Effect of amino acid proline on some growth characteristics of cowpea which exposed to drought stress

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Abstract. The study was conducted in Al-Youssoufia region which located in North West of Baghdad city during the growing season of 2018-2019. The experiment was aimed to demonstrate the optimum concentration of amino acid proline that reduce the effect of drought stress. By using three time for irrigation (4, 8, 12) day and four concentrations of proline (0, 20, 40, 60) mg. L\(^{-1}\) and their interaction on some growth characteristics: Root length, dry weight, nitrogen, phosphorous and potassium content, carbohydrate percentage and peroxidase activity in vegetative part. Data were statistically analysed to find out the least significant difference (LSD) between treatments at 0.05 level. The results indicated the increase of proline concentration from (0 to 60) mg.L\(^{-1}\) caused significant decrease in the average of growth characteristics and peroxidase activity unite.mg.proline\(^{-1}\) with increase in the average of irrigation periods under drought stress.

Keywords. Proline, Cowpea, drought stress.

1. Introduction

The Cowpea (Vigna unguiculata L.) is a specific type of small oval bean with black dot on it, and have different colors such as; red white, black and brown and although it is very popular for its flavor and delicious taste [1]. The cowpea contains all the essential vitamins and minerals including vitamins A, B and C, folic acid, iron, potassium, magnesium, calcium, selenium, sodium, zinc, copper and phosphorus [2]. People with diabetes can depend cowpea on their diet because it have magnesium in high levels which improve bone health and play a key role in carbohydrate metabolism [3], and can help the body to maintain balanced levels of blood sugar, and it essential for people with colitis because of its rich source of fiber and it can also improve the efficiency of digestion and help in eliminating urination problems [4] it used as a treatment for anemia and iron deficiency, and it is rich with antioxidants vitamin A and C which are benefit for the skin, and for hair, its solution prevent hair loss, and is very rich in vitamin B1 (Thiamine) there for play a role in preventing heart failure and controlling ventricles of the heart [5]. The treatment with amino acid proline it play positive role correlation between proline accumulation and plant stress, it plays three major roles during stress like...
as metal chelator, antioxidative defense molecule and a signaling molecule. Review of the literature indicates that a stressful environment results in an overproduction of proline in plants which in turn enhance stress tolerance by maintaining cell turgor or osmotic balance and stabilizing membranes, and minimize concentrations of reactive oxygen species (ROS) within normal ranges, thus preventing oxidative burst in plant [6]. Proline can enhanced stress tolerance when supplied exogenously at low concentration, but have a toxic effects when supplied exogenously at higher concentration. Plants are subjected to various types of environmental stresses, which include salinity, water deficit, temperature extremes, toxic metal ion concentration and UV radiation. The exogenous applied proline at seedling stage or at vegetative stage of Zea mays resulted in enhanced growth under water deficient environment [7]. The present study aimed to study the effect of increasing concentration of proline and irrigation times and their interaction on growth of cowpea plant and to determine the suitable concentration of proline acid that can avoid the decrease in water content in the plants.

2. Materials and Methods

The experiment was conducted in growth season at 2018-2019 in the Al-Youssoufia region which located in northwest of Baghdad city. The experiment designed at four levels of proline and three time of irrigation, (3x4x3) by using 30 plants in each treatment unit which was designed according to the Randomized Complete Block Design (R.C.B.D) with three replication.

2.1. Soil analysis

Top soil samples were taken from the (0-30) cm layers. Samples were air dried and sieved to a particle size (2 mm) for soil chemical analysis [8] the result of the chemical and physical properties of the soil used in the experiment.

| pH  | EC ds.m⁻¹ | N mg.kg⁻¹ | P mg.kg⁻¹ | Soil texture |
|-----|-----------|------------|-----------|--------------|
| 7.08| 2.6       | 0.132      | 23.10     | Sand g.Kg⁻¹  |
|     |           |            |           | Silt g.Kg⁻¹  |
|     |           |            |           | Clay g.Kg⁻¹  |
|     |           |            |           | 200          |
|     |           |            |           | 240          |
|     |           |            |           | 390          |

2.2. Studied characteristics

2.2.1. Dry weight (g)

Shoot dry weight were calculated by using sensitive balance after drying in an oven at temperature (60±0.2) C° until weight constant.

2.2.2. Root length

Root measurements were taken from the area associated with the stems to the furthest penetration from the soil and left in the water until the disposal of all clay.

2.2.3. Determination of the Nitrogen concentration (%)

To determine the nitrogen, known weight of plant samples, digested according to [9] method. Nitrogen was determined in the shoot by micro-Kjeldahl using the following equation:

\[ \%N = \frac{V_1 \times V_2 \times N_1 \times 14 \times 100}{A \times B \times 1000} \]

In which:
V1= HCl volume from the burette.

V2= Total volume of digested plant sample in (50) ml.

N1= Used HCl normality (0.005 N).

14= Nitrogen atomic weight.

100= Conversion to the percentage rate.

A= Digested plant sample solution in the distillation unit.

B= The weight of the dried plant digested sample.

1000= To convert mg. to g. unit.

2.2.4. Determination of soluble carbohydrate percentage

The stock solution of glucose and fructose is prepared by solute (50) gm of glucose and (50) gm of fructose in one liter distilled water, then prepared many concentration of them like (0.0, 0.2, 0.4, 0.6, 0.8, and 1.0) mg.L⁻¹, (1) ml of each concentration and (1) ml of phenol indicator (5%) is added to each concentration, mixture is read by spectrophotometer at (488) nm wave length. From the relationship between the concentration curve is drawn [10].

2.2.5. Determination of total phosphorus content (mg,plant⁻¹)

Estimate phosphorus concentration in spectrophotometer digested samples and at length 882 nm according to [11], the concentration was multiplied by plant dry weight to estimate the total phosphorus content.

2.2.6. Determination of total potassium content (mg,plant⁻¹)

Potassium concentration in digested samples was first determined by the flame spectrophotometer according to [8] it was calculated by multiplying the potassium concentration by dry weight of plant to estimate total potassium content.

2.2.7. Determination of antioxidant enzyme (Super oxide dismutase) (SOD) U.ml⁻¹

Estimated by method [12] by used reagents:

- Nitro blue tetrazolioum.
- Ribovlavin

2.2.8. Prepare solution volume

Table 2. Preparation of solution.

| Solution | 2 | 2 | 3 | 4 | Total volume |
|----------|---|---|---|---|--------------|
| Component | Potassium phosphate buffer 82.4 ml.mol | Amino acid L. methionine 14 ml.mol. | Tritron-X 1% | 14.4 ml.mol + 10 ml d.w | - |
Prepare riboflavin in solution 47.7 micromole by dissolving 0.0018 gram with distilled water and complete volume to 100 ml of distilled water

2.2.9. Method of work

Crush 1 gm of soft vegetative tissue from 90-day-old sample with 10 ml potassium phosphate buffer (0.1) molar and kept under the temperature of 3°C refrigeration for 24 hours and put it on centrifuge at 1000 rpm for quart of an hour, 1.5 ml from total volume above in the tubes and add 40 microliter of the solution filtrate the transferred to spectrophotometer for absorbance reading at 560 wavelength and comparison with blank sample which did not contain plant tissue were added to then just distilled water, samples were then brought to light using two lamps (20 watt) in box for ten minutes then read the absorbance below the same wavelength the standard was drawn and the inhibitor ratio was calculated from the follow equation:

\[
\text{Enzyme activity} = \frac{\text{Sample inhibition ratio}}{\text{Highest inhibition ratio}} \times \frac{\text{Dilution coefficient(D.F)}}{\text{Volume of samples}} = \frac{60}{40}
\]

3. Results and Discussion

Effect of proline on some growth characteristics of cowpea plant exposed to water stress:

3.1. Dry weight

In Table (3) showed that there was significant increasing at (P= 0.05) in the dry weight with the increasing proline concentration without irrigation time and irrigation time without proline, the dry weight means increased with increasing in the proline levels from (0 to 40) gm.plant-1 this resulted significant in the average dry weight, an increase of (38.397%). The results also indicated a significant increase in the rate dry weight with increases the irrigation time from (4 to 8) day an increase of (7.710%). The effect of bilateral overlap of the study workers showed results, there was significant increase in this characteristic. The highest value for dry weight was at concentration 40 mg.L⁻¹ proline acid and (8) day irrigation time, where it reached (2.704 gm.plant⁻¹) compared with (0) mg.L⁻¹ proline and (4 day) where it reached to (1.995 gm.plant⁻¹) an increase of (35.538%). We conclude that the spacing of irrigation time affects dry weight as it leads to a decrease in photosynthesis rate as well as few absorption of important nutrient and consequently in metabolism, it is related reduced dry weight by low plant elongation rate and low leaf area rate, where dry matter is the net production of photosynthesis and depends on the balance between two processes photosynthesis and respiration, therefore spraying with proline acid increased that plant ability to build photosynthesis by controlling the opening and closing of stomata the ability of plant to build chlorophyll pigments and prevent them from decomposing and thus helped to balance taking CO₂ and water loss during transpiration [16]. It is believed that the effects of saturation mater deficit and the accumulation of ABA and pick up the leaves, close the stomata, decrease the CO₂ gas representation and increase the concentration of IAA-oxidase enzyme which oxidation of natural oxygen in the area of separation of the abscission zone which caused accumulation of ethylene hormone that causes the distraction of chlorophyll [17]. It is believed that the lack of water leads to an increase accumulation of hydrogen peroxide (H₂O₂) and inhibition of energy production by enzyme NADPH oxidase [18].
### Table 3. Effect of different levels of amino acid proline on length of root (cm) of cowpea plant which exposure to drought stress.

| Irrigation time | Concentrations of spraying proline (mg.L\(^{-1}\)) | Mean |
|----------------|-----------------------------------------------|------|
|                | 0          | 20 | 40 | 60 |
| Every 4 days   | 4.50       | 5.53 | 6.40 | 4.13 | 5.14 |
| Every 8 days   | 4.30       | 5.03 | 6.17 | 6.07 | 5.39 |
| Every 12 days  | 3.20       | 4.25 | 5.23 | 5.07 | 4.95 |
| LSD (0.05)     |            | 1.25 |     |     | 0.62 |
| Mean           | 3.00       | 4.94 | 5.93 | 5.29 |     |
| LSD (0.05)     |            | 0.72 |     |     |     |

#### 3.2. Root length

In Table (4) it can be observed that there was significant increasing in the root length with increasing in the proline without irrigation time in (40) mg.L\(^{-1}\) concentration which were (5.93) cm root length. In the irrigation time without proline we observed that there was significant increasing in the root length with increasing in the irrigation time at (8) day compared with other irrigation time which recorded (5.93) cm root length compared with other periods. The proline with irrigation time interaction showed that the increasing in the proline and irrigation time levels from (40 mg.L\(^{-1}\) and 8 day) led to significant increasing in the levels root length values at rat of (6.17) cm compared with another means. This may be due to increased dehydration causes to dysfunction of the internal hormonal system so down the gibberellic acid hormone, this leads accumulation of abscisic acid in the plant which reduces the division and size of cells in the apical areas [13]. The water stress is thought to be leads to increase the activity of free radicals of the effective oxygen and nitrogen group and inability for that the plant is inhibited and scavenged in chloroplasts and mitochondria stops the process CO\(_2\) stabilization and accumulation of dry matter [14], for that inhibits root growth, and water stress is thought to decrease in the oxygen content due to the activity of the IAA oxidase enzyme which prevents the descent oxygen and the factor of the leaves which causes weakness in growth of root [15].

### Table 4. Effect of different levels of amino acid proline on dry weight (g) of cowpea plant which exposure to drought stress.

| Irrigation time | Concentrations of spraying proline (mg.L\(^{-1}\)) | Mean |
|----------------|-----------------------------------------------|------|
|                | 0          | 20 | 40 | 60 |
| Every 4 days   | 1.995      | 2.317 | 2.571 | 1.780 | 2.166 |
| Every 8 days   | 1.850      | 2.317 | 2.704 | 2.616 | 2.333 |
| Every 12 days  | 1.545      | 1.805 | 2.186 | 2.432 | 1.992 |
| LSD (0.05)     |            | 0.396 |     |     | 0.198 |
| Mean           | 1.797      | 2.094 | 2.487 | 2.276 |     |
| LSD (0.05)     |            | 0.229 |     |     |     |

#### 3.3. Effect of different levels of amino acid proline on content of macro elements (NPK) of cowpea plant which exposure to drought stress

In Tables (5, 6, 7) showed that there was significant decrease in the means of nitrogen phosphor and potassium which affect by drought stress when irrigation intervals diverged from 4 days to 12 days the means decreased specials at 12 days an decreased of (8.070, 8.994, 20.717) % for N, P and K sequentially compared to 4 day treatment. The proline without irrigation time we observe through same Tables there was increased (NPK) means in concentration of proline at (40) mg.L\(^{-1}\) an increase of (38.372, 50.000, 57.418)% sequentially compared to control treatment without spraying proline (0) mg.L\(^{-1}\). The interaction between treatment was significant, an increase at (40 mg.L\(^{-1}\) and 8 day) for N
and P and (20 mg.L⁻¹ and 4 day) for K (35.523, 51.445, 74.944) % compared with (0) proline and (4) day irrigation time. Metabolism disorder of nucleic acid, amine acid and protein where it is believed to affect straining dehydration in polyribosomes and low content in polyribosomes ATP levels and nitrogen content and effect on metabolism disorder due to the increase in effective oxygen compounds, this leads to an increase in the activity of nitrat-redutase and hydrolysis of nucleic acid that effect the absorption of mineral [19]. It is also believed that the cause of low protein content is an increase in activity enzymes such as lipoxygenase, protease and RNase are caused by drought stress and they act on reducing nucleic acid metabolism, as well the glutathione concentration to be increasing at extreme stress to release the accumulation of glutamate resulting from the decomposition of organelles and cell membranes [20], polyamines like glutathione and some amino acids such as proline ammonia modification to maintains the cell's osmotic pressures resulting from the effect of cell water loss due to dehydration which ultimately leads to increase cell osmosis and water absorption [21].

Table 5. Effect of different levels of amino acid proline on nitrogen percentage (%) in vegetative total of cowpea plant which exposure to drought stress.

| Irrigation time | Concentrations of spraying proline (mg.L⁻¹) | Mean   |
|----------------|---------------------------------------------|--------|
|                | 0   | 20  | 40  | 60  |        |
| Every 4 days   | 1.050 | 1.220 | 1.353 | 0.937 | 1.140 |
| Every 8 days   | 0.973 | 1.137 | 1.423 | 1.377 | 1.228 |
| Every 12 days  | 0.813 | 0.950 | 1.150 | 1.280 | 1.048 |
| LSD (0.05)     |       | 0.209 |        |        | 0.104 |
| Mean           | 0.946 | 1.102 | 1.309 | 1.198 |        |
| LSD (0.05)     |       | 0.121 |        |        |        |

Table 6. Effect of different levels of amino acid proline on phosphorus percentage (%) in vegetative total of cowpea plant which exposure to drought stress.

| Irrigation time | Concentrations of spraying proline (mg.L⁻¹) | Mean   |
|----------------|---------------------------------------------|--------|
|                | 0   | 20  | 40  | 60  |        |
| Every 4 days   | 0.173 | 0.204 | 0.246 | 0.136 | 0.189 |
| Every 8 days   | 0.162 | 0.189 | 0.262 | 0.229 | 0.210 |
| Every 12 days  | 0.126 | 0.158 | 0.183 | 0.219 | 0.172 |
| LSD (0.05)     |       | 0.049 |        |        | 0.024 |
| Mean           | 0.154 | 0.184 | 0.231 | 0.192 |        |
| LSD (0.05)     |       | 0.028 |        |        |        |

Table 7. Effect of different levels of amino acid proline on potassium percentage (%) in vegetative total of cowpea plant which exposure to drought stress.

| Irrigation time | Concentrations of spraying proline (mg.L⁻¹) | Mean   |
|----------------|---------------------------------------------|--------|
|                | 0   | 20  | 40  | 60  |        |
| Every 4 days   | 1.353 | 2.367 | 2.210 | 1.987 | 1.979 |
| Every 8 days   | 1.270 | 1.640 | 2.113 | 1.763 | 1.696 |
| Every 12 days  | 1.260 | 1.630 | 1.787 | 1.600 | 1.569 |
| LSD (0.05)     |       | 0.282 |        |        | 0.141 |
| Mean           | 1.294 | 1.879 | 2.037 | 1.783 |        |
| LSD (0.05)     |       | 0.163 |        |        |        |

3.4. Carbohydrate concentration

In Table (8) showed that there was significant decrease in the means of carbohydrate under effect of irrigation time from (4 to 12) day the means decreased carbohydrate and decreased of (26.23%)
compared with (4) day. As for the effect of proline without irrigation periods, the effect was significant in increasing the percentage of carbohydrates at concentration (20 mg.L\(^{-1}\)) an increase rate estimated at (58.87\%) compared with zero concentration. The interaction between proline and irrigation time was significant at (40 mg.L\(^{-1}\)) and (4 day) an estimated increase at (74.9\%) carbohydrate compared with (0) proline and (4 day) irrigation time. The reduction of carbohydrates are due to the dehydration which effect in photosynthesis as the effect of water tension begins to close the stomata first accompanied by a shortage of the amount of carbon dioxide entering and installed in the leaves results in a significant drop in photosynthesis and this affects the amount of nutrients finally in the overall growth of plant [22].The increase in the percentage of carbohydrates due to effect of proline in increasing leaf area and number of leaves, as well as increasing leaf content of chlorophyll this will increase the efficiency of photosynthesis and then produce carbohydrates [23].

**Table 8.** Effect of different levels of amino acid proline on carbohydrate percentage (%) in vegetative total of cowpea plant which exposure to drought stress.

| Irrigation time | Concentrations of spraying proline (mg.L\(^{-1}\)) | Mean (\%) |
|-----------------|-----------------------------------------------|-----------|
|                 | 0                                      | 20        | 40        | 60        |
| Every 4 days    | 15.15                                  | 24.66     | 26.42     | 22.19     | 22.11     |
| Every 8 days    | 14.09                                  | 23.61     | 18.32     | 19.73     | 18.94     |
| Every 12 days   | 12.86                                  | 18.60     | 17.23     | 16.56     | 16.31     |
| LSD (0.05)      |                                        | 2.78      |           |           | 1.39      |
| Mean            |                                        | 14.03     | 22.29     | 20.66     | 19.49     |
| LSD (0.05)      |                                        |           |           |           | 1.60      |

3.5. Peroxidase enzyme

In Table (9) showed that there was significant at all treatment, the means of peroxidase enzyme under effect of irrigation time increased by increasing the irrigation time, and the time of (12 day) highest value of the enzyme an increase of (88.46 unit. mg.plant\(^{-1}\)) compared with (4 day) irrigation treatment. As for the addition of increased concentration of proline we note decrease in the content of the peroxidase enzyme especially at concentration 60 unit.mg.plant\(^{-1}\) and a decreased as (36.36 unit.mg.plant\(^{-1}\)). The interaction between increased proline spraying and (8 day) irrigation time inhibited the activity content of peroxidase enzyme and decreased as (46.67\%) compared with (0) proline unit (4) day irrigation time. Irrigation spacing led to an increase in the activity of the enzymatic oxidation system, which includes super enzymes SOD and peroxide resulting from the activity of oxidized enzymes and free radicals be mater stress and reduced scavenging [24]. Increasing the activity of the enzyme peroxidase by increasing the production of hydroxyl radical and single oxygen with water stress effect is also believed to increase concentration the activity of malonedihyde is vital guide for the plant to provoke antioxidant production [25].

**Table 9.** Effect of different levels of amino acid proline on plant content of peroxidase enzyme (Unit. mg protein\(^{-1}\)) in vegetative total of cowpea plant which exposure to drought stress.

| Irrigation time | Concentrations of spraying proline (mg.L\(^{-1}\)) | Mean (unit.mg.plant\(^{-1}\)) |
|-----------------|-----------------------------------------------|-----------------------------|
|                 | 0                                      | 20        | 40        | 60        |
| Every 4 days    | 0.03                                  | 0.028     | 0.022     | 0.026     | 0.026     |
| Every 8 days    | 0.039                                | 0.032     | 0.024     | 0.016     | 0.029     |
| Every 12 days   | 0.059                                | 0.050     | 0.048     | 0.042     | 0.049     |
| LSD (0.05)      |                                        | 0.008     |           |           | 0.004     |
| Mean            |                                        | 0.044     | 0.036     | 0.031     | 0.028     |
| LSD (0.05)      |                                        |           |           |           | 1.60      |
4. References

[1] Gonçalves A, Goufo P, Barros A, Domínguez-Perles R, Trindade H, Rosa EAS, Ferreira L and Rodrigues M 2016 Cowpea (Vigna unguiculata L. Walp), a renewed multipurpose crop for a more sustainable agri-food system: nutritional advantages and constraints J. Sci. Food Agric. 96 2941.

[2] Olusanya AO, Gidon OO, Emmanuel TK, Akinhide MA, Aash T and Ademayowa AO 2016 Yield and growth characteristics of cowpea (Vigna unguiculata) as effected by prior heat stress and nutrient addition African J. Agric. Res. 11 2269.

[3] Silveira JAG, Costa RCL, Viegas RA, Oliveira JTA and Figueiredo MVB 2003 N-compound accumulation and carbohydrate shortage on N2 fixation in drought-stressed and rewarded cowpea plants.

[4] Francar FP 1999 Alteration of water stress effects in cowpea by Bradyrhizobium spp. Inoculation Plant Soil 207 67.

[5] Carvalho M, Lino-Neto T, Rosa E and Carnide V 2017 Cowpea a legume crop for a challenging environment J. Sci. Agric. 97 4273.

[6] Cvíková M, Gemperlová L, Martincová O and Vanková R 2013 Effect drought and combined dough and heat stress on polyamine metabolism in proline over producing tobacco plants Plant Physiol Biochem. 73 7.

[7] Ali O, Ashraf M and Athor HU 2007 Exogenously applied proline at different growth stages enhances growth of two maize cultivars grown under water deficit conditions Pak. J. Bot. 39 1133.

[8] Page AL, Miller RH and Kenney DR 1982 Method of soil analysis, 2nd (ed) Argon. 9, publisher, Madisian, Wiconsin.

[9] Gresser MS and Parson JW 1979 Sulpheric perchloric acid digestion of plant material for the determination of nitrogen, phosphorus, calcium and magnesium Anal. Chem. Acat. 109 431.

[10] Herbert D, Philips PJ and Strange RE 1991 Methods in microbiology Academic Press. London.

[11] Matt KJ 1970 Colorimetric determination of phosphorus in soil and plant materials with ascorbic acid Soil, Sci. 109 214.

[12] Beyer FW and Fridowich I 1987 Assaying for superoxide dismutase activity. Some large consequences of minor changes in conditions Anal. Biochem. 161 559.

[13] Jain VK 2010 Fundamentals of plant physiology S. Chand & Company Ltd.

[14] Nobel PS 2009 Physicochemical and environmental plant physiology 4th ed. Elsevier lac. Oxford. UK. 635.

[15] Shahhid AA 2013 Physiology of reconstruction in sub-plants installed and under proof and proposed Baghdad, Iraq 228.

[16] Raven JA 2002 Selection pressures on stomatal evolution New Phytol. 153 371.

[17] Rao, KVM, Raghavendra AS and Redoly KJ 2006 Physiology and molecular biology of stress tolerance in plants Springer. Dordrecht, Netherlands 345.

[18] Cheseman IM 2007 Hydrogen peroxide and plant stress, a challenging relationship Plant Stress 1 4.

[19] Igor CA, Gonzales EM, Morino D, Ladera R, Larranazar E and Quintana E 2011 Physiological response of legume nodule to drought Plant Stress. Sci. 24.

[20] Rao, NKS, Shivashnakara KS and Laxman RH 2016 Abiotic stress physiology of horticultural crops Springer. India: 368.

[21] Dawood MG 2016 Influence of osmoregulators on plant tolerance to water stress Sci. Agri. 13 42.

[22] Singh BB, Mai-odomi Y and Terao T 1999 A simple screening method for drought tolerance in cowpea Indian J. Genet. 59: 211-220.

[23] Bradford KJ and Hsiao TC 1982 Physiological responses to moderate water stress 263.
Ahari AK 2006 A study of superoxide dismutase activity and superoxide production in kiwi fruit MSc. Thesis. University of Canterbury

Shankers AK and Ventateswarlu B 2011 Abiotic stress response in plant-physiological biochemical and genetic perspectives. INTECH. Pup. Rijeka. Croatia 440.