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Influence of Gibberellic Acid and ß-Cyclodextrins on Morphology and oil content of *Lavandula angustifolia* L

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ABSTRACT

Lavender (*Lavandula angustifolia* L) is an important medicinal and ornamental flower plant. This study aimed to evaluate the effectiveness of GA3 and β-CD on lavender growth and oil content under our regional conditions. Field experiment was conducted through 12/3 to 27/12/2024 at the Grdarasha research center field, Ministry of Agriculture and water resources, Kurdistan region-Iraq. The experiment was laid out in Randomize Completely Block Design replicated three, included effect of GA3 (0, 150 ,300. 450 mg.L^{-1}) and β-CD (0 , 1.5 , 3.0 , 4.5 mg.L^{-1}) on growth , flowers oil content of (*Lavandula angustifolia* L. cv. Hemus) .Regarding GA3 treatment, the results showed that the highest number of branches.plant^{-1}(43.25%) was observed from 300mg.L^{-1}, number of flower.plant^{-1} (513.11) measured 450mg.L^{-1} and highest oil content per 50g dry weight of flowers (0.51ml) measured from 450 mg.L^{-1}. However, β-CD caused highest plant height and number of branches. plant^{-1} (45.96 and 45.43 % respectively) in 4.5 mg.L^{-1}. Best result of oil content (0.55ml) was obtained from 450mg.L^{-1} GA3 and 4.5 mg. L^{-1} β-CD combination treatment.

KEYWORDS: Lavender; volatile oil; Gibberellins; β-Cyclodextrin; Flowering.

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تأثير حامض الجبرليك وبيتا-سايكلودكسترينات في الصفات المورفولوجية ومحتوى الزيت لنبات الخزامى (*Lavandula angustifolia* L.)

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الملخص

الخزامى (***Lavandula angustifolia* L.**) يعدّ من النباتات الطبية والزينة المهمة. هدفت هذه الدراسة إلى تقييم فعالية حامض الجبرليك (**GA3**) وبيتا-سايكلودكسترين (**β-CD**) في نمو نبات الخزامى ومحتوى زيته تحت ظروف منطقتنا. نُفذت التجربة الحقلية خلال الفترة من 3/12 ولغاية 2024/12/27 في حقل مركز بحوث كرداراشا التابع لوزارة الزراعة والموارد المائية في إقليم كردستان–العراق. صممت التجربة وفق ترتيب القطاعات العشوائية الكاملة وبثلاث مكررات، وتضمنت تأثير أربعة تراكيز من **GA3** (0، 150، 300، 450 ملغم.لتر$^{-1}$) وأربعة تراكيز من **β-CD** (0، 1.5، 3.0، 4.5 ملغم.لتر$^{-1}$) في نمو ومحتوى زيت أزهار الخزامى (الصنف **Hemus**). أظهرت نتائج معاملات **GA3** أن التركيز 300 ملغم.لتر$^{-1}$ حقق أعلى عدد فروع للنبات (43.25 فرع.نبات$^{-1}$)، بينما سجل التركيز 450 ملغم.لتر$^{-1}$ أعلى عدد أزهار للنبات (513.11 زهرة.نبات$^{-1}$) وأعلى محتوى زيتي لكل 50 غم وزن جاف من الأزهار (0.51 مل). في المقابل، سبّب **β-CD** عند التركيز 4.5 ملغم.لتر$^{-1}$ زيادة في ارتفاع النبات وعدد الفروع للنبات (45.96 و45.43 على التوالي). وأظهرت أفضل نتيجة لمحتوى الزيت (0.55 مل) من خلال التداخل بين 450 ملغم.لتر$^{-1}$ **GA3** و4.5 ملغم.لتر$^{-1}$ **β-CD**..

الكلمات المفتاحية: الخزامى؛ الزيت الطيار؛ الجبرلينات؛ بيتا-سايكلودكسترين؛ التزهير.

INTRODUCTION

Lavender (*Lavandula angustifolia* L.) is a strongly aromatic shrub in the Lamiaceae family it is native to the Mediterranean region needs at least 6-8 hours of daily sun exposure and prefers warm and moderately dry climates, mild winters and sunny summers (Niksic et al., 2016 and Oskouie et al., 2018).Generally lavender essential oil contain, flavonoids and phenolics, terpene derivatives

depend on species, the main constituents of *Lavandula angustifolia* are linalool and linalool acetate , lavendulol and lavendulyl acetae (Yurteri and Seyis). Act as sedative, carminative, antiseptic, analgesic ,anti-inflammatory and antimicrobial and purposes (Biesiada et al.,2008 and Munõz-Bertomeu et al.,2008). Lavender is propagated by seeds and stem cuttings, the seedlings then transplanted to open field. Some studies using gibberellins and beta-cyclodextrin were demonstrated in several purposes .Gibberellic acid (GA3) plant hormone is a tetracyclic di-terpenoid compound and stimulating the growth and development; as seed germination, trigger transitions from meristem to shoot growth and juvenile to adult vegetative stage to flowering (Gupta et al., 2013).Lavender seedlings supplemented with 0. 1, 2 and 2.5 $mg.L^{-1}$ of GA3 the study shows that, 2.5 $mg.L^{-1}$ was the most favorable for leaf development. But decrease the number of leaves and plant apical necrosis (Oliveira et al.,2019). El-Naggar et al.(2020) reported that Matricaria chamomilla significantly affected by foliar application of (0.0, 100 and 200 $mg.L^{-1}$),200 $mg.L^{-1}$ had best results in plant height, plant fresh and dry weight ,number of flower head per plant ,fresh and dry weight of flower yield and oil yield.$plant^{-1}$. Praneetha et al.(2020) found that the higher concentration of GA3 among (0,100 and 200 $mg.L^{-1}$) foliar spray on lavender plant recorded earliest flowering and highest leaf area , plant high , chlorophyll content , no.florets , spike number, spike length , flower oil yield per $plant^{-1}$ and per hectar. Schriner and Klett (2022) Found that pretreating of lavender (*Lavandula angustifolia* L.), mother plants with GA3 (100 $mg.L^{-1}$) caused significant increase in shoot length , number of shoot per cuttings. İzmirli and Yıldırım (2023) studied several GA3 concentrations (0, 200, 400 and 600 $mg.L^{-1}$) on oil yield of lavender flowers , they found that 400 $mg.L^{-1}$ gave the most significant result. Cyclodextrins (CD) are white crystalline powder defined as the class of cyclic oligosaccharides which contains glucopyranose units, there are three naturally occurring cyclodextrins: α- cyclodextrin (α-CD), ß -cyclodextrin (ß -CD) and y̆-cyclodextrin (y̆–CD). CD are less accessible for bioconversion to the desired product due to their lipophilic nature, this property confines their use as precursors to enhance productivity (Sharma and Baldi, 2014).No research has been found about the effect of CD on lavender plant after reviewing the literature, however there are relevant studies that explore the impact of CD on other plant species .Cavallaro et al. (2013) recorded that Cyclodextrins are helpful molecular chelating agents that include some organic molecules within a cavity created by their ring-shaped structure. They have been shown to improve the rooting process in globe artichokes both in vitro and ex vitro by complexing auxins. They discovered that the percentage of rooted plantlets was significantly higher in treatments where NAA was supplied with β cyclodextrins separately (83%) or included in nanosponges as a complex of NAA and β-CD (78%) compared to the 65% recorded in the medium where NAA was used alone. According to studies of Vercelli et al. (2015) using of B-cyclodextrin-based nanosponge complex (Fe-NS) was more effective over FeSO4 to control chlorosis and increased dry weight and content roots and shoots of

hydroponically cultivated sweet corn and tomato plants. Loni et al.(2023) reported that basil (Ocimum basilicum L.) significantly affected by foliar application of β-cyclodextrin nanoparticles (0, 10, 50, 100 mg.L^{-1}), but 100 mg.L^{-1} had best results in increasing fluorescence number and essential oil in flowers , moreover ,in the same concentration flower yield per unit area was increased. Lavender cultivation and the related scientific researchers are quite limited in our region, which is why this study aimed to assess the effectiveness of two growth regulators (GA3 and β-Cyclodextrins) on vegetative and reproductive trails of lavender(*Lavandula angustifolia* L. hemus cultivar) under field condition of Erbil governorate.

MATERIALS AND METHODS

This experiment was carried out on lavender (*Lavandula angustifolia* L. hemus cultivar) to investigate the effect of GA3 and β-CD foliar application on its growth and oil yield in flowers during 22/2/2024 to 27/12/2024 at Grdarasha research center open field, Ministry of Agriculture and water resources, Kurdistan region-Iraq, (latitude north 36.6o , longitude east 44.03o at the altitude 436meters).

Plant material and cultivation conditions :

Plastic bags measuring 20 cm in length by 16 cm in breadth were used to plant the 10-month-old uniform seedling of *Lavandula angustifolia* L. The bags were filled with 1:1 soil and peat moss (pH = 6, organic matter 85%, and N:P:K = 210:120:260). On murch 12, 2024, the uniform seedlings were moved to the open field. the physical and chemical method of field soil were takin from (Estefan et al. 2013), are shown in the (table 1). The research center of the Ministry of Agriculture and Water Resources in the Kurdistan region of Iraq provided the metrological data for the trial period (table 2). This study was conducted using a Factorial Randomized Complete Block Design (F-RCBD), with three blocks (100 cm between them), each block contain sixteen plots (plots dimension was 120 x 100 cm). In one plot six plants were planted in two rows, with 40 cm between plants in the same row and 100 cm between rows. Foliar spray for both GA3 (0, 150 ,300. 450 mg.L^{-1} modified from İzmirli and Yıldırım (2023) and β-CD (0 , 1.5 , 3.0 , 4.5 mg.L^{-1} modified from (Kapildev et al., 2020) were applied on lavender plants (9ml.$plant^{-1}$ according to the treatments)

Table 1. Some physical and chemical properties of the experimental field soil.

Properties	Field soil
pH	7.81
Electro conductivity (EC)	0.3 $dS.m^{-1}$

Organic matter	1.07 %
Nitrogen	8.42 %
Phosphor	5.43 %
Potassium	1.83 %
Clay	38.4 %
Silt	42.9 %
Sand	18.7 %
Soil Texture	Silty Clay L.

Table (2): Meteorological data during the experimental period.

Months	Temperature °C			Relative humidity %		
	Min.	Max.	Avg.	Min.	Max.	Avg.
March	4.94	25.59	15.79	15.65	89.3	53.22
April	12.61	36.33	25.50	8.78	75.99	36.89
May	12.35	42.17	28.55	5.82	88.3	29.86
June	22.98	45.91	38.98	4.16	35.71	12.06
July	27.14	45.8	39.43	5.75	31.98	14.52
August	26.67	46.08	39.54	5.93	33.34	13.85
September	20.33	44.84	33.85	7.98	47.53	19.98
October	9.87	36.48	26.07	7.51	48.96	19.09
November	3.10	26.36	17.77	15.54	91.6	48.11
December	1.63	22.03	13.08	12.71	82.1	42.94

Preparation of treatments solutions:

The higher concentrations as stock solution for each GA3 and β-CDs were prepared (Wt(mg)/V(ml)distilled water).The other remaining treatments were obtained by using of diluting process from stock solution with distilled water. Each plant was sprayed with both GA3 and β-CD solutions twice according to their treatments , the first application was in 26-4-2024 and the second after 15days, only distilled water was used for control treatment.

Parameters:

Morphological vegetative measurements were taken for all plants at the end of experiment, include: plant height (%), number of branches/plant^{-1}(%). Number of leaves plant^{-1}(%), fresh and dry weights of 100 leaves (g). However, flowering characteristics were taken throughout the growing season , include; number of spike.plant^{-1} , spike length (cm) , number of flower.plant^{-1} and flower ending (days) ,the yield of fresh and dry weights of flowers(g) per plots (AL-Barazanchi et al .,2023). Flowers oil content was estimated by using hydro distillation method ,50g dry flowers were takin added to one litter distil water then boiled for oil extraction with the method of (Pljevljakusic et al ., 2023)(Muhammed et al., 2025).

Data analysis :

The data gathered were subjected to analysis of variance, and at the probability level ($p \leq 0.05\%$), the treatment averages were compared using least significant differences (L.S.D.). SPSS (Statistical Package for the Social Sciences) was used to perform the statistical analysis (Tumiran et al., 2023).

RESULTS AND DISCUSSION

Vegetative growth:

Table (3) shows that GA3 affected significantly on number of branches and fresh weight of 100 leaves among all vegetative growth parameters. The best value of number of branches (43.25%) was obtained from 450mg.L^{-1} GA3 , highest fresh weight of 100 leaves (3.58%) was recorded from control .While the lowest value (27.76%) was recorded from control and lowest fresh weight of 100 leaves (3.15) obtained from 300mg.L^{-1} GA3. The same table illustrates the effect of β-CD on lavender vegetative growth it had a significant effect on plant height, number of branches plant^{-1}. The highest value of plant height and number of branches (45.96 and 45.43% respectively) were recorded from 4.5mg.L^{-1} β-CD. While the lowest of plant height (37.69%) was observed in control treatment, but the lowest number of brunch (25.02%) was recorded from1.5mg.L^{-1}β-CD. However, number of leaves plant^{-1}, fresh and dry weights of 100 leaves, were not responded significantly. All of the investigated vegetative growth characteristics were significantly impacted by the interaction between the various concentrations of GA3 and β-CD, according to the analysis of variance data. The interaction between 450mg.L^{-1} GA3 and 4.5mg.L^{-1} β-CD produced the greatest number of branches (63.84%), while the treatment of 1.5ml.L^{-1} β-CD without GA3 produced the highest value of plant height (51.70%). However, the highest number of leaves (659.25%) recorded from interaction between 300 mg.L^{-1} GA3 and 3.5mg.L^{-1} β-CD . The best 100 leaves fresh weight (4.07%) and dry weight (1.70%) were recorded from 3 and 4.5mg.L^{-1} β-CD respectively without GA3 . However, the shortest plant hight (29.96%) was observed from control. The least value of number of branch.plant^{-1} (13.83%) was found in the interaction treatment of 300mg.L^{-1} GA3 and 3ml.L^{-1} β-CD . Lowest number of leaves.plant^{-1} (321.56%) was observed (300mg.L^{-1} GA3 without β-CD). While the fresh and dry weight of 100 leaves (2.96 and 1.27g respectively) were illustrated in the treatment of 450mg.L^{-1} GA3 and 3mg.L^{-1} β-CD .

Table 3. Effect of GA3, β-CD and their interaction on vegetative growth parameters of *Lavandula angustifolia* L.

Treatments		Parameters				
GA3 (mg.L^{-1})	β-CD (mg.L^{-1})	Plant hight (%)	No.branch (%)	No.leaves (%)	F.Wt.100 Leaf (g)	D.Wt.100 Leaf (g)
0		38.00	27.76	423.80	3.58	1.56
150		40.58	32.44	426.12	3.47	1.46
300		44.45	34.56	448.56	3.15	1.42
450		42.71	43.25	529.70	3.45	1.47
L.S.D		**N S**	**12.86**	**N S**	**0.42**	**N S**
	0	37.69	32.49	455.56	3.44	1.47
	1.5	42.03	25.02	452.89	3.36	1.50
	3.0	40.05	35.07	398.40	3.38	1.43
	4.5	45.96	45.43	521.32	3.47	1.52
L.S.D		**7.32**	**12.86**	**N S**	**N S**	**N S**
	0.0	29.96	28.33	540.06	3.48	1.49
0	1.5	51.70	15.76	396.53	3.22	1.40
	3.0	31.13	32.82	413.66	4.07	1.65
	4.5	39.20	34.13	494.66	3.57	1.70
	0.0	33.36	20.96	349.31	3.60	1.53
150	1.5	36.56	31.86	357.37	3.65	1.49
	3.0	43.20	46.50	503.12	3.39	1.46
	4.5	49.20	30.45	411.12	3.24	1.38
	0.0	43.12	39.13	321.56	3.35	1.42
300	1.5	38.27	31.95	402.30	3.02	1.59
	3.0	46.75	13.83	659.25	3.09	1.35
	4.5	49.67	53.33	571.53	3.15	1.33
	0.0	44.32	41.54	600.61	3.34	1.43
450	1.5	41.60	20.49	437.41	3.57	1.52
	3.0	39.12	47.12	509.24	2.96	1.27
	4.5	45.79	63.84	540.06	3.93	1.67
L.S.D.<0.05		**14.64**	**25.73**	**271.12**	**0.85**	**0.28**

Reproductive growth:

The table (4) indicates that GA3 affected significantly on number of flowers.plant^{-1} , fresh and dry weight of flowers . The best value of number of flower.plant^{-1} (513.11) was obtained from 450mg.L^{-1} and the lowest (377.27) was recorded from 300mg.L^{-1}GA3 . However, the highest fresh and dry weights of flowers (120.65 and 111.30g respectively) were recorded from control, while the lowest (101.83 and 92.39 respectively) were obtained from 450mg.L^{-1} GA3. The same table illustrates that lavender reproductive growth parameters were not significantly responded to β-CD foliar application .The interaction between GA3 and β-CD caused significant effects on spike length, number of flowers.plant^{-1} , time to flower ending , fresh and dry weight of flower . The best value of spike length (17.75cm) was measured in the treatment of 150mg.L^{-1} GA3 without β-CD, best number of

flowers.plant^{-1} (567.53) was obtained from 3mg.L^{-1} β-CD without GA3 .The best value of flower ending (266.33days) was recorded from 450mg.L^{-1}GA3 with 1.5mg.L^{-1} β-CDs, and the highest value of fresh and dry weights of flowers (146.02 and 135.92 respectively) were measured from 4.5mg.L^{-1} β-CD without GA3 .However, the shortest spike length (13.22cm) was measured from interaction between 300 mg.L^{-1}GA3 with 1.5mg.L^{-1} β-CD . Moreover, the lowest number of flower.plant^{-1} (306.96) , and flower ending (225days) , were recorded from 300mg.L^{-1} GA3 in two treatments 1.5mg.L^{-1}, 0.0β-CD respectively .The lowest fresh and dry weights (83.83 and 76.82 respectively) were recorded from control .

Table 4. Effect of GA3, β-CD and their interaction on flowering parameters of lavender (*Lavandula angustifolia* L.).

Treatments		**Parameters**				
GA3 (mg.L^{-1})	**β-CD (mg.L^{-1})**	**Plant hight (%)**	**No.branch (%)**	**No.leaves (%)**	**F.Wt.100 Leaf (g)**	**D.Wt.100 Leaf (g)**
0		15.87	17.41	510.99	243.00	120.65
150		16.26	16.30	428.98	237.08	102.73
300		14.47	15.30	377.27	237.50	105.43
450		15.35	19.08	513.11	246.50	101.83
L.S.D		**N S**	**N S**	**125.21**	**N S**	**12.27**
		0	16.17	17.17	465.84	233.58
	1.5	1.5	15.58	17.38	473.35	244.50
	3.00	14.65	16.63	454.79	241.00	103.10
	4.5	15.54	16.90	436.37	245.00	108.88
L.S.D		**N S**	**N S**	**N S**	**N S**	**N S**
0	0.0	16.65	15.83	457.81	237.00	83.83
	1.5	15.37	16.86	470.33	245.00	115.14
	3.0	15.02	17.44	567.53	229.00	137.60
	4.5	16.43	19.51	548.29	261.00	146.02
150	0.0	17.75	15.33	408.97	235.33	133.03
	1.5	16.21	21.11	553.79	226.33	98.05
	3.0	14.86	14.10	388.90	251.66	89.44
	4.5	16.24	14.66	364.28	235.00	90.40
300	0.0	15.14	17.33	469.22	225.00	117.49
	1.5	13.22	14.33	306.96	240.33	123.83
	3.0	13.40	16.44	359.69	239.66	89.58
	4.5	16.11	13.10	373.20	245.00	90.81
450	0.0	15.16	20.21	527.37	237.00	103.74
	1.5	17.51	17.22	562.30	266.33	99.49
	3.0	15.32	18.55	503.04	243.66	95.77
	4.5	13.40	20.33	459.73	239.00	108.30
L.S.D		**3.77**	**N S**	**250.42**	**26.99**	**24.53**

3.3. Oil content:

Results in figure (1) indicates that GA3 affected significantly on oil content (ml.50g) dry weight flower of *Lavandula angustifolia* L , the highest oil content (0.51ml.50g D.Wt) was obtained from 450mg.L^{-1} GA3 , and the lowest (0.44ml.50g D.Wt)was from control . However, β-CD foliar spraying had no significant effect. Interaction of GA3 and β-CD had significant influence on flowers oil content .The highest content (0.55ml.50g D.Wt) was measured in interaction treatment from 450mg.L^{-1} GA3 and 4.5mg.L^{-1} β-CD .The lowest content (0.41ml.50g D.Wt) was measured from 4.5mg.L^{-1} β-CD without GA3.

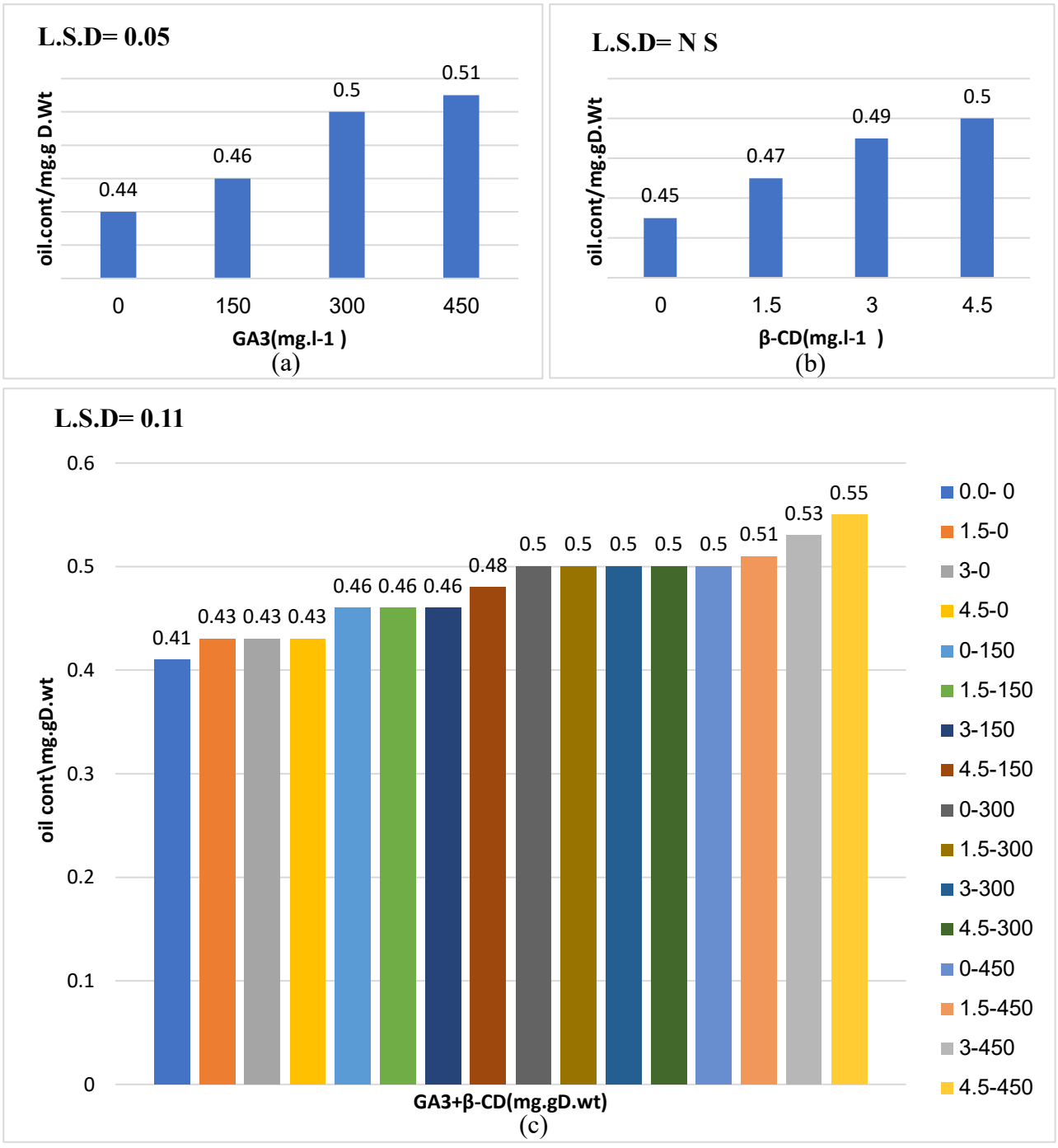

Figure 1. Effect of GA_3 (a), *β*-CD(b) and their interaction(c) on oil-content (ml.50gDr.wt) of lavender flowers

DISCUSSIONS:

The obtained results indicated that both GA3 and ß-CD enhancing growth characteristics and oil yield of lavender transplants, especially in the combination treatments. Growth regulators, such as GA3, must be used in blooming crops in a way that is unique to their activity and safe for the environment and toxicology. The application of growth regulators such as GA3 has finally affected the growth and flower output of flowering crops by regulating their physiological activities. GA3 use promotes better growth, development, and early side-shoot formation (Pradeepkumar et al., 2020). By boosting photosynthetic enzymes, leaf area, more light trapping to increase photosynthetic rate, and appropriate metabolism of antioxidant enzymes to normal levels, GA3 improves source and sink potential and increases nutrient uptake efficiency. (Handaragall et al., 2013). The most popular cyclodextrin is ß-CD, which is non-toxic, environmentally biodegradable, and reasonably priced. It is made from starch and consists of seven glucose groups. Its interior cavity diameter is between 0.60 and 0.65 nm. (Da Silva et al., 2013). CD are obtained through the enzymatic degradation of potatoes; corn and rice starch (Bezerra et al 2020). Starch is an important resource for plants, it is starch is a simple substance, composed of glucose polymers, indeed, most plants produce starch as a form of non-structural carbohydrate in their plastids, by polymerizing photo-assimilated glucose and packaging it into dense, semi-crystalline granule (Zeeman and Solhaug, 2022). ß-CD is enhancing therefore the efficiency of the active ingredient when applied on treatment of flowering plants. Therefore, this might be considered a more economical, sustainable, and sensible usage of this regulator. (Da Silva et al., 2013). In addition to carbohydrates and other nutrients, the rest of the plant provides the apex with a range of hormonal and other variables. Gibberellins' function in regulating phase transition is therefore intricate, species-specific, and most likely involves interactions with other elements. (Taiz and Zeiger. 2002).

So, application of these two plant growth stimulators finally affected on lavender growth, flower and oil production.

CONCLUSION:

The results obtained from the present investigation revealed from the discussion above that GA3 significantly increases number of branches, and β-CD significantly improve all studied vegetative growth characteristics likewise the interaction between GA3 and β-CD especially in highest concentrations. However, the highest number of flowers plant^{-1} was recorded from 450mg.L^{-1}GA3. GA3 and β-CD interaction significantly influence spike length, number of flowers.plant^{-1} , time to flower ending , fresh and dry weight of flowers. Moreover, oil content of (ml.50g) dry weight of lavender flowers was positively affected by GA3 the best amount of oil content was in 450mg.L^{-1} treatment. The interaction of450mg.L^{-1} GA3 and 4.5 ml. l^{-1} β-CD showed the highest efficacy in

flower oil content and it could be used as treatment in cultivation of *Lavandula angustifolia* L for growth and oil production.

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