Zinc uptake potential in *Cyperous esculentus*, Linn

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ABSTRACT

The macrophyte Cyperous esculentus Linn. was exposed to the of Zinc (Zn) viz. 1 ppm, 2 ppm, 3 ppm, 4 ppm and 5 ppm and studied its potential of Zn absorption for different exposure durations for zinc absorption and absorption potentials was observed with the interval of 5 days for continuous thirty days, arranging all sets simultaneously alongwith a set of control without Zn for the comparison in same environment following similar all other operating conditions. The present studies revealed Zn absorption was higher at initial period of exposure and gradually reached to the saturation in all the exposed Zn concentrations. The Zn absorption was relatively higher at 3 ppm exposure concentration and all above exposure concentrations. The absorption potential was higher in the roots of Cyperous esculentus L than the absorption potential of its shoots at all exposed concentrations of Zn. The TF was highest (0.498) in set 6 after 30 days of absorption indicating high rate of transfer. The study concluded that, Cyperous esculentus L. is capable to absorb and tolerate Zn at higher concentrations. It is hyper accumulator of Zn. Therefore, it can be used in the sustainable treatment of sewage using Ecofriendly Natural Treatment Systems of Phytoremediation for Pollution remediation in the innovative constructed wetlands like floating wetland reactor systems.

Keywords: Constructed wetland, *Cyperous esculentus* L., Metal concentrations, Aquatic Macrophyte, Emergent aquatic plant, Phytoremediation, Water Pollution

1. INTRODUCTION

The sedges including *Cyperus esculentus* L. are placed in the order Graminales, class Angiospermae with subclass Monocotyledoneae, and family Cyperaceae. There are approximately 75 genera and over 4000 species in this Cyperaceae family, with an estimated 600 species in the genus *Cyperus* [35]. Of these 600 species, two are most notable for their negative impacts they have on agricultural farming. These two weeds are *Cyperus esculentus* L. CYPES (yellow nutsedge) and *Cyperus rotundus* L. CYPRO (purple nutsedge). These both sedges are commonly found in shallow water regions of wetlands, especially prolific in disturbed agricultural soils, where they benefit from irrigation, fertilization and tillage practices [17]. Reasons for their success which are attributed are their perennial nature, prolific tuber production, and the length of time that tubers can survive while remaining dormant [16]. Many methods have been employed to control the dominance of these weeds. There is no any efficient method for the comprehensive removal of these weeds to completely eradicate from agricultural area, has yet to be discovered. The reason for the successful survival of these two weeds lies in their botanical characteristics and ability to survive in any unfavorable environmental conditions.

The Cyperaceae resembles the Gramineae (grass family), both of which are Monocotyledoneae, but have a number of distinct notable featured differences. Wills [101] noted that the Cyperaceae possess three-ranked leaves with one-third phyllo-taxy. These three-ranked leaves have closed leaf sheaths, and usually they have solid stems, but have no ligule, and each flower is subtended by a single glume or scale. There are some distinct structural characteristics of *Cyperus esculentus* L. which have been reported by Wills [101]. The leaves of the yellow nutsedge are 4 - 9 mm in width and 200 - 900 mm in length. The color is pale green and each leaf is three-ranked and corrugated in cross-section. The rachis is 20 - 90 mm in length. It is terminated by an umbel. Each umbel has an inflorescence of a cluster of flower-bearing rays. All of these are emanating from the same level, possessing a number of short rays with two to nine longer rays.

The umbels are between the leaves at the same level, which are all longer than the longest ray. Each of the inflorescences have golden-brown, simple to compound spikelets arranged along an elongated axis. These spikelets are generally four-ranked but may be some times two ranked. These spikelets are flattened seed-bearing structures and are of the sizes between 1.5-3 mm wide and 5-30 mm long. The achenes are of the sizes 1.2-1.5 mm in length, yellowish-brown and three-angled. They are sessile on a spikelet. The achenes are covered by a thin oblong glume or scale.

The *Cyperus esculentus* L. are re-produced annually by seed propagations and perennially re-produced by bulbs from the base of their leaf fascicles, or from rhizomes which extend outward from their bulbs, or by the tubers which are 10-20 mm long and which are often produced at the end of rhizomes [99]. During the growing season the rhizomes produced by the plant either develop into a new bulb, from which a new plant grows, or into a dormant tuber which may lie underground for a number of years [33], [40], [43], [86], [89]. The *Cyperus esculentus* L. is distinguished from the *Cyperus rotundus* L. by its yellowish-brown inflorescence which is pinnately arranged along an axis. Its pale green leaves have long needle-like tips and grow upright. Its weak rhizomes often terminate in bulbs and rarely produce chains of tubers [101].

The *Cyperus esculentus* L. possess two photosynthetic pathways, the conventional C_3 Calvin cycle as well as the efficient C_4 dicarboxylic acid photosynthetic pathway [19], [23], [29]. As is known that the plants with the C_4 pathway are characterised by the Kranz-type leaf structure, where sheaths around the vascular bundles compartmentalize the photosynthetic events, *Cyperus esculentus* L. poses this characteristic. Such pathway allows for efficient uptake of carbond dioxide from the adjacent air as well as from carbon dioxide produced by cellular respirations [101]. The Therefore, the plants enjoy the benefit that they can incorporate CO_2 from warmer air and also at greater light intensities than conventional C_3 plants. Consequently, C_4 plants grow best between day-night temperatures of 25-30°C and 31-36°C. This means, this temperature is 10-20°C warmer than those observed for C_3 plants [19], [29]. This pathway also influences the optimum amount of light the plant needs, with C_3 plants being saturated between 20 and 30% of full sunlight compared to C_4 plants those saturate between 50% and more of full sunlight [101]. Black et al. [19] reported that these plants fix CO_2 at higher temperatures and light conditions, as well as having rhizomes that spread quickly and give rise to new plants. Therefore, such plants have the potential to become serious weeds which includes *Cyperus esculentus* L due to which farmers are most sufferers. Tuber germination and dormancy are two reasons to which farmers have tried to target in order to remove *Cyperus esculentus* L. There is currently no simple method for the removal of tubers of *Cyperus esculentus* L., which may, if not removed, remain lying dormant for a number of seasons before germinating. These tubers are highly resilient. They can survive in extreme conditions of flooding, drought, heat, as well as with the lack of aeration [40]. Most herbicides target the aerial part of this weed plant which brings limited success. The plant dies back for a short period and again it sprouts with no sign of major damage.

The *Cyperous esculentus L.* is one of the emergent aquatic macrophyte plants of common wetlands and is also known as Tiger nut or tigernut vernacularly popular by the name Lavhale in local Marathi language. It is present in many water logged regions and the major water bodies of all tropical and subtropical regions and is considered as invasive species in India. *Cyperous esculentus L.* is one of the indigenous macrophyte plants in India. It is perennial Grass-like other plants native to the Old World. It produces sweet nut-like tubers known as “earth almonds” which is edible [25]. The *Cyperus esculentus* L is commonly located in a number of countries around the world. In many countries and localities including India it is common than any other notorious weed species; colder climates are the only restriction on its dominance in some countries. Conceptually, spread of such plant causes major harm to other native ecosystem dwellers due to alterations, among these, Cyperous esculentus L. is a major one. By the late 1970's it was considered as a weed in 90 tropical and subtropical countries as it had a negative impact on approximately 52 crop species. Consequently, it was given the notorious title of being the world's worst weed [40]. The *Cyperus esculentus* L is a highly capable plant that is able to survive in almost every conceivable habitat with little regard for soil type, pH, humidity, soil moisture and elevation [40], Ranade and Bums [71] reported that *Cyperus esculentus* L does not grow well in soils with high concentrations of salt. Furthermore, due in part to its C_4 photosynthetic pathway, the plant *Cyperus esculentus* L cannot tolerate shade. Holm et al. [40] reported that when other plants, such as cane or plantation trees, grow to a sufficient height to block out the sun, *Cyperus esculentus* L withers and dies, leaving only dormant tubers behind. The *Cyperus esculentus* L is more tolerant to colder conditions and wet soils. It is commonly found primarily along river banks, roadsides, all types of shallow wetlands and ditches, and in moist fields, heavily irrigated crops and on low ground. It can grow better at a pH between 5 and 7 without any observable problems and is relatively tolerant of shading which make it fit to work for the industrial effluents to treat in phytoremediation process.

The *Cyperous esculentus L.* is world’s one of the most common macrophyte. It is highly tolerant to both, soil and water contaminants and high load of nutrients from sewage, industrial effluents or other polluted waters. It grows luxuriously in irrigated conditions and shallow regions of sewage. It is tolerant to changing environments except light shading and drastically affects the other nearby plant communities like crops in agricultural fields. Presence of *Cyperous esculentus L.* decreases the growth of crops by reducing the available nitrate, ammonium, total nitrogen, total phosphorous in soils and decreases dissolved oxygen concentration, changes pH and permanganate index and total bacteria in water littoral and sub-littoral zones of water bodies. It provides ecological benefits such as it increases water clarity by reducing the pollutants [27], [88] and is useful for *in-situ* treatment of wastewater, especially household wastewater and municipal sewage using constructed wetlands [3], [6], [57]-[59], [64], [68], [88], [94], [103]. If its growth is in excess or unwanted in constructed wetlands, it can be easily removed from the wetlands by Hand picking, hand pulls easily.

Zinc is one of the most abundant elements in the Earth's crust. Its concentrations in the environment are rising by anthropogenic activities, almost exponentially due to addition of zinc. Almost in all parts of the world, Zn is one of the major pollutants of aquatic and terrestrial ecosystems [81]-[82]. Zinc in the forms of different salts has many applications routinely. Most of the zinc is added to the environment through the industrial activities, like mining of ores, fossil fuel, through solid waste combustion, hazardous waste disposals, and wastes from different processing units such as steel processing. Zinc has a major role to play in various physiological and metabolic processes of variety of organisms [2], in a many enzyme systems which contribute to the energy metabolism, transcription and translation [1]. The zinc salts are common constituents in the processes of preservation of wood, fertilizers, and active catalysts, various nutritional or medicinal supplements, in the textile processes, rubber and ceramic industrials. It is also used as an agent in galvanizing to prevent corrosion of metals. Zinc chloride is used in smoke bombs for dispersal of public crowds and also in different fire fighting exercises. Zinc is used commonly in its chemical compound forms like nitrate, chloride, sulphate, oxide, and sulphide for medical and dental purposes. Two of its forms, zinc chloride ($ZnCl_2$) and zinc sulfate ($ZnSO_4$) are commonly used in the production of chemical fertilizers for agriculture and also in the manufacturing of herbicides and pesticides[78].

The heavy metals like Cd, Cu, Cr, Mn, Fe, Pb, Ni and Zn are commonly released pollutants discharged effluents from various industries of India. Zinc is one of these major pollutants, which also results from anthropogenic activities and natural processes of weathering. As the zinc is one of the common constituents in various industries, the wastewater released from these industries have zinc as a water pollutant, due to its presence in large quantities [9], [34]. Such polluted wastewater if is not treated effectively and satisfactory, the contamination of water-bodies like rivers and deposition of zinc-polluted sludge on their banks are ultimate consequences.

All the water bodies get affected by the discharges from metal manufacturing and chemical industries, the run-off following precipitation on soils high in zinc content, including agro-soils receiving zinc based fertilizers. Particles released from vehicle tyres and brake linings are also a source of zinc in the environment [98]. Zinc (Zn) is one of the essential growth elements for human beings and vegetation growth. Scientific studies have proved that Zn is also involved in bone formation. However, increased intake of Zn can cause muscular pain and intestinal haemorrhage in human beings [41], [44]. Even if it is present in less quantity and enters in human’s body, it adversely affects the human’s health. In brief, , human beings can handle the large extent of zinc in different forms in routine life. But if it is too much, it can cause major health problems and hence it is problematic [32].

Zinc has restricted mobility from its parent rocks by weathering or from any other natural sources and hence it shows low concentrations in water samples [69] . In water bodies like lakes, reservoirs and rivers, some zinc remains in dissolved state in the water or as fine suspended particles, while the other zinc settles down to the bottom regions of it in association with heavier particles. Rajkovic *et al*. [70] have noticed that elevated zinc levels are toxic to some species of aquatic life. Environmentally, zinc is generally considered as a toxic element and has the potential to bioaccumulate in the food chain [1], [99].

2. Experimental Procedures:

Yellow nut-sedge (*Cyperous esculentus*, Linn) macrophytes collected from a local water-body. The plant samples collected were rinsed with tap water to remove adhered matters, any epiphytes and insect larvae grown on entire plants. Plastic tubs of 20 liters capacity were used for conducting the experiments. The same sized sampled macrophyte plants were selected and placed in plastic tubs filled with tap water in triplicates of six sets in same surrounding environment. The experimental sets were placed under natural sunlight for one week to get adapted to the anthropogenic conditions and then the plants were taken for further experimental studies. A stock solution (1000 mg/L) of zinc was prepared in double distilled water with analytical grade $ZnSO_4.7H_2O$. It was further diluted as per experimental requirements. The yellow nut-sedge (*Cyperous esculentus*, Linn) macrophytes maintained in tap water were supplemented with these freshly prepared aqueous solutions of 1, 2, 3, 4 and 5 ppm (mg/L) concentrations of Zn. One of these triplicate set of plants was not exposed to Zn metal solution to serve as controls for the reference and comparison. All sets of experiments were performed in same environment with similar all other operating conditions. The total period of tests conducted was from start up with count of 0 days to continuous up to 30^{th} day with the intermediate and uninterrupted interval of 5 days for the needful analysis. Tap water was added daily to compensate for water lost through plant transpiration, sampling and evaporation. The yellow sedge (*Cyperous esculentus*, Linn) macrophyte plant samples from each experimental set were harvested after each of the test durations at the interval of 5 days. They were separated into shoots and roots, and were analyzed for respective uptake potential of Zn accumulation. The experimental details were similar to the earlier studies reported elsewhere [81]-[82].

The yellow sedge (*Cyperous esculentus,* Linn) sampled macrophyte plants were washed with tap water and then rinsed with double distilled water to wipe out adhering substances, if any. The roots and shoots were separated, softly make water-free by tissue papers, slowly crushed, blended to homogenize and then these were dried in an oven at 60°C for 24 hours. The all dried samples were pulverized to fine powder and sieved (0.15 mm) adopting the procedure described by Kalra [43]. Separately prepared powder of shoots and roots of plant were directly digested with nitric and perchloric acid to get a transparently clear solution. This clear solution was further diluted to 50 ml with double distilled water [10] to make up and equalize the volume. Zinc (Zn) contents were determined by EDTA Complexometry-Back Titration method as described by Nicolaysen [62] and confirmed [42] . The analytical procedure was confirmed each time by analyzing 2 blanks considering all laboratory and analytical conditions being equal. The translocation factor for Zn was determined from the results obtained using following formula;

Translocation factor (TF) = MCS/MCR………………………..………………..(1)

Where, MCS stands for Metal Concentration in Shoot and MCR stands for Metal Concentration in Root.

3. Results and Discussions:

The removal of heavy metals constituents from industrial effluents, household wastewater and municipal sewage are of paramount importance and need to be taken into consideration as the environmental problems associated with water polluted with heavy metals. Aquatic macrophytes can be used for heavy metal remediation as well as in the study of quality of water quality and aquatic ecosystems and in monitoring of metals and other pollutants [56], [67]. Phytoremediation is one of the effective and affordable technological solutions to the metal contamination and pollution problems. It is the application of plants for in situ or ex situ treatment for remediating the polluted soil, industrial effluent, water or waste water [87]. The green plants including aquatic and terrestrial macrophytes degrade, assimilate, metabolize, or detoxify inorganic and organic pollutants from the polluted environment. Phytoremediation is sustainable, cost effective and simple technology based on the use of specially selected metal-accumulating plants to remove toxic metals [12]. There are number of aquatic plants capable to absorb and accumulate Zn from water and waste water. Zinc is readily absorbed in the emergent macrophytes including the *Cyperous esculentus L.* as Zn is one of the 17 essential micronutrients required by the plants for their healthy growth. Zn is one of the important nutrients for the growth and also for various other developmental and physiological processes of plants. It is one of the 8 essential elements required by the plants for performing various physiological and metabolic mechanisms [26]. Ultimately, it has caused the healthy growth of *Cyperous esculentus L.* in the all sets arranged in present investigations. Moreover, it is absorbed in roots and shoots and got magnified in the all treatment sets arranged irrespective of the exposed various Zn concentrations. Though, the Zn is an essential micronutrient and it is required by the plants for their healthy growth while performing various physiological processes. But if its level is highly elevated then it may prove toxic. Ultimately, it can cause phyto-toxicity in plants. The threshold levels of Zn toxicity various from species to species, type of plant species, nature of growth media, concentrations of Zn contamination in growth media and the time of exposure. In plants, Zn toxicity occurs at concentration range between 400-500 μg/g in the leaves of macrophytes with the visible sign of excess level of Zn in plants such as chlorosis or necrosis of young leaf of plants [80]. But, no such noticeable phyto-toxic effect was observed on *Cyperous esculentus L.* in present studies. It reveals that the macrophyte *Cyperous esculentus L.* is tolerant to the higher concentrations of Zn and hence is a hyper accumulator for Zn. It can be used for remediating the Zn for effluents and sewage with phytoremediation using constructed wetlands.

Table 1: Absorption potential in the Roots of *Cyperous esculentus*, Linn exposed to various concentrations of Zinc at different time intervals.

Zinc conc. (ppm)	**Exposure period (Days)**						
0	0	5	10	15	20	25	30
0.0 (Set 1) Control	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1.0 (Set 2)	0.00	4.4	9.2	14.2	16.1	17.5	18.0
2.0 (Set 3)	0.00	5.5	11.6	16.1	18.7	20.4	21.7
3.0 (Set 4)	0.00	8.3	14.4	19.6	23.2	23.9	24.1
4.0 (Set 5)	0.00	9.5	18.1	20.5	23.6	24.9	25.8
5.0 (Set 6)	0.00	10.9	19.8	24.1	25.8	26.9	27.3
1.0 (Set 2)	0.00	4.4	9.2	14.2	16.1	17.5	18.0

Table 2: Absorption potential in the Shoots of *Cyperous esculentus*, Linn exposed to various concentrations of Zinc at different time intervals.

Zinc conc. (ppm)	Exposure period (Days)						
0	0	5	10	15	20	25	30
1.0 (Set 1) Control	0.01	00	00	00	00	00	00
1.0 (Set 2)	0.00	0.8	2.4	3.7	5.6	7.8	8.4
2.0 (Set 3)	0.00	1.8	3.7	5.0	7.2	8.4	9.4
3.0 (Set 4)	0.00	2.9	4.5	6.2	8.1	9.7	10.6
4.0 (Set 5)	0.00	3.2	5.3	7.2	9.5	10.4	11.5
5.0 (Set 6)	0.00	3.4	5.6	7.6	10.3	12.3	13.6

Heavy metals in undesirable concentrations are ecologically harmful and important environmental pollutants. Many of them are toxic even at very lower concentrations. Various plant species show different responses and behaviors regarding their abilities to accumulate metal elements in their roots, shoots and other parts. Therefore, it is useful to identify the plant organ that absorbs the highest amount of metals [15], [85]. The results presented in Table 1 and Table 2 indicates that the zinc tends to accumulate more in the roots of *Cyperous esculentus L.* than its shoots. The shoots of aquatic plant *Cyperous esculentus L.* accumulated lower concentrations of Zn than roots, which is well substantiated with the findings of Baldantoni et al. [15]. If the plants are exposed to higher concentrations of Zn, it causes toxicity and reduces the growth of main root. It also retards the growth of lateral roots as reported by Ren and his co-researchers [77]. But, no such effects were noticed in present studies.

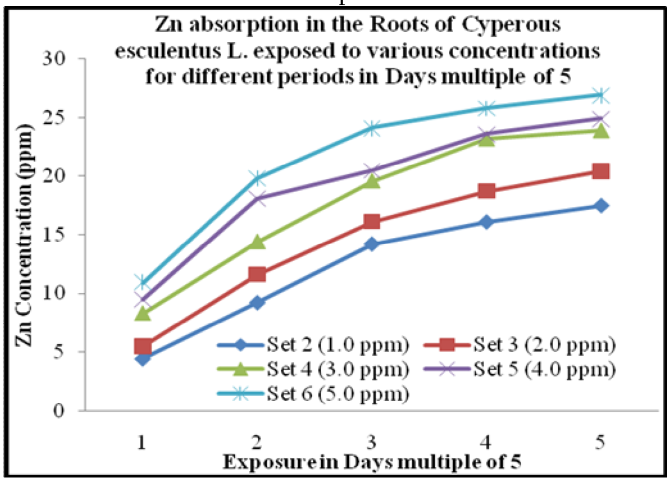

Fig.1: Zn absorption in the Roots of *Cyperous esculentus L.* exposed to various concentrations for different periods in Days multiple of 5.

Absorption of Zn in the roots of *Cyperous esculentus L.* was relatively rapid in the initial periods in all the experimental sets for 10 days and was slowed down thereafter. The absorption rate was turned to almost study state after 25 days of exposure in almost all Zn exposed experimental sets. There was no change in the Zn concentration of plant samples grown in control set (Fig.1).

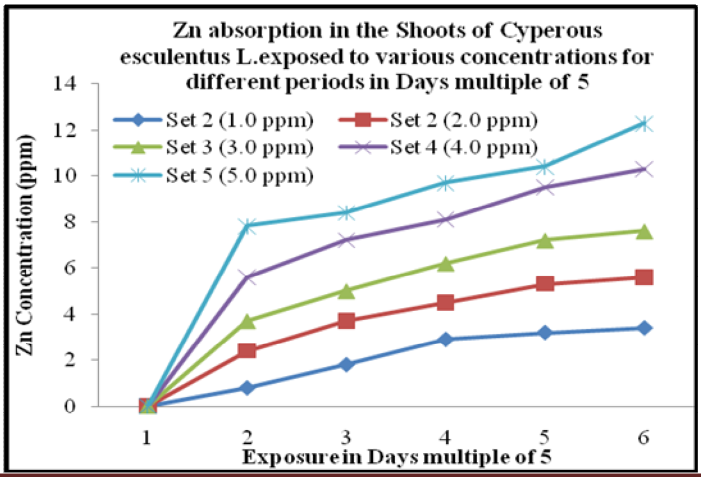

Fig.2: Zn absorption in the Shoots of *Cyperous esculentus L.*exposed to various concentrations for different periods in Days multiple of 5.

The rate of absorption of Zn in shoots was lower than the absorption in roots of *Cyperous esculentus L.* in all the Zn exposed sets. The Zn concentrations for entire experimental period in control were nil indicating that the absorption of Zn in all other sets was due to the exposed concentrations of Zn. The trends of absorption of Zn in shoots of test plants in all experimental sets other than control were almost similar to the trend in roots, with increasing absorbed quantities in higher exposure concentrations (Fig.2). As the rates of Zn absorption were higher at higher exposure concentrations and increasing at initial period, found slightly reduced indicating that they were tending to steady state after 25 days.

Table 3: TF factor of *Cyperous esculentus L.* exposed to various concentrations of zinc at different time intervals.

Zn Conc. ppm)	**Transfer Factor at Different Exposure periods (Days)**						
0	0	5	10	15	20	25	30
(Set 1) Control	0.00	00	00	00	00	00	00
1. 0 ppm (Set 2)	0.00	0.182	0.261	0.261	0.348	0.446	0.467
2. 0 ppm (Set 3)	0.00	0.327	0.319	0.311	0.385	0.412	0.433
3. 0 ppm (Set 4)	0.00	0.350	0.313	0.316	0.349	0.406	0.440
4. 0 ppm (Set 5)	0.00	0.337	0.293	0.351	0.403	0.418	0.446
5. 0 ppm (Set 6)	0.00	0.312	0.283	0.316	0.399	0.457	0.498

Most of the aquatic macrophytes have naturally developed their abilities for the acquisition of relatively less abundant micronutrients such as Cu, Zn, Ni and Mn from the surrounding growth media such as water, waste water or soil. Sometimes, those are highly reactive and potentially toxic to these macrophyte plants. The uptake, transport and accumulation of these abundant micronutrients are coordinated and routinely regulated in plants as per their requirements. A few of these macrophytes are naturally tolerant to specific one or more metals. They are capable to absorb and accumulate these metals in substantial quantities in their biomass during their growth due to their effective uptakes and translocation abilities [81]-[82]. These plants have evolved the effective transfer and translocation mechanism that can concentrate these metals in their different plant parts from low concentrations to high water concentrations. Therefore, they are regarded as accumulator macrophyte plants. The results obtained in present investigation indicate that *Cyperous esculentus L.* is a hyper accumulator for Zn. The uptake and transfer of heavy metals from water to different plant parts is a process of significant importance and determining of Transfer factor (TF). Transfer Factor is a key parameter to assess the availability of elements and hyper-accumulation capacity of the aquatic plant species and their phytoremediation potentials [65]. Therefore, a detailed study on the metal transfer from water to plant and metal translocation to its parts reflect more light on the metal accumulation potentials of *Cyperous esculentus L.*aquatic macrophyte plant. Therefore, transfer factor for Zn translocation in shoot of *Cyperous esculentus Linn.* from its root in each set was determined. It is observed that the TF was highest (0.498) in set 6 after 30 days of absorption indicating high rate of transfer. The TF was relatively higher with the Zn absorption period in all the experimental sets except control set. TF indicated ability of *Cyperous esculentus L.* in translocation of the metals from its roots to the shoots. The results for TF are perfectly similar to the observations of Baker [12]. Transfer factor can be used to estimate plant's potential for phytoremediation purpose. Higher value indicates higher transfer of metal absorbed. The transfer factor in any plant if is greater than 1 ((TF > 1) then it signifies that the plant is capable in translocation of the heavy metal from its root to the shoot [13]. The calculated values of TF factor in present investigation (Table 3) are relatively higher in all exposure concentration in all Zn exposed sets of *Cyperous esculentus L.* and are comparatively higher that TF factors in water hyacinth (*Echhornia crassipes* L) and water lettuce (Pistia stas ratiotes L) published elsewhere [81]-[82].

Distribution of the elements among plant organs depends on the metal mobility. The plants translocate the essential trace elements like Mn, Cu and Zn from the roots into the shoot tissues for metabolic use, and no pathways for the transport of toxic trace elements like Cr, Ni, or Pb to these tissues which has been scientifically confirmed [21], [48], [93]. It is likely that the protective mechanisms in macrophytes and other plants prevent entry of these toxicants from penetrating into the shoot and other plant parts after absorbing in the roots. Some toxic elements can be accumulated in a harmless or non-dangerous form even in other associated organisms provided with detoxification mechanisms, such as the production of metal binding thyoneins or calcium phosphate granules [74]. Comparing the results obtained in present studies, it can be concluded that Zn gets accumulated, concentrated and partly in roots, but some of its amount gets transferred and accumulated in the shoots of the *Cyperous esculentus L.* macrophyte plants which are exposed to various concentrations of Zn. The Zn is primarily accumulated in the root and partially transferred to shoots, probably in order to protect other plant parts from harmful effects of metals.

The *Cyperous esculentus Linn* has higher potential for Zn absorption and accumulation as noticed in the present investigation. Similar observations on absorption potential and translocation ability of different macrophytes in their roots and shoots have been reported by many workers. Water lettuce (*Pistia stratiotes* L.), Water hyacinth (*Eichhornia crassipes* L) are much studied in this regard by many researchers [4], [6], [24], [28], [36]-[38], [50], [54], [60], [63], [75]-[76], [79], [84], [95], [102]. Similar observations are reported by many others [7], [22], [31], [46], [51], [81]-[83], Many scientific studies have also pointed out that heavy metals are not only retained in the roots and transferred to the shoots. These metals also get deposited in the leaves. Such metal deposition reported by many scientists [49], [55], [61], [73] is at these concentration levels. It may of the order of 100 to 1000 times higher than are normally found in non-hyper accumulator plant species. Thus, such hyper accumulator macrophytes may be preferred to use them effectively for phytoremediation treatment processes in the Natural Treatment Technologies for treating any wastewater contaminated with Zn as one of the contaminants. The floater constructed wetland systems would be more appropriate for its use in phytoremediation [27], [81]-82], [88]. Presently, we know various physicochemical methods for remediation of heavy metals from the terrestrial and aquatic environment are not feasible due to energy intensiveness and expensive too. Therefore, there is urgent need of eco-friendly and sustainable biological treatment system, which can provide suitable alternative solution and replace these traditional treatment systems. Phytoremediation of sewage and industrial effluents through aquatic macrophytes is emerged as simple, cost effective and self-sustaining alternative of the traditional treatment methods. It is advisable from the present studies that the *Cyperous esculentus L.* can be recommended for phytoremediation using constructed wetland systems for the industrial waste water treatment units and other effluent treatment units including sewage and trade effluents having Zn as major polluting constituent as it is effective, efficient, ecofriendly, better, cost effective or cheaper and hyper tolerant absorber of Zn. It can serve the purpose of sustainable and long running treatment process. It is useful for constructed wetlands for both, in-situ treatments and ex-situ treatments. If the floating aquatic systems such as newly designed and developed by present researcher's research groups [27], [81]-[82], [88] and are used, there is no need of any additional area for developing the treatment units or treatment set up facilities which overcomes the problem of shortage of land availability. The treatment of effluents can take place with in-situ method and monitored easily at the effluent flow channels or open storages. Such treatment processes does not need any highly trained manpower, does not need electricity and any other mechanized systems.

4. Conclusions:

The research findings of present investigation revealed that the high accumulation of Zn metal takes place in roots of *Cyperous esculentus L.* than its shoots at any level of Zn concentration. The shoot of emergent plant *Cyperous esculentus L.* accumulated lower concentrations of Zn than roots and no any sign of toxicity is observed indicating that *Cyperous esculentus L.* is a hyper accumulator of Zn. The present investigation has led to conclude that, *Cyperous esculentus L.* is not only a good hyper absorber of Zinc but also is highly tolerant hyper accumulator of Zn. It is therefore advisable to recommend for its use in Natural Treatment System of Phytoremediation to serve the sustainable and Ecofriendly treatment technology for controlling the pollution with in-situ design of constructed wetlands like floating wetland reactor systems that can resolve the problem of zinc contamination.

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