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PHYSIOLOGICAL PARTICULARITIES OF *PORTULACA OLERACEA L.* PLANTS

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ABSTRACT

Portulaca oleracea L., considered by many a weed, is in fact a plant with multiple food and medicinal values, and with a specific adaptation to stress conditions.

Grown in water supply option conditions, the plant has a C4 type metabolism, but in drought conditions, it uses the way of closing the stomata during the day, achieving a CAM type metabolism. The high values of the stomatal conductance recorded in the dark and the high contentof malic acid in the leaves especially in the morning, indicate this adaptation.

Plants exposed to water stress also showed higher values of suction force and higher percentages of bound water.

INTRODUCTION

Common purslane, *Portulaca oleracea*, is a highly variable, weedy plant in the (*Portulacaceae*) family with a wide distribution. Although it is likely native to North Africa, the Middle East, and the Indian subcontinent, it had reached North America by pre-Columbian times and was in Europe by the late 16 th century. It is now naturalized in most parts of the world, both tropical and temperate – equally at home in flower beds, cultivated fields, and roadsides or other disturbed or waste places. It has been grown for more than 4,000 years as a food and medicinal plant and is still cultivated in many places today. It is considered quite nutritious because it is unusually high in omega-3 fatty acids (found mostly in fish and flax seeds) and contains significant amounts of vitamins A and C, as well as calcium, iron, magnesium and potassium and antioxidants.
https://hort.extension.wisc.edu/articles/common-purslane-portulaca-oleracea/

P. oleracea can be used as a demulcent, diuretic, anti inflammatory and antibiotic (Cowper, 1996).

From a typical or disturbed habitat, purslane grows rapidly, producing flowers, fruits and seeds within 6 weeks of germination. It has a wide tolerance of photoperiod, light intensity, temperature, moisture and soil type. Seeds germinate under conditions that enhance the survival of seedlings. C4 metabolism allows *P. oleracea* to optimize photosynthesis in conditions of high heat and bright sunlight while enduring periods of limited water availability (Koch and Kennedy, 1982).

Lara et al. (2003) suggested that there is an induction of a Crassulacean acid-like metabolism (CAM) after 21-23 days of drought stress in *P. oleracea.*

P. oleracea appears to be an excellent candidate for inclusion in saline drainage water reuse systems (Grieve and Suarez, 1997). It is highly tolerant of both chloride- and sulphate-dominated salinities, is a moderate selenium accumulator and a valuable vegetable crop for human consumption and for livestock forage. It is also a source of a gum with emulsification properties that can be used in the food industry (Garti et al., 1999).

El-Keblawy and Al-Ansari (2000) investigated the effects of site of origin, time of seed maturation and seed age on germination behaviour. Light is required for germination, but the temperature requirement is variable. Seeds can germinate at 10°C in the northern USA and in India, seeds germinate over the range 10-40°C, but not above 50°C. Germination response to light and temperature varies according to the site of origin and the time of seed maturation. In the dry season, seeds that developed on the upper 20% of the plant were less dormant than seeds from the lower 20%.
(https://www.cabi.org/isc/datasheet/43609).

MATERIAL AND METHOD

The experiments carried out between June and September 2021 aimed at knowing the physiological particularities of the *Portulacaoleracea* plants (fig. 1).

Fig. 1.*Portulacaoleracea L.*

Portulacaoleracea is an annual herbaceous plant commonly found in southern Romania, especially in vegetable crops.
Stems are cylindrical, up to 30 cm long, 2-3 mm in diameter, green or red, swollen at the nodes, smooth, glabrous apart from the leaf axils, and diffusely branched, and the internodes are 1.5–3.5 cm in length. Purslane leaves are alternate flat, fleshy, having variable shapes, obovate, 1–5 cm long, 0.5–2 cm across, obtuse or slightly notched at the apex, tapering at base, sessile or indistinctly petiolate, glabrous, smooth, and waxy on the upper surface, with entire margin, small stipules, and cluster of hairs up to 1 mm long (Md. Kamal Uddin, 2014).

Flowering initiates during June to September. The flowers form groups of two to five at the tips of the stems.

The flowers are minute or small having yellow, color with five petals and typically open only on hot and sunny days from mid-morning to early afternoon. Fruit consists of almost round to egg-shaped capsules, usually about 4–8 mm long that open around the middle to release the seeds. Seeds are tiny, less than 1 mm in diameter, circular to egg shaped, flattened, and brown to black with a white point of attachment. Numerous seeds are produced. (Md. Kamal Uddin, 2014).

After germination, purslane branches almost immediately. Flowers can be produced in day lengths from 4-24 hours. There is no flowering photoperiod. Capsule production and overall plant growth increase with day length. Capsules can mature under soil conditions of high or low moisture. Flowers will not open on cloudy days or days when the temperature is below 21°C. When opened, they remain open for four hours. The flowers are self-fertile and do not exhibit apomixis. No insect pollinators have been observed during a three-year study. Some investigators have said that the flowers are wind-pollinated, but the pollen is very sticky, a characteristic that is not present in windborne pollen (https://www.cabi.org/isc/datasheet/43609).

Vegetative reproduction can occur by the development of adventitious roots from the base of cut shoots, but there is no evidence of adventitious rooting from unwounded shoots(https://hort.extension.wisc.edu/articles/common-purslane-portulaca-oleracea/) Purslane grows in full sun in almost any soil, from muck high in organic matter to heavy clay. It does best in warm weather, and young plants will remain small and stunted when conditions are cool. C4 metabolism allows *P. oleracea* to optimize photosynthesis in conditions of high heat and bright sunlight while enduring periods of limited water availability (Koch and Kennedy, 1982). Lara et al. (2003) suggested that there is an induction of a *Crassulacean acid metabolism* (CAM) after 21-23 days of drought stress in *P. oleracea.*

Determinations were performed on plants grown on dry and irrigated clay soil and the results were compared.

The analyzed physiological indices have been the photosynthesis intensity, transpiration intensity,stomatal conductance, total water content, the water types (bound and unbound water), the pHof the cellular juice, the suction force, the content of pigments and the amount of malic acid.

Photosynthesis, transpiration and stomatal conductance were determined with the portable Lci apparatus.

The total water content was determined gravimetrically by drying the plant material at the oven at 105 ^{0}C.The water forms (bound and unbound) were determined by the Artihovski method (Boldor O., 1983).

The suction force of the parenchyma was determined by immersing equal portions of leaves in solutions with different concentrations of sucrose, determining the isotonic solution and enforcing Avogadro's law (Boldor O., 1983).

The pH of the cellular juice has been determined with a Hanna portable pH meter from the juice obtained after pressing the vegetal material with a specially designed stainless steel press.

The quantity of chlorophyll pigments from the leaves has been determined with the Minolta chlorophyll Meter.

The amount of malic acid in the leaves was determined by the chromatographic method. The method was performed with a Surveyor Thermo Electron system at 10°C by using a potassium dihydrogen orthophosphate buffer (pH 2.8) as mobile phase, an Hypersil Gold aQ Analytical Column and diode array detection at λ=214 nm (NourVioleta et al, 2010).

RESULTS AND DISCUSSIONS

The total water content of leaves

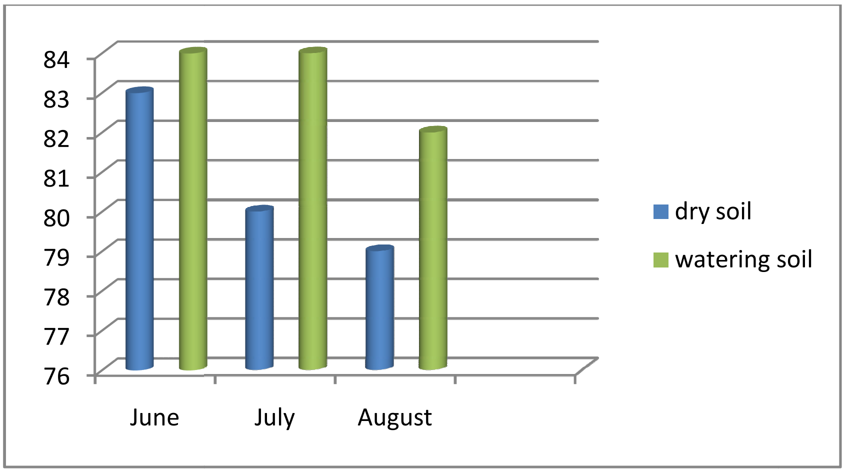
The total water content of the leaves showed insignificant variations in the plants grown on irrigated land. On dry soil, the percentage of total water was 83% in June, but reached 79% in August (graph 1).

The free and bound water

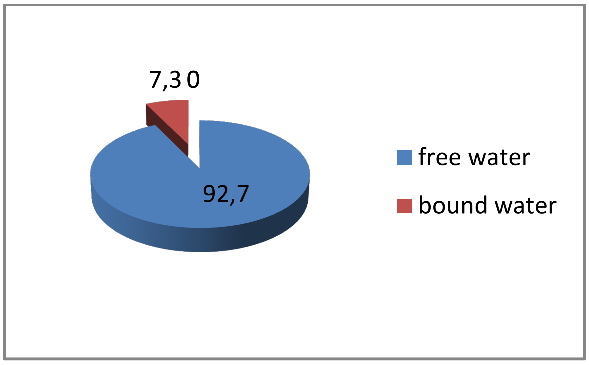
The determinations made in August showed significant differences in the content of the two forms of water. In plants grown on irrigated soil, bound water was minimal (7.3%) (graph 2).

In the leaves of plants grown on dry soil, the percentage of bound water increased to 21.9%(graph 3).

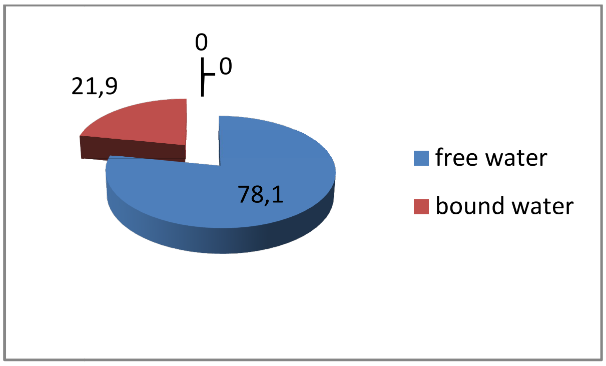
Increasing the percentage of bound water in plants that grow on dry soil is an adaptation that ensures drought resistance.



Graph. 1. The total water content (%) of *PortulacaoleraceaL.*leaves in watering and dry soil



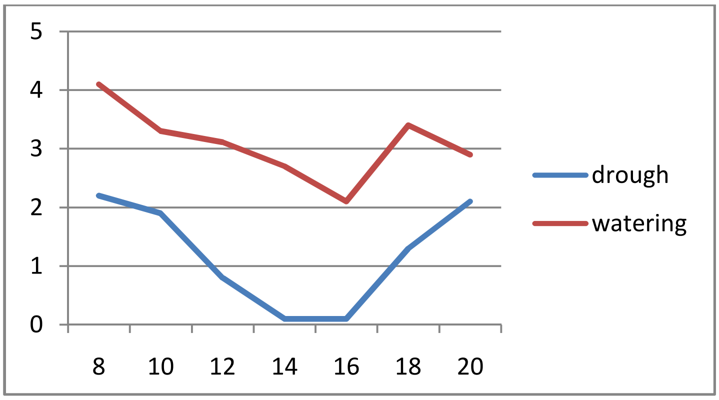
Graph 2.The content in bound and free water in *Portulacaoleracea*plants normally supplied with water during the summer (%)



Graph 3.The content in bound and free water (%) in *Portulacaoleracea*plants grown on dry soil during the summer

The transpiration of leaves

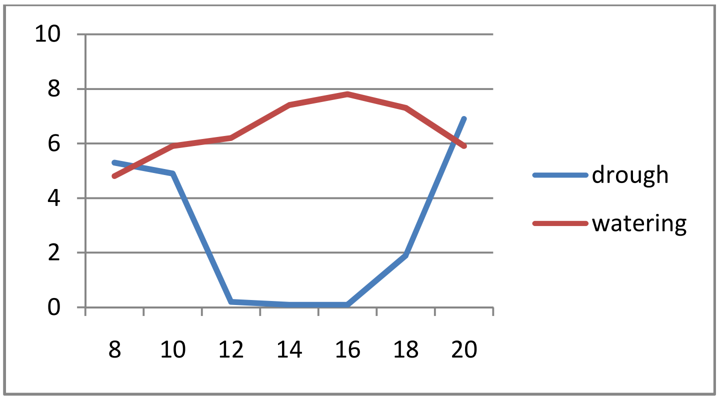
The intensity of transpiration was determined at different time intervals during the day, to make the graph of diurnal variation in both variants. The data obtained indicate first of all that the plant has low values of transpiration, regardless of the degree of water supply.
In plants subjected to water stress, the process stops after the first hours of the morning and resumes in the evening, but with low values (graph 4).
Suppressing transpiration after the first hours of the morning in non-irrigated plants ensures that a relatively constant water content is maintained during the day. This way of stopping transpiration is specific to CAM plants. The data agree with those in the literature that indicate such a metabolism in some *Portulaca* species (Koch and Kennedy, 1982,Lara et al.,2003, CallegariRenata et al., 2020).



Graph. 4. The diurnal variation of leaves transpiration (mmol / m ^{2} / s)

The intensity of photosynthesis

Graph 5 shows an evolution of photosynthesis similar to the process of transpiration. Thus, in plants grown in drought conditions there is a significant reduction in photosynthesis after 10 am. The process intensifies in the evening and exceeds the value recorded at 8 am.In plants located on irrigated soil, photosynthesis shows insignificant variations during the day.



Graph 5.The diurnal variation of photosynthesis (μmol /m^2 /s)

C4 metabolism allows *P. oleracea* to optimize photosynthesis in conditions of high heat and bright sunlight while enduring periods of limited water availability (Koch and Kennedy, 1982). Lara et al. (2003) suggested that there is an induction of a *Crassulacean acid-like metabolism* (CAM) after 21-23 days of drought stress in *P. oleracea.*

CallegariRenata et al. (2020) characterized the morphologic features of the collected species and the impact of water availability on CAM photosynthesis between the genotypes investigated by comparing CAM-related features. For this purpose, one-month-old plants were kept next to each other in well-watered or dry conditions for 30 days or exposed to drought for 30 days, followed by two days of complete rejuvenation. To prevent plant death, drought treatment consisted of water retention for ten consecutive days, followed by a period of 20 days in which a small volume of water (10 ml) was added to the pots whenever the drought content groundwater reached values close to zero (usually every four days). Drought treatment has promoted a marked reduction in plant size in all genotypes compared to well-watered counterparts.

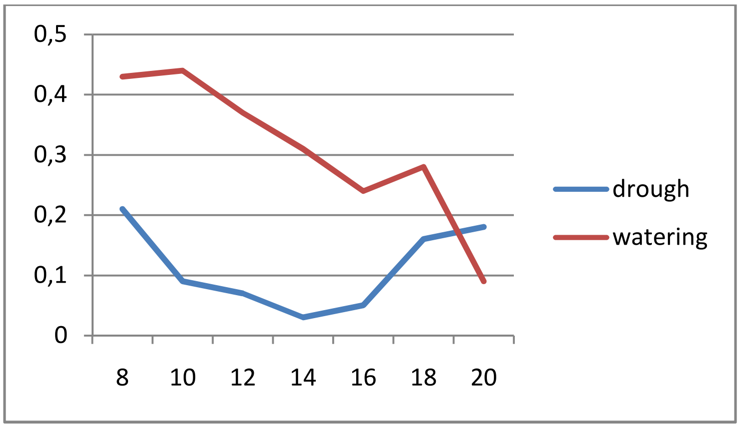
Stomatal conductance

Stomatal conductance directly modifies plant water relations and photosynthesis.

Many studies have explored the relationship between drought stress and stomatal conductance. Through these experiments, researchers have found that a drought resistant plant regulates its transpiration rate via stomatal conductance. This minimizes water loss and allows the plant to survive under low water conditions (Li, Yuping, 2017).

While variations in light are the most diurnally fluctuating factor modulating gs in many environments, changes in other variables also influence gs; for example, stomata can exert a major control of assimilation under low humidity or high (Ball et al. 1987,Damour et al. 2010 quoted by Grace et al, 2016).

The stomatal conductance of Portulacaoleracea plants exposed to water stress shows significant variations during the day(graph 6). Very high values recorded in the evening indicate a behavior similar to CAM plants.



Graph 6. The diurnal variation of stomatal conductance (mol /m^2 /s)

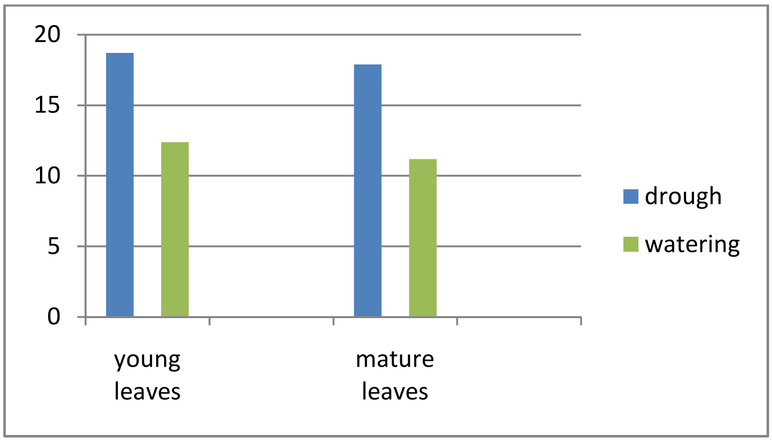
Many environmental factors affecting stomatal conductance have been intensively studied, but temperature has been largely neglected, although it is one of the fastest changing environmental variables and is increasing due to climate change (Urban J., 2017).As the temperature rises, so did the plants transpiration at least the isohydric ones, adjust their GS in response to the water potential of the leaves (Klein T., 2014).

The suction force of the parenchyma

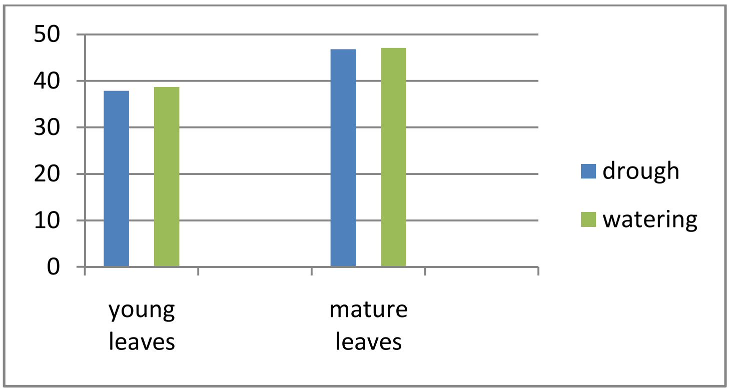
The suction force of the leaves increases as they dehydrate. In plants grown on dry soil, the average determinations indicate a value of 18.7 atm. For plants that have been watered, the maximum value recorded is 12.4 atm (graph 7). The highest values of suction force are recorded in both variants in young leaves.

The content in clorophyll pigments

The amount of chlorophyll was determined in the young and mature leaves of both variants. The graphical data (graph 8) indicate a lower amount in non-wetted plants, but the differences are not significant. Thus, it can be considered that this species water stress does not modify the synthesis of pigments. This can demonstrate that the plant is naturally adapted to grow in dry environments. The reduction of photosynthesis is therefore not caused by the lower content in pigments.



Graph 7. The suction force of leaves (atm)

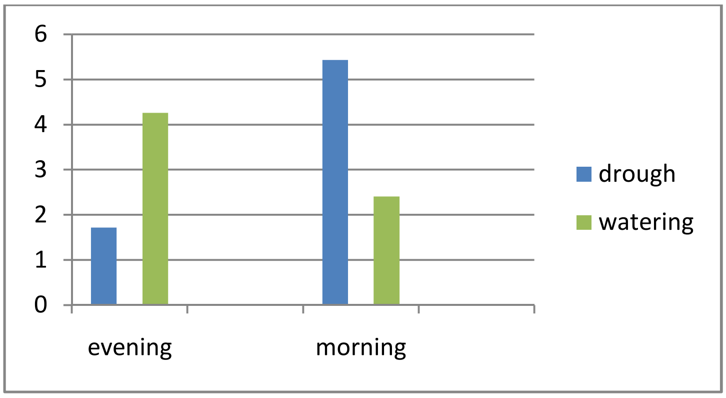


Graph.8. The content in clorophyll pigments (SPAD unities)

The amount of malic acid in the leaves

The malic acid content was determined in the leaves detached from the plants in the evening and in the morning. The large amount of malic acid determined in the morning in plants grown in drought conditions indicates that these plants adapt their metabolism in this way to save water(graph 9). During the day, closed stomata reduce water loss, but also suppress photosynthesis. During the night the stomata open and carbon dioxide enters and the synthesis of malic acid takes place. The differences registered in the two variants indicate that the species *Portulacaoleracea* has a dual behavior. If there is water in the environment, the synthesis takes place during the day. In times of drought, the plant behaves like a CAM plant.

Studies conducted on several species of *Portulaca* have highlighted this aspect.Under well-watered conditions, P. *papillatostellulata, oleracea, trituberculata*and *edulis*, the latter at very low levels, displayed accumulation of malate overnight (positive Δmalate), whereas malate levels in the remaining genotypes decreased overnight (negative Δmalate). All genotypes presented positive Δmalate under drought treatment, with the lowest and highest Δmalate values (26.7 and 157.2 μmol malate per g dry weight, respectively) detected in oleracea and trituberculata, respectively. Nocturnal malate accumulation was consistently reduced following rewatering in all subspecies (CallegariRenata et al. (2020)



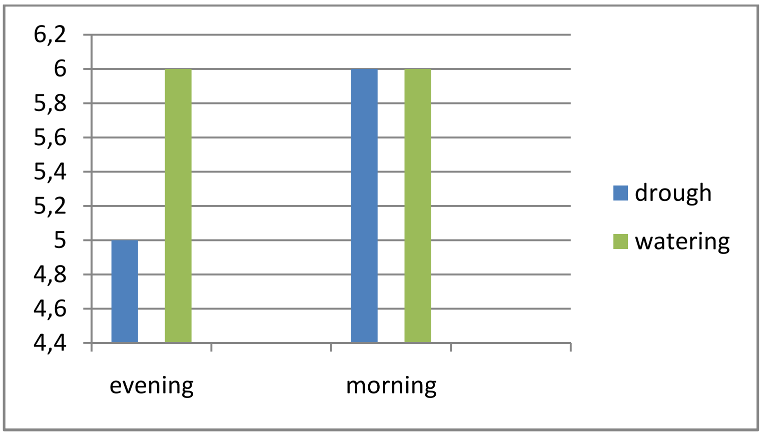
Graph 9. The amount of malic acid in the leaves(mg/100gfresh matter)

pH value of the cell juice

From the cellular juice obtained by pressing the leaves collected in the evening and in the morning, the pH was determined. The values obtained show that in plants grown in drought conditions the vacuolar pH has lower values in the morning - 5. During the evening, the pH is 6 (graph 10).

The accumulation of malic acid during the night and the large amount of carbon dioxide entering the leaves explain these differences.

In plants well supplied with water there are no differences in the values of this parameter.



Graph. 10.pH value of the cell juice

CONCLUSIONS

- *Portulacaoleracea L*. is a species adapted to drought conditions
- The high percentage of total water in the leaves gives that juiciness of the leaves, characteristic of plants with adaptation to drought
- Bound water in higher quantities also indicates an increased resistance capacity
- The stomatal conductance decreases during the day in plants grown on dry soil. As a result, the intensity of transpiration is reduced
- Photosynthesis is suppressed during the day, but intensifies during the night.
- The high content of malic acid and the lower pH determined in the morning indicate this fact. Thus, the plant has a behavior similar to CAM type plants

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