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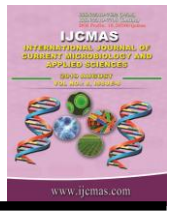

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Organic Farming Enlivening the Ladakh Subsistence Agricultural System

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A B S T R A C T

Subsistence farming of Ladakh region is a production management system also identified as Remarkable land use systems excluding of all synthetic off-farm inputs but rely upon agri-livestock livelihood options best suited for sustainable development involving crop rotations, crop residues, animal manures, off-farm organic waste for nutrient mobilization and plant protection, etc which promotes biodiversity and agro-ecosystem health. The traditional Ladakh agriculture is unique and representative of Himalayan agriculture and its conservation of old land races of cultivated plants, especially of barley and alfalfa, is of global importance. Use of organic manures by Ladakh farmers has brought soils organic matter from medium to high on cultivated lands and switched to avoid using fertilizers and maintaining the taste of their own management system with limited resources.

Introduction

Organic farming is much native to India and still being followed in Sikkim and Ladakh region, but it is forgotten owing to the modern agriculture which commenced Green revolution which gave although India a good impression of self-reliance but due to input-output relationship for resource poor farmers of dryland agriculture is still a challenge, unfriendly affair to environment for future agriculture. There is an increasing awareness about organic agricultural practices in the world. Presently it is taking U-turn towards native agriculture. Organic Farming is the need of hour to get rid of chemical fertilizers, pesticides and growth regulators etc. Use of organic manures ensure proper availability of

nutrients due to their conservation and moisture holding capacity to supply in readily available forms and improve soil texture and health as compared to chemical fertilizers. Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological process, biodiversity and cycle adapted to local conditions. Ladakh is one of the high altitude region in Jammu and Kashmir State where still subsistence agriculture (native) survive with mono-cropping (May-September) and remaining period and is a region where still organic farming works under subsistence system as Ladakh is cut-off from all directions. This region is amongst the highest inhabited coldest arid and sparsely arid and sparsely stations in the world, is very rugged part of the state being rough and rocky consisting of countless mountain peaks and sandy valleys that form the part of drainage systems of the river Indus. Ladakh which is situated in the Trans-Himalayan with the region being one of the coldest arid and sparsely populated regions. It is a place of limited resources with an extreme climate.

The Himalayan mountain range has significant bearing on the climate of India, as its towering height created a vast rain-shadow zone in the north. The cold dry tracts of the zone referred to as cold arid region, spread over in the northern states of India. Ladakh being at high altitude, suffers from an extremely harsh climate during winter (-30^0C) and remains cut off for almost seven months i.e. from October-May from rest of the world by surface transportation. Agriculture is the most prominent occupation of the people of Ladakh and also the main source of income and survival since time immortal. Agriculture with harvesting glacier water in the lap of Himalaya has come-up as a small-scale farming system, well adapted to this unique and extreme environment. The distinct ecosystem has led to a development of a distinctive agriculturally based economy under which the barter system flourished for many centuries. With traditional production of wheat, barley, buck wheat, oats, mustard, radish, pea (Black and Grey), sewdes/ rutabaga, coriander, fenugreek and turnip etc. were grown, but in recent years a wide range of vegetables and fruits and different varieties of wheat, barley, mustard has been introduced and are being grown successfully. According to a report by the defense Institute of high-altitude research of the Defense Research and Development Organization, 32 different types of vegetables and fruits are been successfully being grown (Anonymous, 2012). The soil characteristics of the region are different than from the other zones due to extreme climatic conditions, vegetation and topography. The soil profile being poorly developed leads to variation in the physico chemical, morphological and microbiological properties but also a variation in its genetic and classification can be observed. The soil moisture remains frozen during winters with low relative humidity during the summer months causing barren topography of the region.

Materials and Methods

A total of nine different types of samples were collected from different regions for this study (Table 1). The analysis for the samples were carried out at ICAR-CAZRI, Jodhpur, Rajasthan for Total (%) of N, P, K, Available (ppm) N, P, Zn, Cu, Fe, Mn, carbon (%) and Density (Mg m^3). The samples were first sun dried and the dried at 60°C in a hot air oven till a constant weight was obtained. When dried and brittle, the samples were powdered in a thoroughly cleaned mechanical grinder. They were weighed and then were digested in HNO_3:$HClO_4$:H_2SO_4(10:4:1) (Jackson, 1973) on a hot plate and filtered. The extracts after dilution were analyzed for various parameters by means of standard approaches.

Results and Discussion

Survey carried out in Tribal Sub-Plan adopted villages revealed that Ladakh is the one region in India where sustainable development is the only way ahead. Dry toilets, water efficient crops, cooperative farming, a democratic society and living in harmony with nature are not ideals here. Agricultural system is a unique one or in the other words, livelihoods are restricted to agriculture and livestock rearing. The soil is sandy and retains little water. Still farming community rely on subsistence agriculture with few interventions made by governmental agencies like CAZRI, DIHAR, State departments by distributing improved seeds, control of weeds, line-sowing, awareness through trainings and demonstrations.

Survey carried out in different parts of region revealed that it experiences mean annual precipitation of 80-300 mm, which is scanty and negligible in the thirsty laps of mountains. Himalayan Mountains and the Indus river system are two of the gigantic land features that limit the possibility of large scale agricultural activities in Leh region. However, it is unique and representative of the Tibetan plateau. Its agriculture in the past rendered the region self-sufficient in food grains especially with small land holdings. Families rely more essentially on subsistence agriculture based on principal crops like wheat, barley and potato on their stone-built terraces. Potato, being main vegetable, is a main cash crop grown during May-September in the region. The art of crop production which is and seems as old as civilization itself and its essential features have remained largely unchanged over the ages. The soils of the region are gravelly and sandy loams on the alluvial fans to sandy to silt clay loam on the Indus plains. The sandy loam texture high stone and gravel percentage, low water holding capacity, high bulk density results in a low fertile soil (Butola *et al.,* 2012). The soils of Ladakh fall under order entisol where there is no defined soil layers as they are still under active soil forming stage. The solar radiation is as high as 6-7 kwh/sq m, which is among the highest in the world. Because of the thin atmosphere, solar radiation is quite extreme. Humidity levels range from 6-24% making the air very dry. Agriculture and harvesting glacier water in the lap of Himalaya has developed a small-scale farming system adapted to this unique and extreme environment. Families rely essentially on subsistence agriculture based on principal crops like wheat, barley and potato. Potato, being main vegetable during winter season is a main cash crop grown during May-October in the region. The art of crop production which is as old as civilization itself and its essential features have remained largely unchanged over the ages. Terraced fields on slopes of high mountains are irrigated with glacial melt-water and fertilised with undecomposed farm-yard-manure, human "night soil". These are applied with traditional manures although not properly decomposed but supply good amount of organics and provide valuable support in building soil tilth (Table 1). Although farmers have very low interest in using chemical fertilizers but to boot the crop growth at the initial stage, a starter dose of fertilizers like urea, DAP and muriate of potash are applied. Every household also has small vegetable garden along with sufficient orchard of apple or apricot, with few animals, such as, goats, sheep, cows and dzo (a cross between a yak and a local breed of cow). Crop productivity in cold deserts is very low and (Table 3) and size of livestock is tremendously declined in recent years and fully based on human labour.

The energy budget studies also revealed the status of input-output ratio such as barley (2.5), wheat (3.5), pea (0.3), potato (0.6), onion (0.3), other vegetables (0.2) and alfalfa (0.7) (Raghuvanshi *et al.,* 2018). Even with such harsh climatic conditions, agriculture by

almost any measure is extremely successful as it represents a unique way of human survival and progress. Although simple, it is ecologically sustainable, and just as important, people are supported by community bonds that provide a deep sense of psychological security.

Prioritizing crop sowing is a very amazing and competitive phenomenon when all the farmers remain on the fields and women being a main stakeholders support the sowing along with folk songs. Germplasm of food crops, acclimatized to West Himalayan cold deserts, is saved and conserved year after year. The traditional germplasm used in Ladakh are ne-nak, yang-ma, yang-kar, sermo, tug-zur of barley, buck-suk of alfalfa, to-chen of small and big wheat, sner-mar of pea, nyas-kara of mustard, ta-wo of buck wheat are involved in folk songs revealing the sustainability of local germplasm. Since inception, conservation of old land races of cultivated plants, especially alfalfa, is of global importance. In case of fragmented land holdings, sowing is prioritized according to altitudinal zonation. This helps to tide over the rather limited growing period by synchronising harvesting, threshing and storage before the onset of winter. In this manner scarcity of labour is also coped with effective and efficient crop management. The individual farmer is thus able to attend to his fragmented land holding which are spaced over varying altitudes. In a majority of situations, land holdings are only one to two hectares, but easily sufficient. In fact, in most of the situations, only limited plains within Indus valleys are utilized for agricultural activities.

Prospects of organic farming in Ladakh

Basically in Ladakh farmers are used to organic farming the reasons behind this is that Ladakh is belong to far-flung area in ancient time due to lesser road connectivity it is not possible to the farmers to fetch chemical fertilizer by their own. Presently, with the opening of Srinagar corridor in 80s, situation has tremendously changed and self-sufficiency is declining due to change in taste. But having realized the ill effects of using pesticides and other chemicals which bring damages to the ecosystem, farmers again in Ladakh has initiated avoiding pesticides to save soil which they have developed. With the help of Ladakh Autonomous Hill development Council (LAHDC) and its policies, Ladakh farming society rely more on using organically developed products, organic pits for organic manure, use of night soil, leaf-litter, its ashes, FYM, Changthangi manure, mulching, goat-manure etc. Ladakhi farmers are applying manures to enrich their soils since inception. Acahrya *et al.,* (2012) revealed that the type of soil depends on the weathered rock and are mostly sandy to sandy loam in nature and are medium to medium high in organic matter but with poor water holding capacity, but have significant impact on soil fertility and its productivity. As maintenance Organic matter is crucial assuring physical, chemical and biological fertility (Izaurralde *et al.,* 2001) and farmers are more concerned about ecosystem and environmental services. The amount of organic matter and nutrient elements in animal manure may vary due to genetics of the animals, their growth stage and diet, the type of bedding used as well as building and storage management (Malusa *et al.,* 20). Sources of organic manure are FYM, goat/ sheep manure, changthangi manure, poultry, vermicompost, horse, yak dung, night soil, etc. Average content of macronutrients in animal manures of different origin is given in Table 1. For improving the soil fertility, farmers use the processed night soil. Recycling of human and animal excreta in soils of Ladakh was an old and time immemorial practice but modern toilet practices corruption the ancient nigh soil preserving technology. Manurial application supports plant growth at least for 3-4 years.

Night soil- It was the most popular source of nutrients and soil amendment which was being used in the traditional system of agriculture, but in recent times with the increase in usage of inorganic fertilizers and the building of modern flush toilets, its usage is decreasing rapidly. It is generally a mixture of well decomposed human fecal material mixed with soil and urine. Generally, the local toilets are two storied and are designed in such a way that the fecal material is collected in the lower structure. After it is used by a human, some soil is also thrown down with the help of spade. At times dried cow dung in pulverized form, tree leaves are also used. The waste in the lower portion decomposes with time and the lower portion is emptied out during winter after sorting out the un-decomposed material and is transported to the fields. With time the microbes and insects present in the night soil are completely eradicated due to the drastic differences between temperature during day and night where at night it is extremely cold and during day time there is extreme solar radiation and the putrefied material before cultivation is distributed evenly on the fields. Gupta (2015) revealed that with the increasing awareness of healthy living and highlighting the harmful effects of chemical fertilizers and pesticides, there is now a great demand for organic farming. For this purpose, initial inputs such as organic manures, bio-fertilizers, seeds for green manuring and botanical pesticides are required. Farmers are resource poor even with less 2 hectare land on an average but still maintain demand for organic manures to enrich their soil and follow improved technologies to enhance their production as well as to maintain original taste of the products. In Ladakh, still one can buy a organic products at a very cheaper rates.

Goat/ Sheep Droppings- the sheep/ goat population in the district was recorded to be 340158 (Anonymous2016), with pashmina goat being in the highest number in the Changthang region. Goat droppings being dry as compared to other cattle dung are much easier to work with and also their decomposition is faster. It was observed that goat goat/ sheep dropping had higher concentrations of N making it a good source of nitrogen and with a higher scope of organic fertilizers.

Poultry Feces-the poultry population of the district was recorded to be 20829 (Anonymous, 2016). Poultry feces are regarded as the most nutritive and best manure as it contains both feces and the urine. It has been observed to have the highest amount of Nitrogen and Phosphorous content. Since it contains high amount of Nitrogen, they are categorized as hot manure therefore to avoid damage to the plants proper decomposition is required where leaving them open in the sun can reduce the N content drastically. High amount of P can also interfere with soil adsorption of other nutrients like Zn and Fe (Table 2). CowDung-The Cattel (Cow/Bull) in the district was recorded to be 12977 (Anonymous2016). It is the most common and popular manure after night soil which was used in the traditional agricultural system. Cow dung was observed to have the highest amount of N and organic carbon and unlike the horses, due to their effective digestive system they digest the seeds of the weeds also which is consumed with the grasses. The cattle shed where a layer so soil is added regularly where dung and urine are absorbed in it and which is emptied out to the fields and evenly distributed before cultivation.

Yak Dung-The yak population in the district was 18877 (Anonymous, 2016). Yaks are majorly reared in the Nubra and Changthang region of the district and their dung is used as soil amendment here. In the summer season the yaks are left to graze in the pastures which are usually away from the village known as Dok/Phu.

Table.1 Sample location

S. No	Sample Content	Sample Location	Block
1	Night Soil	Sheynam	Leh
2	Goat/ Sheep Dropping	Aangkung	Nyoma, Changthang
3	Poultry Feces	ChushotYogma	Chushot
4	Cow Dung	Kilibug	Thiksey
5	Yak Dung	Khardong	Disket, Nubra
6	Compost	Kilibug	Thiksey
7	Vermicompost	Shey	Thiksey

Table.2 Carbon and micro nutrient content

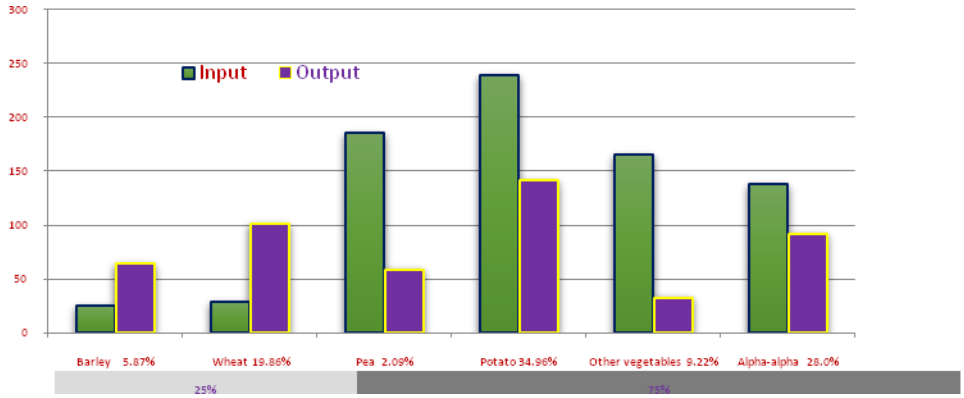
Sample No.	Sample Content	Carbon (%)	Zn	Cu	Fe	Mn
			ppm			
1	Yak Manure + Soil	15.12	0.68	0.13	22.09	3.81
2	Yak Manure Pure	28.86	0.81	0.19	18.36	1.76
3	Night Soil	2.12	1.19	0.35	31.28	2.10
4	Goat Manure Pure	41.27	0.51	0.16	8.50	0.70
5	Cow Manure Pure	36.69	0.71	0.26	25.95	2.55
6	Cow manure + soil	18.50	0.51	0.34	9.52	0.61
8	Compost	17.71	0.72	0.16	19.99	0.72
9	Vermicompost-1	12.15	1.02	0.36	28.92	2.53
10	Vermicompost-2	8.07	0.72	0.15	24.17	2.15
11	Poultry Manure	33.69	1.91	0.36	5.69	1.06

Table.3 Density and macro nutrient content

Sample No	Sample Content	K	P	N	P	K	Density (Mg m^3)
		Ppm		Total (%)			
1	Yak Manure + Soil	47.24	13.60	1.38	0.23	62.82	1.33
2	Yak Manure Pure	14.38	29.22	2.14	0.70	69.82	1.13
3	Night Soil	23.94	9.97	0.35	0.35	71.21	1.93
4	Goat Manure Pure	51.44	24.06	2.74	0.70	70.01	0.89
5	Cow Manure Pure	18.43	16.18	2.30	0.76	61.97	1.29
6	Cow manure + soil	42.52	24.48	1.61	0.66	69.72	0.88
8	Compost	11.79	13.74	1.58	0.50	68.97	1.20
9	Vermicompost-1	26.66	28.18	1.17	0.97	71.21	1.26
10	Vermicompost-2	18.15	11.79	0.69	0.41	75.35	1.24
11	Poultry Manure	19.72	74.21	5.95	2.54	0.00	0.94

Table.4 Crop productivity of village Saboo

Crops	Seed Input (kg/ha)	Yield output (kg/ha)		Manure used (kg/ha)
		Grain	Straw	
Barley	200	528	1320	200
Wheat	284	820	2105	242
Pea	260	1350	450	3960
Tuber (Mainly Potato)	1720	12900	2150	5340
Other Vegetables*	2.6	612.2	896	3900
Onion	2.6	342.5	-	3512
Alfalfa (Fresh)	26.4	9784		3321



Energy budget of different crops in village Saboo (unit in each case= value X 10^5 k cal/ha /year)

Manurial application on farm and incorporation

During the winter times the yaks come down to the villages and are kept in sheds known as Yak Las which is an open field with fencing. Yak manure was found to have a good percentage of carbon, and Available P, K, Fe and Zn.

In recent times modern and developed manures like compost and vermicompost are being introduced and their production techniques are also being taught to farmers where it is getting a good response.

These manures are a good source of nutrients (Macro and Micro) they are known to increase the microbial activities in the soil due to which breakdown of the nutrients occur rapidly.

Compost- they are the organic manures which has been decomposed in a process called composting. In this various waste products like farm waste leaves etc. are mixed and decomposed in pits or heaps while at the same time maintaining proper moisture and temperature. It is help full for the soil as it acts as a soil conditioner, a source of nutrients, humus and also acts as a natural pesticide. It also helps in controlling soil erosion.

Vermicompost- Vermicomposting is the process of composting with the help of certain species of earth worms. The worm cast is the end product of this composting technique. These casts are known to have higher inundation of nutrients and they also take less time to form, but proper upkeep is required especially in the winter timing where temperatures in the region drop below 0 degrees. The nutrients being water soluble are easily available to the plants.

Organic matter breaks down over time through biological activity and chemical weathering. Some of it breaks down quickly, other parts of it break down very slowly. The primary factors in determining the breakdown rates are temperature, moisture and oxygen levels. In Ladakh, extremes cold and dry slows down the decomposition and well-drained sandy to sandy loamy soils lose a greater percentage of soil organic matter every year. Survey revealed that in Stakmo village, Leh, it was reported by the village community that it is mandatory to add sufficient amount of organic manure to soil every year using donkeys traditionally known as *BUNGLUD* which is a ancient composting method of organic fertilisation in Ladakh where soil fertility has been maintained in this way since inception.

Further they reported that adding organic manures not only contribute to soil fertility but improve sandy soils physical condition especially in Ladakh cold arid region. Mr Zubair, Progressive farmer and Director, Ladakh Organic Farmers' Foundation (LOFF) NGO reported that he has been training people of adjoining areas including students for upgrading the existing organic farming practice to improve the crop productivity in a sustainable way.

Uniform seed broadcasting with approximately higher seed rate is performed girls in cold desert areas. One handful of seed is uniformly broadcast in three to four equal lots. The quantity of seeds thrown in each lot is determined by the distance of furrows made during ploughing. It also reduces labour requirement.

Distribution of organic manure along with night soil at the rate of 20 to 25 kg of organic manure is scattered in the fields. This technique aims at uniform distribution of organic manure. It is reported that the quantity of manure spread is optimum for the plot of land falling in the range of seven steps taken by the woman. With the broadcasting of crop seeds, weeds find opportunity and become integral part of cultivated lands which not only compete for space and moisture, but also reduce the yields significantly and quality of produce. Weeding is only performed by farm women in a group only in vegetables not in wheat and barley and upto some extent in pea crop. Being an integral part with crop, weeds constitute 30 per cent biomass obtained after harvesting. In cultivated lands and vegetable lands, the commonly found weeds are

Efforts

One day conference on Ladakh organic farming was organised by LAHDC, Leh in collaboration with Ladakh Environment and Health Organisation (LEHO) on August 6

2018 at Leh and declaration on Biodiverse, Organic and Climate Resilient Himalaya to meet SDGs (Sustainable Development Goals) was also signed by Hill Council, Leh, Government of Sikkim, Navdanya and LEHO. There is a need to integrate the scientific innovations and interventions with traditional knowledge to design organic agriculture for Ladakh region so as to bring farmers into a stream especially under cold arid region taking into consideration the challenges ahead with regard to rising temperature and incidence of insect-pests.

Efforts are being made by the body LAHDC taking its delegation of officers for Organic Farming study tour and interacted with farmers and the State Agriculture & Horticulture experts for exploring prospects for organic farming in Leh-Ladakh.

The Women's Alliance of Ladakh consisting of 4000 women in 113 villages are making efforts to protect Ladakh's environment and preserving their culture and even persuading farmers of the cold desert to practice organic farming and traditional water harvesting as farmers face water scarcity because of low snowfall in recent years.

The traditional Ladakh agriculture is unique and representative of Himalayan agriculture and its conservation of old land races of cultivated plants, especially of barley and alfalfa, is of global importance. In spite of such conditions, traditional way of agricultural practices has been successful in enabling the land to bear a self-sufficient produce. In recent years due to the increase trend of using high yielding varieties put pressure on resource poor farmers creating nutrient stress and forci ng farmers to go for fulfilling NPK demand. According to a report in the year 2015-16, 6377 quintiles of chemical fertilizers were distributed to farmers (Anonymous, 2016) but lately Ladakh is moving towards organic farming which is being promoted by various government and non-government organizations under the leadership and guidance of LAHDC, due to which a wide range of organic manures are being introduce and also the traditional methods being improved. Traditionally night soil and cattle manure were the primary source of soil nutrients along with occasional use of goat/sheep droppings and yak dung depending on availability. With the introduction manures like compost and vermicompost, which have a higher nutrient concentration, people are also being awarded and trained about the methods of their production. Organic matter not only contribute to soil fertility and tilth by providing various macro and micro nutrients but also provides carbon and other constituents that effect soil humus content, biological activities and soil physical structure like aeration, water holding capacity and structure (Anbuselvi, 2010).

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