On the ecology and nutritional value of two *Echinochloa* species (*Echinochloa colona* and *Echinochloa stagnina*) in Egypt

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Abstract

In arid and semi-arid countries, where drought prevails together with population growth and limited food resources led to the search for non-conventional alternatives resources for food or feed. In the present study, the ecology, phytochemical composition, and nutritional value of two *Echinochloa* species (*Echinochloa colona* (L.) Link and *E. stagnina* (Retz.) P. Beauv.) collected from the canal banks of the Nile Delta, Egypt were investigated. The soils of *E. stagnina* had the highest values of moisture content (24.35%), water holding capacity (45.85%), pH (8.12), electric conductivity (5 ds m⁻¹), chloride (1.15%), sulphates (0.95%), organic carbon (2.52%) and Na⁺ (66.78 mg kg⁻¹). The cover percentages of *E. stagnina* showed positive significant correlations with water-holding capacity, organic carbon, pH, EC, Na⁺ but negative correlations with sand-fraction and sulphates. The shoot of *E. stagnina* had the highest values of moisture (11.20%), fibers (27.65%), crude proteins (6.90%), total carbohydrates (70.36%), but the shoot of *E. colona* had the highest contents of total fats (2.80%) and digestible carbohydrates (43.18%). The shoots of *E. stagnina* had the highest values of flavonoids (6.88 mg g⁻¹ dry weight), alkaloids (5.66 mg g⁻¹ dry weight), tannins (18.23 mg g⁻¹ dry weight), saponins (1.99 mg g⁻¹ dry weight) and total phenols (33.09 mg g⁻¹ dry weight). Regarding nutritional status, *E. colona* had the highest total digestible energy (60.55%) and nutritive value (11.11%) while *E. stagnina* had the highest caloric value (219.72 kcal/100 g dry matter) and potential energy (315.21 kcal/100 g dry matter). The two *Echinochloa* grass are rich-source in nutrients and showed a great energy value. Therefore, the studied grasses are candidates as feed for livestock or as supplementary feed but after detailed toxicological studies.

Keywords: Anti-nutritional compounds, forage, grasses, nutritive value

1. Introduction

In arid and semi-arid countries, the vast dry-lands coupled with great population growth and limited sources of food and feed led to a search for alternatives and non-traditional food and feed resources for both humans and animals [1]. Grasses (family Gramineae) is among the largest and invaluable family. Grasses are widely distributed all over the world under different climate and soil conditions [2]. Grasses are highly contributed to animal-feeding due to their high contents of nutritive rate [3]. This nutritive importance is attributed to their rich-content of carbohydrates, proteins, minerals and fibers. Therefore, for any rangeland rehabilitation strategy, it must include the planting of grasses to maintain a continuous supply of fodder for livestock. The nutritive quality of any plant is attributed to its composition and palatability [4]. In the present study, two *Echinochloa* species were selected, *Echinochloa colona* (L.) Link and *Echinochloa stagnina* (Retz.) P. Beauv. *E. colona* is an erect, annual summer rhizomatous grass/weed, globally considered as one of the most nuisance weeds [5, 6]. It is native to tropical and subtropical Asia, Africa and Australia and competes with crops. The high competition of *E. colona* is attributed to its rapid-growth, short-dormancy, allelopathic potential, high-seeds production, high adaptation and resistance against herbicides [6, 7, 8]. *E. colona* has reported as the most common annual weeds in summer crops, orchards and fallow-lands in many countries such as Egypt, Malaysia, Kenya, Japan, Colombia, USA, etc. [9, 10, 11]. *E. colona* preferred moist loamy soils and dominates on heavy-textured soils along the swamps, banks of canals and lakes, neglected lands, and field crops (maize, rice, tomatoes, etc.) [12]. The wide ecological niche of *E. colona* promotes its negative impacts on field crops through the globe [6].
Echinochloa stagnina (commonly known as burgu or amshot) is a perennial emergent grass, native in tropical Africa and Asia [13]. This plant grows in canal banks, swampy habitats, and occasionally forms a floating mat singly or together with other Echinochloa species on the surface of the water. This plant is characterized by its resistance to both harsh-condition and floods [14]. In Mali, during the scarcity-period, the dried-culms and grains of E. stagnina are used as food. In addition, E. stagnina is used as a forage for animals during the dry-season [15]. Ado et al. [16] reported the importance of E. stagnina to improve the structure and reduce salinity in vertisols soils. Also, several studies [17, 18] highlighted the phytoremediation potential of E. stagnina. Moreover, E. stagnina is cultivated as a crop and also to remove pollutants and reduce salinity from soils. E. stagnina provides a substrate for fish breeding and feeding during floods [14].

To our knowledge, there is no previous study that addressed the ecology and nutritional status of E. colona and E. stagnina in Libya. Therefore, the main objectives of the present study were 1) to characterize the main features of habitats where the two Echinochloa species are growing and 2) to address the nutritional status of both Echinochloa species.

2. Materials and methods

a. Floristic sampling

Along with the canal banks habitats at the north of the Nile Delta of Egypt (Figure 1), 60 sampled plots (25 m² each) for the two Echinochloa species (30 plots per each one) were selected. The Nile Delta belongs to the arid climate where hot-dry summer and milder rainy winter. The plant nomenclature was explored according to [19]. The cover percentages of two Echinochloa species as compared with the associated species were visually estimated.

![Map of Egypt shows the Nile Delta region (study area in red colour).](http://www.plantsjournal.com)

Fig 1: Map of Egypt shows the Nile Delta region (study area in red colour).

b. Soil analyses

Per each plot, a composite soil sample at a profile of 30 cm was collected, then air-dried and cleaned by removal of debris. The hydrometer was applied to distinguish different soil texture percentages (sand, silt and clay). In a soil solution of 1:5 (w/v), pH and electric conductivity (EC) were estimated by using pH and conductivity meters (Apera model), respectively. Moisture content, water holding capacity (Hilgard Pan-box method), Cl, HCO₃, SO₄ and organic carbon (OC) were determined according to the USDA/NRCS [20]. The concentrations of Na⁺ and K⁺ were determined using a flame photometer while Ca²⁺ and Mg²⁺ were estimated by an atomic spectrophotometer.

c. Phytochemical analyses of E. colona and E. stagnina

The healthy aboveground shoots of E. colona and E. stagnina were assembled from the canal banks habitats, then washed with tap water, air-dried and well-grounded. Primary constituents (moisture, ash, fibers, total fat, proteins, total carbohydrates and digestible carbohydrates) were estimated following the Association of Official Analytical Chemists [21]. Minerals (Na, K, Ca, Mg, Fe, Zn, Cu, Mn) were estimated in the dried samples after digestion with concentrated HNO₃, by using the flame photometer and atomic spectrophotometer [21]. Flavonoids, alkaloids, tannins, saponins and total phenols were estimated according to the standard methods of [22, 23, 24]. In brief, flavonoids were colorimetrically valued using AlCl₃, saponins by using separation method, tannins by using a vanillin-HCl reagent, alkaloids by precipitation method by using ethanol-acetic acid, while total phenols were spectrophotometrically estimated in presence of Folin-Ciocalteu reagent.

d. Nutritional status measurements

Based on chemical constituents, four categories were used to calculate the energy values of the two Echinochloa species (Table 1).

### Table 1. List of nutritional value categories used in the present study.

| Category                  | Formula                                                                 |
|---------------------------|--------------------------------------------------------------------------|
| Total digestible nutrient (TDN) [25] | TDP (%) = 0.623(100+1.25TF)-CP 0.72, where TF is total fats and CP is the crude proteins. |
| Nutritive value (NV) [25]  | NV (%) = TDP/CP, where TDP is the total digestible nutrient and CP is the crude proteins. |
| Caloric value (CV) [26]    | CV (kcal/100 g dry matter) = 4CP+ 9TF+ 4DC, where CP is crude protein, TF is the total fat and DC is the digestible carbohydrates. |
| Potential energy (PE) [27] | PE (kcal/100 g dry weight) = 3.75TC+ 4CP+ 9TF, where TC is total carbohydrates, CP is the crude proteins and TF is the total fat. |
e. Statistical analyses
To prevent collinearity among the measured soil variables, a Pearson correlation (|r|< 0.7) was considered. Consequently, seven non-linear significant soil factors (sand fraction, water holding capacity, organic carbon, pH, electric conductivity, sulphates and sodium) were kept. To explain the correlation between the cover percentages of two *Echinocloa* species and selected soil variables, response-curves were applied. A Kruskal-Wallis test followed by Bonferroni’s correction was applied to test the significance among mean values of phytochemical constituents of two *Echinocloa* species. All analyses were done in CoStat v. 6.

3. Results and discussion
a. Habitat features of *E. colona* and *E. stagnina*
The prevailing soil-texture of both *Echinocloa* species was a coarse sand texture (>90%) with minute percentages of silt and clay particles (Table 2). The soils of *E. stagnina* had the highest values of moisture content (24.35%) and water holding capacity (45.85%). This finding addressed the suitable habitats of *E. stagnina* where coarse and water-saturated soils [29]. Consequently, this supports its common survival on the canal banks and wetlands in contrary to *E. colona* which widely distributed on the roadsides, abandoned lands and also dry-lands. On the other hand, *E. stagnina* favored slight alkaline, saline and fertile soils as compared with *E. colona*. Soils of *E. stagnina* showed a pH value of 8.12, electric conductivity of 5 dsm⁻¹, chloride of 1.15%, sulphates of 0.95%, organic carbon of 2.52% and sodium value of 66.78 mgkg⁻¹. Therefore, *E. stagnina* able to reduce salinity and this improves its use for reclamation of sodic and alkaline soils [29, 30]. Manidool [12] reported that *E. colona* preferred moist loamy soils and dominates along the swamps, cultivated lands, banks of canals and lakes, neglected lands, and field crops. Moreover, the alkalinity of soil in the study area is not only corresponded to arid-climate but also due to high concentrations of sodium over the other cations. The soil properties of both studied *Echinocloa* species are completely agreed with the soil features of *Paspalidium geminatum* and *Panicum repens* in the same habitats in Egypt [4].

Table 2: Physico-chemical features (average± SE) of the soil samples maintaining the growth of the two *Echinocloa* species.

|                          | *E. colona* | *E. stagnina* |
|--------------------------|-------------|---------------|
| **Physical properties**   |             |               |
| Sand (%)                 | 93.35±1.58  | 90.50±1.16    |
| Silt (%)                 | 5.09±0.35   | 6.80±0.10     |
| Clay (%)                 | 1.56±0.10   | 2.70±0.08     |
| Moisture content (%)     | 20.21±2.03  | 24.35±1.54    |
| Water holding capacity (%) | 40.18±1.50 | 45.85±2.46    |
| **Chemical properties**  |             |               |
| pH                       | 7.48±0.03   | 8.12±0.07     |
| Electric conductivity (dsm⁻¹) | 2.10±0.23 | 5.00±0.08     |
| Cl (%)                   | 0.18±0.00   | 1.15±0.02     |
| SO₄²⁻ (%)                | 0.75±0.11   | 0.95±0.03     |
| HCO₃⁻ (%)                | 0.12±0.00   | 0.31±0.0      |
| Organic carbon (%)       | 1.66±0.11   | 2.52±0.22     |
| Na⁺ (mgkg⁻¹)             | 24.11±2.90  | 66.78±2.50    |
| K⁺ (mgkg⁻¹)              | 4.50±0.34   | 8.8±50.66     |
| Ca++ (mgkg⁻¹)            | 18.11±1.06  | 26.57±1.50    |
| Mg++(mgkg⁻¹)             | 19.44±1.45  | 10.21±1.02    |

The correlations between significant soil variables and cover percentages of *E. colona* and *E. stagnina* are displayed in Figures 2 and 3, respectively. For *E. colona*, there are negative correlations between the cover and water holding capacity, pH, EC, SO₄, Na but positive correlations with sand-fraction and organic carbon. The cover percentages of *E. stagnina* showed positive significant correlations with water-holding capacity, organic carbon, pH, EC, Na but negative correlations with sand-fraction and sulphates. This finding agreed with previous studies [31, 32] that addressed the importance of soil-salinity, texture, fertility and pH on the distribution of plants specifically on the canals banks and roadsides where the study species survive. In addition to the adaptation of the plant itself, there are a group of factors that contributed to its spatial distribution and persistence in its habitat [33].

![Fig 2: Response-curves of *E. colona* cover percentage versus the significant soil factors.](http://www.plantsjournal.com)
b. Phytochemical analysis of two *Echinochloa* species

The proximate composition is the first step towards the potentiality of considering any plant as a good source for food or feed and labeling its nutritional status \[^{[34]}\]. The primary composition, minerals and secondary metabolites of the aboveground shoots of *E. colona* and *E. stagnina* are displayed in Table 3. Except for total fats, potassium, alkaloids and saponins, all the other measured parameters are significantly different \((p < 0.05)\) between the two *Echinochloa* species. The shoot of *E. stagnina* had the highest values of moisture \((11.20\%)\), fibers \((27.65\%)\), crude proteins \((6.90\%)\), total carbohydrates \((70.36\%)\), but the shoot of *E. colona* had the highest contents of total fats \((2.80\%)\) and digestible carbohydrates \((43.18\%)\). The value of moisture content expresses the food quality, palatability, and storage period. The results displayed that, the two *Echinochloa* species had low moisture as compared with two-related grasses *Panicum repens* and *Paspalidium geminatum* \((12.51\% \text{ and } 11.15\%\) respectively) in Egypt \[^{[4]}\]. The ash content which indicated the minerals content was low in *E. stagnina* as compared with *Paspalidium geminatum* \((13.56\%)\) but high in *E. colona* \[^{[4]}\]. The fibers in both *Echinochloa* species showed similar values with *Panicum repens* \((25.67\%)\). A diet that contains rich-fibers is healthy important as it improves digestion \[^{[35]}\]. Adequate concentrations of carbohydrates, proteins and fats in the diet/feed maintain energy and optimal-growth for humans and animals \[^{[36]}\]. The shoots of both *Echinochloa* species attained comparable values of carbohydrates, proteins and total fats with shoots of *P. repens* and *P. geminatum* in Egypt \[^{[4]}\]. Regarding the minerals content, the shoot of *E. stagnina* attained the highest values as compared with *E. colona* shoot (Table 3). Sodium content varied from 12.65 mg g\(^{-1}\) dry weight in *E. colona* to 28.90 mg g\(^{-1}\) dry weight in *E. stagnina*, calcium varied from 4.84 mg g\(^{-1}\) dry weight in *E. colona* to 10.89 mg g\(^{-1}\) dry weight in *E. stagnina* while magnesium ranged between 2.45 mg g\(^{-1}\) dry weight in *E. colona* and 5.09 mg g\(^{-1}\) dry weight in *E. stagnina*. Sufficient minerals in the diet help in building bones and metabolic activities. The values of other essential microelements are displayed in Table 3. The minerals values in the studied *Echinochloa* species are in intimate concord with shoots of *P. repens* and *P. geminatum* \[^{[4]}\]. In the current study, the proximate composition and minerals of the two studied *Echinochloa* species meet the requirements for animal diet.

The food/feed quality depends on the equilibrium between concentrations of nutritional and anti-nutritional contents \[^{[37]}\]. The main anti-nutritional components include alkaloids, saponins, cyanogenic glycosides, phytates, tannins, etc. The shoots of *E. stagnina* had the highest values of flavonoids \((6.88 \text{ mg g}^{-1} \text{ dry weight})\), alkaloids \((5.66 \text{ mg g}^{-1} \text{ dry weight})\), tannins \((18.23 \text{ mg g}^{-1})\), saponins \((1.99 \text{ mg g}^{-1} \text{ dry weight})\) and phenols \((33.09 \text{ mg g}^{-1})\). Low levels of these secondary metabolites are known to have antibacterial, antiviral and antitumor activities \[^{[38]}\]. But high levels reduce the absorption of nutrients and palatability of the feed. Due to the lack of standard optimal/safe-scale of these metabolites, it is difficult to recommend safe levels. As compared with relative grasses, *P. repens* and *P. geminatum* \[^{[4]}\], the two *Echinochloa* species had the highest values of the studied secondary metabolites.

**Table 3:** Primary composition, minerals and secondary metabolites (average ±SE) of *E. colona* and *E. stagnina*. Different letters in the same row are significantly different at \(p < 0.05\)

| Parameter       | *E. colona*       | *E. stagnina*       |
|-----------------|-------------------|---------------------|
| Primary composition (%) | 9.55±0.90\(^a\) | 11.00±1.40\(^b\)  |
| Moisture        | 15.22±1.02\(^b\) | 8.90±0.89\(^b\)    |
| Ash             | 22.80±2.11\(^b\) | 27.65±1.67\(^b\)   |
| Fibers          | 5.45±0.09\(^b\)  | 6.90±0.50\(^b\)    |
| Crude proteins  |                   |                     |
### Nutritional values of *E. colona* and *E. stagnina*

Four categories were measured to detect the forage quality of the studied *Echinochloa* grasses: total digestible nutrients, nutritive value, caloric value and potential energy (Figure 4a, b). *E. colona* had the highest total digestible energy (TDN) (60.55%) and nutritive value (11.11%) while *E. stagnina* had the highest caloric value (219.72 kcal/100 g dry matter) and potential energy (315.21 kcal/100 g dry matter). The value of TDN is low in the two *Echinochloa* species as compared with the value of 66.55% reported by [39] but close similar (61.7%) to that recommended for sheep by NRC [40]. The nutritive value, caloric value and potential energy in the studied *Echinochloa* species exceeds the requirements for cattle as recommended by NRC [40].

![Figure 4: Energy categories a) total digestible nutrients (TDN) and nutritive value (NV), and b) caloric value (CV) and potential energy (PE) of *E. colona* and *E. stagnina.*](http://www.plantsjournal.com)

### 4. Conclusion

The aboveground grazable shoots of *Echinochloa stagnina* had high proximate composition, minerals and secondary metabolites than *E. colona*. However, the two *Echinochloa* species are rich-source in nutrients and showed great energy value. Therefore, the studied grasses are candidates as feed for livestock or as supplementary feed but after detailed toxicological studies.

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