

Influence of Some Ecological Factors on Growth, Productivity, and Chemical Constituents of Spurge (*Euphorbia Condylocarpa* M., Bieb)

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Abstract

Spurge *Euphorbia condylocarpa* is one of the medicinal plants, which contain numerous sorts of phytochemical components. This study aimed to determine the effect of three levels of light intensity (100% (L1: received natural sunlight, 80% (L2: the glass house covered with one layer of tulle fabric to minimize the light intensity to 80%), 120% (L3 where electric light was added to make light intensity to 120%)), soil moisture content (SM 1: 100%, SM 2: 75%, SM 3: 50% field capacity (FC)), under applied two levels of organic fertilizer (OF1; control, OF2; 10%) on growth, productivity, and chemical constituents of *E. condylocarpa* plants. Results showed that L3 significantly increased root tuber fresh weight, total chlorophylls, total protein content, and total phosphorus content, however, proline decreased, while L2 significantly decreased number of leaves, root tuber fresh weight, root tuber dry weight, and chl. a content of leaves but proline content of leaves increased. SM1 significantly increased number of leaves, chl. b content, carotene, and total soluble carbohydrates, SM2 significantly increased total phosphorus, but decreased ch. b content, and total soluble carbohydrates. OF2 significantly increased stem diameter, total chlorophylls, proline content of leaves, and total potassium, while OF1 significantly decreased stem diameter, and total potassium content, while zinc increase in dry leaves. Triple interaction treatment L3SM2OF2 significantly increased number of branches, stem diameter, water content of shoot system, biological yields, shoot fresh weight, total chlorophylls, and total soluble carbohydrates in dry weight of leaves. It was concluded that this plant needs different condition for improve growth and development.

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Introduction

Spurge (*Euphorbia condylocarpa* M. Bieb.), is a glabrous perennial herb with (10-35) cm high and fusiform cylindrical tubers, it belongs to Euphorbiaceae, which is one of the most extensive families of medicinal plants globally. This family contain all variety of plants cover from herbs, shrubs to woody trees, *Euphorbia* is the most extensive genus in this family (Ismaeel and Aliwy, 2023). *Euphorbia condylocarpa* is grown in mountain slopes in limestone with oak trees and is distributed in Turkey, Iran, Northern Iraq, and the Caucasus (Georgia, Armenia, Azerbaijan, and Russia) (Behçet, 2025). The biodiversity collection of this plant has been recited in several forest zones of Iraq involving Ruwanduz Gorge, Gali Warte, Haji Omaran, Darbandi Basian, and

Qopi Qaradax (Pahlevani, 2014).

The root and leaves of spurge plant has traditional medicine for treating of cancer, costiveness, and migraine, by extracting various phenolics from the plants root (Nasrollahzadeh *et al.*, 2014). Secondary metabolites, which involve of alkaloids, steroids, flavonoids, terpenoids, tannin, and saponin, are the final product of primary metabolites that possess some profitable biological tracts such as antioxidant activity, antimicrobial activity, antibacterial, antifungal activity (Anarado *et al.*, 2020).

Among of the main environmental factors, solar radiation is the extremely significant one that regulates photosynthesis, plant growth survival, and adaptation. In specific habitat, light intensity (LI) varies temporarily (seasonally and diurnally) and spatially. Plants develop plasticity to cope with changes in light intensities. Many plants can develop anatomical, physiological, morphological, and biochemical alternation to different light intensities (Celis-Plá *et al.*, 2021). Light is crucial environmental aspect impacting plant growth, development, and secondary metabolism (Fan *et al.*, 2019). Soil moisture (SM) is also, an important factor for plant growth and development and access nutrients from it (Liang *et al.*, 2022). When the soil moisture reaches field capacity, the plant roots capable of absorb adequate amounts of nutrients and produce more vegetative growth and chemical compounds. The rainfall gradient and availability of SM content integrated with the diversity, distribution, and primary productivity of plant communities (Chaturvedi and Raghubanshi, 2018), available soil moisture content has an important influence on plants water relations which directly impacting photosynthesis and stomatal conductance (Vennam *et al.*, 2023). Organic fertilizer (OF) is also the great plant growth factors that improve the soil properties such as supply the soil with nutrients, increasing soil pores and air exchange in the plant root zone (Abdaljabar *et al.*, 2025). Organic fertilizer improves water holding capacity of sandy soil and drainage in clay soil, it found in positive contribution to soil fertility, resulting in crop yield without causing any environmental water, soil pollution hazards, also assist to avoid disease increasing, re-equipment of plants nutritional and improve plant tolerance, this action relive more stresses (Sharma and Chetani, 2017). The aim of this study is to determine the effects of light intensity, soil moisture content, organic fertilizer and their interaction on growth, productivity, chemical constituents of Spurge (*Euphorbia condylocarpa* M., Bieb) plants.

Materials and Methods

Study area

A factorial experiment (with three factors) was conducted in green house of Biology Department, College of Science, Salahaddin University, from November 1st, 2024 to April 22nd, 2025 to determine the effect of three light intensities (LI), 100%, 80%, 120% of the ambient sun light; the three soil moisture contents, 100%, 75%, 50% of the field capacity (FC) of the soil; and the two organic fertilizer percent application (Peat moss) (0.0% and 10 % incorporated v/v with the soil), and their interactions on the growth, development, chemical constituents and productivity of spurge (*Euphorbia condylocarpa* M. Bieb) plants. The experiment was applied according to CRD with four replications.

Description of the research pots

Each plastic pot was filled in five kilograms of air-dried soil. Pots were green color, with a diameter of 25 cm in length and 18 cm in depth with holes in the bottom to drain out the excess water. The soil was sieved with 2 mm pore size sieves.

Preparation and analysis of the soil used in the study

The soil was prepared for air drying, grinding, and passing through a 2 mm sieve. The soil texture was estimated by the pipette method as indicated by (Ryan *et al.*, 2001). The soil PH was estimated by a PH meter, and an EC meter was used to determine the electrical conductivity (EC) of

the soil as indicated by (Shanon *et al.*, 2020) Nitrogen was measured by the kjeldahl method; potassium and magnesium were determined by (Ryan *et al.*, 2001), soil minerals such as Ca, Mn, Fe, and Zn were determined using X-ray fluorescence (XRF) equipment according to (El-Bahi *et al.*, 2013) as shown in Table 1.

Soil moisture content

The moisture content of the soil was determined according to (Ryan *et al.*, 2001). 100 g of a moist soil sample is taken into aluminum dish and dried in an oven at 105 °C for 24 hours. After that period, the dish with an oven dried soil is cooled in a desiccator and reweighed. The loss of the weight is soil moisture.

$$\text{Moisture content (\%)} = \frac{FW-DW}{DW} \times 100$$

Where *FW*: fresh weight of the sample, *DW*: dry weight of the sample after oven drying.

Field capacity (FC) of the soil

The field capacity of the soil was determined by the methods described by (Almaz *et al.*, 2023).

Table 1. Some physical and chemical properties of the soil used in the study

Properties	Parameters	Value
Physical properties	Soil Texture	Sandy loam
	Soil Structure	Sand :70.80%
		Silt: 21.25 %
		Clay: 7.95%
	Soil Moisture	3.1%
	PH	7.0
EC	1.2 (ml s cm ⁻¹)	
Chemical properties	N	0.35%
	P	4.29 ppm
	Ca	101.892 (g kg ⁻¹)
	Mg	15 ppm
	Mn	740.379 ppm
	Fe	345.802 ppm
	Zn	58.220 ppm

Preparation of spurge *Euphorbia condylocarpa* plants

Spurge plants were obtained from the mountains area of Hiran-Iraqi Kurdistan, and authenticated by the Herbarium of the Biology Department, College of Education, Salahaddin University, Table 2. The fresh plant tubers were taken by selecting a healthy-looking and equal-sized plant with lots of young growing branches on it as shown in Figure 1. Plant tubers were planted by inserting one root tuber to 4 cm deep in each 72 pots.



Figure 1. Flower, tuber roots, and whole (*Euphorbia condylocarpa* M. Bieb) plant

Table 2. Scientific Classification of *Euphorbia condylocarpa* plant

Scientific classification of <i>Euphorbia condylocarpa</i> M. Bieb	
Domain	Eukarya
Kingdom	Plantae (plants)
Subkingdom	Tracheophytes (vascular plants)
Superdivision	Spermatophyta
Division	Magnoliophyta (seed plant)
Subdivision	Angiosperme (Magnoliophyta)
Class	Equisetopsida
Subclass	Magnoliidae
Order	Malpighiales
Family	Euphorbiaceae
Genus	<i>Euphorbia</i>
Species	<i>Condylocarpa</i>
Binomial name	<i>Euphorbia condylocarpa</i> M. Bieb

Light intensity

In this experiment, the greenhouse was divided into three parts; each part was used as a growth chamber for growing spurge plants. The first part was used for L1 treatment, which received natural sunlight at 100% light intensity, and the second part was used for L2 treatment, which was covered with one layer of tulle fabric to minimize light intensity to 80% of the ambient natural light intensity, and the third part was used for L3 treatment, which an electric light was added to make light intensity 120%. A light meter was used to measure light intensity in the three parts of the greenhouse.

Vegetative growth characteristics

1. Plant height (cm)

Plant height was measured using a metal measuring tape from the contact point between the stem and soil surface to the endpoint (top) of the main stem for every plant in all treatments and replications.

2. Number of leaves (leaves per plant)

The number of leaves was recorded for every plant in the study.

3. Number of branches (No. B) (Branch per plant)

The number of branches was recorded for every plant for the study.

4. Stem diameter (mm)

Stem diameter was determined by hand caliper micrometer above the soil surface at the maturity stage before harvesting.

5. Total plant leaves area (cm²) TPLA

The area of one leaf was measured according to the copy method by (Adil, 2012) and the total plant leaves area were calculated as follows:

$$\text{TPLA} = \text{the area of one leaf} \times \text{number of leaves per plant}$$

6. Root tuber diameter (RD) (cm)

The root diameter (RD) was measured using caliper.

7. Shoot fresh weight (Sh. FW) (g plant⁻¹)

The aerial parts were cut from the soil surface point and weighted with an electrical a sensitive balance.

8. Shoot dry weight (Sh. DW.) (g plant⁻¹)

After recording the fresh weight, the samples were air-dried, then weight again to record dry weights. The following equation were utilized as mentioned by Khaleel and Sarmamy (2023):

$$\text{Sh. DW. (g)} = \text{leaves DW (g)} + \text{stems DW (g)}$$

9. Root tuber fresh weight (R. FW) (g plant⁻¹)

Root tuber fresh weights were recorded using sensitive balance.

10. Root tuber dry weight (R. DW) (g plant⁻¹)

Root tuber dry weight was measured after drying using a sensitive balance.

11. Biological yield in fresh weight (g plant⁻¹)

The biological yield was obtained after the summation of shoot fresh weight and root tuber fresh weight.

Biochemical analysis of leaves of Spurge plants

Photosynthetic pigments determination (mg g⁻¹ fresh weight or mg g⁻¹ dry weight)

Chlorophylls (chlorophyll a, chlorophyll b, and total chlorophyll) and carotenes were measured, by taking 0.5 g of fresh leaves that was extracted in 10 ml of (95% v/v) ethyl alcohol per a sample. Leaves were left in a solvent in darkness at room temperature for three sequential days, the concentration of pigments was measured using spectrophotometer. The absorbance of the extract was recorded at wavelength 665, 649, and 452 nm against extraction ethanol as a control. The following equations were utilized to convert these readings to pigment content in the leaf as mentioned by (Pompelli *et al.*, 2013):

$$\text{Chlorophyll a (}\mu\text{g per ml solution)} = (13.70) (A_{665}) - (5.7) (A_{649})$$

$$\text{Chlorophyll b (}\mu\text{g per ml solution)} = (25.80) (A_{649}) - (7.60) (A_{665})$$

$$\text{Total chlorophylls (}\mu\text{g per ml solution)} = \text{Chl. a} + \text{Chl. b}$$

$$\text{Carotenoids (car) (}\mu\text{g per ml solution)} = ((1000) \times (A_{470}) - (2.13 \times \text{Chl. a}) - (97.63) \times \text{Chl. b}) / 209$$

Where: *A*: absorbance, *Chl. a*: chlorophyll a, *Chl. b*: chlorophyll b, *Car*: carotenoid.

Proline determination

Proline was assessment as stated by the colorimetric methods as described by Bates *et al.* (1973), approximately 0.5 g of plant materials was homogenized in 10 ml of 3% aqueous sulfosalicylic acid and the homogenate was filtered through Whatman no. 2 filter paper, 2 ml of filtrate was reacted with 2 ml of acid ninhydrin (acid ninhydrin was prepared by warming 1.25 g of ninhydrin with 30 ml of glacial acetic acid and 20 ml of 6 M of phosphoric acid) and 2 ml of glacial acetic acid for 1 hour in water bath at 100°C and the reaction terminated in an ice bath, the reaction mixture extracted with 4ml of toluene, mixed vigorously with a test tube stirrer for 15-20 sec. the chromophore containing toluene was aspirated from the aqueous phase, warmed at room temperature and the absorbance read at 520nm, using toluene for a blank. The calibration curve was prepared using purified (Figure 2), the results were expressed as $\mu\text{g g}^{-1}$ fresh weight of leaves.

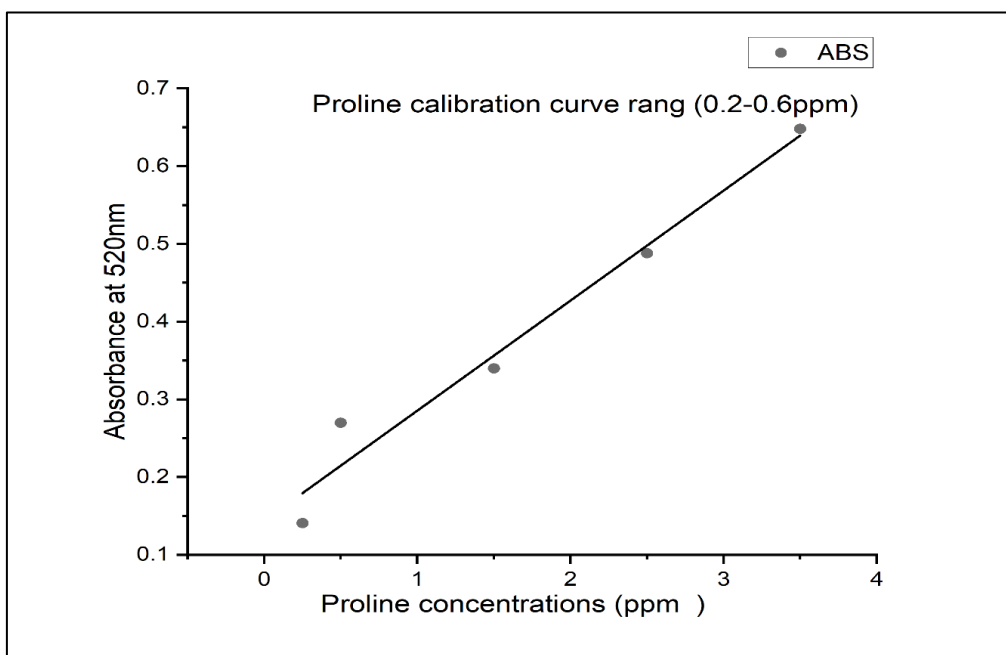


Figure 2 Calibration curve for evaluation of free proline concentrations in leaves

Determination of total soluble carbohydrates (mg/g dry weight)

The total soluble carbohydrates from the dry weight of leaves were estimated by using the anthrone method according to that employment by Sakr and Arafa (2009). It was extracted from 0.1 g of Dry leaves matter by ethanol 80% for overnight at laboratory temperature, then filtered through Whatman No.1 filter paper, then adding 4mL of anthrone reagent (dissolve 200 mg of anthrone reagent in 100ml of concentrated H₂SO₄) to 0.1 M l filtrate, then complete to 1 ml of D.W., and heated for 10 min in a boiling water bath, cool rapidly in ice water and developed green color was read at 630 nm by spectrophotometer. To prepare a standard curve, different concentrations of L-glucose were prepared (100 mg of glucose in 100 ml of distilled water), (Figure 3).

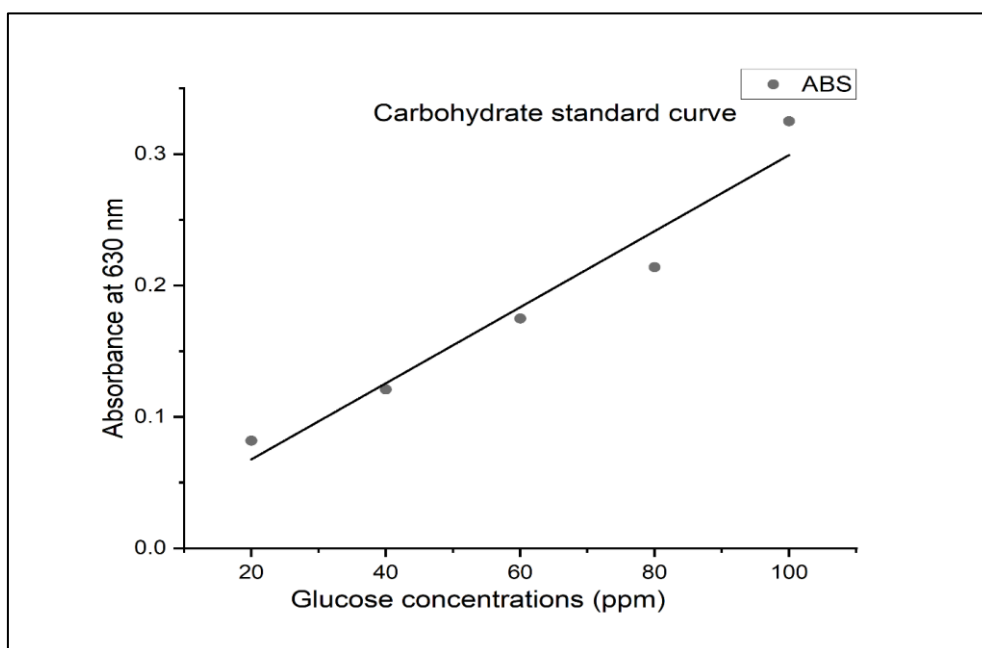


Figure 3. Calibration curve for evaluation of total soluble carbohydrate concentrations

Determination of total phenolic compounds in spurge leaves (TPC)

The total phenolic content was estimated by Folin-Ciocalteu reagents as methods described by Kalpoutzakis *et al.* (2023): the extract was prepared from spurge leaves, by maceration 0.5 g of powdered plant parts (which dried in an oven at 70 °C for 24 hours) in 15 ml of acidic methanol(0.1 ml HCl(conc.37%) completed with 100 ml of methanol). In a dark place, the extract was left for 48 hours at room temperature then filtered using filter paper. Three milliliters of distilled water were added to one ml of methanolic extract, followed by 0.5 ml of (10%) Folin- Ciocalteu reagent, then left for 3 minutes, 2 ml of Na₂CO₃ (20%) was added the mixture was allowed to stand for one hour in the shade with intermittent shaking. 25 ml of distilled water was added to each sample, then the absorbance was measured at 650nm. The phenolic contents of the extract were expressed as mg Gallic acid equivalents per gram sample in dry weight (mg g⁻¹), Figure 4.

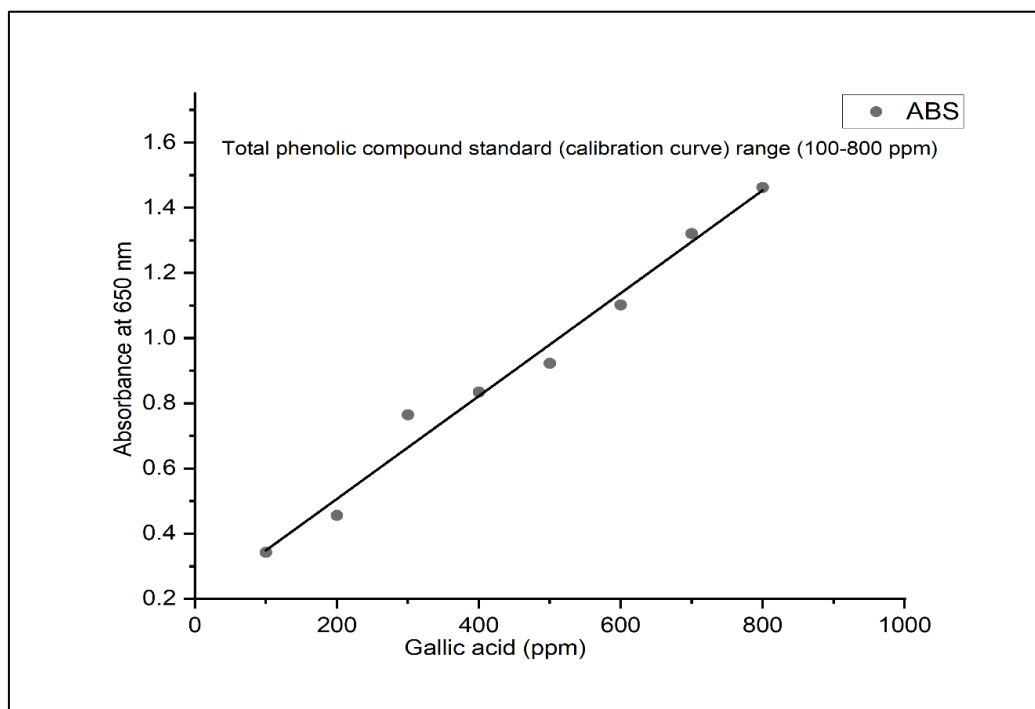


Figure 4. Calibration curve for evaluation of phenolic compound concentrations

Chemical analysis of spurge in dry leaves

Sampled of spurge leaves were dried in an oven at 70°C for 48 hours then grinded in an electrical stainless-steel mill and passed through a 2 mm sieve samples were put back in the oven until a constant dry weight was obtained for each replicate of the experiment. 0.3 g of dried ground samples was digested by adding 10 ml of each of concentrated H₂SO₄ and H₂O₂, with heating for 5 hours by apparatus employed digestion at 180°C as described by Ryan *et al.* (2001).

Total nitrogen (mg g⁻¹)

The total nitrogen was determined by the kjedahl method as described by Abrams *et al.* (2019).

Total phosphorus (mg g⁻¹)

The total phosphorus was determined using the spectrophotometer method as described by Ryan *et al.* (2001).

Total potassium (K⁺) (mg g⁻¹)

The total potassium was determined by the flame photometer as described by Ryan *et al.* (2001).

Determination of micronutrients Mn and Zn (ppm) in dry leaves

The minerals were estimated from Spurge plants using X-ray fluorescence (XRF) according to Kntapo *et al.* (2018). The leaves sample were dried in an oven at 70°C and ground to a tiny powder by an electrical grinder, then sieved through a 2mm sieve. The powder of each sample was put in the disc container of the XRF to determine the concentration of minerals.

Statistical Analysis

Data was analyzed statistically according to Statistical Package for the Social Science (SPSS) programs, Version 27, and the means were compared using Duncan Multiple Range Test at a probability of 0.05 of significance. For drawing graphs, Excel 16 was used.

Results and Discussion

Effect of Light intensity, soil moisture, organic fertilizer on some vegetative characteristics of *E. condylocarpa* plant

Plant height (cm)

Table 3 showed significant differences between double interactions of treatments, in their effects on the height of spurge plants. The double interactions L1SM2, L2OF1, SM1OF1, SM1OF2, SM2OF2, and SM3OF1 decreased the plant height significantly to 12.750, 13.183, 14.377, 13.544, and 13.383 respectively compared to L3SM3, L3OF2 and SM3OF2, which increased plant height to 17.900, 17.077, and 18.500 cm respectively, these results support the results that observed by Herod and Martina (2024), that light availability in particular played a crucial aspect in potential growth, which agreement with results obtained by Lee and Kim (2024).

Triple interactions treatments among light intensity, soil moisture content, and organic fertilizer showed different effects, the combined interaction L2SM2OF1 decreased plant height of spurge significantly to 11.666 cm compared to L2SM1OF2 and L1SM1OF2 that increased plant height to 17.866 and 20.800 cm respectively. Lv *et al.* (2021) showed that when plant exposed to low light environment for more period, it has more mechanism one of the increasing plant heights, and morphological structure and material accumulation in plants are closely related to light intensity both low and high intensity are detrimental to plant growth.

Number of leaves per plant (No. of leaves)

Table 3 showed that the treatments and their interaction affected significantly on number of leaves of spurge plants. Light intensity (L2: 80%) decreased number of plants leaves significantly to 19.444 compared to L1(100%) which registered the highest number of plants leaves significantly to 27.777, Soil moisture (%100FC) significantly increased number of leaves to 27.055 compared to SM3: 50%FC which decreased number of leaves to (18.555). Double interaction treatments L2SM3, L2OF1, and SM3OF1 decreased number of leaves of spurge plants significantly to 14.333, 15.444 and 15.00 respectively compared to 19.833, 30.000, and 29.222 leaves for L1SM1, L1OF1, and SM1OF2 interactions respectively, these results partially agreed with those found by Noraldeen *et al.* (2023), and the triple interaction treatment L2SM3OF1 decreased number of spurge plant leaves significantly to 12.666 leaves compared to 34.666 leaves for L1SM1OF2. Shade inhibits the number of petioles, number of root nodules and yield production.

Number of branches (no. of B) (branch plant⁻¹)

Table 3 reveals that double interaction treatments L1SM1, SM2OF1, SM1OF2 increased the number of plant branches significantly to 5.666, 4.222, and 4.333 compared to L2SM2, SM2OF1 respectively, which decreased number of branches to 2.166, 1.777 respectively. Triple interaction treatments among light intensity, soil moisture content, and organic fertilizer showed different effects, L3SM2OF2, L3SM3O2 increased the number of branches of spurge plant significantly to 3.66, 6.00 respectively, compared to L2SM3OF1 that decreased number of branches to 1.000, these

results partially agreed with those found by Shihab *et al.* (2024), which indicated that water stress reduce leaf area, chlorophyll pigments, lead to decrease cell division in the plant.

Total plant leaf area(cm²)

Generally, light intensity, soil moisture content, and organic fertilizer as well as their interaction have not shown significant effects on total leaf area (Table 3).

Table .3 Effect of Light intensity, soil moisture, organic fertilizer on some vegetative growth characteristics of Spurge plants

Factors and their levels	Plant height(cm)	No. of leaves	No. of branches	Total plant leaf area (cm ²)
L1 (100%)	13.800 a	27.777 a	3.833 a	36.070 a
L2 (80%)	13.852 a	19.444 b	3.166 a	22.917 a
L3 (120%)	16.016 a	21.722 ab	2.944 a	33.689 a
SM1 (100%) FC	13.736 a	27.055 a	4.277 a	32.795 a
SM2 (75%) FC	13.988 a	23.333 ab	2.666 a	31.539 a
SM3 (50%) FC	15.944 a	18.555 b	3.000 a	28.342 a
OF1 (0% control)	12.737 a	17.500 a	2.994 a	24.776 a
OF2 (10%)	14.060 a	20.500 a	3.307 a	26.413 a
L1SM1	13.816 ab	29.833 a	5.666 a	40.702 a
L1SM2	12.750 b	27.833 ab	2.666 ab	34.393 a
L1SM3	14.833 ab	25.666 ab	3.166 ab	33.117 a
L2SM1	12.241 b	25.667 ab	4.000 ab	24.871 a
L2SM2	14.216 ab	18.333 ab	2.166 b	23.074 a
L2SM3	15.100 ab	14.333 b	3.333 ab	20.805 a
L3SM1	15.150 ab	25.666 ab	3.166 ab	32.812 a
L3SM2	15.003 ab	26.000 ab	3.666 ab	37.151 a
L3SM3	17.900 a	15.666 ab	2.500 ab	31.104 a
L1OF1	13.766 ab	30.000 a	4.222 a	40.809 a
L1OF2	13.833 ab	25.555 ab	3.444 a	31.332 a
L2OF1	13.183 b	23.444 ab	3.000 a	24.224 a
L2OF2	14.522 ab	15.444 b	3.333 a	21.589 a
L3OF1	14.955 ab	23.777 ab	3.111 a	34.505 a
L3OF2	17.077 a	19.666 ab	2.777 a	32.837 a
SM1OF1	13.094 b	24.888 ab	4.222 a	30.413 a
SM1OF2	14.377 b	29.222 a	4.333 a	35.178 a
SM2OF1	14.433 b	23.111 ab	1.777 b	33.969 a
SM2OF2	13.544 b	23.555 ab	3.555 ab	29.109 a
SM3OF1	13.388 b	15.000 b	2.222 ab	25.900 a
SM3OF2	18.500 a	22.111 ab	3.777 ab	30.785 a
L1SM1OF1	15.000 abc	25.000 ab	2.000 ab	32.700 a
L1SM1OF2	20.800 a	34.666 a	3.000 ab	29.509 a
L1SM2OF1	15.066 abc	25.333ab	3.111 ab	37.892 a
L1SM2OF2	15.433 abc	30.333 ab	3.000 ab	36.410 a
L1SM3OF1	13.66 bc	18.000 ab	3.666 ab	22.342 a
L1SM3OF2	16.466 abc	33.333 ab	3.333 ab	24.268 a
L2SM1OF1	12.333 bc	24.333 ab	2.000 ab	22.154 a
L2SM1OF2	17.866 a	27.333 ab	4.666 ab	24.268 a
L2SM2OF1	13.366 bc	17.666 ab	1.000 ab	22.990 a
L2SM2OF2	15.066 abc	19.000 ab	3.333 ab	23.157 a
L2SM3OF1	11.666 c	12.666 b	1.00 b	27.358 a

L2SM3OF2	12.816 bc	16.000 ab	4.333 ab	21.670 a
L3SM1OF1	12.83 bc	25.333 ab	2.666 ab	27.658 a
L3SM1OF2	16.833 abc	33.333 ab	3.666 a	38.576 a
L3SM2OF1	11.833 bc	24.333 ab	1.333 ab	25.643 a
L3SM2OF2	15.066 abc	27.666 ab	4.000 ab	23.0257 a
L3SM3OF1	12.633 bc	14.333 ab	5.333 ab	24.652 a
L3SM3OF2	15.000 abc	18.000 ab	6.000 a	38.571 a

*L: light intensity; SM: soil moisture; OF: organic fertilizer.

The means in each category of column followed by the same letters are not significantly different at $p < 0.05$ according to Duncan's Multiple Range test.

Effect of Light intensity, soil moisture content, organic fertilizer and their interactions on stem and tuber diameter, water content, and biological yields of *E. condylocarpa*

Stem diameter (cm)

Table 4 exhibited that OF2 caused significant increase in stem diameter of spurge plant 1.026 cm compared to 0.854 cm for OF1 that decreased stem diameter significantly. The interaction treatments SM1OF2 increased stem diameter to 1.010 cm as compared to 0.853 cm for SM2OF1 which decreased stem diameter significantly, these results agreed with those revealed by Deng *et al.* (2024). Triple interactions treatments L3SM1OF2 caused significant increase in stem diameter to 1.333 cm as compared to 0.732 cm for L3SM2OF1, the interplay of light and water condition may influence the cell proliferation and enlargement process that lead to collar diameter expansion through lateral meristem activity (Ibeh and Akinyele, 2024).

Root tuber diameter (cm)

Table 4 reveals significant differences between double interactions treatments in their effects on root tuber diameter of spurge plant. The double interactions L3SM3, L3OF2, and SM3OF2 increased root tuber diameter significantly to 6.783, 6.588, 6.455 cm compared to L1OF1, L1OF2, L2OF1, L2OF2, L3OF1, SM1OF1, SM1OF2, SM2OF1, SM2OF2, SM3OF1, which decreased root tuber diameters to 4.366, 4.868, 4.716, 4.744, 4.766, 5.255, 4.811, 4.844, 4.533, 5.244, 5.066, 4.666, 5.044 cm respectively. Results were conformity with the finding of Yin *et al.* (2025), Organic fertilizer contributing of plant hormones that work on the cell division and expansion of the cells as well as formation of additional rings on the roots .

Water content (g plant⁻¹)

Table 4 illustrate that SM3 caused significant increase in water content of spurge plant to 2.146 g. plant⁻¹ as compared to 1.246 g. plant⁻¹ for SM1. Interaction treatment L1SM3, L1OF2, L2OF2, L3OF2, SM3OF2 increased water content to 2.316, 2.164, 2.016, 1.991 g. plant⁻¹, as compared to L3SM1, L1OF2, L2OF1, L3OF2, L3OF1, SM1OF2, SM2OF1, SM3OF1, and SM1OF1, which decreased water content of spurge plant to 0.955, 1.885, 1.111, 1.108, 0.912, 1.580, 1.613, 1.700 g. plant⁻¹ respectively. Triple interaction treatment L3SM1OF2 increased water content of shoot system significantly to 2.82 g. plant⁻¹ compared to L1SM3OF1, L2SM3OF1 that decreased water content significantly to 0.640, 0.960 g. plant⁻¹ respectively. (Herod and Martina, 2024) reported that the interaction of light intensity, nutrients and soil moisture has effect on plant biomass and photosynthesis. Decrease in soil moisture content significantly decrease water content of the plant due to dehydrated of the plant (Aliarab *et al.*, 2020).

Biological yield (g)

Table 4 showed that L2 caused a significant decrease in biological yield (dry weight) of spurge plant to 10.127g compared to 13.129 and 12.485 g for L1 and L3 respectively. The double interactions L2SM1, L2OF1 decreased biological yield significantly to 8.576 and 9.285g respectively to L1SM1, L1SM2, L3SM3, L3SM2, L3SM3, L1OF1, L1OF2, and L3OF2 which

registered 13.828, 12.391, 13.568, 12.203, 13.423, 13.517, 12.741 and 13.623 g respectively compared to which decreased biological yield significantly to L2SM1, L2OF1 respectively. Triple interactions L1SM1OF2, L3SM1OF2, and L3SM3OF2 increased biological yield to 14.930, 15.116 and 14.156 g respectively compared to 8.093 g for L2SM3OF2.

Table 4. Effect of Light intensity, soil moisture, organic fertilizer on stem and tuber diameter, water content, and biological yields of Spurge plants

Treatments	Stem diameter (cm)	Root tuber diameter (cm)	Water contents (g plant ⁻¹)	Biological yield (g plant ⁻¹)
L1 (100%)	1.069 a	4.755 a	2.025 a	13.129 a
L2 (80%)	1.005 a	5.033 a	1.563 a	10.127 b
L3 (120%)	1.015 a	5.716 a	1.550 a	12.485 a
SM1 (100%) FC	1.123 a	4.888 a	1.246 b	11.276 a
SM2 (75%) FC	0.971 a	4.866 a	1.746 ab	11.834 a
SM3 (50%) FC	0.995 a	5.750 a	2.146 a	12.630 a
OF1 (0% control)	0.854 b	4.362 a	1.173 b	10.470 a
OF2 (10%)	1.026 a	4.857 a	1.653 a	11.267 a
L1SM1	1.210 a	4.366 b	1.763 abc	13.828 a
L1SM2	0.966 a	4.868 b	1.995 abc	12.391 a
L1SM3	1.033 a	5.216 ab	2.316 a	13.568 a
L2SM1	1.033 a	5.133 ab	1.020 bc	8.576 b
L2SM2	1.008 a	4.716 b	1.558 abc	10.908 ab
L2SM3	0.983 a	5.250 ab	2.113 ab	10.898 ab
L3SM1	1.128 a	5.166 ab	0.955 c	11.823 ab
L3SM2	0.946 a	5.200 ab	1.686 abc	12.203 a
L3SM3	0.983 a	6.783 a	2.008 abc	13.423 a
L1OF1	1.050 a	4.744 b	1.885 b	13.517 a
L1OF2	1.088 a	4.766 b	2.164 a	12.741 a
L2OF1	0.975 a	5.255 b	1.111 b	9.285 b
L2OF2	1.036 a	4.811 b	2.016 a	10.970 ab
L3OF1	0.995 a	4.844 b	1.108 b	11.343 ab
L3OF2	1.074 a	6.588 a	1.991 a	13.623 a
S1OF1	1.010 bc	4.533 b	0.912 c	11.043 a
S1OF2	1.237 a	5.244 b	1.580 bc	11.508 a
S2OF1	0.853 c	5.066 b	1.613 bc	11.594 a
S2OF2	1.089 ab	4.666 b	1.880 ab	12.074 a
S3OF1	0.986 bc	5.044 b	1.700 bc	11.321 a
S3OF2	1.004 bc	6.455 a	2.590 a	13.938 a
L1SM1OF1	1.003 abc	6.766 ab	1.456 abc	11.916 abc
L1SM1OF2	1.253 ab	6.800 a	2.560 ab	14.930 a
L1SM2OF1	0.966 abc	4.200 abc	1.416 abc	10.383 abc
L1SM2OF2	0.926 abc	6.200 abc	1.956 abc	14.023 ab
L1SM3OF1	0.996 abc	5.033 abc	0.640 c	11.370 abc
L1SM3OF2	0.943 abc	5.300 abc	1.270 abc	12.276 abc
L2SM1OF1	0.940 abc	3.866 bc	1.830 abc	10.026 abc
L2SM1OF2	1.126 abc	6.633 abc	2.395 abc	11.770 abc
L2SM2OF1	0.860 bc	5.500 abc	1.293 abc	10.703 abc
L2SM2OF2	1.141 abc	3.933 abc	1.823 abc	11.113 abc
L2SM3OF1	1.030 abc	4.766 abc	0.960 c	9.060 bc

L2SM3OF2	0.937 abc	5.500 abc	1.080 bc	8.093 c
L3SM1OF1	1.086 abc	4.500 abc	1.813 abc	12.020 abc
L3SM1OF2	1.333 a	5.933 abc	2.820 a	15.116 a
L3SM2OF1	0.732 c	5.500 abc	2.130 abc	13.696 ab
L3SM2OF2	1.200 abc	3.866 bc	1.860 abc	11.086 abc
L3SM3OF1	0.933 abc	3.800 c	1.136 bc	12.700 abc
L3SM3OF2	1.133 abc	4.933 abc	2.390 ab	14.156 a

*L: light intensity; SM: soil moisture; OF: organic fertilizer.

The means in each category of column followed by the same letters are not significantly different at $p < 0.05$ according to Duncan's Multiple Range test.

Effect of Light intensity, soil moisture content, organic fertilizer and their interactions on stem and tuber diameter, water content, and biological yields of Spurge plants

Root tuber fresh weight (g)

Table 5 indicated that L1, L3 caused significant increase in root tuber fresh weight of spurge plant 10.652, 10.222 g respectively, compared to 8.553 for L2, which decrease root tuber fresh weight significantly. The double interactions L1SM1, L1SM2, L1SM3, L3SM1, L3SM2, L3SM3, L1OF1, L1OF2, and L3OF2 increased root tuber fresh weight significantly to 10.966, 10,223, 10.768, 9.838, 10.001, 10.8288, 11.158, 10.146, 10.948 g respectively compared to 6.955, 7.756 g for L2SM1, L2OF1, which decreased root tuber fresh weight of spurge plant respectively. Triple interactions L1SM1OF2, L3SM1OF2, L3SM2OF1 decreased root tuber fresh weight significantly to 11.46, 11.71, 11.54g respectively compared to 6.713 g for L2SM3OF2. Plants that grow on low light conditions grow at the reduced rate due to the lack of enough energy needed for the processes in the plant (Al-Dulaimi *et al.*, 2025).

Root tuber dry weight (g per plant)

Table 5 showed that L1 increased root tuber dry weight significantly to 5.954 g compared to 4.205 g for L2. The double interactions L1SM3, L3SM1, L1OF1, L1OF2 and L2OF2 significantly increased the root tuber dry weight to 6.450, 6.350, 5.853, 6.055, and 5.566 g respectively compared to 3.576 and 3.503 for L3SM1 and L3OF1 respectively. Majeed and Ahmed (2023) showed that organic fertilizer increases absorption of water and nutrients and improved the soil properties.

Shoot fresh weight (g per plant)

Table 5 illustrated that double interaction L3OF2 and SM3OF2 increased shoot fresh weight significantly to 2.674, 2.893 g respectively compared to L2OF1, SM1OF2, SM2OF1, and SM3OF1 (1.528, 1.868, 1.688, and 1.737 g respectively). Triple interactions treatments L1SM1OF2 increased shoot fresh weight significantly to 3.470 g compared to L1SM1OF1, L1SM2OF1, L1SM3OF2, L2SM1OF1, L2SM2OF1, L2SM3OF2, and L3SM1OF2 decreased shoot fresh weight significantly to 1.720, 1.570, 1.270, 1.293, 1.343, and 1.320 g respectively compared to other triple interaction treatments. Al-Dulaimi *et al.* (2025) showed that high light provides additional energy for chemical processes during photosynthesis leading to more food production in the plant.

Shoot dry weight (g per plant)

Commonly, light intensity, soil moisture content, organic fertilizer, as well as interaction treatments have not shown any significant effects on shoot dry weight (Table 5).

Table 5. Effect of Light intensity, soil moisture, organic fertilizer on stem and tuber diameter, water content and biological yields of Spurge plants

Treatments	Root tuber fresh weight (g)	Root tuber dry weight (g)	Shoot fresh weight (g)	Shoot dry weight (g)
L1 (100%)	10.652 a	5.954 a	2.476 a	0.510 a
L2 (80%)	8.553 b	5.102 ab	1.574 b	0.450 a
L3 (120%)	10.222 a	4.205 b	2.260 a	0.506 a
SM1 (100%) FC	9.253 a	4.382 b	2.022 a	0.474 a
SM2 (75%) FC	9.861 a	5.117 ab	1.973 a	0.479 a
SM3 (50%) FC	10.314 a	5.762 a	2.315 a	0.513 a
OF1 (0% control)	8.759 a	4.259 a	1.574 a	0.422 a
OF2 (10%)	9.252 a	4.500 a	1.889 a	0.433 a
L1SM1	10.966 a	5.530 abc	2.461 a	0.490 a
L1SM2	10.223 a	5.883 ab	2.168 a	0.551 a
L1SM3	10.768 a	6.450 a	2.800 a	0.490 a
L2SM1	6.955 b	4.041 bc	1.621 a	0.481 a
L2SM2	9.358 ab	5.583 abc	1.550 a	0.381 a
L2SM3	9.346 ab	5.683 abc	1.551 a	0.489 a
L3SM1	9.838 a	3.576 c	1.985 a	0.451 a
L3SM2	10.001 a	3.885 bc	2.201 a	0.505 a
L3SM3	10.828 a	5.153 abc	2.595 a	0.561 a
L1OF1	11.158 a	5.853 a	2.358 abc	0.506 a
L1OF2	10.146 a	6.055 a	2.594 ab	0.515 a
L2OF1	7.756 b	4.638 ab	1.528 c	0.440 a
L2OF2	9.350 ab	5.566 a	1.620 bc	0.461 a
L3OF1	9.496 ab	3.503 b	1.846 abc	0.443 a
L3OF2	10.948 a	4.906 ab	2.674 a	0.569 a
SM1OF1	8.866 a	4.371 a	2.176 ab	0.510 a
SM1OF2	9.640 a	4.394 a	1.868 b	0.439 a
SM2OF1	9.905 a	5.230 a	1.688 b	0.440
SM2OF2	9.816 a	5.004 a	2.258 ab	0.519 a
SM3OF1	9.583 a	5.257 a	1.737 b	0.495 a
SM3OF2	11.045 a	6.266 a	2.893 a	0.532 a
L1SM1OF1	10.196 abc	4.873 a	1.720 b	0.536 a
L1SM1OF2	11.460 a	5.433 a	3.470 a	0.586 a
L1SM2OF1	8.813 abc	3.356 a	1.570 b	0.426 a
L1SM2OF2	11.190 ab	4.413 a	2.833 ab	0.586 a
L1SM3OF1	8.673 abc	3.386 a	2.269 ab	0.570 a
L1SM3OF2	11.003 ab	3.766 a	1.270 b	0.333 a
L2SM1OF1	8.733 abc	4.733 a	1.293 b	0.536 a
L2SM1OF2	9.960 abc	6.633 a	1.810 ab	0.443 a
L2SM2OF1	9.360 abc	5.833 a	1.343 b	0.356 a
L2SM2OF2	9.356 abc	5.333 a	1.757 ab	0.406 a
L2SM3OF1	7.196 bc	4.146 a	1.863 ab	0.516 a
L2SM3OF2	6.713 c	3.936 a	1.380 b	0.446 a
L3SM1OF1	9.820 abc	6.166 a	2.200 ab	0.413 a
L3SM1OF2	11.716 a	6.733 a	1.340 a	0.563 a
L3SM2OF1	11.543 a	6.500 a	2.153 ab	0.536 a
L3SM2OF2	8.930 abc	5.266 a	2.183 ab	0.566a
L3SM3OF1	10.730 ab	5.580 a	1.970 ab	0.441 a
L3SM3OF2	8.903 abc	5.480 a	2.953 ab	0.538 a

*L: light intensity; SM: soil moisture; OF: organic fertilizer.

The means in each category of column followed by the same letters are not significantly different at $p < 0.05$ according to Duncan's Multiple Range test.

Effect of Light intensity, soil moisture, organic fertilizer on photosynthetic pigments of leaves of *E. condylocarpa* plant

Chlorophyll a (chl. a) (mg g⁻¹)

Table 6 displays that L2 decreased chl. a of leaves in spurge plants significantly to 0.364 mg g⁻¹ compared to L1 and L3. The SM1 decreased chl. a content of leaves significantly to 0.405 mg g⁻¹ compared to SM2 and SM3. There were significant differences between double interaction treatments in their effects on chl.a content, the highest weight was registered for L3OF2 (0.887 mg g⁻¹) compared to the lowest weight (0.360 mg g⁻¹) that registered for L2SM1. Significant differences also shown between triple interactions in their effects on chl.a content and the highest weight (0.899 mg g⁻¹) was registered in L1SM1OF1 compare to the lowest weight (0.354 mg g⁻¹) in L1SM1OF1. It was reported that light intensity was beneficial to increase the chlorophyll content in plants, which appropriate light intensity can reduce damage of leaves and formation of related tissue, in turn promote chlorophyll synthesis (Qin *et al.*, 2024).

Chlorophyll b (chl. b) (mg g⁻¹)

Table 6 showed that SM1 increased chl. b content of leaves of spurge plants significantly to 0.418 mg. g⁻¹ compared to SM2, which decreased chl. b content to 0.302 mg. g⁻¹. The double interactions L2SM2, L2OF2, SM2OF2, SM3OF1, SM3OF2 increased chl. b content significantly to 0.517, 0.500, 0.469, 0.467, and 0.441 mg. g⁻¹ respectively compared to L1SM1, L2SM1, L3SM1, L1OF1, L2OF1, SM1OF1, SM2OF2 which decreased chl. b content to 0.239, 0.284, 0.365, 0.292, 0.351, 0.250, 0.342 mg. g⁻¹ respectively. (Zhang *et al.*, 2021) found that too much or too little light treatments reduced the photosynthetic pigments in plants and inhibit photosynthesis in plants.

Total chlorophyll (total chl.) (mg g⁻¹)

Table 6 reveals that L3 and OF2 increased total chl. s, significantly to 1.852, 1.356 mg. g⁻¹ compared to L1 and L2, and OF1 respectively, which decreased total chl. s to 1.085, 1.159, and 0.869 mg. g⁻¹, which decreased chl. s content respectively. The double interactions L3SM3, L1OF2, L3OF2, SM2OF1, SM2OF2, SM3OF1, and SM3OF2 increased total chl. s of leaves content to 1.345, 1.251, 1.337, 1.149, 1.186, and 1.193 respectively compared to other double interaction treatments. Triple interactions L1SM1OF1, L1SM1OF2, L1SM1OF1, L1SM2OF2, L3SM1OF2, L3SM2OF1 increased total chl. s content significantly to 1.335, 1.307, 1.254, 1.320, 1.283, 1.260 mg. g⁻¹ respectively compared to other triple interaction treatments. (Minotta and Pinzauti, 1996) found that the rate of total chlorophylls more sufficient for high bright process in bright light under high light condition and high nutrient supply.

Carotenoid content (mg g⁻¹)

Table 6 indicates that SM2, and SM3 increased carotenes contents to 0.151, and 0.168 mg g⁻¹ respectively compared to SM1, which decreased carotenes content to 0.079 mg g⁻¹. The double interactions L1SM2, L1SM3, L3SM3, L3OF2, SM2OF1, SM2OF2 and SM3OF, increased Car. content to 0.177, 0.143, 0.178, 0.174, 0.140, 0.165, and 0.156 mg g⁻¹ respectively compared to other double interaction treatments. Triple interactions L1SM1OF2 and L3SM2OF1 increased carotene content significantly to 0.188 and 0.178 mg g⁻¹ respectively compared to other triple interaction treatments. (Paiva *et al.*, 2003) found that photosynthetic pigments were increased (especially carotenoids) in *Tradescantia pallida* increased under full sunlight, which play in light absorption and transfer to chlorophylls.

Table 6. Effect of Light intensity, soil moisture, organic fertilizer on photosynthetic pigments of leaves of Spurge plants

Treatments	Chl. a (mg g ⁻¹)	Chl. b (mg g ⁻¹)	Total chl. (mg g ⁻¹)	Carotenoid (mg g ⁻¹)
L1 (100%)	0.545 a	0.347 a	1.085 b	0.140 a
L2 (80%)	0.364 b	0.319 a	1.159 b	0.124 a
L3 (120%)	0.518 a	0.394 a	1.852 a	0.134 a
SM1 (100%) FC	0.405 b	0.418 a	1.001 b	0.079 b
SM2 (75%) FC	0.507 a	0.302 b	1.511 a	0.151 a
SM3 (50%) FC	0.515 a	0.330 ab	1.585 a	0.168 a
OF1 (0% control)	0.411 a	0.323 a	0.869 b	0.106 a
OF2 (10%)	0.435 a	0.312 a	1.356 a	0.117 a
L1SM1	0.472 cd	0.239 d	0.712 d	0.070 c
L1SM2	0.827 ab	0.419 ab	1.247 b	0.177 a
L1SM3	0.831 ab	0.427 ab	1.259 ab	0.143 a
L2SM1	0.360 e	0.284 cd	0.623 d	0.058 c
L2SM2	0.444 d	0.517a	0.969 c	0.116 b
L2SM3	0.419 de	0.477 ab	0.959 c	0.120 b
L3SM1	0.537 c	0.365 bc	0.902 c	0.65 c
L3SM2	0.810 b	0.477 ab	1.287 ab	0.159 ab
L3SM3	0.887 a	0.458 ab	1.345 a	0.178 a
L1OF1	0.602 b	0.292 c	0.894 b	0.106 cd
L1OF2	0.818 a	0.432 ab	1.251 a	0.154 ab
L2OF1	0.388 c	0.351 bc	0.733 c	0.070 d
L2OF2	0.427 c	0.500 a	0.974 b	1.271 bc
L3OF1	0.603 b	0.417 ab	1.020 b	0.093 cd
L3OF2	0.887 a	0.450 ab	1.337 a	0.174 a
SM1OF1	0.429 b	0.250 c	0.671 c	0.050 b
SM1OF2	0.484 b	0.342 b	0.826 b	0.079 b
SM2OF1	0.680 b	0.469 a	1.149 a	0.140 a
SM2OF2	0.707 a	0.473 a	1.186 a	0.165 a
SM3OF1	0.702 a	0.467 a	1.181 a	0.156 a
SM3OF2	0.723 a	0.441 a	1.193 a	0.138 a
L1SM1OF1	0.899 a	0.436 abc	1.335 ab	0.167 ab
L1SM1OF2	0.875 ab	0.480 ab	1.307 ab	0.188 a
L1SM2OF1	0.733 c	0.521a	1.254 ab	0.149 abc
L1SM2OF2	0.886 a	0.433 abc	1.320 ab	0.167 ab
L1SM3OF1	0.523 de	0.280 cde	0.804 d	0.022 f
L1SM3OF2	0.551 d	0.450 ab	1.001 c	0.108 cde
L2SM1OF1	0.388 hg	0.550 a	0.938 c	0.128 cde
L2SM1OF2	0.450 ef	0.404 abcd	0.854 c	0.113 cde
L2SM2OF1	0.446 ef	0.488 a	0.934 c	0.093 de
L2SM2OF2	0.442 ef	0.547 a	0.989 c	0.140 abc
L2SM3OF1	0.354 g	0.258 de	0.612 e	0.090 e
L2SM3OF2	0.366 hg	0.315 bcde	0.681 e	0.027 f
L3SM1OF1	0.819 ab	0.415 abcd	1.235 b	0.172 ab
L3SM1OF2	0.843 ab	0.439 abc	1.283 ab	0.115 cde
L3SM2OF1	0.860 ab	0.399 abcd	1.260 ab	0.178 a
L3SM2OF2	0.793 bc	0.440 abc	1.233 b	0.168 ab
L3SM3OF1	0.523 de	0.217 e	0.740 e	0.038 f
L3SM3OF2	0.534 d	0.261 de	0.795 d	0.102 cde

*L: light intensity; SM: soil moisture; OF: organic fertilizer.

The means in each category of column followed by the same letters are not significantly different at $p < 0.05$ according to Duncan's Multiple Range test.

Effect of Light intensity, soil moisture, organic fertilizer on some chemical constituents of Spurge leaves

Total soluble carbohydrates in dry leaves (mg g^{-1})

Table 7 reveals that SM1 increased total soluble carbohydrates (TSC) content in leaves of spurge plants significantly to $35.085 \text{ mg. g}^{-1}$ as compared to SM2 which decreased TSC content to $29.361 \text{ mg. g}^{-1}$. OF2 increased TSC content significantly to $31.320 \text{ mg. g}^{-1}$ compared to OF1 which decreased TSC content to 28.513 . The double interactions L3SM1 and SM1OF2 increased TSC content significantly to 36.724 , and $36.063 \text{ mg. g}^{-1}$, respectively compared to L1SM2, SM2OF1, SM2OF2, and SM3OF1, which decreased TSC content to 27.631 , 28.257 , 30.465 , and $28.638 \text{ mg. g}^{-1}$ respectively. The triple interactions L2SM1OF2, L2SM3OF2, L3SM1OF2, and L3SM3OF2 increased TSC content to 37.152 , 37.141 , and $37.299 \text{ mg. g}^{-1}$ respectively compared to L1SM2OF1, L2SM1OF1, L3SM1OF1, and L3SM2OF2, which decreased TSC content to 26.366 , 26.166 , 25.728 , 27.097 , and $26.886 \text{ mg. g}^{-1}$ respectively. (Glowacz *et al.*, 2015) showed that soluble sugar content significantly increased with increased light intensity, which lead to increased photosynthesis process in plants.

Total protein content (mg g^{-1})

Table 7 displays that L3, and OF2 increased total protein contents (TPC) in leaves of spurge plants significantly to 274.814 , and $253.012 \text{ mg. g}^{-1}$ respectively compared to L1, and OF1, which decreased TPC significantly to 247.592 , $242.613 \text{ mg. g}^{-1}$ respectively. The double interactions L3SM2, L3OF2 and SM2OF2 increased TPC significantly to 294.583 , 295.771 and $287.777 \text{ mg. g}^{-1}$ respectively compared to other double interaction treatments (Miao *et al.*, 2023) reported that increasing light intensity beneficial for the synthesis of proteins, which lead to plant growth.

Proline content ($\mu\text{g g}^{-1}$)

Table 7 reveals that L2 and OF2 increased proline content of leaves significantly to 23.267 , and $21.454 \mu\text{g g}^{-1}$ respectively compared to L3, and OF1, which decreased PC significantly to 20.783 , $19.999 \mu\text{g. g}^{-1}$ respectively. The double interactions L2SM2, L2OF1 and SM1OF2 increased proline content significantly to 23.302 , 24.203 , $24.910 \mu\text{g. g}^{-1}$ respectively compared to L2SM3, L3SM2, L3SM3, L3OF2, SM1OF2, SM3OF2 respectively compared to other double interaction treatments. Triple interactions L1SM3OF2 and L2SM2OF1 increased proline content significantly to 25.472 and $25.568 \mu\text{g. g}^{-1}$ respectively compared to other triple interaction treatments. These results partially agreed with those founded by Kijowska-Oberc *et al.* (2023).

Total phenolic content in dry leaves ($\mu\text{g g}^{-1}$)

Table 7 showed that the triple interactions L1SM2OF2, L1SM3OF2, L2SM1OF2, L2SM1OF2, L3SM1OF1, L3SM2OF1, and L3SM3OF2 increased total phenolic content of leaves to 27.034 , 29.970 , 28.384 , 29.026 , 27.742 , and $28.266 \mu\text{g g}^{-1}$ respectively compared to L1SM3OF1, which decreased TPHC significantly to $16.483 \mu\text{g g}^{-1}$, these results agreed with those found by Mohagheghian *et al.* (2025), that drought stress significantly increase total phenolic content. Under high light stress, poly phenols often produced in the plant tissue as some form protective agents.

Table 7. Effect of Light intensity, soil moisture, organic fertilizer on some chemical constituents of Spurge leaves

Treatments	Total soluble carbohydrates (mg g^{-1})	Protein content (mg g^{-1})	Proline content ($\mu\text{g g}^{-1}$)	Total phenolic content ($\mu\text{g g}^{-1}$)
L1 (100%)	31.483 a	247.592 b	21.566 ab	25.983 a
L2 (80%)	31.520 a	253.209 ab	23.267 a	23.397 a
L3 (120%)	33.067 a	274.814 a	20.783 b	23.967 a

SM1 (100%) FC	35.085 a	243.919 a	22.768 a	24.874 a
SM2 (75%) FC	29.361 b	267.145 a	21.910 a	24.144 a
SM3 (50%) FC	31.623 ab	264.552 a	20.939 a	24.330 a
OF1 (0% control)	28.513 b	242.613 b	19.999 b	21.504 a
OF2 (10%)	31.326 a	253.012 a	21.454 a	23.438 a
L1SM1	34.918 ab	234.305 b	21.815 abc	26.871 a
L1SM2	27.631 b	261.527 ab	21.264 bc	25.793 a
L1SM3	31.900 ab	246.944 b	21.618 abc	25.285 a
L2SM1	33.613 ab	239.490 b	23.521 ab	24.521 a
L2SM2	29.506 ab	245.324 b	23.302 a	20.862 a
L2SM3	31.440 ab	274.814 ab	20.979 bc	24.807 a
L3SM1	36.724 a	257.963 ab	22.966 abc	23.226 a
L3SM2	30.946 ab	294.583 a	19.165 c	25.777 a
L3SM3	31.530 ab	271.898 ab	20.219 bc	22.898 a
L1OF1	32.737 a	238.518 b	21.994 ab	27.161 a
L1OF2	30.229 a	256.666 b	21.138 ab	24.805 a
L2OF1	30.621 a	241.975 b	24.203 a	23.657 a
L2OF2	32.418 a	264.444 b	22.331 ab	24.277 a
L3OF1	33.271 a	253.858 b	21.406 ab	23.257 a
L3OF2	32.862 a	295.771 a	20.161 b	23.537 a
SM1OF1	34.106 ab	248.240 bc	20.625 b	22.331 a
SM1OF2	36.063 a	239.598 c	24.910 a	27.414 a
SM2OF1	28.257 c	246.512 bc	22.068 ab	24.330 a
SM2OF2	30.465 bc	287.777 a	21.752 b	23.958 a
SM3OF1	28.638 c	256.018 bc	20.495 b	23.794 a
SM3OF2	34.608 ab	273.048 ab	21.383 b	24.866 a
L1SM1OF1	33.106 abcd	261.851 bc	21.026 abcd	21.127 ab
L1SM1OF2	29.953 abcd	281.944 bc	19.413 cd	24.670 ab
L1SM2OF1	26.366 cd	245.648 bc	18.286 d	24.520 ab
L1SM2OF2	35.526 abc	343.518 a	20.043 cd	27.034 a
L1SM3OF1	26.366 cd	270.277 bc	20.461 bcd	16.483 b
L1SM3OF2	35.526 abc	245.649 bc	25.472 a	29.970 a
L2SM1OF1	25.728 d	260.555 bc	22.203 abcd	21.230 ab
L2SM1OF2	37.152 ab	289.074 b	19.755 cd	28.384 a
L2SM2OF1	30.030 abcd	246.944 bc	25.568 a	20.728 ab
L2SM2OF2	28.983 bcd	243.703 bc	25.036 ab	20.997 ab
L2SM3OF1	35.189 abc	241.111 bc	23.000 abcd	25.033 ab
L2SM3OF2	37.152 ab	237.870 bc	24.043 abc	24.010 ab
L3SM1OF1	27.097 cd	245.648 bc	18.256 d	29.026 a
L3SM1OF2	36.721 ab	248.240 bc	24.981 ab	21.0543 ab
L3SM2OF1	28.376 bcd	246.934 bc	22.351 abcd	27.742 a
L3SM2OF2	26.886 cd	276.111 bc	20.176 cd	23.844 ab
L3SM3OF1	32.536 abcd	233.333 bc	18.415 c	25.476 ab
L3SM3OF2	37.299 ab	235.277 bc	25.216 ab	28.266 a

*L: light intensity; SM: soil moisture; OF: organic fertilizer.

The means in each category of column followed by the same letters are not significantly different at $p < 0.05$ according to Duncan's Multiple Range test.

Effect of Light intensity, soil moisture content, organic fertilizer and their interactions on some mineral nutrients content of *E. condylocarpa* leaves

Total nitrogen in dry leaves (mg g⁻¹)

Table 8 reveals that double interaction treatment L3OF2 increased total nitrogen content (TNC) significantly to 43.482 mg g⁻¹ compared to L1OF1 and L2OF1, which decreased TNC to 39.329 and 39.841 mg g⁻¹ respectively. Triple interaction treatment L1SM1OF2 increased total nitrogen content significantly to 45.111 mg g⁻¹ compared to L2SM2OF2, L2SM3OF1 and L2SM3OF1, which decreased TNC significantly to 38.992, 38.577, 37.333 mg g⁻¹ respectively. (Liu *et al.*, 2022) illustrated that light supply increased nutrient absorption, which increased photosynthetic rate, lead to plant growth.

Total phosphorus in dry leaves (mg g⁻¹)

Data recorded in Table 8 showed that L3 increased total phosphorus content (TPHC) significantly to 3.909 mg g⁻¹ compared to L1, and L2, which decreased total phosphorus content to 3.023, and 2.623 mg g⁻¹ respectively, as well as SM2 increased total phosphorus content to 3.537 mg g⁻¹ compared to SM1, which significantly decreased total phosphorus content to 2.723 mg g⁻¹. The double interaction treatments L3SM2, L3SM3, L3OF2, and SM2OF1 increased TPHC to 4.3344, 4.191, 4.217, and 3.769 mg g⁻¹ compared to other double interaction treatments. Triple interaction treatments L1SM1OF1, L1SM2OF1 and L1SM2OF2 increased TPHC significantly to 4.370, 4.421 and 4.268 mg g⁻¹ respectively compared to other triple interaction treatments. (Cheng *et al.*, 2014) found that increasing light intensity significantly enhanced phosphorus up take capacity from the soil by roots lead to plant growth.

Total potassium content (mg g⁻¹)

Table 8 reveals that OF2 increased total potassium content of dry leaves in spurge plants significantly to 5.285 mg g⁻¹ compared to OF1, which decreased TPC significantly to 4.820 mg g⁻¹. The double interactions L3SM2 and SM2OF2 significantly increased TPC to 6.178 and 6.015 mg g⁻¹ respectively compared to L3SM1, L3SM3, L3SM3, and SM3OF1 (4.719, 4.937, 4.726 mg g⁻¹ respectively). Triple interaction treatment L3SM2OF2 significantly increased TPSC to 6.724 mg g⁻¹ compared to other triple interaction treatments. application of organic fertilizer provide essential elements for plant growth, and nutrients supply capacity, showed that reducing field capacity significantly decrease growth, flowering, and biochemical test, this reduce can decrease the process cell division and cell elongation in plant cells (Fadhil *et al.*, 2024).

Manganese content in dry leaves (Mn) ppm

Table 8 displays that double interactions SM1OF1, SM1OF2, SM2OF1, SM3OF1, and SM3OF2 increased manganese content of leaves of spurge plant to 331.472, 369.580, 371.472, 322.311, 364.226 ppm respectively compared to SM2OF2 (271.069 ppm). Triple interactions L1SM1OF2, L1SM3OF2 and L3SM2OF1 increased Mn content significantly to 402.091, 417.366 and 418.476 ppm respectively compared to L1SM2OF2, L2SM2OF2, and L3SM2OF1, which decreased Mn content significantly to 252.010, 277.896, and 238.300 ppm respectively. (Liu *et al.*, 2023) found that light supply has a significant effect on absorption of nutrients such as manganese, which is a part of chlorophyll content lead to increased plant growth.

Zinc content in dry leaves (Zn) ppm

Table 8 showed that OF1 increased zinc content of leaves in spurge plant to 210.507 ppm compared to OF2 which decreased zinc content to 213.170 ppm. The double interaction L1SM1, L2SM2, L3SM2, L3SM3, L3OF2, and SM3OF1 increased Zn content significantly to 226.082, 219.360, 220.944, 226.334, 224.795, 225.291, and 228.066 ppm respectively compared to L1SM1, L2SM1, L1OF2, L2OF1 and SM3OF2 (198.610, 184.310, 195.818, 196.735, 198.274 ppm respectively). Triple interaction treatments L1SM1OF2, L2SM1OF1, L3SM1OF1 and L3SM3OF2 increased Zn content significantly to 228.775, 228.696, 231.609, 229.909 ppm respectively, compared to L2SM1OF2, L2SM3OF1, L3SM3OF2, L3SM1OF2, and L3SM2OF2 (185.193, 179.104, 189.533, 180.854, and 174.991 ppm respectively), these results agreed with those finding

by (Khaleel and Sarmamy, 2022). Effect of zinc on yields on plants under influence of stress led to increase yield of the plant.

Table 8. Effect of Light intensity, soil moisture, organic fertilizer on some mineral nutrients content of Spurge leaves

Treatments	Total nitrogen (mg g ⁻¹)	Total phosphorus (mg g ⁻¹)	K (mg g ⁻¹)	Mn (ppm)	Zn (ppm)
L1 (100%)	40.471 a	3.023 b	5.566 a	346.152 a	210.308 a
L2 (80%)	40.391 a	2.623 b	5.258 a	325.380 a	203.607 a
L3 (120%)	42.049 a	3.909 a	5.278 a	348.374 a	218.323 a
SM1 (100%) FC	40.173 a	2.723 b	5.158 a	350.367 a	206.096 a
SM2 (75%) FC	40.822 a	3.537 a	5.752 a	321.270 a	212.972 a
SM3 (50%) FC	41.917 a	3.295 ab	5.192 a	348.367 a	213.170 a
OF1 (0% control)	39.012 a	2.883 a	4.820 b	320.367 a	210.507 a
OF2 (10%)	40.641 a	2.806 a	5.285 a	314.269 a	192.509 b
L1SM1	39.238 a	2.540 c	5.537 abc	342.561 a	226.082 a
L1SM2	41.844 a	3.487 ab	6.039 ab	350.333 a	198.610 b
L1SM3	40.331 a	3.042 bc	5.123 abc	345.563 a	206.232 ab
L2SM1	40.006 a	2.439 c	5.219 abc	336.489 a	184.310 b
L2SM2	39.251 a	2.780 bc	5.041 bc	297.653 a	219.360 a
L2SM3	41.917 a	2.651 bc	5.516 abc	341.998 a	206.944 ab
L3SM1	41.274 a	3.191 abc	4.719 c	372.051 a	207.887 ab
L3SM2	41.371 a	4.344 a	6.178 a	315.825 a	220.749 a
L3SM3	43.503 a	4.191 a	4.937 c	357.246 a	226.334 a
L1OF1	39.329 b	2.902 bc	5.475 a	367.496 a	224.795 a
L1OF2	41.613 ab	3.144 bc	5.657 a	324.809 a	195.818 b
L2OF1	39.841 b	2.713 c	5.189 a	330.129 a	196.735 b
L2OF2	40.942 ab	2.534 c	5.328 a	320.630 a	210.480 ab
L3OF1	40.617 ab	3.601 ab	5.142 a	374.580 a	211.354 ab
L3OF2	43.482 a	4.217 a	5.414 a	322.167 a	225.291 a
SM1OF1	39.718 a	2.728 b	4.987 ab	331.153 a	206.950 ab
SM1OF2	40.627 a	2.719 b	5.329 abc	369.580 a	205.242 ab
SM2OF1	39.442 a	3.769 a	5.489 abc	371.472 a	220.695 ab
SM2OF2	42.203 a	3.305 ab	6.015 a	271.069 b	205.249 ab
SM3OF1	41.168 a	3.224 ab	4.726 c	322.311 a	228.066 a
SM3OF2	41.668 a	3.366 ab	5.658 ab	364.226 a	198.274 b
L1SM1OF1	41.896 abc	4.370 a	4.387 e	312.401abc	223.893 ab
L1SM1OF2	45.111 a	4.039 ab	5.487 b-e	402.091 a	228.775 a
L1SM2OF1	39.303 abc	4.421 a	5.987 abcd	379.640 ab	218.288 abc
L1SM2OF2	43.438 ab	4.268 a	6.369 abc	252.010 c	223.206 ab
L1SM3OF1	43.244 abc	3.317 abcd	5.176 cde	326.450 abc	219.490 ab
L1SM3OF2	39.304 abc	3.065 abcd	4.262 e	417.366 a	196.283 ab
L2SM1OF1	41.688 abc	2.673 bcd	5.053 de	311.196 abc	228.696 a
L2SM1OF2	42.146 abc	2.630 bcd	5.979 cde	372.799 ab	185.193 cd
L2SM2OF1	39.511 abc	3.261 abcd	5.129 cde	317.410 abc	221.570 ab
L2SM2OF2	38.992 bc	2.298 cd	4.953 de	277.896 bc	217.550 abc
L2SM3OF1	38.577 bc	2.037 d	5.266 cde	344.396 abc	179.104 c
L2SM3OF2	41.435 abc	2.840 bcd	5.171 cde	328.581 abc	189.533 bcd
L3SM1OF1	39.920 abc	2.630 bcd	4.738 de	373.338 ab	231.609 a

L3SM1OF2	40.743 abc	3.454 abc	5.509 b-e	317.788 abc	180.854 d
L3SM2OF1	39.513 abc	3.626 abc	5.353 b-e	418.476 a	220.229 ab
L3SM2OF2	44.177 ab	3.347 abcd	6.724 a	238.300 bc	174.991 d
L3SM3OF1	37.333 c	2.830 bcd	4.520 e	322.614 abc	222.255 ab
L3SM3OF2	41.143 abc	2.251 cd	6.553 ab	362.508 ab	229.909 a

*L: light intensity; SM: soil moisture; OF: organic fertilizer.

The means in each category of column followed by the same letters are not significantly different at $p < 0.05$ according to Duncan's Multiple Range test.

Conclusions

The results of study can conclude that there were significant differences in these three factors on their effects on the growth characteristics of *E. condylocarpa* plants. Light intensity (100%) increased number of leaves, root tuber fresh weight, root tuber dry weight, and chlorophyll a content of leaves, also light intensity (120%) increased biological yield of dry weight, root tuber fresh weight, total chlorophyll, and total protein content of leaves. Spurge plant required (100%) field capacity of water supply to significant increase the plant growth and biomass, as SM1 (100% FC) increased number of leaves, chlorophyll b content, and total soluble carbohydrates of leaves. Organic fertilizer (10%) increased stem diameter, total chlorophylls, total protein content, total soluble carbohydrates, proline content, and potassium content of leaves. Double interaction L3OF2 increased plant height, number of branches, tuber diameter, water content, tuber fresh weight, shoot fresh weight, chlorophyll a, total chlorophyll, carotenoid content, total nitrogen, total phosphorus, and zinc content. Triple interaction L1SM1OF2 increased plant height, tuber diameter, tuber fresh weight, carotenoid content, tuber fresh weight, shoot fresh weight, total nitrogen, manganese, and zinc content. The spurge plant required the 100% of field capacity of water supply and 120% of light intensity required to gain the highest plant growth and biomass. Application 10% of organic fertilizer to spurge plants necessary for high plant growth and biomass. Further studies are necessary about the combined nutrient elements with light intensity, to determine the proper fertilizer combinations to the plant growth, and good quality as a medicinal plant.

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Conflicts of interests

The authors confirm that there are no conflicts of interest in this research.

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Author contribution

The first author wrote the original draft, performed the experiment, and collected the data, the second author edit and finalize the manuscript. All authors read and agree to the submission of the manuscript to the journal.

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