Alinteri J. of Agr. Sci. (2022) 37(1): 22-26
e-ISSN: 2587-2249
info@alinteridergisi.com

http://www.alinteridergisi.com/
DOI:10.47059/alinteri/V37I1/AJAS22005

RESEARCH ARTICLE

The Response of Growth and Yield of Sweet Pepper (Capsicum Annuum) to the Spraying with Nano-amino Acids and Potassium Silicate

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ARTICLE INFO

Article History:
Received: 22.05.2022
Accepted: 14.06.2022
Available Online: 25.07.2022

Keywords:
Capsicum Annuum
Potassium Silicate
Nano Amino Acids
Vegetative Growth
Yield

ABSTRACT

Current study was carried out in the Department of Horticulture and Forestry, Directorate General for Agriculture in Najaf province, during 2021 spring season to determine the response of growth and yield of (*Capsicum annuum* L.) to the spraying with nano-amino acids and potassium silicate. 12 treatments including four concentrations of nano-amino acids as a foliar feed (0.0, 0.5, 1.0 and 1.5ml.L^{-1}) and three concentrations of potassium silicate (0, 2 and 4ml.L^{-1}) were applied by spraying these concentrations of the vegetative growth of sweet pepper cv. California Wonder. A factorial experiment was arranged using randomized complete blocks design (RCBD) with three replicates and the ANOVA analysis was done using least significant difference test (L.S.D.) at 5% level of significance (P>0.05). Results showed that treatment of spraying 1.5ml.L^{-1} of Nano amino acids was exceled other treatment of foliar spraying in all studied traits, and gave the highest average of growth, yield including plant height, total number of leaves, leaf area, dry weight of total vegetative, dry weight of root, fruits number, the yield of a single plant and total yield. The treatment of spraying 4ml.$L^{-1}$of potassium silicate was significantly exceled other concentrations and gave the highest increasing in vegetative and quantitative indicators.

Please cite this paper as follows:

Ajil, A.H. and Jaafar, H.S. (2022). The Response of Growth and Yield of Sweet Pepper (Capsicum Annuum) to the Spraying with Nano-amino Acids and Potassium Silicate. *Alinteri Journal of Agriculture Sciences, 37*(1): 22-26. doi: 10.47059/alinteri/V37I1/AJAS22005

Introduction

Sweet pepper (*Capsicum annuum* L.) belongs to Solanaceae family, and it is a summer vegetable plant, its original home is Central and South America and from there it's cultivation was spread globally including Iraq as it cultivated in spring in fields and protected cultivation in autumn (Hassan et al. 2014). Sweet pepper is an important fruit vegetable due to its nutritional value as it fresh fruits contain carbohydrates, proteins, potassium, calcium, iron and vitamin A, C, E, as well as it has a medical importance and control sugar level in blood, as anti-cancer, and reduces the harmful triglyceride in the body and arthritis treatment (Mustafa 2010).

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The use of fertilizers and organic materials that manufactured by nanotechnology is very common as it environmentally friendly, reduce the pollution as well as its importance in developing sustainable agriculture, where it becomes possible to exploit small portable nanomaterial's particles to build smart compost which improves the efficiency of nutrients and reduces the cost of protecting the environment (Cui et al. 2010). Amino acids are considered one of essential contains of protein formation and nuclear acids, as it enter in the formation of plant tissues, chlorophyll, capture the nutrients in the soil and increased its readiness, absorption by plant roots, and the addition of amino acids to the vegetative growth by spraying depends on plant need, its stage of growth, as it absorb from stomata in leaves and affected by surrounding temperatures of plant (Stino et al. 2010). Sweet pepper is

distinguished by the weakness of its roots which is not able to compensate for the water lost by transpiration especially when temperatures rise during the growing season which leads to weak the vegetative growth, falling flowers and newly formed fruits, distorting the shape of fruits and make it small in size (Borass et al. 2011). Therefore, it is necessary to use techniques that increase the plant tolerance to heat stress including anti-transpiration such as potassium silicate as chemical compounds that control the movement of stomata and prevent their opening, in addition to stimulating the increase of antioxidant systems which leads to improving plant growth particularly in areas with high temperatures (Epstein 2009). It also works to strengthen cell walls which lead to mechanical support for the aerial parts of the plant (Guerriero et al. 2016).

Potassium is an essential macro nutritional element that activating more than 60 enzymes contributed in many biological activities, and has a role in photosynthesis as well as transporting water and nutrients to other parts of plant (Naseem et al. 2019). Thus, the aims of current study were to examine the physiological effects of Nano amino acids on vegetative and yield of sweet pepper indicators, determine the best concentration of potassium silicate on the growth and yield of plant and study the interaction between the studied factors.

Materials and Methods

This experiment was conducted in spring season in a 56m length x 9m width shad in the Department of Horticulture and Forestry, Directorate General for Agriculture in Najaf province. Ten samples of greenhouse soil were taken randomly from 0-30cm depth before planting then samples were mixed very well and analysed to measure chemical and physical characteristics of these samples (Table 1).

Table 1. Chemical and physical characteristics of field soil before planting

Soil separators	Unit	Amount
Clay	$g.kg^{-1}$	160.00
Silt		243.70
Sand		596.30
Soil texture		Sandy-loamy
pH of soil		7.3
Electric conductivity EC	$dS.m^{-1}$	2.9
Nitrogen	$mg.kg^{-1}$	3.8
Phosphorous	$mg.kg^{-1}$	2.6
Potassium	$mg.kg^{-1}$	254
Calcium	$mg.kg^{-1}$	1.9
Organic matter	%	1.1

Sweet pepper seeds (California Wonder) cultivar produced by US Agri seeds (America) were used as this cultivar is one of registered cultivars by the national committee to certify and protect agricultural cultivars No. 95 in 26/9/2021. Seeds were sown in cork bowls with a capacity of 209 seeds in 15/2/2021, bowls were filled with sandy soil and peat moss in 1:2 ratio respectively. Seedlings were serviced for 45 days then field soil was prepared by tilling in 30 to 40cm depth, levelling and adding $40m^3.h^{-1}$ of organic fertilizer as well as sterilization the soil against nematodes and fungal diseases using tetracozole (Al-Dajawy 1996). The distance between each line was 1m, drop irrigation system was set up in the field, and the distance between each plant was 0.40m. When plants become have 3-4 leaves and 15cm length, seedlings were shifted to the field in 1/4/2021, the number of plants in the experimental unit is 15 plants in an area of $3.2m^2$ (3.2 x 1m).

The experiment included two main factors, the first factor was the foliar feed of amino acids (Optimus plus produced by Agre sciences (Turkey) using nanotechnology and contains 30% amino acids, 3% organic nitrogen, 5% nitrogen) with four concentrations 0, 0.5, 1.0 and $1.5ml.L^{-1}$ (Al-Kaqanie 2021) by spraying these concentrations three times during the season, the first spraying was applied after 20 days of planting followed by the second and third spraying after 14 days of each. The second factor was foliar spraying of three concentrations of potassium silicate 0, 2 and $4ml.L^{-1}$. The vegetative growth of sweet pepper was sprayed in early morning until it fully wet using hand sprayer with adding washing liquid as diffuser (Al-Sahaf 1989). Randomized Complete Block Design (RCBD) was used to arrange the factorial experiment with three replicates and 36 experimental units, ANOVA analysis was done and the differences between means compared using least significant difference (L.S.D.) at 5% level of significance (P>0.05) (AL-Rawi and Khalf 2000). The vegetative and quantitative indicators of the experimental units were randomly measured as follows:

Plant height (cm) was measured using measuring tape and the number of total leaves ($leaf.plant^{-1}$) in the main stems of plants was calculated. Leaf area ($cm^2.leaf^{-1}$) was measured using scanner and Imagej program. Dry weight of total vegetative ($g.plant^{-1}$) estimated in the end of season (Al-Sahaf 1989). Dry weight of total root ($g.plant^{-1}$) estimated following Al- Al-Aqayshi (2020). The number of fruits in each plant ($fruit.plant^{-1}$) in experimental unit was divided on the number of plants then means were taken. The yield of each plant ($g.plant^{-1}$) was calculated by total yield of plants in each experimental unit divided on the number of plants and the total yield ($ton.h^{-1}$) was calculated following Al-Aqayshi (2020).

Results and Discussion

1. Vegetative Growth Indicators

Results of Table 2 showed that there were significant differences between treatments of nano-amino acids on the vegetative growth indicators including plant height, total number of leaves, leaf area, dry weight of total vegetative, dry weight of root and the ratio of shoot and root. Treatment of spraying $1.5ml.L^{-1}$ of Nano amino acids gave the highest average of vegetative growth and recorded 67.29cm of plant height, total leaves number 285.6 $leave.plant^{-1}$, leaf area $47.97cm^2.leaf^{-1}$, dry weight of total vegetative $195.5g.plant^{-1}$, dry weight of total root $24.77g.plant^{-1}$ and the ratio of shoot and root 7.74 compare to control treatment which gave the lowest value of these traits and recorded 54.56cm, 243.9 $leaf.plant^{-1}$, $32.95cm^2.leaf^{-1}$, $141.6g.plant^{-1}$, $19.26g.plant^{-1}$ and 7.67 respectively. The reason for that may be attributed to the role of nano-fertilizers in the physiological processes in plant and its tissues content of nutrients as the nano-fertilizers have a large surface area which makes its solubility high in

different solvents such as water and increases its penetration to the surfaces in contact with it such as roots and leaves as well as providing large area for metabolic reactions and increases the average of photosynthesis thus increase the vegetative growth (Qureshi et al. 2018). Foliar feeding with amino acids improves the indicators of vegetative growth through its role in building the enzyme systems and various purine and pyrimidine bases and increasing the formation of nucleic acids DNA, RNA (Francesco and Michele 2009). In addition to its role in building and producing plant hormones such as gibberellins, oxins and cytokines which encourage cell division and elongation that reflected in the increase in plant height (Kadhm and Kadhm 2013). Amino acids are essential source of nitrogen for many organic compounds as it enter in the building of chlorophyll, proteins, nucleic acids, protoplasmic structure and increase photosynthesis and releasing energy necessary for these processes (Al-Sahaf 1989; Abdel-Aziz and Balbaa 2007). The importance of amino acids lies in the production of energy for the vital processes of plant including absorbed, transition and growth by decomposition to ammonia and organic acids that are oxidized at Krebs cycle to produce energy (Goss 1973). Amino acids also have an important role in regulating the osmotic and water effort of the cell thus increasing its ability to draw water and nutrients from the growth medium and then increasing the vegetative growth of plant (Abo-Dahy and Al-Uonis 1988; Amini and Ehsaanpour 2005). Foliar spraying of amino acids has contributed to treating the lack of nutrients that occurs during the growing season of the plant (Al-Hamadany and Mohammed 2014), as well as it has a positive effect in reducing the damage caused by abiotic stresses such as high temperatures. The reason for the increase in the dry weight of total vegetative is due to the increase of plant height and the number of its leaves which is associated with an increase in the efficiency of carbon metabolism. These results are consistent with what Faraj and Abdel-Wahab (2011) obtained on tomato plant, Ibrahim and Al-Zubaidy (2016) on eggplant, Al-Zamily (2018) on sweet pepper.

Results of Table 2 also indicated that there were significant effects of spraying sweet pepper plants with potassium silicate when the 4ml.L^{-1} concentration gave the highest average of the vegetative growth indicators amounted 67.17cm of plant height, total leaves number 280.8 leave.plant^{-1}, leaf area 45.86cm^2.leaf^{-1}, dry weight of total vegetative 181.9g.plant^{-1}, dry weight of total root 22.91g.plant^{-1} and the ratio of shoot and root 7.87 compare to control treatment (spraying with water only) which gave the lowest value of these traits and recorded 56.28cm, 214.9 leaf.plant^{-1}, 35.66cm^2.leaf^{-1}, 153.5g.plant^{-1}, 21.58g.plant^{-1} and 7.51 respectively. The foliar feeding with potassium silicate gives protection to plant tissues from unfavorable climatic conditions and reduces water loss thus improving the water content of the plant (Shahata 2013). The increasing in the vegetative indicators may attributed to potassium element which has a role in stimulating more than 60 enzymes involved in the metabolic processes, regulate the opening and closing of stomata and translating of nutrients from leaves to other parts of plant as well as cell division and elongation (Taiz and Zeiger 2006, 2010), and the effective effect of silicate in improving, availability and regulating the nutritional and hormonal balance in the plant and then improving physiological processes which positively affects the vegetative indicators (Liang et al. 2007; Zhu et al. 2019).

The interaction between spraying Nano amino acids and potassium silicate treatments had significant effect on the average of vegetative growth when the treatment of spraying 1.5ml.L^{-1} concentration of Nano amino acids and potassium silicate gave the highest average of vegetative growth amounted 73.47cm of plant height, total leaves number 302.4 leave.plant^{-1}, leaf area 52.67cm^2.leaf^{-1}, dry weight of total vegetative 214.3g.plant^{-1}, dry weight of total root 26.11g.plant^{-1} and the ratio of shoot and root 7.74 compare to control treatment which gave the lowest value of these traits and recorded 52.35cm, 177.2 leaf.plant^{-1}, 30.87cm^2.leaf^{-1}, 138.6g.plant^{-1}, 18.90g.plant^{-1} and 7.30 respectively.

Table 2. The effect of spraying Nano amino acids, potassium silicate and their interaction on vegetative growth indicators of sweet pepper

Treatments			Plant height (cm)	Leaves number (leaf.plant-1)	Leaf area (cm2.plant-1)	Dry weight of total vegetative (g.plant-1)	Dry weight of total vegetative (g.plant-1)	The ratio of shoot and root
Concentrations of nano-amino acids (ml.L-1)		0	54.56	243.9	32.95	141.6	19.26	7.67
		0.5	62.39	214.7	40.72	165.2	21.43	7.69
		1	64.31	242.7	44.73	177.6	23.57	7.65
		1.5	67.29	285.6	47.97	195.5	24.77	7.74
L.S.D 0.05			2.22	6.60	1.55	6.87	0.23	0.10
Potassium silicate (ml.L-1)		0	56.28	214.9	35.66	153.5	21.58	7.51
		2	63.00	244.5	43.27	174.4	22.28	7.69
		4	67.17	280.8	45.86	181.9	22.91	7.87
L.S.D 0.05			1.92	5.72	1.35	5.95	0.21	0.08
Nano amino acids x potassium silicate	0	0	52.35	177.2	30.87	138.6	18.90	7.33
		2	54.33	250.8	32.69	141.8	19.32	7.71
		4	57.00	303.6	35.50	144.3	19.57	7.96
	0.5	0	55.83	180.9	33.20	152.8	20.98	7.43
		2	63.67	205.7	43.97	167.5	21.43	7.64
		4	67.67	257.4	45.00	175.3	21.89	8.00
	1	0	57.77	237.6	37.87	158.0	22.89	7.58
		2	64.60	231.0	45.87	180.9	23.73	7.61
		4	70.57	259.6	50.46	193.9	24.10	7.77
	1.5	0	59.00	264.0	40.68	164.4	23.55	7.69
		2	69.40	290.4	50.55	207.7	24.66	7.80
		4	73.47	302.4	52.67	214.3	26.11	7.74
L.S.D 0.05			3.85	11.44	2.69	11.91	0.41	0.17

2. Yield and its Contents Indicators

Table 3 showed that there were significant effect of spraying Nano amino acids on yield indicators including (fruits number, the yield of each plant and total yield), as the treatment of 1.5ml.L^{-1} concentration of Nano amino acids gave the highest average of fruits number, yield for each plant and total yield and recorded 34,77 fruit.plant^{-1}, 2.49 kg.plant^{-1} and 20.90 ton.h^{-1} respectively compare to the lowest average 23.80 fruit.plant^{-1}, 1.22 kg.plant^{-1} and 10.22 ton.h^{-1} in control treatment. Results also showed that there was significant effect of spraying potassium silicate on yield traits when the treatment of 4 ml.L^{-1} of potassium silicate was exceled other concentrations and gave highest average of yield traits and recorded 32,22 fruit.plant^{-1}, 2.26 kg.plant^{-1} and 18.96 ton.h^{-1} respectively in comparison with the lowest average in control which recorded 25,75 fruit.plant^{-1}, 1.43 kg.plant^{-1} and 11.98 ton.h^{-1} respectively. The reason may be due to potassium silicate contribution to achieving moisture balance and increasing the water content of plant as sweet pepper is sensitive to water stress (Yildirim et al. 2012; Abdallah 2019), in addition to the lack of water and high temperature increase the transpiration which results in lack of water in plant tissues (Ismail 2010). Spraying with potassium silicate leads to a delay in the aging of leaves and the death of plant parts which in turn leads to an increase in the efficiency of photosynthesis (Al-Solag 2007; Toshan et al. 2013; Javan 2013).

Results also indicated significant effect of the interaction between spraying of Nano amino acids and potassium silicate concentrations on yield traits when 1.5ml.L^{-1} concentration of Nano amino acids and 4ml.L^{-1} concentration of potassium silicate gave the highest average of pods number, yield for each plant and total yield and recorded 380,00 fruit.plant^{-1}, 2.89 kg.plant^{-1} and 24.27 ton.h^{-1} respectively compare to the lowest average 20.66 fruit.plant^{-1}, 0.86 kg.plant^{-1} and 7.26 ton.h^{-1} in control treatment (no spraying). It can be concluded that spraying of Nano amino acids and potassium silicate concentrations on yield traits when 1.5ml.L^{-1} concentration of Nano amino acids and 4ml.L^{-1} concentration of potassium silicate gave the best average of vegetative and yield indicators.

Table 3. The effect of spraying Nano amino acids, potassium silicate and their interaction on yield and its contents indicators of sweet pepper

Treatments			**Fruits number (fruit.plant^{-1})**	**Yield of single plant (kg.plant^{-1})**	**Total yield (ton.hectare^{-1})**
Concentrations of nano-amino acids (ml.L^{-1})		0	23.80	1.22	10.22
		0.5	28.08	1.06	13.43
		1	32.61	2.19	18.38
		1.5	34.77	2.49	20.90
L.S.D 0.05			0.39	0.02	0.21
Potassium silicate (ml.L^{-1})		0	25.75	1.43	11.98
		2	30.47	1.94	16.26
		4	32.22	2.26	18.96
L.S.D 0.05			0.33	0.02	0.18
Nano amino acids x potassium silicate	0	0	20.66	0.86	7.26
		2	23.75	1.26	10.61
		4	27.00	1.53	12.81
	0.5	0	24.75	1.24	10.39
		2	28.50	1.66	13.90
		4	31.00	1.91	16.00
	1	0	27.25	1.63	13.65
		2	33.66	2.23	18.74
		4	36.91	2.71	22.76
	1.5	0	30.33	1.98	16.61
		2	36.00	2.60	21.81
		4	38.00	2.89	24.27
L.S.D 0.05			0.67	0.04	0.36

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