Gunny bag based soil columns for crop diversification in rice field to enhance livelihood security of land scarce farmers

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Crop diversification in waterlogged rice field using gunny bag based soil columns produced 3–4 tonnes of *kharif* rice, 4.5–5.4 tonnes of *rabi* rice along with other vegetable crops worth Rs 0.5–3.0 lakh/ha with higher B : C ratio for cucurbits. Crop diversification in rice field using gunny bag/hessian based soil columns increased cropping intensity by 100–200%, generated additional returns and increased employment opportunities. In this process, nearly 1500 to 5000 number of gunny bags (capacity 50 kg) can be used per hectare rice land in an economical manner. Even if 1.0% (0.4 M ha) of the total rice acreage in India and Bangladesh (40 M ha) is diversified, about 10 lakh tonnes jute fibre will be utilized. It will increase the marketing opportunities of raw jute fibre, provide nutritional and livelihood security to resource-poor farmers.

Keywords: Crop diversification, economic benefit, gunny bag, vegetable production, waterlogged rice field.

RICE low lands limit cultivation of vegetables or other dicots in them owing to its anaerobic nature. Profitable crop diversification in waterlogged rice land using gunny bag/hessian reinforced soil columns avoiding anoxia, has opened up new vistas which will strengthen resource-poor rice farmers' economy of South East Asian countries. Water is quickly drained off from soil columns by gravity and lateral flows owing to its meshy nature. Experiments were conducted in *kharif* and *rabi* seasons of 2011 to 2017, at ICAR-Central Research Institute for Jute and Allied Fibres (ICAR-CRIJAF), Barrackpore, India, main farm and demonstrations were also made in some selected farmers' fields in West Bengal (North 24 Parganas, Hooghly, Murshidabad, West Midnapur and Jhargram). Gunny bag/hessian reinforced soil columns of varied dimensions (22.5–45 cm in height and 45 cm diameter) were developed in waterlogged rice field to grow vegetable crops avoiding anoxia. The hydrograph of ponding varied from 0 to 30 cm during rice growth. In *kharif* rice-vegetable relay system, yield of rice was 3–4 t/ha (fine rice cv. Banskati and Satabdi) along with other vegetable yield (cucurbit, legumes and solanaceous crops) from 15 to 50 t/ha using common resources for 60 days in association. In *rabi* rice–vegetable relay system, rice yield was 4.5 to 5.4 t/ha and that of cucurbit, it varied from 55 to 150 q/ha, ginger 600 q/ha, amorphophallus 120 q/ha, and colocasia 20–25 tonnes tuber/ha. These vegetable crops generated additional income of Rs 0.5–4.50 lakh/ha without hampering rice yield in between two rice crops, when this rice land usually remains fallow[1–3]. Under irrigated condition, cropping intensity of the traditional rice–rice cropping system (200%) increased up to 400% rice–vegetable–rice–vegetable system. It has been recorded that to diversify rice low lands in an economical manner, about 1500 to 5000 number of gunny bags weighing 750 to 2500 kg jute fibre will be consumed in one hectare area. Experiments were conducted over the years both at ICAR-CRIJAF and farmers' fields to diversify waterlogged rice fields, growing vegetables on gunny bag based soil columns as inter/relay crops to increase farmers' income, cropping intensity and establish the utility of gunny bags in agricultural fields, as a non-traditional sector.

Field experiments were conducted during *kharif* and *rabi* seasons from 2011 to 2017, at ICAR-CRIJAF, Barrackpore, West Bengal in randomized block designs (RBDs) replicated thrice. The soil of the experimental site was sandy-clay-loam in texture having 44% sand, 28% silt and 28% clay. Available nitrogen (N), phosphorus (P) and potassium (K) content of the soil were 180, 34 and 133 kg/ha respectively. To validate the results, commercial trials were also conducted in different soils in different districts of West Bengal such as North 24 Parganas, Hoogly, Purba and Paschim Midanapur, Cooch Bihar, Murshidabad, Jhargarm, etc. with the help of Department of Agriculture, Government of West Bengal and different Farmers' clubs. The validity of the results was also tested in Odisha and Assam through ICAR-AINP JAF, Barrackpore.

For making soil reinforced jute columns and to suit different water depths in rice low lands, gunny bags (once used for rice sale) were cut into hollow columns of 11.25 to 45 cm height and 45 cm diameter. Jute hessians (180 to 230 GSM) were also cut into pieces of 85 cm in length and 30–45 cm in width. Both the cut ends at length were stitched together with jute thread and were given the hollow cylindrical shape having a radius of 13.5 cm and 30–45 cm height. These open ended gunny bags and meshy cylindrical hessians were soaked in systemic fungicide and pesticide solution for an hour to increase their longevity in waterlogged rice fields. These were fixed vertically on fertilized puddled soil by inserting 4–5 tough green jute sticks (45 cm length) and few strong bamboo pegs along their inner walls, which acted as pillars. After this, farmyard manure and fertilized puddled soils were filled alternately in four layers of equal depth in the gunny bag/jute hessian reinforced soil columns for healthy establishment of vegetable seedlings in these soil columns. Gunny bag/jute hessian reinforced soil columns

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were tied with their pillars using jute threads outwardly in circular fashion. The soil columns were left as such for 15 days for drainage of excess water from soil columns to create an aerobic zone above the puddled soil for easy growth and development of dicot vegetable crops (Figure 1). The row to row spacing between columns was 4 m and within the row, the column distances were 2 m. For other crops the spacing was as usual in arable lands. Rice was transplanted after soil column preparation.

In *kharif*, 15 to 20 days after rice transplantation (1st to 2nd week of September), treated seeds of vegetable crops (bottle gourd, bitter gourd, pumpkin, cucumber, coriander, spinach and field beans, etc.) and seedlings (tomato, brinjal, cauliflower, cabbages) were planted on the soil columns (Figure 2). In *rabi* rice, cucurbits (pumpkin, ash gourd, sponge gourd, snake gourd, bottle gourd, etc.), solanaceous crops (brinjal and tomato), crucifers (cabbages, radish, cauliflower), coriander and ginger were sown on 30 cm to 45 cm height soil columns at 25 to 45 days after rice transplantation. Colocasia tubers and amorphophallus corm, ginger rhizomes, etc. were also sown in summer rice-relay, at 25 days after rice transplantation. To avoid waterlogging stress and for better economy from medium lands (0–30 cm water) over traditional rice cultivation in *kharif*, land transformation was made by developing 22.5 cm to 45 cm high gunny bag based soil columns where cabbage, cauliflower, *Dioscorea alata*, brinjal, parwal, sweet corn, etc. were grown as sole crops. In traditional rice-fallow areas, the saline rice fields were also diversified with gunny bag based soil columns to grow vegetables with rice in *kharif* season.

For healthy establishment of vegetables on soil columns, 100–200 ml 3% mixed fertilizer (N : P : K :: 10 : 26 : 26) solution and 2% urea solution were added alternately in each column at weekly intervals. Starting from planting of sprouted seeds/seedlings, the column soil surfaces were sprayed repeatedly with fungicides (Carbendazim, Mancozeb, Blitox, etc.) and systemic insecticides at weekly intervals to prevent seedling mortality and damage by fungus and insect attack. To avoid interference from rice plants, inverted umbrella type gabions were made around each column by inserting 6–8 ft long bamboo jute/sticks around the columns and the gabions were loosely knitted by jute fibres.

After rice harvest, the cucurbit twigs were trailed on ground and the vegetable crops were grown as per recommended management practices. For cucumber and field beans, scaffolds were made. Root system of the vegetables spread well on the uncultivated rice field even if the soil remained sticky after rice harvest. Irrigation and granular fertilizers (as per recommended dose) were applied directly in zero till situation immediately after

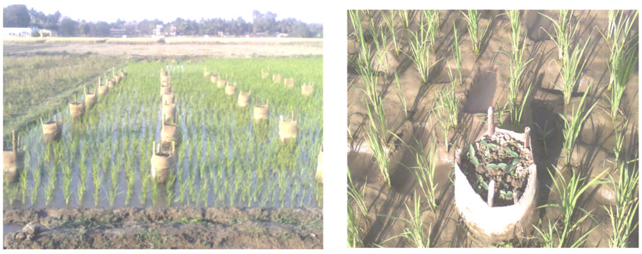

Figure 1. Gunny bag/jute reinforced soil columns in waterlogged rice field for vegetable cultivation avoiding anoxia.

Figure 2. Tomato cultivation to diversify *rabi* rice field.

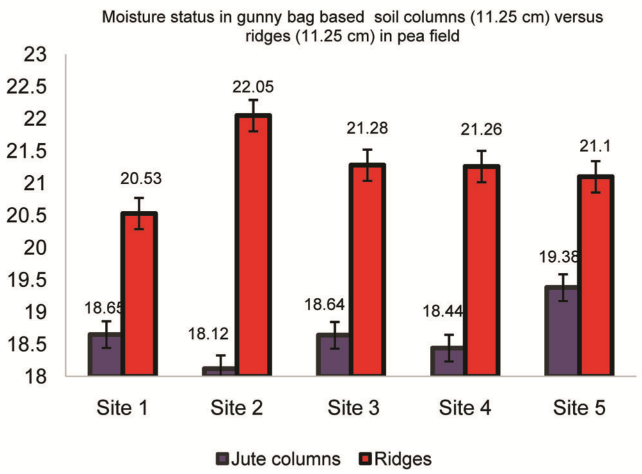

Figure 3. Moisture status in gunny bag based soil columns versus ridges in pea field during *rabi* season.

Figure 4. Cauliflower and cabbage as inter crop with rice on gunny bag soil columns.

Table 1. Vegetables production in *kharif* rice field in dual culture on medium land using gunny bag based soil columns and its economics

Crops	Jute bags/ha	Rice yield (t/ha)	Relay/inter crop yield (q/ha)	Gross return from relay/inter crops (Rs/ha)	Cost of cultivation of relay/inter crops (Rs/ha)	Net return from relay/inter crops (Rs/ha)	Return per unit cost (Rs/Rs)
Pumpkin	412	3.0	173	208,000	50,282	157,718	4.14
Bottle gourd	412	3.0	210.46	315,633	55,173	260,460	5.71
Bitter gourd	827	3.0	24.80	124,000	50,121	73,879	2.47
Arhar	1046	3.0	18.82	90,352	57,693	32,659	1.57
Ginger	1046	3.0	9.93	59,600	87,653	–28,053	0.68
Radish	1046	3.0	24.0	48,000	39,601	8,399	1.21
Kharif spinach	1046	3.0	26.14	52,280	36,601	15,679	1.32
White amaranth	1046	3.0	78.42	47,052	36,601	10,451	1.28
Brinjal	1046	3.0	125	125,000	81,101	43,899	1.54
CD (5%)	–	–	29.49	42,050	7,600	41,690	0.60

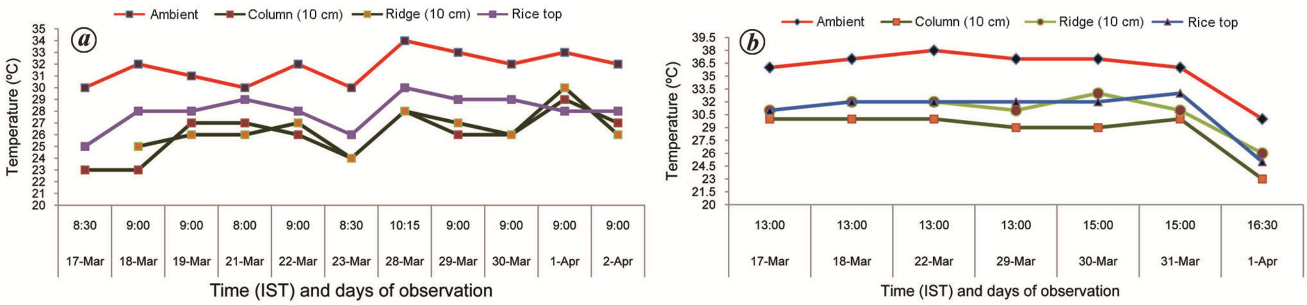

Figure 5. ***a***, Desirable soil temperature of columns during morning hours for optimum development of carrot in summer. ***b***, Desirable soil temperature of columns during noon hours for optimum development of carrot in summer.

Figure 6. Readymade winter okra and mustard seedlings in jute packets for sequential planting in rice-relay system.

rice harvest. In summer rice–vegetable relay, the cucurbits were grown on scaffolds to avoid fruit rot by soil contact.

To grow pumpkin, bottle gourd and field beans in rice field, around 1250 columns/ha are required which costs around Rs 18,750/ha only @ Rs 15/column. In conventional sole vegetable production in low rice lands sacrificing rice crops, on mega ridges (1 m base width × 50 cm height, at a spacing of 1 m), the cost involved to transform the rice field is around Rs 40,000/ha. Cucurbits of each column were allowed to grow in an area of 8 m^2 land only. For easy movement and intercultural operations of vegetable crops in rice field, rice transplantation along the columns should be skipped which is an established recommendation to minimize pest and disease attack in rice fields, especially for brown planthopper. Loss of rice area in this process will be around 625 m^2/ha (6.25% of a hectare) which sacrifices around 3 quintal raw rice/ha considering the total rice yield as 5 t/ha. Water productivity of rice field is obviously high as remunerative vegetables are grown together.

The columns remained stable up to eight months in rice field. The hydrograph of ponding ranged between 0 cm and 30 cm during rice growth. The oxygen diffusion rate of gunny bag/hessian reinforced soil columns (up to 15 cm depth) was more than two times (280 μg/m^2/sec, ODR Meter, Eikjelkamp, The Netherlands) the conventional ridges (115 μg/m^2/sec). The moisture content of these soil columns varied from 18.5% to 19.38% over 20.53% to 22.05% in conventional ridges (Figure 3). Thus gunny bag/hessian reinforced soil columns maintained better air and moisture regime in rhizosphere over

Table 2. Rice midland (0–30 cm) transformation using gunny bag based soil columns for vegetable production in *kharif* season

Treatments	Jute bag column height (cm)	Columns/ 50 kg jute bag	Plot size (m^2)	Date of sowing	Columns developed/ ha	Filling cost (Rs/ha)	Jute bags used/ha	Yield (q/ha), numbers	Total variable cost (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B : C ratio
Kharif onion (Agrifound light red)	15.00	6	24.9	4 September, transplanting	28,846	43,269	4808	220	189,643	444,000	254,357	2.34
Brinjal (Shyamla bhangar)	22.50	4	38.0	18 June	21,052	42,104	5263	247	194,328	494,000	299,672	2.54
Green pea	11.25	8	22.1	14 October	36,231	36,231	4529	113	169,051	339,000	169,949	2.01
Carrot	11.25	8	24.7	16 October	29,100	29,100	3636	129	148,919	387,000	238,081	2.59
French bean	11.25	8	35.5	16 October	20,281	20,281	2535	81	135,753	283,500	147,747	2.09
Radish (cv. Kalayani white) – Arhar	22.50	4	12.9	26 June–25 August	18,518	37,036	4629	218, 27	183,876	598,000	414,124	3.25
Cabbage	15.00	6	24.0	10 August	30,000	45,000	5000	300	192,523	600,000	407,477	3.11
Cauliflower (Don)-cauliflower-broccoli	22.50	4	12.9	21 June to 15 October	18,518	37,036	4629	26985 (nos 500 g each)	178,584	223,388	44,804	1.25
Parwal (local)	22.50	4	12.9	21 June	18,518	14,998	4629	94	136,870	188,000	51,130	1.37
Basil + maize + ridge gourd	22.50	4	12.9	28 June–30 June	18,518	37,036	4629	21, 50, 59	178,244	218,470	40,226	1.23
Ground nut (local)	22.50	4	13.0	25 June	27,692	55,384	6923	14	195,086	55,840	–139,246	0.29
Rice-bottle gourd relay	30.00	3	16.8	6 September	833	2,499	208	28, 422	51,340	450,000	398,660	8.76
Rice–pumpkin relay	30.00	3	16.8	6 September	833	2,499	208	28, 238	51,140	266,000	214,860	5.20
Bottle gourd-rice relay	45.00	2	74.0	6 June–6 September	540	2,160	270	94, 40	38,891	133,000	94,109	3.42
Tomato	22.50	4	12.9	10 September	18,518	37,036	4629	77	172,324	115,550	–56,774	0.67
Dioscorea	22.50	4	40.3	12 March	19,851	39,702	4962	242	176,449	484,000	307,551	2.74
Ginger	22.40	4	36.0	15 February	25,000	50,000	6250	156	319,115	936,000	616,885	2.93
Sole rice	–	–	16.8	6 September	–	–	–	40	55,000	72,000	17,000	1.31
CD ±	–	–	–	–	–	–	–	–	8034	8076	8032	0.08

Table 3. Additional vegetables production from *rabi* rice field as intercrop using gunny bag based soil columns and its economics

Crops	Jute bags used/ha	Rice yield (t/ha)	Relay/inter crop yield (q/ha)	Gross return from relay/inter crops (Rs/ha)	Cost of cultivation of relay/inter crops (Rs/ha)	Net return from relay/inter crops (Rs/ha)	Return per unit cost (Rs/Rs)
Cabbage	12405	4.5	51	51133	39818	11,315	1.28
Brinjal	12405	4.5	152	150000	66316	83,684	2.26
Carrot	12405	4.5	28.3	42500	36816	5,684	2.80
Tomato	12405	4.5	69	103000	37316	65,584	0.30
Onion	12405	4.5	12.3	11333	33316	–21,983	0.34
Chilli	12405	4.5	11.8	35400	36316	–916	0.97
Cauliflower	12405	4.5	29	29000	36316	–7,316	0.80
Coriander	12405	4.5	9.3	46500	36316	10,184	1.28
Radish	12405	4.5	33	50000	36311	13,689	1.38
CD (5%)	NS	NS	5.60	7343	7495	–	0.31
CV (%)	–	–	7.37	9.74	10.86	–	14.21

conventional ridges during the growth period of vegetables.

Different cucurbits, field beans and solanaceous vegetable crops grew well on jute reinforced soil columns (Figure 1) and produced higher yields. In rice–vegetable relay system, the rice yield varied from 3 to 4 t/ha (cv. Banskati and Satabdi), followed by vegetable yield of 15 to 50 t/ha. From rice field, as off season intercrop, spinach, coriander, radish, cauliflower and cabbages were harvested within 45–90 days of sowing from soil columns and yielded 24–25 quintal (q) fresh vegetables per hectare (Tables 1 and 2, Figure 4). Brinjal and tomato yield varied from 200 to 300 q/ha. These vegetable crops generated an additional income of Rs 0.5 to 3.0 lakh/ha without hampering rice. In transformed rice midlands, using gunny bag soil columns, yield of *kharif* onion, cauliflower, cabbage, parwal, brinjal, tomato, dioscorea and ginger were 220, 135, 300, 94, 247, 77, 242 and 156 q/ha respectively (Table 2). Similar responses were also obtained over the years from farmers' fields and the technology is being disseminated by the Department of Agriculture, Government of West Bengal through different projects like ATMA and different farmers' clubs of West Bengal.

The hydrograph of ponding in *rabi* rice varied from 0 to 5 cm during rice growth period. In this system, 4.5 t/ha rice along with late cabbage (51 q), carrot (28.3 q), brinjal (152 q), tomato (69 q), coriander (9.3 q), onion (12.3 q), summer radish (33 q) and chilli (11.8 q) were harvested (Table 3). Highest gross return and return per unit cost were obtained from brinjal, carrot, cabbage, coriander and radish. In hot summer, the temperature inside the rice canopy and soil columns (10 cm depth) was lower by 3–9°C compared to ambient temperature. The lower column temperatures facilitated development of fleshy roots of summer radish and carrot (Figure 5). Lower rice canopy temperature helped in better setting of tomato fruits in hot summer and increased shelf life and freshness of ripened tomato fruits, cabbage and coriander. Cucurbit yields in summer rice–relay system varied from 55 to 150 q/ha, ginger 600 q/ha (single rhizome cluster was up to 4.5 kg/ha), amorphophallus 120 q/ha and colocasia yielded 20–25 tonne tuber/ha along with 4.5 tonne summer rice/ha. This process consumed about 1125 gunny bags/ha (50 kg capacity, weighing 7 q jute fibre). Similar results were also recorded from farmers' fields.

To address the issue of soil salinity (1.69 dSm^{-1}) at Najat, Sandeshkhali-1, North 24 Parganas, soil columns (45 cm × 45 cm) were also developed in saline rice soils in farmers' fields in *kharif* rice–vegetable relay system, with the help of the Department of Agriculture, Government of West Bengal. The soluble chloride and sulphate salts of Na, Ca and Mg from the soil of the columns were washed away by rain and thus created a favourable environment for easy establishment of vegetables in rice field, avoiding salinity stress. The vegetable crops matured well before the rise of saline salts in summer months (April–May) through capillary rise in upper soil layer and thus escaped the salinity problems. The vegetable (different cucurbits and tomato) yield ranged between 15 and 20 t/ha along with 3–5 tonne rice/ha. Two hundred per cent cropping intensity was established over 100% cropping intensity in traditional rice–fallow system, avoiding salinity stress.

To cope with late harvest of rice and timely planting of sequential crops under waterlogged muddy condition, 20–25 days old established field crop (mustard, etc.) and vegetable (cucurbits, okra, raj mash) seedlings (developed in small jute bags, 10 cm × 7–10 cm, Figure 6) were found effective which increased the cropping intensity of low lands. These crops escaped cool temperatures and performed well in winter season[4]. In this rice–vegetable relay, 28 q mustard, 40 q round bitter gourd, 40 q raj mash, 35.8 q cucumber and 65 q winter okra per hectare (November–May) were harvested.

For wasteland management (having no groundwater contribution), a system was simulated on brick lined floor, developing gunny bag based soil columns (22.5 cm height × 45 cm diameter) over it. Selected crops were sown in early August on columns and were harvested after maturity. We successfully harvested sweet corn

(32,000 cobs/ha), radish (128 q/ha), vegetable brassica (130 q/ha), spinach (40 q/ha) and pumpkin (182 q/ha) (45 cm × 45 cm columns, having pitcher within the columns). Crops were successfully grown under rainfed conditions with two–three additional irrigation as drought prevailed during entire September. Herein, 4000 jute bags were used in one hectare land.

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Grassland productivity during early winter in Ladakh, India

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Agro-pastoralism is the backbone for the sustenance of livelihood of people in semi-arid mountainous deserts of Ladakh, India. Livestock comprising sheep, goat, yak, donkey and horse, play an important role in human survival by providing fuel, transport, wool, milk, organic manure, meat and hide. Deficiency of fodder is the major constraint in livestock production system in this area; hence grassland vegetation available for grazing is important for livestock feeding and nutrition. The present study was aimed to evaluate grassland productivity in different villages of Leh, Ladakh. Productivity of grasslands in the study area ranged from 0.7 to 8.8 q/ha, reflecting low values and wide variability. Nutrient availability in grasses was poor, while fibre content was high. Supplementation of feed, fodder or concentrate ration is therefore essential to meet the nutritional requirements of the livestock largely dependent upon grazing in those grasslands.

Keywords: Agro-pastoralism, early winter, grassland productivity, livestock, nutrient availability.

TOPOGRAPHY of Ladakh, India is characterized by undulating terrain interspersed with rocky hills and elevation ranging from 4500 to 5880 MSL. In addition, due to the extreme cold, aridity, high radiation and strong winds, majority of Ladakh's landscape is more suitable for livestock husbandry than crop cultivation. Therefore, livestock husbandry is the main livelihood of Ladakh with the livestock population nearly 3.3 times the human population[1]. For centuries, agro-pastoralists in Ladakh have produced the finest pashmina wool apart from meat, dairy products and organic fertilizers.

Grazing resources are limited to areas along water bodies like reservoirs, rivulets and rivers. Grass cover along the river bank is the main food source available for livestock in the region. Due to low precipitation, plant productivity is very low[2]. The growing season is confined to short-duration species grown during June to August in summer, and vegetation is characterized by alpine steppe communities with medium to sparse cover (20%); the dominant gross species include *Carex* and *Stipa* grass species. Availability of grass cover has been found to be 40–70% deficient in cold arid regions[1]. Nevertheless, domesticated animals with the exception of donkeys and horses usually spend the summer grazing in high-elevation pastures and small grasslands. Therefore, estimation of grassland productivity and nutritional quality assessment of the available grasses could help evaluate sustainability of livestock in the Ladakh region.

Random samples of vegetation from the grazing areas in the villages of Thang (Sub-division Nubra, Block Turtuk), Hundar (Sub-division Nubra, Block Diskit), Suspol (Sub-division Likir, Block Saspol), Nimoo (Sub-division Likir, Block Nimoo), Likir (Sub-division Likir, Block Nimoo) and Yakma Chuchot (Sub-division Leh, Block Chuchot) in Leh district, Ladakh were collected during October 2019. In each village, 10 quadrants of 1 m each from different grassland sites used for livestock grazing, largely along the river bank or natural water channel side were selected. Samples of the grass cover were clipped 1 cm above the ground from area under the quadrant and stored in brown-paper envelopes. Thereafter, the samples were transported to the ICAR-National

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