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Original Article: Association of Aquatic Weed Abundance and Water Quality, Gezira Scheme Canals, Sudan

Samah O. A. Alhadari[1] , **Awadallah B. Dafaallah**[2,3]*, **Mohamed S. Zaroug**[2], **Nasir A. Ibrahim**[4], **Nosiba S. Basher**[4]

[1] *Crop Protection Research Center, Agricultural Research Corporation, Sudan.*
[2] *Department of Crop Protection, Faculty of Agricultural Sciences, University of Gezira, Sudan.*
[3] *National Center for Vegetation Cover Development and Combating Desertification (NCVC), Ministry of Environment, Water and Agriculture, Kingdom of Saudi Arabia.*
[4] *Department of Biology, Faculty of Science, Imam Mohammed Ibn Saud Islamic University, Saudi Arabia.*

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***Corresponding Author:**
Awadallah B. Dafaallah
(awadna2020@gmail.com)

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ABSTRACT

Water weeds are notorious for causing various troubles. Gezira Scheme in Sudan is being choked by the increasing proliferation of aquatic weeds. This study aimed to look at the association between aquatic weed abundance and water quality in some canals in Sudan's Gezira Scheme in the year 2018. The study area included 18 sites, i.e. 6 canals classified into 3 parts (beginning, middle, and end). The abundance of aquatic weed species was evaluated visually at each site using a scale of (0-5), and water quality was examined by assessing physical, chemical, and biological properties. Descriptive statistics and variance analysis were used to analyze the data. The findings revealed that community structure was comprised of significant changes in the abundance of aquatic weed species throughout the year, as follows: floating (1.7-2.1), emergent (0.2-0.3), submergent (0.3), and bank aquatic weeds (1.5-2.2). In winter and summer, the most abundant species were *Vossia cuspidata* (4.0) and *Cynodon dactylon* (3.0-3.7). Temperature and turbidity were shown to be the most critical elements in restricting the development and abundance of aquatic weeds, along with alkalinity, salinity, and nutrients. The canals are habitat to a diverse range of living organisms, including animals, bacteria, fungi, and algae, which indicates the water's appropriateness for the presence and development of aquatic weeds. All of these insights will be valuable in the management of aquatic weeds in Gezira scheme's canals.

Introduction

Aquatic plants are plant species that thrive entirely or partially in the water (Kheir, 1992). They are classified into three types based on their growth pattern since various growth patterns necessitate various management. The types are: (i) free floating on the water surface, (ii) rooted in the sediment with floating or emergent shoots/leaves, and (iii) sediment-rooted or un-rooted submerged plants with their shoots (nearly) totally submerged (Hussner et al., 2017). Abdu (1979) grouped aquatic weeds in Sudan's Gezira irrigation system into two groups: emergent and bank aquatic weeds, and submergent aquatic weeds. Druijff (1979) characterized aquatic weeds into five groups: floating, emergent, weeds extending from the bank into the water, submergent, and bank aquatic weeds.

Aquatic plants are generally affected by variables that are inextricably linked to water body limnology, such as physical factors, sediment, climate, and hydrology. These variables are influenced by the characteristics of waterbodies as well as the agricultural components of their watershed. Furthermore, biological interactions such as competition, predation, and disease have an impact on aquatic plants (Lacoul and Freedman, 2006). Aquatic plants, like all the other plants, need light and CO_2 (or even other inorganic carbonaceous materials) for photosynthesis, oxygen for respiration, water, and nutrients such as nitrogen, phosphorus, and others to survive or thrive. The pH, alkalinity, water hardness (temporary or permanent), conductivity, and dissolved gases such as oxygen and CO_2 levels are all common water quality characteristics that influence aquatic weeds. These parameters can be treated independently or together, as the level of one parameter influences or is correlated to the levels of the others. Changes in environmental variables influence the number of aquatic plants. This information can be utilized to determine the presence or absence and populations that are trustworthy markers of significant changes in their environment, including those that could serve as ecological integrity standards (Crossley, 2002).

Sudan's Gezira Scheme was the country's first large-scale irrigated agricultural development (Plusquellec, 1990) plays an important role in Sudan's agricultural sector (Eldaw, 2004). The scheme was created in the 1920s with the primary goal of producing cotton. Other crops were initially cultivated to just provide food for agricultural laborers and to aid in the conservation and protection of soil nutrients. Cotton, wheat, and groundnut/sorghum are grown in a four-course rotation that also includes fallow land (Plusquellec, 1990). The irrigated area is located south of Khartoum city in the smooth, fertile plains, between latitudes 13˚ 30 North and 15˚ 30 North, and longitudes 32˚ 15 East and 33˚ 45 East. The scheme's total initial area was approximately 476,700 hectares at the time of its inception in 1925. (1.135 million feddans). The initial area was expanded to the southwest in the early 1960s to incorporate the Manaqil Extension, bringing the scheme's total area under irrigated agriculture to 882,000 hectares (2.1 million feddans). Water is delivered to the scheme's irrigated areas *via* two main canals (the Gezira and Managil main canals), which connect to the Sinnar Dam. The main canals are divided into major canals, which are further subdivided into the minor canals that transport irrigation water to field ditches *via* gated field outlet pipes noun as (*Abu* XXs). Every (*Abu* XX) has nine canals noun as (*Abu* VIs) that irrigate 37.8 hectares (90 feddans). Each canal (Abu VI) irrigates 4.2 hectares (ten feddans). Aside from the canalization system, the irrigation network of Gezira scheme includes a drainage system comprised of major and minor drains (Eldaw, 2004).

The designation of the canals provides ideal conditions for the growth of aquatic weeds, so that the study of their abundance is important to identify species and community and to identify the existence or potential of problems of aquatic weeds (Alhadari *et al.*, 2020c). Likewise, the study of water quality parameters (physical, chemical, and biological) is of high significance that might affect the community composition of aquatic plants in the canals in winter and summer. As a consequence, the current study was conducted to assess the relationship among both aquatic weed abundance and water quality across several minor canals at Centre Group at Gezira Scheme, Sudan (2018).

Materials and Methods

2.1. Location

The research was conducted at Gezira Scheme's center group. The research region is located across latitudes 14° 15 North and 14° 20 North and longitudes 33° 20 East and 33° 30 East (Table 1). The region's climate is semi-desert, with just an average rainfall range between 100 mm and 250 mm, with the annual rainfall lasting from June to October and dry weather lasting from March to June. The yearly evapotranspiration average is 2400 mm/year. The average yearly lowest and highest temperatures are 12 °C in January and 42 12 °C in May. The area's soil is heavy (clay 60%), with a pH of 8-8.5, low organic matter and nitrogen, enough potassium, and low accessible phosphorus (Elbasher, 2016).

Table 1. Geographical distribution of aquatic species in six canals of center group at Gezira scheme, Sudan, in winter and summer, 2018, as determined by a geographical positioning system (GPS)

Name	Point	Longitude	Latitude
Barakaat 1	Beginning	556806	1586755
	Middle	556850	1585328
	End	556896	1583869
Barakaat 2	Beginning	555618	1584060
	Middle	555556	1586072
	End	555508	1587616
Barakaat 3	Beginning	552489	1588669
	Middle	552459	1589987
	End	552409	1591852
Al sunni	Beginning	546090	1594068
	Middle	546310	1594166
	End	546882	1594402
Al Ibrahimi	Beginning	545118	1596717
	Middle	546169	1597163
	End	547181	1597560
Hajj Al-Nour	Beginning	544331	1580564
	Middle	544777	1580072
	End	545011	1579801

2.2. Experimentation

Six canals in the Gezira Scheme's Centre Group were chosen at random for the study: *Barakaat* 1, *Barakaat* 2, *Barakaat* 3, *Al sunni*, *Al Ibrahimi*, and *Hajj Al-Nour*. Each canal includes three sections: beginning, middle, and end. As a result, the study area is composed of 18 sites (six canals x three sections). The abundance of aquatic weeds at every site was evaluated, and water quality parameters associated with changes in aquatic weed seasonal growth were investigated in summer and winter. The research includes all aquatic species found in canals and their banks. The research was carried out in 2018 in winter (January, February, and March) and summer (August, September, and October). The sites were visited once a month for three months in every season.

2.3. Aquatic weeds abundance

Visual observation was used to gather data on the abundance of aquatic weeds. Yousif (2019) recommended this technique. Visual observation was used to evaluate the abundance of aquatic weed species in the beginnings, middles, and ends of the canals, using a scale of (0 - 5) where:

0 ≡ Not present.

1 ≡ Any number of plants spouse to cover less than 5% of water surface.

2 ≡ Any number of plants spouse to cover 5 to 25% of water surface.

3 ≡ Any number of plants spouse to cover 25 to 50% of water surface.

4 ≡ Any number of plants spouse to cover 50-75% of water surface.

5 ≡ Plants that spouse to cover more than 75% of the area.

2.4. Water quality

The physical, chemical, and biological characteristics of water were determined at each study site to assess water quality. Surface water samples were taken at each research site every three months during the summertime and the wintertime. Plastic bottles of l liter capacity were used for the collection and preservation of water samples from beginnings, middles, and ends of the canals. Care was taken to prevent samples against sunlight while transporting them to the laboratory. The samples were stored in an air-cooled chamber until analysis in the laboratory.

2.4.1. Physical characteristics

Determination of water temperature (Thermometer measurement)

Water temperatures of the site visits were recorded at sampling sites using a mercury thermometer at 30-min sampling intervals (APHA 1995, 2550 B, 2-59).

2.4.2. Chemical characteristics

Determination of water pH

The pH was determined using the electrometric method. The pH of water samples was determined with the aid of a pH meter (ISO CL 8-5.3. SOP/WTD/01).

Determination of water conductivity

The conductivity was determined by using the conductivity meter. The unit for total dissolved salts (TDS) was (mg L^{-1}), and the unit for electrical conductivity (EC) was (dS m^{-1}). A conductivity meter (APHA 1995, 2510A, 2-43) (ISOCL 8- 5.3. SOP/WTD/03) is utilized for measuring EC and TDS.

Determination of water total hardness (mg/l)

The total hardness (mg/l) was determined using the EDTA titrimetric method. Ethylene diamine tetra acetic acid (EDTA) forms a soluble chelated complex in alkaline conditions. When a small amount of Erichrome black -T indicator was added to the water sample under alkaline conditions, the Ca^{++} and Mg^{++} ions developed a wine-red color. When this was titrated against EDTA, the Ca^{++} and Mg^{++} ions complexed with EDTA produced a sharp change in color from wine red to sky blue (APHA 1995, 2340, 2-35) (ISOCL 8-5.3. SOP/WTD/07).

Determination of water calcium (mg/l)

Calcium (mg/l) was determined by using the EDTA titrimetric method. When EDTA was added to water that contains both calcium and magnesium ions, it initially combines with calcium. Ca++ can be directly determined by titrating the sample which was made sufficiently alkaline (2.00 ml of NaOH solution) against EDTA using the Murexide indicator. The endpoint is the solution changes from pink to clear purple color (APHA 1995,3500-Ca, 3-56) (ISOCL 8- 5.3. SOP/WTD/08).

Determination of water magnesium (mg/l)

The magnesium (mg/l) was determined using the EDTA titrimetric method. Magnesium ions were calculated by subtracting the total hardness and calcium ions from the water sample (APHA 1995, 3500-Ca, 3-56) (ISOCL 8- 5.3. SOP/WTD/08).

Determination of water sodium (Na^+ mg/l)

The sodium (Na^+ mg/l) was determined using the flame photometric method. The amount of sodium was determined by Flame photometry 410 (APHA 1995, 3500-Na D, 3-96) (ISOCL 8-5.3. SOP/WTD/10).

Determination of water potassium (K^+ mg/l)

Potassium (K^+ mg/l) was determined using the flame photometric method. The amount of potassium was determined by Flame photometry 410 (APHA 1995, 3500-Na D, 3-96) (ISOCL 8-5.3. SOP/WTD/10).

Determination of water chloride (Cl^- mg/l))

Chloride (Cl^- mg/l) was determined by using the argentometric method. The silver nitrate was titrated with chloride and potassium chromate using as an indicator to indicate the end point of this titration. Prior to the formation of red silver chromate, silver was quantitatively precipitated.

Determination of water bicarbonate (H CO_3^- as mg/l)

The bicarbonate (HCO_3^- as mg/l) was determined by using the titrimetric method. Bicarbonates were estimated by titrating the sample against (1N HCl) using Methyl orange as an indicator till the solution turns from orange to pink (Wilcox and Hatcher 1950 USDA California para 16).

Determination of water carbonate (CO_3^{--} as mg/L)

Carbonate (CO_3^{--} as mg/L) was determined using the titrimetric method. The carbonate content of water sample was determined by titrating it with a strong acid, H_2SO_4, and using phenolphthalein to serve as an indicator. A pink to colorless end point was observed (Wilcox and Hatcher 1950 USDA California para 16).

Determination of water turbidity

Turbidity was determined using the turbidity meter (NTU). Turbidity was measured using a turbidity meter and demonstrated in Nephelometric turbidity units (NTU) (APHA 1995, 2130 B, 2-9) (ISOCL 8- 5.3. SOP/WTD/03).

2.4.3. Biological characteristics

Water samples were taken from the six canals during the wintertime and summertime to check for the existence of biological entities. In addition, some water samples were transported to the laboratory for samples culturing to give an indication of the presence of any microorganisms like fungi and bacteria. The samples were streaked on plates containing nutrient agar (NA) medium using a sterilized loop. The plates were incubated at room temperature for 24 hours.

2.5. Statistical analysis

At p 0.5, data were subjected to descriptive analysis as well as analysis of variance. To distinguish between significant means, Duncan's Multiple Range Test was used. The data was analyzed using Microsoft Excel, Statistics 8, and MSTATC.

Results

3.1. Abundance of aquatic weeds

In winter, the abundance of floating weeds was greater in the canal beginnings (25- 50%) than in the middles (5-25%) and ends (5%). In summer, the abundance of floating weeds in canal beginnings and middles was greater (5-25%) than in canal ends (5%) (Table 2). During the winter season, *Azolla* sp., *Ipomoea aquatic*, and *Ludwigia palustris* was abundant approximately at a constant percentage (5-50%) at the beginning, middle, and end, *Pistia stratiotes* was available only at the beginning (5-25%), while *Vossia cuspidata* was more abundant compared to the rest of the floating weeds, where it is available at a ratio of (> 75%) and (50-75%) and (50-75%) at the beginning, middle and end, respectively. In summer, *Ipomoea aquatica* was abundance at a constant percentage (5-50%) at the beginning, middle and end, *Ludwigia palustris* and *Pistia stratiotes* disappeared at the end, while *Vossia cuspidata* was more abundant compared to the rest of the floating weeds, where it was available at a ratio of (50-75%) at the beginning, middle and end.

Table 2. Abundance of floating weeds in the six canals in center group at Gezira scheme, Sudan in winter and summer, 2018

Species	**Beginning**	**Middle**	**End**	**Average ∓ STDEV**
Winter season				
Azolla sp.	2	2	2	2.0 ∓ 0.00
Ipomoea aquatic	2	3	2	2.3 ∓ 0.6
Ludwigia palustris	2	2	0	1.3 ∓ 1.2
Pistia stratiotes	2	0	0	0.7 ∓ 1.2
Vossia cuspidate	5	4	3	4.0 ∓ 1.00
Average	2.6	2.2	1.4	2.1 ∓ 0.6
Summer season				
Echinochloa stagnina	0	0	0	0.0 ∓ 0.0
Ipomoea aquatic	2	2	2	2.0 ∓ 0.0
Ludwigia palustris	2	2	0	1.3 ∓ 0.2
Pistia stratiotes	2	1	0	1.0 ∓ 1.0
Vossia cuspidate	4	4	4	4.0 ∓ 0.0
Average	2	1.8	1.2	1.7 ∓ 0.2

**** Scale: 0≡ absent, 1≡ (< 5%), 2≡ (5-25%), 3≡ (25-50%), 4≡ (50-75%), 5≡ (> 75%).***

Emergent weeds were absent in the beginnings and middles of canals and plentiful, but of small cover in ends of canals (> 5 %) in winter. In summer, emergent weeds were absent in all sections of canals (Table 3). In winter, *emergent weeds (Cyperus alopecuroides, Polygonum glabrum, and Typha latifolia) were not available at the middle and end, Cyperus alopecuroides was available at a constant percentage (< 5%), Polygonum glabrum was not available throughout the season, while Typha latifolia was available only at the end (< 5%). In summer, Cyperus alopecuroides appeared at the beginning (< 5%), Polygonum glabrum was not available throughout the season, while Typha latifolia was available only at the end (< 5%).*

Likewise, submergent weeds were present only in the end of one canal (Baraakat II) in plentiful, but of small cover (> 5 %) in the winter season (Table 4) and completely absent in all three sections of canals in summer. Najas pectinate was available only at the end (< 5%).

The abundance of bank aquatic weeds was higher in the ends of canals (25 – 50%) and equal in the beginnings and middles of canals (5-25%) in winter, and also equally in beginnings, middles, and ends of canals in the summer season (5-25%) (Table 5). In winter, *Cynodon dactylon* was available at a ratio of (50-75%) at the beginning and (25-50%) at the middle, while *Ipomoea hildebrandtii* was not available throughout the season. In winter, *Cynodon dactylon* was available at a constant percentage a ratio of (25-50%) at the beginning, middle, and end, while *Ipomoea hildebrandtii* was not available throughout the season.

Table 3. Abundance of emergent weeds in six canals in center group at Gezira Scheme, Sudan in winter and summer, 2018

Species	Beginning	Middle	End	Average∓ STDEV
Winter season				
Cyperus alopecuroides	0	1	1	0.7 ∓ 0.6
Polygonum glabrum	0	0	0	0.0 ∓ 0.0
Typha latifolia	0	0	1	0.3 ∓ 0.6
Average	0	0.3	0.7	0.3 ∓ 0.4
Summer season				
Cyperus alopecuroides	1	0	0	0.3∓0.6
Polygonum glabrum	0	0	0	0.0∓0.0
Typha latifolia	0	0	1	0.3∓0.6
Average	0.3	0	0.3	0.2∓0.2

**** Scale: 0≡ absent, 1≡ (< 5%), 2≡ (5-25%), 3≡ (25-50%), 4≡ (50-75%), and 5≡ (> 75%).***

Table 4. Abundance of submergent weeds in six canals in center group at Gezira Scheme, Sudan in winter, 2018

Species	Beginning	Middle	End	Average ∓ STDEV
Najas pectinata	0	0	1	0.3∓0.6
Average	0	0	1	0.3∓0.6

**** Scale: 0≡ absent, 1≡ (< 5%), 2≡ (5-25%), 3≡ (25-50%), 4≡ (50-75%), and 5≡ (> 75%).***

Table 5. Abundance of bank aquatic weeds in six canals in center group at Gezira Scheme, Sudan in winter and summer, 2018

Species	Beginning	Middle	End	Average ∓ STDEV
Winter season				
Cynodon dactylon	4	4	3	3.7 ∓ 0.6
Ipomoea hildebrandtii	0	0	2	0.6 ∓ 1.2
Average	2	2	2.5	2.2 ∓ 0.3
Summer season				
Cynodon dactylon	3	3	3	3 ∓ 0.0
Ipomoea hildebrandtii	0	0	0	0.0 ∓ 0.0
Average	1.5	1.5	1.5	1.5 ∓ 0.0

**** Scale: 0≡ absent, 1≡ (< 5%), 2≡ (5-25%), 3≡ (25-50%), 4≡ (50-75%), and 5≡ (> 75%).***

Generally, floating weeds were of higher abundance in the beginnings and middles of the canals compared with the abundance in the ends of these canals. Emergent weeds were absent in canals except for very low abundance in the ends of canals in winter. Submergent weeds were present only in winter and were abundant, but of small cover in the end of only one canal (*Baraakat* II). Bank aquatic weeds were equally in abundance in beginnings and middles of canals with high abundance in the ends of canals in the winter season compared with other sections.

3.2. Water quality

3.2.1. Physical characteristics

The temperature of surface water increased in summer (38 °C) compared with winter (24 °C) (Tables 6 and 7).

3.2.2. Chemical characteristics

The results of chemical water quality indicated that most of the parameters decreased when comparing summer and winter (Tables 6 and 7). The pH was decreased from 7.47 to 6.88, TDS from 203.9 to 186 mg/l, Ca^{++} from 1.6 to 1.2 meq/l, Mg^{++} from 0.73 to 0.65 meq/l, Na^{+} from 10.2 to 4.3 ppm, K^{+} from 5.4 to 2.1 ppm and HCO_3^- from 2.12 to 1.91 meq/l. On the other hand, EC (0.2 dS/m) and Cl^- (1.2 meq/l) were not changed with the changes of seasons. Moreover, $CO3^{=}$ did not found in the water of canals. However, turbidity increased in the summer season (186 NTU) compared to winter (34 NTU).

There were no considerable differences between the values of most parameters in the heads, middles, and ends of all canals with an exceptional case of turbidity that decreased from the heads to the ends.

Table 6. Analysis of physical and chemical characteristics of water in six canals in Center group at Gezira scheme, Sudan in winter, 2018

Parameters	**Beginning**	**Middle**	**End**	**Average ∓STDEV**
Temperature (ºC)	21.5 ∓ 0.7 (10:00 AM)	23.5 ∓ 2.1 (11:00 AM)	27∓5.7 (1:00 PM)	24 ∓ 2.8
pH	7.45∓0.29	7.4 ∓0.39	7.52∓0.30	7.47∓0.04
EC (dS/m)	0.20∓0.00	0.20∓ 0.00	0.20∓0.00	0.20∓0.00
TDS (mg/l)	210.2∓13.8	206.3∓12.7	195.7∓ 29.8	203.9∓7.4
Ca^{++} meq/I	1.6 ∓0.1	1.6 ∓0.1	1.6 ∓0.2	1.6 ∓2.7
Mg^{++} meq/I	0.74∓0.05	0.74 ∓0.09	0.69∓0.17	0.72 ∓0.03
Na^{+} ppm	10.6∓1.30	10.2∓1.45	9.7∓2.87	10.2 ∓0.45
K^{+} ppm	3.35∓0.91	3.17∓0.71	9.62∓3.55	5.38 ∓ 3.67
Cl^{-} meq/I	1.27∓0.10	1.2∓0.13	1.2 ∓0.00	1.22∓0.04
HCO_3^{-} meq/I	2.16∓0.09	2.1∓0.13	2.1 ∓0.07	2.12∓0.03
CO_3^{-} meq/I	0.0 ∓ 0.00	0.0∓0.00	0.0 ∓0.00	0.0 ∓ 0.00
Turbidity NTU	30 ∓ 3.5	30 ∓7.8	44 ∓ ٤.2	34 ∓ 2.8

Table 7. Analysis of physical and chemical characteristics of water in six canals in center group at Gezira scheme, Sudan in summer, 2018

Parameters	**Beginning**	**Middle**	**End**	**Average ∓STDEV**
Temperature (°C)	36∓1.4 (10:00 AM)	37.5∓2.1 (11:00 AM)	.41∓1.4 (1:00 PM)	38∓1.6
pH	7.03∓0.46	6.80∓0.41	6.80∓0.20	6.88∓0.13
EC (dS/m)	0.20∓0.00	0.20∓0.00	0.20∓0.00	0.20 ∓ 0.0
TDS (mg/I)	186 ∓9.23	187∓5.89	186∓6.86	186∓0.58
Ca^{++} meq/I	1.22∓0.11	1.23∓0.13	1.28∓0.07	1.24∓0.03
Mg^{++} meq/I	0.64∓0.03	0.65∓0.02	0.66∓0.02	0.65∓0.01
Na^{+} ppm	4.1 ∓0.36	4.1 ∓0.30	4.6 ∓ 0.35	4.3 ∓ 0.29
K^{+} ppm	2.07∓0.27	2.07∓0.34	2.02∓0.26	2.05∓0.03
Cl^{-} meq/I	1.3 ∓0.10	1.2 ∓0.13	1.2 ∓ 0.13	1.2 ∓ 0.06
HCO_3^{-} meq/I	1.99∓0.18	1.88∓0.21	1.86∓0.20	1.91∓0.07
CO_3^{-} meq/I	0.0 ∓0.00	0.0 ∓0.00	0.0 ∓ 0.00	0.0 ∓ 0.00
Turbidity NTU	239∓59.4	19 3∓7.1	125 ∓74.2	186∓ 2.6

3.2.3. Biological characteristics

The findings revealed that several species of animals, such as fish and frogs, were present in water samples collected from the six canals during both winter and summer (Table 8). It also consisted of invertebrates such as insects; Dragonflies, Mayflies, Mosquitoes, snails; pouch snails and Mollusca, spiders, and worms. Culturing of water samples indicated that water samples have no fungi but consisted of three species of bacteria.

Table 8. Analysis of biological characteristics of water in six canals in center group at Gezira scheme, Sudan in winter and summer, 2018

Organisms		**Detection**	
		Winter season	**Summer season**
Vertebrates	Fish	+	+
	Frogs	-	+
Invertebrates	Dragonflies	+	+
	Mayflies	+	+
	Mosquitoes	+	+
	Snails	+	+
	Spiders	+	+
	Worms	+	-
Fungi		-	-
Bacteria		+	+
Algae		+	-

**** + Detected***
**** - Not detected***

Discussion

According to the findings, *Vossia cuspidata* and *Cynodon dactylon* dominate all other aquatic species in terms of abundance. *Typha latifolia* and *Najas pectinata* have very low abundance values. This research demonstrated the significance of abundance in the community structure of aquatic weeds, as described by (Ghavzan et al., 2006; Alhadari et al., 2020a; 2020b). Floating weeds and bank aquatic weeds were more abundant than other species. This is most likely owing to the siltation of canal bottoms and sometimes accumulations of submerged weeds, which creates favorable habitats for species such as *Vossia cuspidat*, *Cynodon dactylon*, and *Ipomoea aquatica*. Along with *Ischaemum afrum*, the most frequent bank weeds were *Acacia* spp. The majority of the canals were free of submerged weeds, which might be attributed to the hydrological characteristics of the canals, such as depth with fast stream and mechanical clearance. Abdel Gadir also reported on this (1986, 1987). The findings revealed that the abundance of various species in the canals was greater in the winter season than in the summer season, as previously reported by Abdel Gadir *et al.* (1986,1987), and was attributed primarily to the turbidity of water in summer compared to the clearest water in winter.

Also, the results of water quality indicated that water temperature is an important factor, because changes in temperature during summer and winter may affect the growth of aquatic weeds. Sharon (1997) stated that the temperature of a river is significant because it affects the rate of photosynthesis and has a direct effect on the development of aquatic weeds. Furthermore, Sand (1989) mentioned that temperature is a significant factor that affects the establishment of aquatic macrophytes. The higher the temperature, the greater the requirement for oxygen, and food and the faster the growth rate. This might explain the temperature effect on the growth rate of some emergent weeds during the summer season compared with the winter season. The Absence of submergent weeds in most canals in summer, where the temperature and turbidity were higher than in the winter season referred to the effect of temperature and turbidity on the growth of submergent weeds. This also agreed with McCaffrey (2019) who reported that high turbidity affects submerged plants by preventing sufficient light from reaching them for photosynthesis. High turbidity also has the capacity to significantly increase the water temperature. While, water temperature is affected by air temperature, stormwater runoff, groundwater inflows, turbidity, and exposure to sunlight. The pH levels increased in the winter months (pH 7.47), while the rate of growth of most aquatic weeds increased when matched to summer (pH 6.88). This agreed with Titus *et al*. (1990). Although, high pH levels (pH 9) may limit the growth of aquatic weeds due to low levels of dissolved CO_2 and low pH levels (below pH 5) may affect HCO_3^- ions. Where HCO_3^- ions are nearly absent and inorganic carbon is available mainly as dissolved CO_2, and thus acquisition of carbon can become the rate-limiting step of photosynthesis (Haines, 1980).

Salinity also influences the growth of aquatic weeds. Where the distribution and abundance of most aquatic weeds in the canals particularly floating weeds increased with increases in TDS in winter and decreased in summer. This finding is also consistent with McCaffrey (2019), who mentioned that salt content is usually highest during the low flows, which increases as water levels decrease and affects nutrient availability to plant root systems. The typical (EC) range in irrigation water is (0-3 dS/m^{-1}) (Ayers and Westcot, 1985). This means that conductivity was very low (0.2 dS/m^{-1}) in both summer and winter, pointing to a low concentration of dissolved electrolyte ions present in the water. The specific ions in the water are not identified by conductivity. Significant increases in conductivity, on the other hand, may indicate that polluting discharges have entered the water (McCaffrey, 2019).

The results revealed that almost all chemical properties of water rose in winter as compared to summer. Rises in nutrient (chemical element) concentrations throughout the winter likely accelerate the growth of floating weeds. This is agreed with (Pieterse et al., 1981). Whereas, free-floating weeds like (water lettuce) *Pistia stratiotes* and (water fern) *Azolla* spp. should obtain all nutrients from the water column. Once nutrient concentrations are low, *Pistia stratriotes* grow more slowly, and the mortality rate may indeed be greater than the rate of growth (Junk and Piedade 1997).

The usual range of (Na^+) in water for irrigation is (0-40 meq/l) (Ayers and Westcot, 1985). The results showed sodium rates were (0.3-0.5 meq/l) during both summer and winter, this is an indication of lower rates of (Na^+) in the canals which agreed with McCaffrey (2019) who reported that sodium is generally found in lower concentration than calcium and magnesium in fresh water and industrial effluents are the major sources of sodium in water. The results also may explain the less importance of sodium uptake for most aquatic plants. This is consistent with (Sculthorpe, 1967), who reported that sodium may excrete from leaf tissue to enable the uptake of other more vital cations, like potassium or calcium, but potassium and calcium are not regarded major obstacles for aquatic plant productivity (Thiebaut et al., 2002). The low concentration of sodium may limit the growth of submergent weeds. This was further mentioned by (Howard-Williams and Liptort, 1980) who reported that in the open water of many aquatic systems as low concentrations of Sodium (Na^+) directly limit the growth of submersed machrophytes.

The usual range of chloride (Cl^-) concentrations in water for irrigation is (0-30 meq/l) (Ayers and Westcot, 1985). The results showed that there was very little chlorine in the six canals. Chloride concentrations in wastewater are higher than in raw water (McCaffrey, 2019). Low concentrations of chloride in water may limit the growth of submergent weeds. This was also reported by (Howard-Williams and Liptort, 1980) who pointed out that in the open water of many aquatic systems as low concentrations of chloride (Cl^-) directly limit the growth of submersed machrophytes.

According to the findings, the water in the canals comprises HCO_3^- as a sort of organic carbon, which increases in winter. The use of HCO_3^- affects the photosynthetic rates and influences in community structure of aquatic weeds. This was consented upon (Sand et al., 1992) who stated that the ability to use HCO_3^-, probably influences the species composition of machrophytes communities strongly, and the availability of HCO_3^- enhanced photosynthetic performance in aquatic species. Bicarbonate is regarded as one of the primary predictors in general since bicarbonate concentration levels are associated to conductivity across most forms of freshwater resources, and pH is further strictly controlled by bicarbonate concentration levels throughout the range of low alkaline to high alkaline waters (Leuven et al., 1992).

Turbidity levels increased during the summer season when compared to clear water during the winter season, affecting the growth, production, and spread of aquatic weeds. During the winter, most aquatic weeds have a high percentage of frequency and abundance. While high turbidity during the summer season prevents sunlight to penetrate deep water and this affects the growth of aquatic weeds, especially submergent weeds. This result was consistent with the findings of Plusquellec (1990), who demonstrated that when there is a massive silt stress in the waterways, sunlight permeation through into the water is constrained and weed development is hindered. In Sudan, the system is designed trying to draw better and clear water from stockpiling at Sennar Dam in January, leading to rapid weed infestation, especially in the canals. Silt is then accumulated inside the sluggish water all around weeds, creating an ideal environment for more weed growth, and worsening the situation. This finding was indeed noted in the Alaska Fact Sheet (Alaska Department of Environmental Conservation, 2015), which stated that turbidity impacts the rate of growth of algae as well as other aquatic plants by reducing the amount of light available for photosynthesis. Because suspended particles absorb more heat, turbidity can raise water temperature. Dissolved oxygen levels fall as a result of these factors.

The findings revealed that the water in the canals in winter and summer contains a diverse range of living creatures. Because they live on the bottom of a stream or lake and do not travel long distances, these organisms are useful indicators of the safety of aquatic habitats. As a consequence, they have no way to migrate away from pollutants or environmental stress easily or quickly. Because different species of living life forms react differently to selective stressors like pollution, silt loading, and habitat changes, quantifying the diversity and density of different living organisms at a given site may offer a view of the environmental conditions of that body of water (WET Foundation Project, 2011).

When multicellular creatures are subjected to an environmental hazard (e.g., carbon emissions, heating because of reduced flows, weak dissolved oxygen due to algal growth, etc.), those that are unaccepting to that strain may perish. Tolerant living creatures frequently colonize the spaces left by intolerant organisms, resulting in an entirely new population of organisms. A body of water that has not been impacted, for example, will usually comprise a vast bulk of living creatures that are sensitive to environmental stress factors, such as mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera). A water body that has been subjected to environmental stress may comprise a vast bulk of living organisms that are tolerant of these conditions, such as leeches (Hirudinea), tubifex worms (Tubifex sp.), and pouch snails (Tubifex sp). (Gastropoda) (WET Foundation Project, 2011).

Conclusion

The aquatic weed community structure in the Gezira scheme's canals comprises various kinds of aquatic weeds with varying abundance. This may be attributed to many factors such as physical, chemical, and biological characteristics of water quality, which affect the growth and abundance of aquatic species in winter and summer. More studies should be conducted to determine water quality conditions in irrigation systems within irrigated schemes to be able to determine how parameters of water quality may affect the growth and abundance of aquatic weeds.

Conflict of interest

No conflicts of interest have been declared.

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