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Morphological Characterization, Biomass and Biofunctional Yield of Some Aquatic Weeds of North Eastern Terai Region of UP

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ABSTRACT
North-Eastern Terai Region of U.P. is situated in the foothill region of Himalaya's and has many water reservoirs Viz. River, ponds, nullah, canals and water ditches. Forty three aquatic plant species from different water reservoirs have been surveyed for morphological characterization, field characterization and biomass yield as a whole and their biofunctional parts viz. leaf, stem, root, flower were also investigated. Categorization of species were done according to their biomass yield, twenty three species fall under category A: 1-4 kg, eight species fall under category B: 4-7 kg, seven species fall under category C: 7-10 kg and five species fall under category D: 10-15 kg /m².The data indicate that aquatic plants can produce huge amount of green biomass and could be exploited as potent source of dietary food/feed supplements and reservoir of many biofunctional secondary metabolites, which can be used as preventive drugs, nutraceuticals, pharmaceuticals and other industrial uses.
Key words: Morphological Characterization, Biomass, Biofunctional yield, Aquatic Weeds.

Introduction

Leaves are valuable source of protein; their exploitation is expected to grow in relation of growing world's food need. To help or prevent certain health problem and adequately feed people, there is need for added contribution from leaves. Green leaves produce primary and secondary proteins and other phytochemicals such as nutraceuticals, pharmaceuticals, pesticides and industrial products. Studies regarding value added trait, such as the biofunctional and biologically active components of green leaves have only recently begun because most especially phytochemical extracted from other plant sources. Not only can biofunctional aquatic plants provide healthy food constituents for use as nutraceutical pharmaceuticals and pesticides but also they can increase healthy food resources worldwide. Aquatic plants have been used in past primarily for forage, food, aquatic pasture, green manuring, salad, shelter and improving water quality. The future of aquatic plants is in a health markets as new medicines, nutraceuticals and to provide people with additional food production as phytopharmaceutical or nutraceutical food [6, 7].

The promise of aquatic plant proteins is potential and their utilization has been reported and advocated by many workers. Aquatic plant is potential source of food, fodder, fibre, oil yielding, paper manufacturing biofertilizer, biofuel, medicine, pharmaceutical, chemotherapeutics/ ethno therapeutics, pesticides, improve water quality and aquatic system conservator [1, 2, 3,7, 8, 9]. Many developed countries viz. USA, Japan, France, Germany etc. are now engaged in exploration of nutraceutical bioactive molecules for commercial use. In India, however, little work has yet been done about the exploration and utilization of aquatic plant as nutraceutical food supplements or preventive drugs.

Aquatic plants play a critical role in natural ecosystem, agriculture and agro forestry where their ability to cleaning water improve water quality and also produce food, shelter and breeding place for fishes and aquatic animals and potent in supplying natural resources and also increase the income of neighboring people residing around the natural aquatic system. Aquatics are tremendous source for discovery of new product of medicinal /nutraceutical value for drug/nutraceutical development [4, 5]. Today several distinct chemicals derived from plant are important preventive medicine /nutraceutical drugs, currently used in one or more countries in the world. Many of drug sold today are simple synthetic modification or copies of naturally, obtained substances. The evolving nutraceutical/ commercial importance of secondary metabolites has in recent years resulted in a great interest in secondary metabolism particularly in the

possibility of altering the production of bioactive plant metabolites as a preventive drugs/ nutraceutical in many ways [8, 10].

Aquatics are nature's gift because of their simplicity, origin and evolutionary significance which was originated in water system and fix higher amount of chemical energy in form of carbohydrates and releases life supporting oxygen (O_2) as a by product of the photosynthetic process. They are rich in protein food; therefore they are regarded as power packs of protein and reservoirs of phytonutrients and power packs of natural energy. Aquatic plants would be better protein producers economically, owing to richness of organic matter in aquatic system. An ideal protein yielding plant should have less fibre and more moisture. It should also have lush dark green leaves and should be free from toxic substances and excessive acid, mucilage and phenol.

Several aquatics produce economically important organic compounds such as phytochemicals and nutraceuticals [11]. However, most aquatic plant species have only begun to be surveyed for chemical or biologically active constituents, and new sources of commercially valuable resources remain to be discovered.

The present study therefore, has been motivated with idea of assessing the Biodiversity, morphological and field characterization, biomass and biofunctional yield of some aquatic plants from the North Eastern Terai region of Uttar Pradesh.

MATERIAL AND METHOD

Biodiversity survey and collection of aquatic plant species from different water reservoir of North-Eastern Terai Region of U.P. were done in different seasons. Identification made with the help of literature, expertise available and herbarium in the Department of Botany, DDU Gorakhpur University, Gorakhpur. Morphological and taxonomical characterizations were done in field survey as well as in laboratory.

Biomass production of different biofunctional parts i.e. leaf, stem, root, flower and whole plant was studied on fresh weight basis. Biofunctional parts were collected from different localities at medium maturity age of the plant species. The fresh weight of the biomass of biofunctional parts were taken at fresh and healthy stage.

RESULT AND DISCUSSION

Biological activities; biofunctional utilization, morphological characterization, biomass and biofunctional yield of 43 aquatic plant species belonging to 22 families from the flora of North-Eastern Terai Region U.P. are presented in Table-1. The plant species are listed in the table according to Bentham and Hooker's system of classification. The Biodiversity survey, biofunctional parts used and utilization of these plants species were given in Table-1.Out of these 43 plant species 5 species were used as leafy vegetable, 9 species as vegetable, 12 species as fodder, 10 species as medicine and 7 species were used commonly as food, fodder and medicine (Fig.-1). The morphological and field characterization, biomass and biofunctional yield of different biofunctional parts were mentioned in Table-1. Table-2 shows categorization of species under survey on the basis of biomass yield (Kg/m^2) which has been grouped into four categories, viz.category1: biomass yield between 1-4 Kg; category 2: biomass yield between 4-7 Kg; category 3: biomass yield between 7-10 Kg and category 4: biomass yield between 10-15 Kg (Fig.-2). The results indicate that aquatic plants produce huge green lush biomass which can be exploited as a potent source of dietary food and feed protein and reservoir of many biofunctional secondary metabolites which can be used as preventive drugs, nutraceutical, pharmaceutical and industrial uses, after removal of its anti nutritional factor.

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Table-1: Morphological characterization, Field characterization, Biomass and Biofunctional yield

Sr. No.	Name of species	Morphological characterization	Field characterization	Biomass (kg /m2)	Biological yield/m2				
					Biofunctional yield (kg/m2)				
					F	L	S	R	WP
1.	*Alternanthera sessilis* L.	Prostrate, branched, glabrous herb, rooting at the nodes, leaves glabrous, 2-10cm. Long. Flower white, 2-3mm.long.	Plant grows in large clumps and at places form dense vegetation growing in marshy place, moist area.	1.955	0.053	0.533	1.155	0.213	1.954
2.	*Alternanthera paranychoides* St.	Prostrate herb, rooting at the nodes, leaves spathulate or ovate, flower white, 2-4 mm long.	Grows luxuriantly on the bank of river Rapti, Gorra, Ramgarh Taal, and even around small ponds and water bodies.	2.355	0.45	0.841	1.570	0.343	2.355
3.	*Aponogeton crispum* Thunb.	A perennial submerged, stoloniferous aquatic herb with tuberous root stocks. Leaves 30-90 cm. long, Sub merged, membranous, with rounded for cardate base. Fl. white.	Commonly found in ponds, ditches, and lakes and in low lying area.	3.750	-	2.750	0.750	0.250	3.750
4.	*Aponogeton natans* L.	A floating aquatic herb Leaves 15-20 cm. long, acute or obtuse, base rounded or cardate. Fl. bluish purple.	Commonly found in ponds, lakes, Taals and other water ditches.	3.850	-	2.650	0.850	0.350	3.850
5.	*Bacopa monnieri* L.	A creeping ascending, glabrous, herb with sessile, oblong, obtuse leaves. Flower bluish purple or white.	Frequently found in marshy places along margins of nullah, rivers taals, lakes etc.	1.950	-	0.750	0.450	0.750	1.950
6.	*Centella asiatica* L.	A prostrate creeping herb, rooting at the nodes, leaves 1.25-7.5 cm.long, reniform or orbicular, glabrous. Flower small, pink, sessile. Fruits 2-seeded, seeds brown oblong.	Commonly found on moist places, meadows, along irrigation channels and other semi aquatic places.	2.350	0.051	1.522	0.672	0.102	2.350
7.	*Cerratophyllum demersum* L.	A submerged, much branched densely leafy, rootless aquatic herb. Leaves 2. Cm. long, whorled much dissected, filiform segments Fl. 1mm. long, minute, green.	Commonly found in Ponds, Tals, lakes and ditches. Luxuriant growth in Bakhira taal.	4.124	-	1.250	2.450	0.375	4.125

8.	*Colocasia esculenta* L.	An erect rhizomatous perennial herb Leaves 15-20 cm. long, Purple blotched petioles, rounded, glabrous.	Found in and along the margins of lakes, ponds and other water ditches.	9.950	0.350	5.250	3.250	1.100	9.950
9.	*Eclipta prostrata* L.	An erect or prostrate, rough, annual herb. Stem often rooting at the nodes, leaves sessile, linear or oblong, Fruits; achenes, winged on the margin.	Commonly found in pastures, wet places, along water channels and rice fields.	3.250	0.221	1.181	1.477	0.369	3.248
10.	*Eichhornia crassipes* (Mart.) Solms.	A floating aquatic herb rooting at the nodes. Leaves 4.5 - 6.5 cm. long, alternate rosullate with spongy petiole in the middle. Fl. 5.5 cm. long, bluish – violet in many flowered spike. Seeds ovoid ribbed.	Commonly found floating in lakes, roadsides and sides of Railway track ditches.	14.202	0.430	9.730	-	4.040	14.200
11.	*Echinochloa crus-gallis* L.	An erect, glabrous annual grass upto 80 cm. long Leaves linear, flat, with finely cartilaginous margins. Sheath compressed. Spikes sessile, many, sub-erect or patent	Commonly found along the margins of lakes, Taals, water ditches and paddy fields.	3.950	0.250	1.150	1.750	0.850	3.950
12.	*Eleocharis dulcis* Burm F.	A densely tufted, perennial sedge upto 40-70 cm high, stem erects stout, longitudinally striated, dark green. Leaf sheaths membranous, purplish.	Abundant in shallow water, along the margins of tall, nullahs and in muddy soil.	3.750	0.050	1.500	1.250	0.950	3.750
13.	*Eragrostis tenella* L.	An erect, ascending, tufted annual grass. Leaves linear, tapering To & five points, flat or fold when dry, sheath ciliate near the mouth. Panicle greenish – purple.	Frequently found in low lying areas.	3.150	0.115	1.235	1.345	0.155	3.150
14.	*Eragrostis unioloidese* Retz.	An erect. decumbent ascending, annual grass Leaves cordate, linear, margins rough, sheaths smooth, glabrous.	Commonly found in moist places.	3.250	0.135	1.350	1.340	0.250	3.250

15.	*Euryale ferox* Salisb.	Large, stemless, prickly herb, laticiferous, rhizomes thick, short, erect, submerged leaves not prickly. Leaf blade sagittate, flower blue, fruit dark purple, globose 4-10 cm.in diameter, spongy, densely prickly, seeds black, 8-many, testa thick, rigid, flowering in summer.	Rotted deep-water aquatics grow in muds and leaves are floated.	5.750	0.355	3.390	0.650	1.450	5.750
16.	*Hygrophilla auriculata* Schum.	An erect annual herb, long white hairs on each node, leaves opposite, in the whorls of 6 each with straw coloured spines. Flowers bluish purple. Capsule oblong or linear, 4-6 seeded. Seeds hairy.	Mainly found along with the margins of lakes, taals, canals and low lying area.	6.950	0.350	2.120	3.750	0.730	6.950
17.	*Hygroryza aristata* Retz.	A floating gross, rooting at the nodes, root in whorls, stem much branched, spongy with leaf sheath. Spike - lets 6 mm long, lanceolate, greenish white, erect, single flowered.	Found in shadow water at Taals, lakes, ponds, ditches chiefly in association with *Ipomoea aquatica* & *Nymphoides indicum.*	1.750	-	0.545	0.755	0.460	1.750
18.	*Ipomoea aquatica* Forsk.	An aquatic trailing herb, rooting at nodes, stem thick, hollow, glabrous, leaves 4-15 cm.long.capsule ovoid, glabrous.	Plants are noticed in the muddy soils of ponds, pools and roadside ditches.	2.350	0.213	0.727	1.564	0.224	2.350
19.	*Lemma minor* L.	A small or minute aquatic herb. Fronds herbaceous, broad obovate, floating, dark green.	Commonly found in still waters of ponds pools and water ditches.	1.540	-	1.440	-	0.100	1.540
20.	*Ludwigia adscendens* L.	Long stem floating on water by means of white air-roots. Flower whitish or pale creamy shade with yellow center. Capsule cylindrical.	Commonly found in ponds, pools, lakes and pig ditches.	3.750	0.125	0.850	1.750	1.050	3.750
21.	*Monochoria hastata* L.	An erect aquatic herb with creeping	Commonly found along the margins of lake, taals and ditches	11.900	0.425	6.750	2.850	1.750	11.900

		rootstocks. Leaves 10-20 cm. long, Flowers 2.8 cm. long, Pale blue or purplish. Capsule 8-10 cm long, enclosed within persistent twisted perianth. Seeds 1mm. long, with brown ribs, yellow.	may also found in moist dry ponds or ditches						
22.	*Monochoria vaginalis* Burm.F.	An erect aquatic herb, linear or ovate, base rounded, flowers 2.5 cm. long, blue in short peduncle racemes.	Frequently found along ponds, lakes, Taals and other water ditches	10.950	0.350	6.350	2.350	1.655	10.950
23.	*Najas gramineae* Del.Fl.	A slender, grassy, sub merged aquatic herb rooting from basal nodes Leaves pseudo whorled linear denticulate. Fl. greenish, solitary naked.	Commonly found in shallow water of ponds, lakes, Taals and ditches in association with U*tricularia flexuose* & V*allisneria spiralis.*	7.110	-	3.250	2.750	1.110	7.110
24.	*Nelumbo nucifera* Gaertn.	Large perennial herb with a stout, creeping underwater rhizome. Leaves large upto 60-cm.in diameters. Flowers white or pinkish red, 10-25 cm. in diameter, fragrant. Fruits consisting of the dry enlarged torus in the cavities of which the carpel are inserted.	Found in taals, ponds, tanks and lakes. Rooted aquatic plant in muddy soils.	5.350	0.800	2.350	1.450	0.750	5.350
25.	*Nymphaea nauchali* Burm.F.	Floating aquatic herb, leaves 15-30 cm. across deeply cardate, sharply toothed. Flower pink to deep red. Fruit berries globose, ripening under water.	Common in Ramgarh Taal, Mahesara Taal and other ponds.	3.950	0.690	1.750	0.850	0.750	3.950
26.	*Nympheaea cerulae* var *stellata* Willd.	A large floating herb leaves elliptical or orbicular, flower blue, white, pink or purple. Fruit globular.	Common in ponds, tanks, taals and lakes. Used for ornamental purpose.	3.850	0.590	1.760	0.855	0.745	3.850
27.	*Nympheaea lotus* Hock F.	Floating aquatic herb. Leaves sub sagittate when young. Flower variable in size and colour,	Commonly found in Ramgarh Taal, Chilua Taal, and water reservoir.	3.275	0.490	1.760	0.650	0.370	3.275

		opening in the morning and closing shortly before noon, seeds numerous.							
28.	*Ottelia alismoides* L.	A submerged aquatic herb, rooting in the mud. Leaves 2.8-5.0 cm. long, crowded broadly ovate or sub – orbicular, apex rounded. Fl. 3-4 cm. long white bisexual, floating, sessile, within a tubular, green, long, and pedunculate.	Commonly found along shallow water of taals, lakes, ponds, ditches.	7.215	0.650	4.415	0.850	1.750	7.215
29.	*Pistia stratiotes* L.	A stemless, free floating aquatic herb. Leaves 3 - 2 cm. long, sessile, densely pubescent, each surrounded by a membranous sheath. Fl. 8 mm. long, unisexual, perianth absent. Pistillate flowers. Fruit green, ovoid, crowned by persistent style.	Commonly found in stagnant water of ponds, lakes, Taals, water reservoirs.	3.670	-	2.750	-	0.920	3.670
30.	*Polygonum barbatum* L.	An erect or ascending annual herb with glabrous stem, thickened at nodes and sub sessile leaves. Flower white in dense erect racemes. Bract glabrous, perianth pinkish white.	Frequently found along margins of water bodies like ponds, pools and ditches.	8.150	0.375	2.065	4.450	1.250	8.150
31.	*Polygonum glabrum* Willd.	An erect or decumbent, glabrous annual herb. Stem usually red, leaves 5-23cm.long, shining, glabrous, gland dotted. Flower light pinkish or white in terminal panicles.	Commonly found along bank of taals, rivers, nullah and other ditches.	8.430	0.385	2.045	3.850	2. 150	8.430
32.	*Polygonum hydropiper L.*	An erect ascending or decumbent herb. Stem glabrous, glandular, nodes swollen. Leaves 5-12 cm. long, Sub-sessile, midrib hairy	Frequently found along marshy places marshy places mainly in cultivated paddy fields.	7.250	0.250	1.100	3.250	2.650	7.250

		glands punctate. Fl. pink in filiform Hexuous racemes.							
33.	*Potamogeton pectinatus* L.	A filiform submerged aquatic herb, stem dichotomously branched, leaves 7.5-16.5 cm.long, alternate. Flower greenish in distant whorls, minute on spikes.	Commonly found along the shallow water margins of lakes, Taals, ponds rivers, chiefly in association with *Aponogeton natans* and *vallisneria sp.*	3.428	-	2.366	0.652	0.408	3.426
34.	*Potamogeton nodosus* Poir.	A submerged rooted, aquatic herb with upper or leaves floating. Flower reddish brown in colour, 4-5 cm.long spikes above the water surface.	Frequently found in ponds, taals, tanks and ditches in association with *Aponogeton natans and nymph ides indicum.*	1.750	-	1.250	0.250	0.250	1.750
35.	*Potamogeton crispus* L.	A slender dichotomously branched, submerged aquatic herb. Leaves 5-15/0.5-1 cm. Long alternate, sessile, stipule small, hyaline caducous.flower small, greenish in short dense.	Commonly found in stagnant water of lakes, Taals and ditches.	2.250	-	1.250	0.650	0.350	2.250
36.	*Ranunculus scleratus* L.	An erect glabrous annual herb, 30-90 cm. tall, .stem succulent, branched, fistular, yellowish green. Flower pale yellow. Fruits achenes, many in oblong to cylindrical heads.	Commonly found along the bank of river Rapti, Gorra, Ramgarh Taal, Mahesara Taal and other water reservoir.	5.012	0.128	1.250	3.250	0.375	5.030
37.	*Rumex dentatus L.*	An erect much branched, annual herb with fistular, grooved stem. Leaves 2.5-10 cm long. Fl. 3 mm long greenish in whorls.	Commonly found along ditches, margins of sewage water and in low lying areas.	5.900	-	3.750	1.250	0.885	5.900
38.	*Sagittaria sagittif*olia L.	An erect aquatic herb with fibrous roots. Leaves radical hastate or sagittate, flower diverging on long petiole. Flower 2-3 cm.long, purplish white in clustered spikes.	Commonly found along the margins of Ramgarh Taal, Mahesara Taal, Bakhira lake and other ponds, pools and ditches.	7.100	0.721	4.260	1.014	1.106	7.101
39.	*Sphaeranthes indicus* L.	A viscous pubescent, much branched annual herb. Leaves sessile, 2.5-5	Frequently found in moist places and rice fields.	3.950	0.139	1.161	2.270	0.278	3.948

		cm.long.dentate or serrate, toothed.flowers pink or purple; heads many, densely packed, heterogeneous.							
40.	*Trapa* oxb.	An attached floating aquatic herb with ascending stems. Floating leaves crowded in the upper part of the stem. Flower white, solitary, sepal's persistant.fruit is nuts angled with a sharp spiny horn on either side.	Commonly cultivated in the ponds, pools, and lakes for its edible fruits.	5.950	-	3.725	0.475	1.750	5.950
41.	*Typha elephantina* Roxb.	An erect 5m. tall perennial herb with creeping rhizomes. Leaves basal membranous sheath, offer undulate, above, the middle broad white margined.	Frequently found in marshy places.	11.200	-	3.250	6.250	1.950	11.200
42.	*Typha angustata* Bory et. Chaub.	An erect aquatic herb e creeping rhizome. Leaves 2-2.6 cm long, radical, erect, acute, longer than the flowering stem Flowers pale coloured.	Commonly found in gregarious patches in marshy places.	13.900	-	3.750	7.500	2.650	13.900
43.	*Veronica anagalis-aquatica* L.	An erect, glabrous semi aquatic herb with fistular stem and sessile leaves. Flower whitish or purplish.	Commonly found along water channels. Shallow water ditches and nullah.	6.750	0.125	2.500	3.250	0.850	6.750

Abbreviation : F = Flower; L = Leaf ; S = Stem ; R = Root; and WP = Whole Plant

Table-2: Categorization of species under survey according to Biomass yield

Category	***Plant***	***Biomass yield Kg/m²***
1	***2***	***3***
A:Biomass yield 1-4kg	***Alternanthera sessilis***	***1.955***
	Alternanthera paranychoides	***2.355***
	Ipomoea aquatica	***2.350***
	Potamogeton nodosus	***1.750***
	Potamogeton crispus	***2.250***
	Potamogeton pectinatus	***3.428***
	Centella asiatica	***2.350***
	Lemna minor	***1.540***
	Hygroryza aristata	***1.750***
	Bacopa monieri	***1.950***
	Nymphaea nauchali	***3.950***
	Nymphaea cerulae	***3.850***
	Nymphaea lotus	***3.275***

	Ludwigia adsendens	*3.750*
	Eclipta prostrata	*3.250*
	Sphaeranthes indicus	*3.950*
	Pistia stratiotes	*3.670*
	Aponogeton crispum	*3.750*
	Aponogeton natans	*3.850*
	Eleocharis dulcis	*3.750*
	Echinocholoa crus-gallis	*3.950*
	Eragrostis tenella	*3.150*
	Eragrostis unioloides	*3.250*
B: Biomass yield 4-7kg	*Euryale ferox*	*5.750*
	Nelumbo nucifera	*5.350*
	Trapa bispinosa	*5.950*
	Ranunculus scleratus	*5.012*
	Veronica anagalis- aquatica	*6.750*
	Hygrophilla auriculata	*6.950*
	Rumex dentatus	*5.900*
	Cerratophyllum demersum	*4.124*
C: Biomass yield 7-10kg	*Sagittaria sagittifolia*	*7.100*
	Polygonum hydropiper	*7.250*
	Polygonum glabrum	*8.430*
	Polygonum barbatum	*8.150*
	Ottelia alismoides	*7.214*
	Colocasia esculenta	*9.950*
	Najas gramineae	*7.110*
D: Biomass yield 10-15kg	*Eichhornia crassipes*	*14.202*
	Monochoria hastate	*11.900*
	Monochoria vaginalis	*10.950*
	Typha angustata	*13.900*
	Typha elephantina	*11.200*

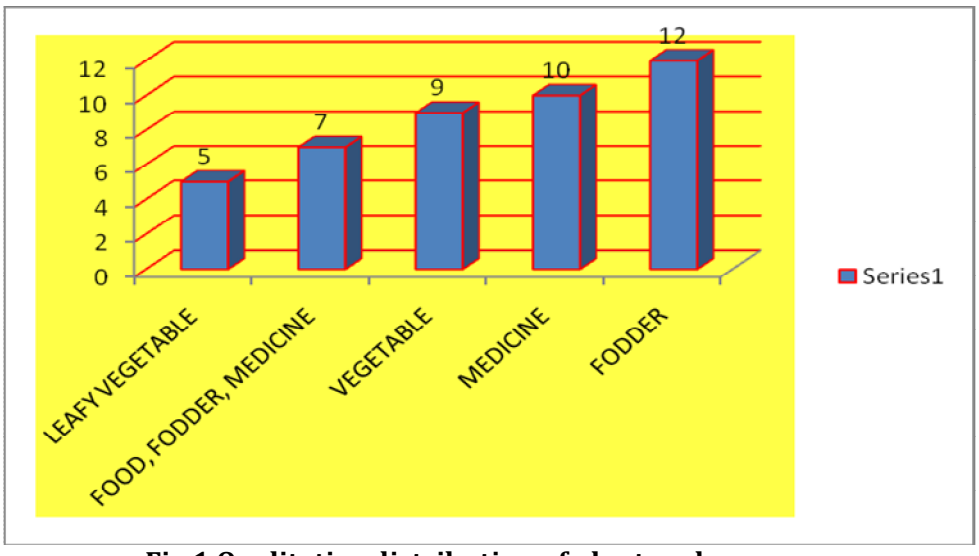

Fig.1 Qualitative distribution of plant under survey

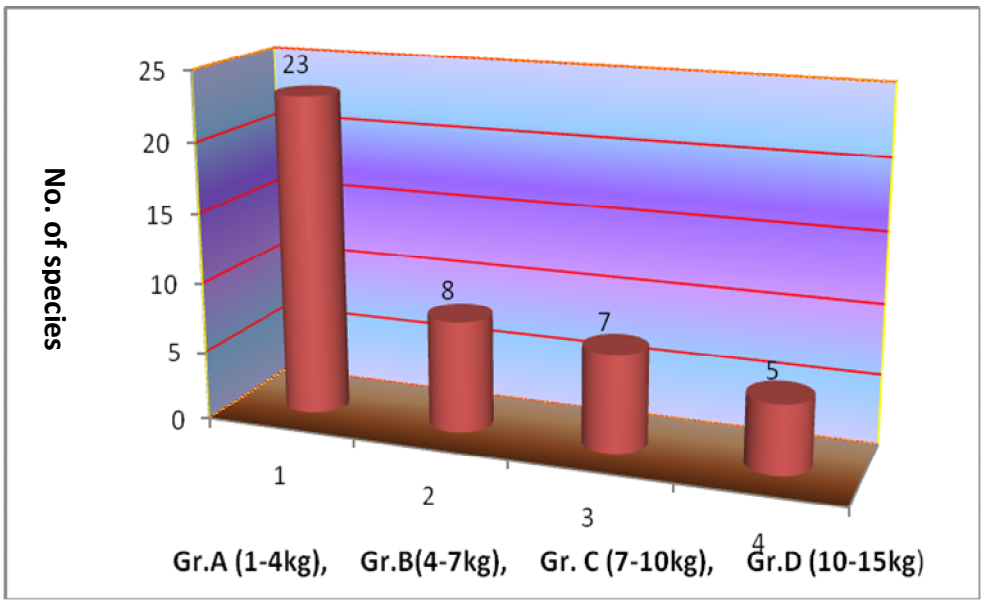

Fig. 2- Biomass production by different plant species

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