b) content (mg/g f.w.) were determined in fresh leaf samples according to Wellburn and Lichtenthaler (1984).

2.6.2.2. Total carbohydrates percentage was determined in dry leaf samples according to the method described by Herbert *et al.* (1971).

2.6.2.3. Proline content (mg/g) was determined in dry leaf samples according to Bates *et al.* (1973).

2.7. Statistical analysis

The obtained data were statistically analyzed using MSTAT Computer Program (MSTAT Development Team, 1989). To verify differences among means of various treatments, means were compared using L.S.D. at 5% probability level.

3. RESULTS AND DISCUSSION

3.1. Vegetative growth and root parameters (Tables, 3-9)

3.1.1. Effect of irrigation level

The irrigation treatments resulted in

significant effects on plant height, fresh and dry weights for the vegetative parameters, as well as for roots fresh and dry weights, in the two seasons, respectively. The number of branches was not significantly affected.

Application of irrigation at 100% f.c. level affected significantly the plant height (118.45 and 119.87 cm), the fresh weight/plant (730.18 and 738.99 g), the dry weight/plant (153.16 and 155.43 g), the roots fresh weight (35.66 and 37.78 g) and the roots dry weight (7.52 and 7.75 g), for the two seasons respectively. Regarding the number of branches/plant there was insignificant effect of the different irrigation levels. Root length, on the other hand increased to the highest values (25.46 and 25.71 cm in the first and second season, respectively) when the lowest irrigation level (60% f.c.) was applied.

3.1.2. Effect of mulching treatment

The effect of mulching treatments on the vegetative growth and the rooting parameters was significant. A pronounced influence on most studied traits was observed with clover hay mulching in both seasons. The registered data were 108.50 and 110.69 cm for the plant height, 17.97 and 18.00 for the number of branches/plant, 694.46 and 695.71 g for the fresh weight/plant, 147.99 and 151.78 g for dry weight/plant, 31.46 and 33.61 g for the roots fresh weight as well 6.95 and 7.26 for roots dry weight in the two seasons, respectively. The mulching treatment reduced the root length to the lowest values in both seasons (18.22 and 18.69 cm, respectively) as compared with the non-mulched treatment (21.78 and 21.33 cm, for the two seasons, respectively).

3.1.3. Effect of spraying with kaolin

Spraying with kaolin was significant in all the studied traits; where the only exception was for the root length, which decreased by increasing kaolin concentration. Spraying with kaolin at 5% resulted in the highest values of plant height (115.44 and 116.44 cm), the number of branches/plant (19.66 and 19.66), fresh weight/plant (724.65 and 720.23 g), dry weight/plant (154.92 and 156.17 g), roots fresh weight (35.69 and 38.42 g) and roots dry weight (7.66 and 7.85 g) in the two seasons, respectively.

3.1.4. Effect of the interaction between irrigation level and mulching treatment

The data revealed that irrigation at 100% f.c. in addition to mulching with clover hay, produced the highest significant values (with a little exceptions) for fresh weight/plant (746.85 and 764.93 g), dry weight/plant (158.75 and 161.20 g), roots fresh weight (37.51 and 39.58 g) and roots dry weight (7.52 and 7.92 g) in both seasons, respectively. On the other hand, irrigation at 100% f.c. without mulching resulted in the highest value of plant height (cm) in the first season (118.57 cm), while 100% f.c. + mulching with clover hay produced the tallest plants in the second season (121.41 cm). this increase was significant with some treatments. Regarding the number of branches, it was observed that irrigation at 80% f.c. in addition to mulching with clover hay produced the highest value in the first season (18.50), while irrigation at 60% f.c. in addition mulching with clover hay produced the highest value in the second season (18.75). Regarding root length, irrigation at 60% f.c. without mulching gave the longest roots, in both seasons (27.42 and 27.17 cm, respectively).

3.1.5. Effect of the interaction between irrigation level and kaolin concentration

A significant effect was observed due to applying different interaction treatments between irrigation levels and kaolin concentrations. Irrigation at 100% f.c., in addition to spraying with kaolin at 5%, resulted in the highest values for plant height (125.00 and 125.83 cm), fresh weight/plant (788.30 and 768.25 g), dry weight/plant (165.20 and 167.10 g), roots fresh weight (41.43 and 42.97 g) and roots dry weight (8.13 and 8.33 g) in both seasons, respectively. Concerning the number of branches/plant, irrigation at 80% f.c. in addition to spraying with kaolin at 5% produced the highest value in the first season (20.50), while irrigation at 60% f.c. combined with spraying with kaolin at 5% resulted in the highest value in the second one (21.83). Regarding root length, application of the lowest level (60% f.c.) without spraying with kaolin produced the longest roots (28.84 and 29.84 cm, in both seasons, respectively).

3.1.6. Effect of the interaction between mulching treatment and kaolin concentration

In this regard mulching with clover hay in addition to spraying with kaolin at 5% produced the highest significant values in most cases, in both seasons. The recorded values were 117.11 and 117.55 cm for plant height, 20.89 and 21.00 for the number of branches/plant, 750.03 and 749.83 for fresh weight/plant, 162.50 and 163.47 g for dry weight/plant, 36.80 and41.17 g

Table (3): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on plant height (cm) of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	93.33	86.33	95.71	89.83	94.66	90.66	97.79	92.66
	1%	96.00	90.33		93.17	98.66	91.66		95.16
	3%	100.00	94.66		97.33	102.33	95.00		98.67
	5%	106.66	98.33		102.50	105.33	104.00		104.67
80%	Unsprayed	97.00	93.00	106.87	95.00	102.33	91.33	107.75	96.83
	1%	106.00	101.33		103.67	103.33	101.33		102.33
	3%	110.33	109.66		110.00	115.33	110.66		113.00
	5%	119.33	118.33		118.83	120.66	117.00		118.83
100%	Unsprayed	112.33	110.30	118.45	111.32	114.33	109.33	119.87	111.83
	1%	116.00	117.66		116.83	120.33	114.66		117.50
	3%	119.66	121.66		120.66	124.33	124.33		124.33
	5%	125.33	124.66		125.00	126.66	125.00		125.83
Mean (B)		108.50	105.52			110.69	106.25		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		98.72	104.55	109.33	115.44	100.44	105.00	112.00	116.44
Mean (A×B)		With	without			With	without		
	60%	99.00	92.41			100.25	95.33		
	80%	108.17	105.58			110.41	105.08		
	100%	118.33	118.57			121.41	118.33		
Mean (B×C)		With	without			With	without		
	Unsprayed	100.89	96.54			103.77	97.11		
	1%	106.00	103.11			107.44	102.55		
	3%	110.00	108.66			114.00	110.00		
	5%	117.11	113.77			117.55	115.33		
L.S.D. at 5% of:									
	A	3.60				3.68			
	B	2.67				2.73			
	C	2.72				2.76			
	A×B	4.63				4.72			
	A×C	4.72				4.77			
	B×C	3.85				3.89			
	A×B×C	6.76				6.75			

Table (4): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on No. of branches of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	14.66	12.00	16.58	13.33	15.33	13.66	17.54	14.50
	1%	16.00	14.00		15.00	17.00	14.00		15.50
	3%	19.66	17.00		18.33	19.33	17.33		18.33
	5%	20.66	18.66		19.66	23.33	20.33		21.83
80%	Unsprayed	16.33	12.33	16.62	14.33	14.33	13.66	16.50	14.00
	1%	17.00	13.66		15.33	16.66	13.00		14.83
	3%	18.66	14.00		16.33	19.66	16.00		17.83
	5%	22.00	19.00		20.50	20.66	18.00		19.33
100%	Unsprayed	14.33	12.66	16.58	13.50	15.00	14.66	16.75	14.83
	1%	18.00	15.33		16.67	17.00	15.33		16.17
	3%	18.33	16.33		17.33	18.66	17.66		18.16
	5%	20.00	17.66		18.83	19.00	16.66		17.83
Mean (B)		17.97	15.22			18.00	15.86		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		13.72	15.67	17.33	19.66	14.44	15.50	18.11	19.66
Mean (A×B)		With	without			With	without		
	60%	17.75	15.42			18.75	16.33		
	80%	18.50	14.75			17.83	15.17		
	100%	17.67	15.50			17.42	16.08		
Mean (B×C)		With	without			With	without		
	Unsprayed	15.11	12.33			14.89	13.99		
	1%	17.00	14.33			16.89	14.11		
	3%	18.88	15.78			19.22	17.00		
	5%	20.89	18.44			21.00	18.33		
L.S.D. at 5% of:									
	A	N.S				N.S			
	B	1.21				1.01			
	C	1.55				1.31			
	A×B	2.09				1.75			
	A×C	2.68				2.28			
	B×C	2.19				1.86			
	A×B×C	3.89				3.22			

Table (5): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on fresh weight/plant (g) of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	602.00	531.30	617.46	566.65	609.10	545.30	611.91	577.20
	1%	641.70	591.20		616.45	552.30	593.30		572.80
	3%	667.20	600.60		633.90	672.40	612.00		642.20
	5%	680.30	625.40		652.85	681.00	629.90		655.45
80%	Unsprayed	601.50	576.00	661.06	588.75	602.30	575.90	672.00	589.10
	1%	664.60	579.50		622.05	677.30	621.70		649.50
	3%	718.30	683.00		700.65	722.10	702.70		712.40
	5%	770.50	695.10		732.80	772.30	701.70		737.00
100%	Unsprayed	692.00	657.50	730.18	674.75	705.70	682.90	738.99	694.30
	1%	719.80	697.90		708.85	769.70	694.10		731.90
	3%	776.30	721.30		748.80	788.10	734.90		761.50
	5%	799.30	777.30		788.30	796.20	740.30		768.25
Mean (B)		694.46	644.68			695.71	652.89		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		610.05	649.12	694.45	724.65	620.20	651.40	705.37	720.23
Mean (A×B)		With	without			With	without		
	60%	647.80	587.13			628.70	595.13		
	80%	688.73	633.40			693.50	650.50		
	100%	746.85	713.50			764.93	713.05		
Mean (B×C)		With	without			With	without		
	Unsprayed	631.83	588.27			639.03	601.37		
	1%	675.37	622.87			666.43	636.37		
	3%	720.60	668.30			727.53	683.20		
	5%	750.03	699.27			749.83	690.63		
L.S.D. at 5% of:									
	A	10.3				13.2			
	B	5.3				10.2			
	C	12.3				10.1			
	A×B	9.2				17.7			
	A×C	21.3				17.6			
	B×C	17.4				14.4			
	A×B×C	30.1				25.0			

Table (6): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on dry weight/plant (g) of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	103.10	82.10	118.84	92.60	113.50	91.10	122.24	102.30
	1%	131.90	97.80		114.85	125.30	97.90		111.60
	3%	146.00	106.70		126.35	147.30	117.90		132.60
	5%	153.70	129.40		141.55	153.00	131.90		142.45
80%	Unsprayed	133.30	123.40	144.16	128.35	146.20	127.50	150.06	136.85
	1%	151.10	129.90		140.50	160.80	139.50		150.15
	3%	159.30	140.30		149.80	164.50	144.10		154.30
	5%	162.50	153.50		158.00	165.90	152.00		158.95
100%	Unsprayed	145.00	136.10	153.16	140.55	148.50	140.30	155.43	144.40
	1%	153.60	145.90		149.75	158.40	143.50		150.95
	3%	165.10	149.20		157.15	166.40	152.10		159.25
	5%	171.30	159.10		165.20	171.50	162.70		167.10
Mean (B)		147.99	129.45			151.78	133.38		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		120.50	135.03	144.43	154.92	127.85	137.57	148.72	156.17
Mean (A×B)		With	without			With	without		
	60%	133.68	104.00			134.78	109.70		
	80%	151.55	136.78			159.35	140.78		
	100%	158.75	147.58			161.20	149.65		
Mean (B×C)		With	without			With	without		
	Unsprayed	127.13	113.87			136.07	119.63		
	1%	145.53	124.53			148.17	126.97		
	3%	156.80	132.07			159.40	138.03		
	5%	162.50	147.33			163.47	148.87		
L.S.D. at 5% of:									
	A	5.0				2.9			
	B	3.2				1.7			
	C	4.6				2.9			
	A×B	5.5				2.9			
	A×C	8.0				5.0			
	B×C	6.6				4.1			
	A×B×C	11.4				7.1			

Table (7): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on root length (cm) of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	26.67	31.00	25.4	28.84	28.00	31.67	25.71	29.84
	1%	26.00	29.00		27.50	26.00	29.00		27.50
	3%	21.00	26.33		23.67	23.00	26.00		24.50
	5%	20.33	23.33		21.83	20.00	22.00		21.00
80%	Unsprayed	22.33	24.67	19.12	23.50	21.33	23.67	19.29	22.50
	1%	18.33	21.33		19.83	20.00	21.33		20.67
	3%	15.33	19.33		17.33	17.33	19.33		18.33
	5%	13.67	18.00		15.84	14.00	17.33		15.67
100%	Unsprayed	16.00	20.33	15.42	18.17	15.67	19.67	15.04	17.67
	1%	14.33	19.00		16.67	14.00	17.33		15.67
	3%	12.67	15.33		14.00	13.00	15.33		14.17
	5%	12.00	13.67		12.84	12.00	13.33		12.67
Mean (B)		18.22	21.78			18.69	21.33		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		23.50	21.33	18.33	16.83	23.34	21.28	19.00	16.44
Mean (A×B)		With	without			With	without		
	60%	23.50	27.42			24.25	27.17		
	80%	17.42	20.83			18.17	20.42		
	100%	13.75	17.08			13.67	16.42		
Mean (B×C)		With	without			With	without		
	Unsprayed	21.67	25.33			21.67	25.00		
	1%	19.55	23.11			20.00	22.55		
	3%	16.33	20.33			17.78	20.22		
	5%	15.33	18.33			15.33	17.55		
L.S.D. at 5% of:									
	A	1.53				1.15			
	B	0.61				0.92			
	C	1.29				0.97			
	A×B	1.06				1.60			
	A×C	1.43				1.42			
	B×C	1.82				1.38			
	A×B×C	3.16				2.38			

Table (8): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on root fresh weight/plant (g) of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	18.40	14.96	22.30	16.68	19.46	14.90	24.51	17.18
	1%	21.66	15.80		18.73	25.06	19.13		22.10
	3%	27.30	19.93		23.62	30.70	20.50		25.60
	5%	32.13	28.20		30.17	36.06	30.26		33.16
80%	Unsprayed	27.33	23.40	29.47	25.37	27.60	21.20	29.92	24.40
	1%	31.46	23.40		27.43	28.93	22.26		25.60
	3%	32.56	26.66		29.61	35.86	25.26		30.56
	5%	36.60	34.33		35.47	41.33	36.93		39.13
100%	Unsprayed	33.00	26.66	35.66	29.83	35.33	29.36	37.78	32.35
	1%	37.33	30.40		33.87	35.86	35.07		35.47
	3%	38.06	36.93		37.50	41.00	39.67		40.34
	5%	41.66	41.20		41.43	46.13	39.80		42.97
Mean (B)		31.46	26.82			33.61	27.86		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		23.96	26.68	30.24	35.69	24.64	27.72	32.17	38.42
Mean (A×B)		With	without			With	without		
	60%	24.87	19.72			27.82	21.20		
	80%	31.99	26.95			33.43	26.41		
	100%	37.51	33.80			39.58	35.98		
Mean (B×C)		With	without			With	without		
	Unsprayed	26.24	21.67			27.46	21.82		
	1%	30.15	23.20			29.95	25.49		
	3%	32.64	27.84			35.85	28.48		
	5%	36.80	34.58			41.17	35.66		
L.S.D. at 5% of:									
	A	1.73				4.34			
	B	1.38				2.91			
	C	3.11				2.43			
	A×B	3.26				5.05			
	A×C	5.39				4.22			
	B×C	4.40				3.44			
	A×B×C	7.63				5.96			

Table (9): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on root dry weight/plant (g) of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	4.40	4.13	5.80	4.27	4.16	4.06	6.07	4.11
	1%	5.33	4.76		5.05	6.26	5.93		6.10
	3%	6.70	6.33		6.52	7.20	6.40		6.80
	5%	7.56	7.20		7.38	7.76	6.80		7.28
80%	Unsprayed	6.73	5.40	6.70	6.07	6.93	5.23	6.88	6.08
	1%	7.40	5.70		6.55	6.96	5.90		6.43
	3%	7.33	6.07		6.70	7.83	6.33		7.08
	5%	7.90	7.03		7.47	8.36	7.53		7.95
100%	Unsprayed	7.16	6.83	7.52	7.00	7.40	6.96	7.75	7.18
	1%	7.30	7.23		7.27	7.66	7.40		7.53
	3%	7.66	7.73		7.70	7.93	7.96		7.95
	5%	7.96	8.30		8.13	8.70	7.96		8.33
Mean (B)		6.95	6.39			7.26	6.54		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		5.78	6.29	6.97	7.66	5.79	6.69	7.28	7.85
Mean (A×B)		With	without			With	without		
	60%	6.00	5.61			6.35	5.80		
	80%	7.34	6.05			7.52	6.25		
	100%	7.52	7.52			7.92	7.57		
Mean (B×C)		With	without			With	without		
	Unsprayed	6.10	5.45			6.16	5.42		
	1%	6.68	5.90			6.96	6.41		
	3%	7.23	6.71			7.65	6.90		
	5%	7.81	7.51			8.27	7.43		
L.S.D. at 5% of:									
	A	0.39				0.26			
	B	0.20				0.20			
	C	0.26				0.19			
	A×B	0.35				0.34			
	A×C	0.45				0.33			
	B×C	0.37				0.27			
	A×B×C	0.64				0.47			

for roots fresh weight and 7.81 and 8.27 for roots dry weight in both seasons, respectively. Unsprayed zinnia plants with kaolin and deprived from mulching produced the longest roots in both seasons giving 25.33 and 25.00 cm, respectively.

3.1.7. Effect of interaction between irrigation level, mulching treatment and kaolin concentration

Effect of the interaction between irrigation levels, mulching treatments and kaolin concentrations was significant. Irrigation at 100% f.c. + mulching with clover hay + spraying with kaolin at 5% produced the tallest plant (125.33 and 126.66 cm), the greatest fresh weight/plant (799.30 and 796.20 g), the dry weight/plant (171.30 and 171.50 g) and the roots fresh weight (41.66 and 46.13 g) in both seasons, respectively. This treatment resulted in the highest value of roots dry weight in the second season (8.70), while the highest value in the first one (8.30) was recorded by irrigation at 100% f.c. + without mulching + spraying with kaolin at 5%. Non-significant differences had been obtained from irrigation at 80% f.c. + mulching with clover hay + spraying with kaolin at 5%.

Concerning the number of branches/plant, there was no significant difference between irrigation at levels + mulching with clover hay + spraying with kaolin at 5%.

Irrigation at 60% f.c. alone increased the root length as reaching to the highest values in both seasons (31.00 and 31.67, respectively) as compared with the other traits.

3.2. Flowering parameters (Tables, 10-13)

3.2.1. Effect of irrigation level

Irrigation at 100% f.c. recorded the highest significant values regarding the number of flowering heads/plant (20.29 and 21.50), flowering head diameter (7.85 and 7.97 cm), flowering heads fresh weight (195.29 and 193.00 g), flowering heads dry weight (31.96 and 30.13 g) in both seasons, respectively.

3.2.2. Effect of mulching treatment

Mulching with clover hay resulted in the highest values regarding the number of flowering heads/plant (21.50 and 21.52), flowering head diameter (7.51 and 7.63 cm), flowering heads fresh weight (182.50 and 179.75 g), flowering heads dry weight (24.47 and 23.44 g) in both seasons, respectively. Such increase was significant for the number of flowering heads/plant, flowering heads fresh and dry weights while it was in-significant for flowering head diameter.

3.2.3. Effect of spraying with kaolin

Spraying with kaolin at 5% was significantly more effective than other concentrations and produced the highest values in relation to the number of flowering heads/plant (23.39 and 23.94), flowering head diameter (7.83 and 8.04 cm), flowering heads fresh weight (187.61 and 186.22 g) and flowering heads dry weight (26.17 and 25.34 g) in both seasons, respectively.

3.2.4. Effect of the interaction between irrigation level and mulching treatment

Irrigation at 100% f.c. in addition to mulching with clover hay resulted in the highest values in both seasons in terms of number of flowering heads/plant (22.08 and 22.58), flowering heads fresh weight (199.42 and 194.92 g) and flowering heads dry weight (34.67 and 32.33 g) in both seasons, respectively. This treatment on the other hand, occupied the second position in case of flowering head diameter (as recorded 7.79 and 7.94 cm in both seasons, respectively).

3.2.5. Effect of the interaction between irrigation level and kaolin concentration

Irrigation at 100% f.c. in addition to spraying with kaolin at 5% resulted in the highest values in terms of flowering heads fresh weight (205.00 and 202.67 g), flowering heads dry weight (37.17 and 35.84 g) in both seasons and flowering head diameter (8.00 cm) in the first season only. Irrigation at 100% f.c. plus spraying with kaolin at 3% resulted in the highest number of flowering heads/plant (24.67) and flowering head diameter (8.15 cm) in the second season. On the other hand, irrigation at 80% f.c. in addition to spraying with kaolin at 5% resulted in the highest number of flowering heads/plant in the first season (24.17).

3.2.6. Effect of the interaction between mulching treatment and kaolin concentration

Mulching with clover hay in addition to spraying with kaolin at 5% gave the highest number of flowering heads/plant (24.66 and 25.55), flowering heads fresh weight (192.22 and 190.11 g), flowering heads dry weight (28.22 and 26.89 g) in both seasons and flowering head diameter (8.15 cm) in the second season only. While, spraying with kaolin at 5% without mulching resulted in the highest flowering head diameter (7.84 cm) in the first season.

Table (10): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on No. of flowering heads/plant of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	17.66	14.00	19.33	15.83	17.66	15.00	19.83	16.33
	1%	18.66	15.33		17.00	20.00	17.00		18.50
	3%	22.66	19.66		21.16	21.66	19.33		20.50
	5%	24.00	22.66		23.33	25.33	22.66		24.00
80%	Unsprayed	20.33	14.66	19.79	17.50	16.33	16.33	19.75	16.33
	1%	19.66	16.00		17.83	19.00	16.33		17.67
	3%	21.33	18.00		19.67	22.66	20.00		21.33
	5%	25.33	23.00		24.17	25.33	22.00		23.67
100%	Unsprayed	19.33	15.00	20.29	17.17	17.33	17.00	21.50	17.17
	1%	20.66	19.66		20.16	21.66	18.33		20.00
	3%	23.66	18.66		21.16	25.33	24.00		24.67
	5%	24.66	20.66		22.66	26.00	22.33		24.17
Mean (B)		21.50	18.11			21.52	19.19		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		16.83	18.33	20.66	23.39	16.61	18.72	22.16	23.94
Mean (A×B)		With	without			With	without		
	60%	20.75	17.91			21.16	18.50		
	80%	21.66	17.92			20.83	18.67		
	100%	22.08	18.50			22.58	20.42		
Mean (B×C)		With	without			With	without		
	Unsprayed	19.11	14.55			17.11	16.11		
	1%	19.66	17.00			20.22	17.22		
	3%	22.55	18.77			23.22	21.11		
	5%	24.66	22.11			25.55	22.33		
L.S.D. at 5% of:									
	A	N.S				0.83			
	B	0.80				1.29			
	C	1.2				1.38			
	A×B	1.39				2.23			
	A×C	2.07				2.38			
	B×C	1.69				1.95			
	A×B×C	2.93				3.37			

Table (11): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on flowering head diameter (cm) of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	6.73	6.66	7.26	6.70	6.90	6.90	7.39	6.90
	1%	7.23	6.96		7.10	7.23	7.20		7.22
	3%	7.60	7.50		7.55	7.66	7.23		7.45
	5%	7.90	7.53		7.72	8.10	7.86		7.98
80%	Unsprayed	6.86	6.43	7.33	6.65	6.86	6.13	7.41	6.50
	1%	7.30	7.00		7.15	7.13	7.53		7.33
	3%	7.63	7.86		7.75	7.66	7.86		7.76
	5%	7.73	7.83		7.78	8.23	7.90		8.07
100%	Unsprayed	7.56	7.70	7.85	7.63	7.83	7.80	7.97	7.82
	1%	7.83	7.86		7.85	7.70	8.00		7.85
	3%	7.93	7.90		7.92	8.10	8.20		8.15
	5%	7.83	8.16		8.00	8.13	8.03		8.08
Mean (B)		7.51	7.45			7.63	7.55		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		6.99	7.36	7.74	7.83	7.07	7.47	7.79	8.04
Mean (A×B)		With	without			With	without		
	60%	7.37	7.16			7.47	7.30		
	80%	7.38	7.28			7.47	7.36		
	100%	7.79	7.91			7.94	8.01		
Mean (B×C)		With	without			With	without		
	Unsprayed	7.05	6.93			7.20	6.94		
	1%	7.45	7.27			7.35	7.58		
	3%	7.72	7.75			7.81	7.76		
	5%	7.82	7.84			8.15	7.93		
L.S.D. at 5% of:									
	A	0.38				0.27			
	B	N.S				N.S			
	C	0.21				0.13			
	A×B	0.28				0.13			
	A×C	0.37				0.23			
	B×C	0.30				0.19			
	A×B×C	0.52				0.33			

Table (12): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on flowering heads fresh weight (g) of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	155.33	138.00	159.58	146.67	154.33	133.33	156.67	143.83
	1%	166.33	147.33		156.83	161.67	144.00		152.84
	3%	172.00	157.67		164.84	168.33	150.67		159.50
	5%	175.33	164.67		170.00	176.67	164.33		170.50
80%	Unsprayed	168.33	159.67	176.00	164.00	170.67	163.67	175.29	167.17
	1%	177.00	165.33		171.17	174.00	162.67		168.34
	3%	186.00	176.00		181.00	182.33	178.00		180.17
	5%	192.00	183.67		187.84	189.33	181.67		185.50
100%	Unsprayed	190.33	180.00	195.29	185.17	187.00	182.67	193.00	184.84
	1%	194.00	189.67		191.84	190.67	184.67		187.67
	3%	204.00	194.33		199.17	197.67	196.00		196.84
	5%	209.33	200.67		205.00	204.33	201.00		202.67
Mean (B)		182.50	171.42			179.75	170.22		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		165.28	173.28	181.67	187.61	165.28	169.61	178.83	186.22
Mean (A×B)		With	without			With	without		
	60%	167.25	151.92			165.25	148.08		
	80%	180.83	171.17			179.08	171.50		
	100%	199.42	191.17			194.92	191.09		
Mean (B×C)		With	without			With	without		
	Unsprayed	171.33	159.22			170.67	159.89		
	1%	179.11	167.44			175.45	163.78		
	3%	187.33	176.00			182.78	174.89		
	5%	192.22	183.00			190.11	182.33		
L.S.D. at 5% of:									
	A	2.50				2.22			
	B	1.52				2.94			
	C	1.86				2.00			
	A×B	2.62				5.09			
	A×C	3.21				3.46			
	B×C	2.62				2.83			
	A×B×C	4.54				4.89			

Table (13): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on flowering heads dry weight (g) of *Zinnia elegans* during 2016 and 2017 seasons.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		2016				2017			
60%	Unsprayed	14.00	10.67	14.08	12.34	13.33	9.67	13.54	11.50
	1%	15.00	11.00		13.00	13.67	11.33		12.50
	3%	16.67	13.00		14.84	16.00	11.67		13.84
	5%	17.33	15.00		16.17	18.00	14.67		16.34
80%	Unsprayed	19.00	14.33	20.50	16.67	20.33	15.00	20.46	17.67
	1%	21.00	15.33		18.17	21.00	15.33		18.17
	3%	24.67	19.33		22.00	24.00	20.33		22.17
	5%	27.33	23.00		25.17	25.67	22.00		23.84
100%	Unsprayed	29.67	25.00	31.96	27.34	28.33	24.33	30.13	26.33
	1%	33.33	27.67		30.50	30.67	25.67		28.17
	3%	35.67	30.00		32.84	33.33	27.00		30.17
	5%	40.00	34.33		37.17	37.00	34.67		35.84
Mean (B)		24.47	19.89			23.44	19.31		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		18.78	20.56	23.22	26.17	18.50	19.61	22.06	25.34
Mean (A×B)		With	without			With	without		
	60%	15.75	12.42			15.25	11.84		
	80%	23.00	18.00			22.75	18.17		
	100%	34.67	29.25			32.33	27.92		
Mean (B×C)		With	without			With	without		
	Unsprayed	20.89	16.67			20.66	16.33		
	1%	23.11	18.00			21.78	17.44		
	3%	25.67	20.78			24.44	19.67		
	5%	28.22	24.11			26.89	23.78		
L.S.D. at 5% of:									
	A	0.64				0.93			
	B	0.58				1.26			
	C	0.82				0.82			
	A×B	1.01				2.19			
	A×C	2.23				1.69			
	B×C	1.16				1.56			
	A×B×C	2.02				2.00			

3.2.7. Effect of the interaction between irrigation level, mulching treatment and kaolin concentration

Irrigation at 100% f.c. + mulching with clover hay + spraying with kaolin at 5% resulted in the highest flowering heads fresh weight (209.33 and 204.33 g) and flowering heads dry weight (40.00 and 37.00 g) in both seasons, respectively. On the other hand, spraying with kaolin at 5% plus mulching with clover hay resulted in the highest number of flowering heads/plant (25.33) in the first season and flowering head diameter (8.23 cm) in the second one when combined with 80% f.c. irrigation level, while the same treatment increased number of flowering heads/plant to the highest value (26.00) as combined with 100% f.c. irrigation level. In general, it is obvious that despite irrigation level and mulching, spraying zinnia plants with kaolin at different concentrations led to increase all the flowering traits as compared with the unsprayed plants.

3.3. Chemical constituents (Tables, 14-15)

3.3.1. Effect of irrigation level

It is clear that increasing irrigation water to the highest level significantly led to produce the highest content of chlorophyll a (0.811 mg/g f.w.) and b (0.251 mg/g f.w.), the highest carbohydrates percentage (32.32 %) and the lowest proline content (0.160 mg/g). In contrast, irrigation at 60% f.c. produced the lowest chlorophylls a (0.603 mg/g f.w.) and b content (0.168 mg/g f.w.), carbohydrates (17.88 %) and the highest proline content (0.220 mg/g).

3.3.2. Effect of mulching treatments

The recorded data revealed that mulching with clover hay significantly increased chlorophylls a (0.0736 mg/g), b (0.213 mg/g) and carbohydrates (30.01 %) to the highest values as compared with non-mulching treatment (0.702 mg/g, 0.200 mg/g and 19.12 % for chlorophylls a, b and carbohydrates, respectively). In contrast, proline content was significantly higher without mulching (0.219 mg/g) than with mulching (0.154 mg/g).

3.3.3. Effect of spraying with kaolin

The data revealed that the higher the kaolin concentrations the more the reduction in both chlorophylls a, b and proline contents. However, not spraying with kaolin significantly produced the highest values (0.783 mg/g, 0.238 mg/g and 0.202 mg/g f.w., for chlorophylls a, b and proline, respectively). The opposite was right in case of total carbohydrates (%), the highest kaolin concentration significantly produced the highest value (26.58).

3.3.4. Effect of the interaction between irrigation level and mulching treatment

Irrigation at 100% f.c. in addition to mulching with clover hay recorded the highest values of both chlorophylls a (0.833 mg/g), b (0.258 mg/g) and carbohydrates (36.30 %). Regarding proline content it was found that irrigation at 60% f.c. without mulching produced the highest value (0.264 mg/g). While irrigation at 100% f.c. in addition to mulching with clover hay gave the lowest value (0.134 mg/g).

3.3.5. Effect of the interaction between irrigation level and kaolin concentration

The irrigation at 100% f.c. and spraying with 5% kaolin significantly produced the highest carbohydrates (35.47%) as compared with other combined treatments. While, irrigation at 100% f.c. without spraying with kaolin increased significantly the contents of chlorophylls a and b (0.870 and 0.280 mg/g, respectively). The highest proline content (0.240 mg/g) was obtained with irrigation at 60% f.c. without kaolin in comparison with irrigation at 100% f.c. and spraying with kaolin at 5% which produced the lowest value (0.151 mg/g).

3.3.6. Effect of the interaction between mulching treatment and kaolin concentration

Mulching with clover hay alone increased significantly both chlorophylls a and b (0.807 and 0.250 mg/g, respectively). While, mulching with clover hay in addition to spraying with kaolin at 5% resulted in the highest carbohydrates content (33.15 %). On the other hand, the control plants contained the highest value of proline content (0.242 mg/g). In contrast, mulching with clover hay in addition to spraying with kaolin at 5% reduced proline content to the lowest value (0.144 mg/g).

3.3.7. Effect of the interaction between irrigation level, mulching treatment and kaolin concentration

Irrigation at 60% f.c. resulted in 13.29% carbohydrate, while irrigation at 100% f.c. level + mulching with clover hay + spraying with kaolin at 5% resulted in significantly the highest carbohydrates content (40.75%). In case of chlorophylls content, the highest values were obtained due to irrigation at 100% f.c. plus mulching with clover hay with no kaolin (0.880 and 0.290 mg/g f.w. for chlorophyll a and b, respectively). On the other hand, the highest proline content (0.299 mg/g d.w.) was obtained by application of irrigation at 60% f.c. only,

Table (14): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on chlorophyll pigments (mg/g f.w.) of *Zinnia elegans* leaves during 2017 season.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		Chlorophyll a (mg/g f.w.)				Chlorophyll b (mg/g f.w.)			
60%	Unsprayed	0.710	0.650	0.603	0.680	0.200	0.180	0.168	0.190
	1%	0.630	0.610		0.620	0.180	0.170		0.175
	3%	0.560	0.650		0.605	0.170	0.150		0.160
	5%	0.510	0.500		0.505	0.150	0.140		0.145
80%	Unsprayed	0.830	0.770	0.743	0.800	0.260	0.230	0.201	0.245
	1%	0.810	0.730		0.770	0.210	0.200		0.205
	3%	0.750	0.700		0.725	0.180	0.180		0.180
	5%	0.700	0.650		0.675	0.180	0.170		0.175
100%	Unsprayed	0.880	0.860	0.811	0.870	0.290	0.270	0.251	0.280
	1%	0.860	0.810		0.835	0.270	0.260		0.265
	3%	0.810	0.760		0.785	0.250	0.230		0.240
	5%	0.780	0.730		0.755	0.220	0.220		0.220
Mean (B)		0.736	0.702			0.213	0.200		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		0.783	0.742	0.705	0.645	0.238	0.215	0.193	0.180
Mean (A×B)		With	without			With	without		
	60%	0.603	0.603			0.175	0.160		
	80%	0.773	0.713			0.208	0.195		
	100%	0.833	0.790			0.258	0.245		
Mean (B×C)		With	without			With	without		
	Unsprayed	0.807	0.760			0.250	0.227		
	1%	0.767	0.717			0.220	0.210		
	3%	0.707	0.703			0.200	0.187		
	5%	0.663	0.627			0.183	0.177		
L.S.D. at 5% of:									
	A	0.03				0.01			
	B	0.02				0.01			
	C	0.03				0.01			
	A×B	0.03				0.01			
	A×C	0.05				0.01			
	B×C	0.04				0.01			
	A×B×C	0.07				0.02			

Table (15): Effect of mulching with clover hay, irrigation level, kaolin concentration and their interaction on carbohydrates percentage (%) and proline content (mg/g d.w.) of *Zinnia elegans* during 2017 season.

Irrigation level (A)	Kaolin concentration (C)	Mulching (B)		Mean (A)	Mean (A×C)	Mulching (B)		Mean (A)	Mean (A×C)
		With	without			With	without		
		Carbohydrates percentage (%)				Proline content (mg/g d.w.)			
60%	Unsprayed	18.93	13.29	17.88	16.11	0.182	0.299	0.220	0.240
	1%	20.49	13.68		17.09	0.178	0.283		0.231
	3%	23.95	14.01		18.98	0.178	0.240		0.209
	5%	24.68	14.04		19.36	0.166	0.236		0.201
80%	Unsprayed	30.53	14.25	23.49	22.39	0.161	0.236	0.179	0.198
	1%	30.60	15.48		23.04	0.156	0.201		0.178
	3%	31.68	15.58		23.63	0.147	0.195		0.171
	5%	34.02	15.78		24.90	0.146	0.193		0.169
100%	Unsprayed	34.44	24.88	32.32	29.66	0.142	0.190	0.160	0.166
	1%	34.66	28.64		31.65	0.142	0.188		0.165
	3%	35.34	29.65		32.50	0.132	0.182		0.157
	5%	40.75	30.18		35.47	0.120	0.182		0.151
Mean (B)		30.01	19.12			0.154	0.219		
Mean (C)		Unsprayed	1%	3%	5%	Unsprayed	1%	3%	5%
		22.72	23.93	25.04	26.58	0.202	0.191	0.179	0.174
Mean (A×B)		With	without			With	without		
	60%	22.01	13.76			0.176	0.264		
	80%	31.71	15.27			0.152	0.206		
	100%	36.30	28.34			0.134	0.186		
Mean (B×C)		With	without			With	without		
	Unsprayed	27.97	17.47			0.162	0.242		
	1%	28.58	19.27			0.159	0.224		
	3%	30.32	19.75			0.153	0.206		
	5%	33.15	20.00			0.144	0.204		
L.S.D. at 5% of:									
	A	0.35				0.005			
	B	0.53				0.006			
	C	0.57				0.006			
	A×B	0.91				0.010			
	A×C	0.99				0.010			
	B×C	2.38				0.008			
	A×B×C	1.40				0.010			

while the lowest value (0.120 mg/g d.w.) was recorded by irrigating at 100% + mulching with clover hay + spraying with kaolin at 5%. Irrigation at 80% f.c. + mulching with clover hay + spraying with kaolin at 3% resulted in mediated values for chlorophylls a and b (0.750 and 0.180 mg/g, respectively), carbohydrates (31.68%) and proline (0.147 mg/g d.w.).

The above mentioned results regarding the negative effects of water deficit were in harmony with those obtained by Khalil *et al.* (2012) who reported that reducing irrigation water levels led to reduce plant height and fresh and dry weights, this was accompanied with increasing proline content of *Jatropha curcas* L. On the contrary increasing levels of water significantly increased growth and productivity of *Ziziphus mauritiana* (Mukherjee *et al.*, 2004). Also, Gomaa *et al.* (2005) emphasized these results on cucumber. On the other hand, soil mulch with Egyptian clover (*Trifolium alexandrinum* L.) gave the best vegetative growth of orange trees (Abdel-Aziz *et al.*, 2014). In this concern, Løes *et al.* (2000) found that in red beet [beetroots] and Dutch white cabbage, using chopped clover (*Trifolium pratense*) as soil mulch, increased the yield levels of both crops. The positive influence of kaolin under water deficit conditions as obtained in this study was reported by many authors on different plants, *i.e.* Javan *et al.* (2013) on soybean, Kachhadiya *et al.* (2010) on *Pennisetum glaucum*, Ezzat *et al.* (2009) on *Solanum tuberosum* L., Thakuria *et al.* (2004) on *Helianthus annuus* L., Karuppaiah *et al.* (2003) on *Solanum melongena* and Agarwal and De (1979) on barley. In this regard, El-Hady and Doklega (2017) reported that application of kaolin with irrigation intervals every 15 days decreased the harmful effects of long irrigation intervals on eggplants during summer seasons. Kaolin led to reduce the amount of recommended water added by 20% of Grand Nain banana planted in sandy soil (Abdel Gawad, 2015). Khalil *et al.* (2012) reported that spraying *Jatropha curcas* L. with kaolin at 6% increased plant height and fresh and dry weights, and reduced proline content when combined with increasing stress to the highest value. Kaolin enhanced plant performance, flower formation, bulb production, nutrient uptake and carbohydrate synthesis of tuberose irrigated at the 80% (ET) treatment (Al-Moftah and Al-Humaid, 2005).

Negative effects of water deficit could be explained by its role in reducing photosynthesis by closing stomata, decreasing the efficiency of carbon fixation process, suppressing leaf formation and expansion (Pallardy, 2008). It is well known that water accounts for between 80–95% of the fresh biomass of non-woody plants and plays an important role in many aspects of plant growth, development, metabolism, etc.. (Salehi-Lisar and Bakhshayeshan-Agdam, 2016). In the same manner soil water is critical to plant growth and development. It is the solvent in which soil nutrients are dissolved before they can be absorbed by plant roots. Once in the plant, water is the medium of transportation of solutes and is required in photosynthesis (Acquaah, 2009). As indicated in this study, only root length and proline content were increased by reducing irrigation water levels. In order to increase water uptake under dehydration conditions, plants expand their roots and produce a ramified root system and under stress conditions plants synthesize compounds such as proteins and amino acids, the accumulation of compatible solutes (osmoprotectants) in order to provide osmotic regulation and adjustment is a well-known mechanism for plant resistance to drought, proline is one of the standard amino acids known as osmoprotectants (Salehi-Lisar and Bakhshayeshan-Agdam, 2016). The present study also focused on the importance of mulching to reduce water consumption. Studies by Namaghi *et al.* (2018) indicated that organic mulches resulted in higher production by reducing soil temperature and evaporation, enhancing organic matter formation and decomposition, and soil nutrient cycling. Brunetti (2014) revealed that organic mulches influence the soil water cycle by increasing retention and percolation and reducing evaporation. Moreover, the absence of a ground cover increases soil evaporation, with consequent water loss and supplemental irrigation needs. Also Harrison (1998) reported that organic mulches tend to buffer soil temperature by keeping the ground cooler in the daytime and warmer at night. On the other hand, organic mulches usually keep the soil temperature warmer in winter than that of uncovered soil. They also add organic matter. Using kaolin in this study proved its positive function as anti-transpirant. In this regard Abdallah *et al.* (2018) found that kaolin application reduced the canopy temperature (Ct) of tomato. A reduction in leaf temperature for plants may cause an increase in carbon gain

(Privé *et al.*, 2006). On the other hand, reflective kaolin spray was found to decrease leaf temperature by increasing leaf reflectance and to reduce transpiration rate more than photosynthesis in many plant species (Nakano and Uehara, 1996). Past studies have confirmed the role of reflective kaolinite coating in reducing the light energy reaching the leaf tissue by about 40% and also a white leaf coating of kaolinite reduced leaf temperatures 3 to 4 ℃ which resulted in transpiration reductions of 22 to 28% for several species (Abou-Khaled *et al.*, 1970). Kaolin application improved the antioxidant capacity in grape berries, which was correlated with the observed increase in secondary metabolites content and regulation (Dinis *et al.*, 2016).

In conclusion, to save about 20% of irrigation water without great quality reduction of *Zinnia elegans*, Jacq. plants, it is recommended to irrigate at 80% f.c. + mulching with clover hay + spraying with kaolin at 3%.

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التأثير التآزري لتغطية التربة وتركيز الكاولين على نباتات الزينيا النامية تحت مستويات ري مختلفة

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ملخص

تم اجراء هذه الدراسة خلال موسمي 2016 و2017 بمحطة بحوث البساتين بالقصاصين، محافظة الإسماعيلية، مصر لدراسة أداء نباتات الزينيا (ألوان مختلطة) النامية تحت مستويات ري مختلفة (60%، 80% و 100% من السعة الحقلية للتربة) والتغطية العضوية لسطح التربة بدريس البرسيم (تغطية وعدم تغطية) بالاضافة الى الرش بالكاولين كمضاد نتح بتركيزات مختلفة (بدون رش، 1%، 3% و 5%). بعض الصفات الخضرية وصفات التزهير والمحتوى الكيميائي تم دراستها في هذا الخصوص. أظهرت النتائج أن زيادة مستوى الرى أدى الى الحصول على زيادة في قيم أغلب الصفات التي تم دراستها مع بعض الاستثناءات. في أغلب الحالات كانت معاملة التغطية أكثر فاعلية من معاملة عدم التغطية. زيادة تركيز الكاولين نتج عنها زيادة ملحوظة في أغلب الصفات محل الدراسة باستثناء طول الجذر، الكلوروفيلات و محتوى البرولين. فيما يتعلق بمعاملات التداخل، فقد وجد أن المعاملة بأعلى مستوى من مستويات الري (100% من السعة الحقلية) + التغطية بدريس البرسيم + الرش بالكاولين بتركيز 5% نتج عنها الحصول على أعلى القيم لأغلب الصفات التي تم دراستها باستثناء عدد الأفرع/نبات، طول الجذر ومحتوى البرولين. بعض معاملات التداخل الأخرى أدت إلى تقليل الأثر الضار لتقليل مياه الري، من هذه المعاملات الري بمستوى 80% من السعة الحقلية + التغطية بدريس البرسيم + الرش بالكاولين بتركيز 3%. أيضاً وجد أن المعاملة بري النباتات عند أقل مستوى (60% من السعة الحقلية) + التغطية بدريس البرسيم + الرش بالكاولين بتركيز 3 أو 5% من الممكن تطبيقها مع نقص محدود في جودة النباتات.

والخلاصة وحتى يتم خفض كمية مياه الري المستخدمة في ري نباتات الزينيا بنسبة 20% وذلك بدون التأثير على جودة النباتات فإنه ينصح بالري بمستوى 80% من السعة الحقلية + التغطية بدريس البرسيم + الرش بالكاولين بتركيز 3%.

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