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Nutritional Qualities and Climate Change Induced Shift in Habitat Distribution of *Morchella esculenta* (L.) Pers. in Himachal Pradesh: A Review

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ABSTARCT: *Morchella esculenta* (L.) Pers. commonly known as 'Guchhi', is nutritionally & medicinally important and is one of the expensive mushrooms. The mycelium of this fungus is commonly present as a mycorrhiza or in saprobic relationship with hardwood and coniferous trees in the temperate climate zone of the Himalaya including Himachal Pradesh. Recently, *Morchella esculenta* has also been reported from the tropical or sub-tropical regions of Himachal Pradesh. The formation and occurrence of *Morchella* fruiting bodies at lower altitudes has been attributed to the climate variations due to global warming. Its fruiting season is from March-July. Nutritionally, this mushroom contains carbohydrates, proteins, all important vitamins, minerals and aromatic compounds. It possesses a wide range of pharmacological properties including antioxidant, antitumor, antimicrobial and anti-inflammatory, also act as an immune-stimulant due to the presence of various active constituents. Ethno-botanically it is used as laxative, purgative, emollient, body tonic, heals the wound and also used for stomach problems. Due to its high commercial cost it plays a very important role in the economy of rural populace. *Morchella* had been reported from sub-tropical and tropical regions of Himachal Pradesh. It had also been reported from the Faizabad and Mount Abu (Rajasthan) at less than 1300m altitude. Various environmental factors such as temperature, pH, light, gaseous regime and disturbance may cause the development of fruiting bodies of *Morchella*. The review reveals that there are very few eco-physiological studies on the erratic occurrence of this mushroom in tropical regions.

Keywords: Climate change, Gucchi, Himachal Pradesh, Himalaya, *Morchella esculenta*.

INTRODUCTION

Mushrooms contain a huge diversity of biomolecules with nutritional and bioactive properties (Kalac, 2009). Some mushroom extract have promising therapeutic effects on cancer, cardiovascular diseases and diabetes (Guillamon *et al.,* 2010). *Morchella esculenta* is one of the most highly priced mushrooms found in the world (Prasad *et al*., 2002). The Original name of this fungus as *Phallus esculenta* was given by Carl Linnaeus and the present name of this fungus i.e. *Morchella esculenta* was given by Elias Magnus Fries in 1801 (Fries, 1753; Persoon, 1801). Throughout the world it is found in temperate regions, commonly in Asia, Himalayan Mountains, Europe, Mediterranean countries and in America (Emery & Barron 2010). In India, it is reported from Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh (Lakhanpal *et al*., 2010). In Himachal Pradesh it is found in the hills of Shimla, Kinnaur, Kullu, Sirmaur, Chamba district among other places. Recently *Morchella esculenta* are also reported from Rajasthan (Paliwal *et al*., 2013). In Pakistan it is naturally grown in various areas including Murree, Margalla Hills, Dir, Chitral, Mingora, Kalam, Kohistan, Tirah, Kurram Agency, Mansehra, Bagh, Chakoti, Quetta, Zayarat and Zhob (Rehman *et al*., 2000; Hamayun *et al*., 2006). Some important nontimber forest products (NTFP) available in J&K are *Saussuria costus* (Falc) Lipsch (Kuth), *Berberis lyceum* Royle (Rasount), *Viola canescence* (Bunafsha), wild apriot, *Dioscorea deltoidea* (Kins), *Aloe vera* Tourn. Ex Linn.(Aloe), *Morchella esculenta* L. (Gucchi) etc (Bagal *et al*., 2022). Various Government and Non-Government Organisations (NGOs) have introduced different preventive measure and policies for the conservation of ethnomedicinal plants species. Now, there is need of collaboration of research communities and government agencies to create awareness among local people and attract pharmaceutical industries to use the medicinal plants for therapeutic purpose at a commercial level (Bhardwaj *et al.,* 2019).

Very recently, *Morshella* was cultivated artificially by the Indian Council of Agriculture Research-run-Directorate of Mushroom Research (DMR) which is a major milestone in the Indian history of mushroom production (Prasad and Gupta 2023).

Morchella esculenta is a very important mushroom of Morchellaceae family (Table 1). The present study was conducted to review the active constituents of *Morchella esculenta* (L.) Pers. and their pharmacological properties, to review the nutritional aspects of *Morchella esculenta* (L.) Pers. and to review the climate change effect on *Morchella esculenta* (L.) Pers. in Himachal Pradesh.

It is commonly known by other names like Guchi, morel, true morel, morel mushroom, yellow mushroom, sponge morel, etc (Dorfelt, 2013). In Nepal it is known as Guchi chyau (Roody, 2003). And other vernacular names of *Morchella esculenta* are discussed in Table 2.

Table 1: Systematic Classification of *Morchella esculenta* (Litchfteld *et al*., 2006).

Kingdom	Fungi
Phylum	Ascomycota
Class	Discomycetes
Order	Pezizales
Family	Morchellaceae
Genus	*Morchella*
Species	*Morchella esculenta* (L.) Pers.

Table 2: Vernacular Names of *Morchella esculenta.*

Sr. No.	Region/ Language	Vernacular Name	Reference
1.	French	Morille	Roody, 2003
2.	Germany	Speisemorchel	
3.	Italian	Spugnola bruna	
4.	Spanish	Colmenilla	
5.	Nepal	Guchi chyau	
6.	India	Guchhi	Paliwal *et al*., 2013
7.	Pakistan	Kerkichoke	Gilani *et al*., 2003
		Gujae	Razaq *et al*., 2010
		Guchhi	Mahmood *et al*., 2011
		Spina Guchhi	Sher *et al*., 2011
		Khosay	Hassan *et al*., 2015

This edible fungus grows on soil rich in organic matter, in loamy soil and is found in various habitats like in coniferous forests, apple orchards, grassy places, etc (Negi, 2006). *Morchella esculenta* is commonly found as a mycorrhizal or saprobic relationship with hard wood and coniferous trees (Hamayun *et al*., 2006). *Morchella esculenta* is found at altitude of 2500-3500 m in forest habitat (Ali *et al*., 2011). The growing season of *Morchella esculenta* is from March to July (Wagay & Vyas 2011). Species of true morels (*Morchella* spp.) are one of the most highly prized and easily identified epigeous macrofungi collected by mycophiles during the spring in temperate regions of the Northern hemisphere (Weber, 1995). Among edible fungi, mushrooms have always remained a subject of interest for the researchers across the world because of their higher price, nutritional value and medicinal properties (Singdevsachan *et al*., 2013). With their ever increasing popularity, harvest of wild morels has become a commercially successful cottage industry in morel rich regions of countries such as India, China, Mexico, Turkey and the United states in the Northern Hemisphere (Pilz *et al*., 2007).

Morchella esculenta is the most important and precious fungal plant which plays an important role in the economy and the price depends upon the quality (Hamayun *et al*., 2006). The price is varied in early, middle and end of the season (Iqbal, 2002). The price of dry morels ranges from Rs. 4000 – 20,000 per kg which makes it one of the expensive mushroom of the world (Negi, 2006; Ali *et al*., 2011). Its price in national market is upto Rs. 20,000 per kg and in international market it is about Rs. 3,00,000 per kg (Sher *et al*., 2014).

Morchella esculenta is associated with diverse ecological niches (Sharma, 1997). It is usually found in various habitats including road sites, road cuts, excavation or near lightly burned grassy areas and swampy ground, mostly it is reported in an area destroyed by fire (Negi, 2006; Huffman & Tiffany, 2001). This mushroom is collected from the wild and is exported to many countries for its excellent culinary properties (Lakhanpal, 1986; Rana, 2002). In North West Himalayas, seven different species of *Morchella* have been analyzed for their nutritional and nutraceutical potential (Lakhanpal *et al*., 2010). True morels (*Morchella* spp.) are commercially important edible mushrooms with a delicate taste and a unique appearance (Hibbett *et al*., 2007). Morels are the most prized and popular mushrooms in most of Europe and North America. Morel products were very early approved by the US Food and Drug Administration (FDA) (Gilbert, 1960). Morels (*Morchella* spp.) are some of the most desirable edible mushrooms known (Royse & May 1990).

There are numerous studies dealing with the spore germination, culture, cytology, morphology, anatomy and physiology of morels, but few reports dealing with the details of morel's reproduction and life cycle (Amir *et al*., 1993; Arkan et al., 1992; Volk *et al*., 1989). *Morchella* as a genus is fairly easy to recognize but the species differentiation within the genus is a difficult task. Six species, namely *Morchella esculenta*, *M. conica*, *M. deliciosa*, *M. angusticeps*, *M. arassipes* and *M. semilibera* have been reported from India (Waraitchi *et al.,* 1976). The local people cook ascocarps (the fruiting body) mixed with rice and vegetables, and consider it as nutritious as meat or fish. It is also used in health care, and medicinal purposes differ among traditional hill societies isolated by linguistic, cultural and terrain barriers (Nautiyal *et al*., 2001; Wasser *et al*., 1999). In India, various studies were conducted for the site evaluation and wild collection of *Morchella* to understand the conditions required for its cultivation (Munjal *et al*., 1977). Edible mushrooms are sources of food all over the world and have high nutritional value almost twice that of any vegetable and are also rich in vitamins B, C, D (Fasidi & Kadiri 1990). It has been estimated that total world production of morels is about 150 tones dry weight, equivalent to 1.5 million tones of fresh morels. India and Pakistan are the major producing countries, each producing about 50 tones of dry morels, all of which is exported (FAO & Ciesla, 2002). It is important to take note of the fact that the most common of all morels, *Morchella esculenta* is said to be poisonous if eaten raw (Lincoff & Mitchel, 1977). In past, the research work done on *Morchella esculenta* is there. But there is very rare research work done on the climate effects on *Morchella esculenta*. There is still need to study the various aspects and climate effects on *Morchella esculenta*.

REVIEW OF LITERATURE

Mushroom species can be used for biomonitoring of heavy metals and radioactivity in polluted soils (Kalac & Svoboda 2000). Morel species are reported to minimize oxidative damage in organisms that occurs in several chronic diseases (Ferreira *et al*., 2009). For centuries, *Morchella esculenta* has been consumed and appreciated for its nutritional value as well as medicinal properties (Wahid *et al.,* 1988). According to Wahid & Sattar (1988) the main components of *Morchella esculenta* are (on dry basis):- protein 32.7%, fat 2.0%, fiber 17.6%, ash 9.7% and carbohydrates 38.0%. *Morchella esculenta* have low fat content with high fiber and all essential amino acids and contain all most all the important minerals too (Sadler, 2003). *Morchella esculenta* is considered to be 'the foods of the Gods', according to the ancient roman history. Morels have adapted to a wide range of unusual habitats and environmental conditions, including river bottoms, dunes, garbage dumps, abandoned coal mines, cellars and basements, saw mills, wood piles, sand bars in rivers, road cuts, excavations, deer trails, orchards, bomb craters and limed soils (Kaul, 1975).

True morels (*Morchella* spp.) belonging to Ascomycota, are consumed and appreciated worldwide due to their savory flavor and multiple bioactivities, including anti-oxidative, anti-inflammatory, antimicrobial, immunostimulatory and antitumor properties (Rosa *et al*., 2010). It was considered that morel's health benefits were attributed mainly to sugar (polysaccharides) and to various constituents such as amino acids, important vitamin, fatty acid, organic acid and minerals (Liu *et al*., 2016). Due to the unique flavor, taste and texture, morels are used in different recipes all over the world. Additionally, morels are used as a laxative, purgative, emollient, body tonic, healing wounds, for stomach problems and other general weakness (Ajmal *et al*., 2015). *Morchella esculenta* contains many biologically active ingredients, such as protein, dietary fibers, vitamins, etc (Gursoy *et al*., 2009). In North West Himalayas, seven different species of *Morchella* have been analyzed for their nutritional and nutraceutical potential (Lakhanpal *et al*., 2010). The *Morchella* genus is one of the most favored mushrooms, and as such, it is highly priced (Duncan *et al*., 2002). The *Morchella esculenta* contains all the important nutrients, from carbohydrates, proteins, polyunsaturated fatty acids, secondary metabolites like phenolic compounds, etc (Heleno *et al*., 2013). *Morchella* used in traditional medicine and it was reported for wounds, for rapid healing, as antiseptic, for digestive system symptoms, as an immunostimulant, as a general tonic, for cold and coughs and it was prescribed for indigestion, excessive phlegm and shortness of breath (Duncan *et al*., 2002). Morels are currently in use as a nutraceutical, as a functional food and a few studies examined their bioactives (Mau *et al*., 2004; Tsai *et al*., 2006). Local people think that a person who found *Morchella esculenta* is very fortunate or luckiest person (Hamayun *et al*., 2003). Generally, it is used for curing of various diseases i.e. intestinal, gastric problem, general body tonic, arthritis, general weakness, stomach problems, also heal the wound, skin beautification, purgative and used as an emollient (Wagay & Vyas 2011).

Mushroom description

Morchella esculenta consist of cylindrical structure. Upper part is known as pileus which possess 70-80% of total plant weight. Pileus is about 3-9 cm long, 2-5 cm wide, round or irregular pits are present. *Morchella esculenta* is whitish to pale grey but at maturity becomes grayish brown (Hamayun *et al*., 2003).

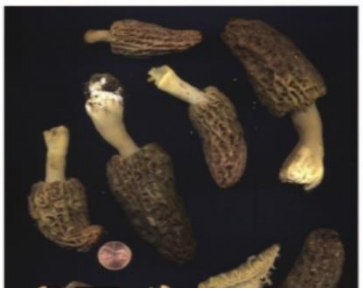
Fig. 1. Fruiting bodies of *Morchella esculenta* (L.) Pers.

Yellow morel mushrooms consist of cap and stipe, cap of mushroom usually consists of yellowish brown colour with conical shape of about 3 to 8 cm diameter and 5 to 12 cm length while stipe have pale cream colour 3 to 12 cm long with 1.5 to 6 cm diameter and tapered toward the top (Hamayun *et al*., 2006). Stipes are slightly enlarged at the base and support the upper part (Negi, 2006). In fresh form the size of *Morchella esculenta* varies from 2cm to 25cm while on drying the size reduces to 0.1 to 10cm (Hamayun *et al*., 2003).

The number of morel species is a matter of debate. Though *Morchella* as a genus is fairly easy to recognize but species differentiation within the genus is difficult, and a variable number of species are recognized by various workers. The genus *Morchella* was reviewed in India by Waraitchi in the year 1976, who presented a key for all the species known from India. According to him, six species under the genus have been identified, which include *M. esculenta*, *M. conica* (syn. *M. elata*), *M. deliciosa*, *M. angusticeps*, *M*. *crassipes* and *M. semilibera*. And the characteristics features of these six species of genus *Morchella* are discussed in Table 3. A number of morels collected in the Northwestern Himalaya have been assigned to the yellow morels (*M. crassipes* and *M. spongiola*) and black morels (*M. elata, M. angusticeps* and *M. gigas*) as reported (Kanwal *et al*., 2011). The local people in the Kullu District of Himachal Pradesh boil fruiting bodies in milk before they consumed (Nautiyal *et al*., 2001).

Table 3: Characteristics Features of Common Edible Species of Genus *Morchella* (Smith & Smith 1970).

Species	Habitat	Characteristics features
***Morchella esculenta* (L.) Pers.** (Common morel)	Usually in or near lightly burned grassy areas and swampy ground.	Pileus not distinctly longitudinally ridged, upto 7-9 cm long and 4-5 cm wide, pits rounded, irregular or at times longitudinally elongated, yellowish, becoming light brownish when dry, edges rounded, lighter than the pits; stipe only slightly enlarged at the base.  **Fig. 2.** *Morchella esculenta* (L.) Pers.
***Morchella conica* (Pers.) Fr.** Syn. *M. elata*	On soil, in open forest, often a year or two after a forest fire.	Pileus can be up to 4-10cm but may occasionally be larger; cone is spindle-shaped with pronounced vertical ridges with cross-connections, producing a series of rectangular hollows up to 1cm long; honey coloured with ridges darkening to brown with age; stipe 2-4 cm, hollow, circular, often enlarged at base or top, white to yellow with a rough surface.  **Fig. 3.** *Morchella conica* (Pers.) Fr. **Photo credit :-** Raman *et al*., 2018.
***Morchella deliciosa* Fr.** (Delicious morel)	On the ground in grassy places, usually at the edge of woods, widely distributed but rare.	Pits or depressions of the pileus grey to fuscous, ridges pallid; fruit bodies typically small. Pileus 2-3 cm long, pit elongated, ridges much lighter than the pits, irregularly anastomosing; stipe up to 2/3 times as thick as the pileus, often enlarged at the base and somewhat lacunose, whitish or yellowish.

		 **Fig. 4.** *Morchella deliciosa* Fr. **Photo credit :-** Baran, 2017.
***Morchella angusticeps* Peck** (Black morel)	On sandy soils in woods. Widely distributed and often associated with *Populus* spp.	Pileus 1-5 cm high, narrowly conic, pallied to greyish young but the borders of the pits darkening finally to black. Heads with greatly elongated pits; stipe equal, nearly as thick as the head, pallid to buff in large forms, the pits blackish like the ribs by maturity.  **Fig. 5.** *Morchella angusticeps* Peck **Photo credit :-** O'Donnell *et al*., 2011.
***Morchella crassipes* (Vent.) Pers.**	On the ground in open places, at the edge of woods.	Pits large and shollow, ridges thin; stipe enlarged and at times lacunose at the base. Pileus sub-conic, usually elongated and 6-12 cm long and 5-6 cm broad or at times larger; pits roundish or irregularly elongated; ribs irregularly anastomosing, edges sharp; stipe stout, upto to 10-11 cm long, 4 cm at apex and 5-7 cm at base, yellowish or whitish.  **Fig. 6.** *Morchella crassipes* (Vent.) Pers. **Photo credit :-** Ali *et al*., 2021.
***Morchella semilibera* DC.**	On the ground in oak or beech woods and usually fruiting about a week before the larger morels appear.	Pileus with conspicuous ridges and in age obtusely conic with a flaring margin, pits elongated, dull yellowish brown, the ribs of the pits discolouring darker than the depressions; stipe 8-10 cm long, 1-2 cm thick at apex, in age clavate and up to 4 cm thick at the base, pallid to yellowish, at times with pinkish discolouration in age, ribbed near the apex, granular furfuraceous.  **Fig. 7.** *Morchella semilibera* DC. **Photo credit :-** Kuo *et al*., 2012.

Active Constituents of *Morchella esculenta*

Morel species are reported to minimize oxidative damage in organisms that occurs in several chronic diseases (Ferreria *et al*., 2009). Fruiting body of *Morchella esculenta* contains a broad range of active constituents which include carotenoids, tocopherols, phenolic compounds and organic acids (Table 4).

Carotenoids contain β- carotene and Lycopene. Tocopherols consist of α- tocopherols γ- tocopherols and δ- tocopherols. Organic acids contains oxalic acid, malic acid, citric acid, fumaric acid and quinic acid (Ajmal *et al*., 2015). Various phenolic, tocopherols, organic acid, and carotenoids are discussed in Table 5. Phenolic compounds, tocopherols and organic acids are considered to be the most responsible for antioxidant activity of mushrooms (Reis *et al*., 2012; Leal *et al*., 2013). Steroids and polysaccharides isolated from the *Morchella esculenta* (Meng *et al*., 2010). The known essential micronutrient minerals are iron, zinc, selenium, manganese, cobalt and copper.

Table 4: Active Constituents of *Morchella esculenta* and Their Pharmacological Properties (Ajmal *et al*., 2015).

Sr. No.	Active constituents	Pharmacological properties
1.	Phenolic compounds	Antioxidant, antimicrobial, anti-allergenic, anti-inflammatory and antitumor (Heleno *et al*., 2013; Halliwell, 2012)
2.	Polysaccharides	Antioxidant (Meng et al., 2010)
3.	Galactomannan	Immunostimulatory (Duncan *et al*., 2002)
4.	Organic acids	Anti-oxidant, neuroprotective, anti- inflammatory and anti-microbial (Heleno *et al*., 2013; Baati *et al*., 2011)
5.	Tocopherols	Strong antioxidant (Heleno *et al*., 2013)

Table 5: Phenolic, Tocopherols, Organic Acids and Carotenoids of *Morchella esculenta* (L.) Pers. Mushroom Per 100g of Dry Weight.

Sr. No.	Compounds	Values and unit	References
1.	α-tocopherol	2.38 µg	Heleno *et al*., 2013
2.	γ-tocopherol	12.41 µg	
3.	δ-tocopherol	48.85 µg	
4.	Total tocopherols	14.79 µg	
5.	Lycopene	0.05 mg	
6.	Oxalic acid	32.25 mg	
7.	Malic acid	199 mg	
8.	Fumaric acid	47.81 mg	
9.	Protocatechuic acid	0.24 mg	
10.	p-Hydroxybenzoic acid	0.10 mg	
11.	p-Coumaric acid	0.01 mg	
12.	Total phenolic compounds	0.35 mg	
13.	Gallic acid	78.18 µg	Yildiz *et al*., 2015
14.	p-hydroxybenzoic	345.83 µg	
15.	Chlorogenic acid	17.32 µg	
16.	Epicatechin	12.35 µg	
17.	p-Coumaric acid	0.53 µg	
18.	Ferulic acid	7.48 µg	
19.	Quercetin	198.8 µg	

Table 6: Bioactive Compounds and Their Function of *Morchella esculenta* Mushroom.

Sr. No.	Bioactive compounds	Function	References
1.	Glycoprotein	Anti-carcinogenic, stimulating leucocyte production to strength immune system	Wei *et al*., 2001
2.	Galactomannan	Stimulate immune system	Duncan *et al*., 2002
3.	Exopolysaccharide	Hypoglycemic, antitumor, and immune stimulating activities	Taskin *et al*., 2011

The microminerals play an important role in the catalytic processes within the enzyme system that include a wide range of enzyme activities associated with metabolic, endocrine and immune system. Glactomannan and polysaccharides isolated from fruiting body of yellow morel mushroom have high immune-stimulatory activities (Duncan *et al*., 2002). Various bioactive compounds with their functions and amino acid content of *Morchella esculenta* mushroom are

discussed in Table 6 and 7.

Antioxidant properties of *Morchella esculenta*

Oxidation is necessary for living organism but oxygen centered free radicals cause oxidative damage including cell death, tissue damage, also causes several diseases including atherosclerosis, diabetes and cancer. The oxidative damage can be reduced by using food containing antioxidant properties (Gutteridge & Halliwell 2010). Morel species are reported to minimize oxidative damage in organisms that occurs in several chronic diseases (Ferreira *et al*., 2009). Several herbs can be used in this regard but mushroom are the most important.

Table 7: Amino Acids Contents of *Morchella esculenta* (L.) Pers. Mushroom (mg/g of dry weight).

Sr. No.	Amino acids	Values and unit	Reference
1.	Aspartic acid	0.43 mg	Tasi *et al*., 2006
2.	Threonine	9.83 mg	
3.	Serine	4.97 mg	
4.	Glutamic acid	3.05 mg	
5.	Glycine	3.85 mg	
6.	Methionine	3.59 mg	
7.	Isoleucine	1.28 mg	
8.	Leucine	1.57 mg	
9.	Tyrosine	0.34 mg	
10.	Phenylalanine	0.61 mg	
11.	Lysine	0.25 mg	
12.	Histidine	1.45 mg	
13.	Arginine	0.63 mg	
Total		**35.67 mg**	

Previous studies have reported the antioxidant activity of mushrooms specially *Morchella esculenta* (Kim *et al*., 2011). Anti-oxidative properties in mushrooms were correlated to different anti-oxidative components such as tocopherols, carotenoids, ascorbic acid and total phenoloics (Barros *et al*., 2010). Although the different phenolic compounds seem to be the most effective group of anti-oxidants, while the role of tocopherols seems to be limited and that of *β*-carotene and lycopene vestigial (Kalac, 2009).

Mycelia of *Morchella esculenta* possess beta-carotene and linoleic acid which exhibit antioxidant activities (Mau *et al*., 2004). Mushrooms are the best source of antioxidants and are of great interest as possible protective agents which help human body to reduce oxidative damage without any interference (Gonzalez *et al*., 2015). All organisms possess self defense system which is not sufficient to protect against oxidative damage. Anti-oxidant food can protect the body from damage. The fruiting body of *Morchella esculenta* shows antioxidant activity (Elmastas *et al*., 2006). Polysaccharides and steroids possess antioxidant properties (Meng *et al*., 2010). Antioxidants were suggested to play a beneficial role by helping cellular defense systems (enzymes and non-enzymatic) cope with oxidative stress. Natural anti-oxidants from plant origin are considered useful as nutraceuticals due to their beneficial effects on health and chronic disease prevention (Croft, 2016). Fatty acids and phenolic compounds are widely present in *Morchella esculenta* which are responsible for the strong antioxidant activity and free radical scavenging abilities (Reis *et al*., 2012; Leal *et al.,* 2013). Due to the ability of arresting the radicals, methanolic extract of fruiting body also shows strong anti-oxidant properties (Heleno *et al*., 2013).

Antimicrobial properties of *Morchella esculenta*

Mycelia of *Morchella esculenta* contain antimicrobial properties (Kalyoncu *et al.,* 2010; Alves *et al*., 2012). Previous studies reported that methanol, ethanol and chloroform extracts of *Morchella esculenta* contain antimicrobial properties (Badshah *et al*., 2012). *Morchella esculenta* shows antibacterial activity against *Salmonella typhimurium, Staphylococcus aureus, Listeria monocytogenes, Enterobacter cloacae* and *Escherichia coli* (Heleno *et al*., 2013). Mushrooms needs antibacterial and antifungal compounds to survive in their natural environment. Therefore, antimicrobial compounds could be isolated from many mushrooms species and could be of beneficial for humans (Yamac & Bilgili 2006). Most of the medicinal extract from mushrooms are different forms of polysaccharides, and all of them are strengtheners of the immune system with few or no side effects (Shittu *et al*., 2005). The methanolic extract from the mushrooms has potent antioxidant properties and antibacterial activities against different bacteria.

Anti-allergenic properties of *Morchella esculenta*

Powder of *Morchella esculenta* can be used as an antiseptic to heal the wounds and used for the treatment of stomach ache (Mohmood *et al.,* 2011).

Anti-inflammatory properties of *Morchella esculenta*

Anti-inflammatory activity of morels was reported, showing significant dose- dependent inhibition of both acute and chronic inflammation (Nitha *et al*., 2007). Inflammation occur due to several reasons

like – due to bite of insects, toxic drugs or due to several chronic diseases (Collins, 1999). Methanolic extract of whole body plant acts as an anti-inflammatory and reduces pain (Kumar *et al*., 2000). Nitha *et al*. (2007) reported the strong anti-inflammatory activity of ethanolic extract of cultured mycelium of *Morchella esculenta*. It inhibits both acute and chronic inflammation.

Anti-tumor properties of *Morchella esculenta*

Polysaccharides extracted from *Morchella esculenta* are potentially tumor resistant (Li *et al*., 2013). Cancer is the major cause of human death. Chemotherapy and radiotherapy are the modern ways of cancer treatment but have a less safety margin because of its adverse effect on the host normal cells. For the control and eradication of cancer, natural products have been used (Gibbs, 2000). In Traditional Chinese Medicine, mushrooms having medicinal properties and commonly used for the treatment of cancer. Various compounds extracted from fruiting body of mycelia possess anti-cancer and anti- tumor properties (Chang and Mshigeni 2001; Pankaj *et al*., 2002). Previous studies had reported the use of *Morchella esculenta* for cancer treatment (Nitha *et al*., 2007). Polysaccharides extracted from the fruiting body of *Morchella esculenta* possess strong antitumor properties (Elmastas *et al*., 2006; Meng *et al*., 2010).

Immunostimulatory properties of *Morchella esculenta*

The galactomannan polysaccharides isolated from *Morchella esculenta* enhances the immune response to different diseases and modulates the immune system. *Morchella esculenta* can enhance the functioning of the immune system, and also contains anti- fatigue, antiviral, antioxidant and antitumor growth properties (Meng *et al*., 2010). *Morchella esculenta* also acts as immune stimulant due to the presence of various active constituents. Mushroom metabolites are also used as adaptogens and immunostimulants, and now are considered to be one of the most useful antitumor agents for clinical use (Franz, 1989; Chang, 1991). Glactomannan and polysaccharides isolated from fruiting body of yellow morel mushroom have high immune-stimulatory activities (Duncan *et al*., 2002).

Nutritional aspects of *Morchella esculenta* (L.) pers.

Fruiting body of *Morchella esculenta* is edible. It is highly nutritious, delicious and healthy. It is rich in protein, carbohydrates, vitamins particularly vitamin B and trace amount of vitamin A, C and D, also contains minerals which include - calcium, iron, copper, zinc, magnesium, manganese, sodium, phosphorous, selenium and potassium (Mattila *et al*., 2001). *Morchella esculenta* are also low in fat and contain low calories (Negi, 2006). *Morchella esculenta* contains 38% carbohydrates, 32.7% protein, 17.6% fibre, 9.7% ash and 2.0% fat (Wahid *et al*., 1988). It also contains 1.82 mg/g magnesium, 0.85 mg/g calcium, 23.5 mg/g potassium, 0.18 mg/g zinc, 62.6 mg/g copper, 195 mg/g
iron, 3.49 mg/g phosphorus, 0.18 mg/g sodium and 54.7 mg/g manganese (Genccelep *et al*., 2009). The different proximates of *Morchella esculenta* are discussed in Table 8.

Table 8: Different Proximates of *Morchella esculenta* Mushroom Per 100 g of Dry Weight.

Proximates	Values and Unit	References
Water	89.61 g	USDA, Basic Report 11228, 2016
Energy	31 kcal	
Protein	3.12 g	
Total lipid	0.57g	
Carbohydrate	5.10g	
Total sugars	0.06 g	
Total dietary fibers	2.8 g	
Fats	2.59 g	Heleno *et al*., 2013
Fructose	0.71 g	
Mannitol	11.54 g	
Trehalose	3.41 g	
Total sugars	15.66 g	
Palmatic acid	9.5 %	
Stearic acid	2.6 %	
Oleic acid	12.43 %	
Linoleic acid	71.81 %	
α- linolenic acid	0.02 %	
Saturated fatty acids	5.4 %	
Monounsaturated fatty acids	13.73 %	
Polyunsaturated fatty acids	13.82 %	
Water–soluble polysaccharides	72.45 %	

Crude Protein	417 mg	Tasi *et al*., 2006
Crude Fiber	117 mg	
Crude Ash	50 mg	
Crude Fats	120 mg	
Reducing sugar	122 mg	
Minerals		
Calcium	2340 mg	Gursoy *et al*., 2009
Iron	304 mg	
Magnesium	22.60 mg	
Phosphorus	195 mg	
Potassium	0.18 mg	
Sodium	3.49 mg	
Zinc	153 mg	
Copper	21.08 mg	
Manganese	22.60 mg	
Cobalt	0.12 mg	
Vitamins		
Thiamin	0.069 mg	USDA, Basic Report 11228, 2016
Riboflavin	0.205 mg	
Niacin	2.252 mg	
Vitamin B-6	0.136 mg	
Folate, DFE	9 µg	
Vitamin D(D2+D3)	5.1 µg	
Vitamin D	206 IU	
Fatty acids, total saturated	0.065 g	
Fatty acids, total monounsaturated	0.052 g	
Fatty acids, total polyunsaturated	0.433 g	

Previous studies also reported a variety of aromatic compounds including aldehydes, acids, ketones, esters and terpene. The major aromatic compound is phenol which is about 50.88%, alcohol is present about 15.55%, ester and carbamic acid is present about 11.37% (Taskeen, 2013). Ethnobotanically it is used as purgative, laxative, body tonic, emollient and also used for stomach problems, heal the wound and for general weakness (Sher *et al*., 2011) (Table 9).

Table 9: Ethnobotanical Uses of *Morchella esculenta* (L.) Pers.

Plant use	Diseases/ Other use	Mode of utilization	References
Whole Plant	Hallucigenic and immuneregulatory		Christine *et al*., 2002; Nitha & Janardhanan 2008
	Intestinal and for gastric problem		Gilani *et al*., 2003
	General body tonic	Fried with cow's ghee and taken after meal.	Ali *et al*., 2011
	Arthritis and general weakness		Wagay & Vyas 2011
	Stomach problems and also heal the wound	Powder form	Fayaz *et al*., 2012
	Vegetable and used in pizza	Cooked	Fayaz *et al*., 2012
	Stomach-ache	Powder	Mehmood *et al*., 2011
	Purgative and used as an emollient		Sher & Yemeni 2011
	For decoration purpose	After boiled in water or milk	Nautiyal *et al*., 2001

Due to its unique flavor and taste local people cook the fruiting body mixed with rice and vegetable and consider it as nutritious as fish or meat. Different recipes of *Morchella* are prepared in three star and five star hotels. The *Morchella esculenta* mostly used as a flavouring in soup, used as salad and side dishes (Prasad *et al*., 2002). The most common method is to cook the *Morchella* with butter. *Morchella esculenta* are taken after meal as cooked with desi ghee (Khan *et al*., 2010) (Table 10).

Proteins obtained from the mycelia of *Morchella esculenta* are comparable to vegetative proteins and can be used as a good source of protein supplement (Taskin, 2013). It is rich in protein which can be more easily digested than other vegetables. *Morchella esculenta* is rich in B-complex vitamins and minerals. It has been discovered that *Morchella esculenta* is useful in the treatment of illnesses like- cold, stomach-ache, head-ache and hepatitis B (Halder & Sharma 2017). *Morchella esculenta* shows a good alternative for anaemia and it also help to regulate the blood sugar level (Sher *et al*., 2011; Sharma & Arora 2017).

Morels are consumed worldwide as food, and in Tibet and India are cooked with vegetables and considered as nutritious as meat or fish (Ajmal *et al*., 2015). *Morchella* sugar profile comprises of 0.21-0.71 g fructose, 0.99-11.54 g mannitol, 43.07 g mannose, 0.086 g arabitol and 1.7-9.54 g glucose per 100g dry weight (Rotzoll *et al*., 2006). Yellow morel mushrooms are generally used for the treatment of digestive disorders, excessive phlegm and for the treatment of asthma and in dry powder form used as an antiseptic, healing the wounds and for the treatment of stomach-ache (Mehmood *et al*., 2011). Morels have been traditionally used for curing various ailments. The species of *Morchella* genus are used in traditional medicines which may help to prevent many diseases (Table 11).

Table 10: Different Recipes of *Morchella esculenta* (L.) Pers.

Plant part	Uses	References
Fruiting body	Cooked with vegetable and rice	Prasad *et al*., 2002
	Taken in the form of soup	
Whole plant	Used in salad	Robinson, 2011
	Cooked with butter	
	Cooked with desi ghee	Khan *et al*., 2010
	Fried with onion, tomato and garlic	Semwal *et al*., 2014
	Used in pizza	Fayaz *et al*., 2012

Table 11: Traditional Use of *Morchella* Species in Medicine (Sayeed *et al*., 2018).

Ailment	Mode of application	Uses
Asthma	Fried fresh or rehydrated fruiting body or decoction.	Controls proper functioning of lungs.
Pneumonia	Decoction of fruiting bodies.	Cures pneumonia.
Respiratory problems	Decoction of fruiting bodies.	Cures all the respirat problems. ory
Dehydration/ bloody stools	Boiled with the addition of little salt / sugar.	Recovers water loss of the body.
Wound healing	Paste of the fruiting bodies with clarified butter (ghee).	Heal the wound fast.
Fever, and cold cough	Soup of whole mushrooms and clarified butter.	Heavy sweating lowers the body temperature.
Stomach pain	Boiled or grinded with raw milk.	Relieves pain.
Pregnancy	Soup, wok fried and stewed.	Provides strength, warmness to the body and considered very nutritious.
Lactating mothers	Decoction and wok fried mushroom.	Highly nutritious, provides energy.
Weakness	Decoction in milk served with honey.	Provides strength to the body.
Dermatological	Paste with water.	Cures many skin problems.

Climate change effect on *Morchella esculenta* (L.) Pers. in Himachal Pradesh.

Morels are cold tolerant and have been found to give fructification at temperature less than 5.6°C (Emery & Barron 2010). Climate change is a major challenge facing our planet today. Due to changing life, perception and lifestyle changes of forest dwellers, the plant are exacerbated and that indigenous knowledge on resource use is being degraded severely (Gadgil *et al*., 1993). Medicinal herbs are regarded as free commodity (zero private cost) to be collected from nature (Kunwar, 2002). Morels are widely distributed in the temperate zones of the world. Morels appear from late April until the end of May, usually for about three weeks only. Morels are produced in

Himalayas and these are mostly exported to European countries, which include Switzerland, France, Germany and Australia. Mountains are early indicators of climate change (Singh *et al*., 2010). Morel export is declining due to climate disturbances (Sabra & Walter 2001; Boa, 2004). Morels are widely distributed in the temperate zones but from past few years morels are reported from the tropical zones. Some of the news reports on occurrence of Gucchi in sub-tropical or tropical region of Himachal Pradesh are as:

1. Gucchi was reported from Hamirpur: In 2019, Gucchi was reported in District Hamirpur (Himachal Pradesh). Hamirpur is a sub-tropical zone. The altitude of the Hamirpur district is about 786 m above the sea level. Gucchi was found in the district Hamirpur, village Mauhi of Balh Panchayat near the drain to Kishori Lal (a local people of the village). Kishori told that in October last year, Gucchi plants were found on the hills near the drain. This time Gucchi has also been found on the roadside in large quantity. Reference:- Punjab Kesari (06-Nov-2019).

2. Gucchi was reported from Sundar Nagar: In 2019, Gucchi was also reported from Sundar Nagar. Sundar Nagar is a town and a municipal council in Mandi district in the Indian state of Himachal Pradesh. The town has an average elevation of 900 m (3,000 ft). Gucchi was found in the main market of Sundarnagar (a plain area) to businessman Ramesh Saini. He was taken out about 250g of bunches from his courtyard. Reference:- Jagran (22-Oct-2019)

3. News report on Gucchi from Ghumarwin: In 2018, Gucchi was reported from Ghumarwin. Ghumarwin is a town and a municipal council in Bilaspur (sub-tropical zone) district in the North Indian Hill State of Himachal Pradesh. Ghumarwin is situated at an average elevation of 700 m or about 2300 ft above the sea level. During the cleaning and pruning, labor found Gucchi in Swami Vivekanand Government College Ghumarwin. Reference:- Divya Himachal (10-Nov-2018).

4. News report on Gucchi from Barthin: In 2018, Gucchi was reported from Barthin. Barthin is a village in Jhandutta Tehsil in Bilaspur District of Himachal Pradesh State. The altitude of Barthin village is about 375 m above the sea level. P.E.T. Sunil Kumar posted in Government Senior Secondary School, Barthin, who is fond of farming in the area. When Sunil Kumar was working in the drain due to domestic work, he saw some Gucchi plants very near the drain. About 8 plants of one species of Gucchi has been found in the drain adjoining Barthin, which is enough for the possibilities like its being in the low-lying areas. Reference:- Punjab Kesari (23-Nov-2018).

5. Gucchi mushroom artificially cultivated in DMR: The Indian Council of Agriculture Research-run Directorate of Mushroom Research (DMR), Solan, has for the first time successfully cultivated the world's costliest *Morchella* mushroom, commonly known as Gucchi. The DMR had made several unsuccessful attempts to cultivate Gucchi mushroom since its inception. Given its potential, Dr. VP Sharma, Director, DMR, assigned the challenge to Dr. Anil Kumar in 2019, who prepared a project "Standardization of cultivation technique for *Morchella* mushroom". Under continuous rigorous in vitro trials on the induction of fruit bodies in gucchi, three small ascomata of 0.5 to 1cm were obtained. In the first seasonal cultivation trail started in October 2019, conidial stage and a mature ascomata of 13 cm length was recorded under greenhouse conditions on April 13, 2020. "I was treading in the positive direction and with continuous efforts, I again succeeded and induced 12 ascomata in the second research trail under greenhouse conditions on February 23," he said. Since the experiment is still in progress, he is hopeful that fruit bodies of Gucchi would keep on appearing at his experimental site till April. "This is for the first time that the ICAR-DMR, Solan, has succeeded in producing fruit bodies of Gucchi mushroom. As a result, India has entered the list of select countries such as USA, China, France etc. that have successfully attempted to cultivate Gucchi mushroom under artificial conditions," said Dr. VP Sharma, Director, DMR. Reference :- The Tribune (26-Feb-2021).

6. First Report of *Morchella* – An Edible Morel from Mount Abu, Rajasthan: Mount Abu is a hill station in the Aravalli range in Sirohi district of Rajasthan state in western India. A recent survey was conducted in the second week of October to study the fungal diversity of Mount Abu, Rajasthan. The area covered included Achalgarh, Nakki Lake, Dhobi Ghat and Trevor's tank. This led to the surprise discovery of a species of *Morchella* in Trevor's tank at a height of 1253.6 m and the prevailing temperature was 26 ± 2°C. The long spell of intermittent rainfall might have been conducive for the subterranean mycelium to produce the fruiting bodies. The authors firmly believe that, beside the Himalayan ranges, the climate of Mount Abu is also suitable for its growth. This is the first report of occurrence of *Morchella* in Mount Abu, Rajasthan (Paliwal *et al*., 2013).

7. A Report on Occurrence of *Morchella* sp. from District Faizabad, Uttar Pradesh: *Morchella* grows at higher altitudes usually on hilly land farms with cool microclimate. Occasional reports on collection of *Morchella vulgaris* Boud. from Assam forest, *M*. *deliciosa* from Amritsar (Punjab), *M. conica* from central India and probably

8. *M*. *esculenta* from Rajasthan have been given by Bhattacharya & Baruah, 1953, Purkayastha & Chandra 1985, Ghurde & Wakode 1981 and Paliwal *et al*., 2013, respectively. *Morchella* sp. has been reported from district Faizabad which lies between the parallels of 26 °47'N to 26°78'N

lataitude and 82.08°E to 82.13'E longitude having an average elevation of 97 meters above the sea level. The specimen of *Morchella* was collected during field trip in the month of December, 2013 near railway station area, Ayodhya, Faizabad (Siddhant *et al*., 2014).

Fructifications (Ascocarps) of bodies of morel fungi (*Morchella* spp.) are highly valued for their medicinal and nutritional qualities (Nitha *et al*., 2007). Ower was the first to produce *Morchella esculenta* ascocarps in vitro (Ower, 1982). Investigations have shown that there is a stage in the life cycle of morels called the sclerotium. It is also experimentally demonstrated that sclerotia are essential in production of fructifications under controlled conditions (Ower *et al*., 1986). Various researchers have contributed greatly for the in vitro production of sclerotia that can be employed for the production of ascocarps (Amir *et al*., 1995). Effects of climate change on fungal distribution and activity are hard to predict because they are mediated in many different ways, including: fungal physiology, reproduction and survival, host physiology, spatial and temporal distribution of hosts and resource availability, and outcome of competitive interspecific interactions (Boddy, 1984). Schmidt (1983) & Buscot (1989) pointed out the role of temperature in their appearance; they demonstrated that the re-heating of the soil, after the snow season in early spring, encourages ascocarp formation. Temperature has also been shown to have an effect on spore germination, growth and development (Schmidt, 1983). Ascospores of *Morchella esculenta* were not found to germinate until the soil temperature exceeded 10°C. *Morchella esculenta* were found to germinate and give fruits at low temperature (below 10°C). Schmidt (1983) proposed that the *Morchella esculenta* is a psychrotolerant fungus, and the fruiting of morels in spring may relate to their competitive abilities at low temperature. Volk & Leonard (1990) suggested that the freezing and thawing association with the winter and early spring lead to the formation of ascocarps. Morels are observed in association with trees in undisturbed habitats, where only a few ascocarps are produced each year spring over a period of several years (Buscot & Roux 1987; Buscot & Kottke 1990).

The accumulation of metals in macro fungi has been found to be affected by environmental and fungal factors (Garcia *et al*., 1998). Environmental factors such as organic matter amount, pH, metal concentrations in soil and fungal factors such as species of mushroom, morphological part of fruiting body, development stages and age of mycelium, biochemical composition, and interval between the fructifications affects metal accumulation in macro fungi (Garcia *et al*., 1998; Kalac & Svoboda 2000). A wide range of environmental factors influence the timing and development of fruit bodies, including nutritional factors, gaseous regime, pH, light, microclimate, disturbance, and inter and intra-specific mycelia interaction (Moore *et al*., 2008). Morels mushrooms are highly valued worldwide, owing to their attractive characteristics and high nutritional value. At the same time, it is important to be aware that morels are characterized by high plasticity in regard to metabolite levels and composition, and as a result in their bioactivity affected by mushroom growth stage and by environmental conditions (Masaphy *et al*., 2010). The effect of high water content is less at cold temperatures than at warmer temperatures, because metabolism is slower at lower temperatures. Though elevated CO_2 affects fungal physiology, the predicted atmospheric increases are unlikely to have little direct impact on mycelium in soil and litter where levels are already above ambient. However, mycorrhizal fungi can be affected indirectly via effects of elevated CO_2 on plant physiology and on fixed carbon entering soil from roots (Treseder, 2004).

Light has a wide range of effects on basidiomycetes fruiting, determining whether or not fruit bodies are produced, their development and numbers produced (Moore *et al*., 2008). Many ascomycete species require exposure to light before they will fruit (Elliott, 1994). *Morchella* requires undisturbed natural conditions (Lakhanpal & Shad 1986). The shady location, higher altitude and western aspect gave the idea that *Morchella* specifically requires less sunlight and cool climate. Lakhanpal & Shad (1986) reported that neutral to alkaline soils were suitable for *Morchella*. Morels usually come up after a rain. The day after a rain is the best time to look for them. This fungus grows naturally on the forest floor rich in humus. If the food supply is sufficient, it collectively forms a compact mycelium on the surface of soil. The ascocarp appears above the soil soon after the rain (Prasad *et al*., 2002). So, *Morchella esculenta* mushroom grows best at low temperature.

Laala *et al*. (2020) carried out a study in three administrative units (tehsils) of Poonch district of Azad Jammu and Kashmir state to record the presence of true morels belonging to genus *Morchella* of class Ascomycetes. A periodic random survey was carried out during the year 2015-16. The four species of genus *Morchella* belonging to family Morchellaceae of order Pezizales and class Ascomycetes were collected from Rawalakot and Hajira tehsils of Poonch district growing at temperature recorded between 3-7 °C (Table 12). However, no morel was found growing in Abbaspur tehsil during the same period. All the four species were observed growing on soil. During collection, the intensity of the morels in Poonch district was *M. esculenta* (40%), *M. elata* (30%), *M. deliciosa* (20%) and *M. semilibera* (10%).

Table 12: Temperature Range and Morphological Features of Morels Recorded from Poonch District of Azad Jammu and Kashmir (Laala *et al*., 2020).

Sr. No.	Scientific name	Edibility	Temp. (°C)	Pileus diameter (cm)	Stipe length (cm)	Spore print
1.	*M. esculenta*	Edible	5	5.0-7.0	5.5-8.0	Yellow
2.	*M. elata*	Edible	7	7.0-7.5	4.5-5.0	Black
3.	*M. deliciosa*	Edible	3	2.0-7.5	1.5-5.0	Pale
4.	*M. semilibera*	Edible	7	1.0-2.5	7.0-10.0	Yellow

Two different types of environmental conditions have been discovered to encourage *Morchella esculenta* ascocarp formation. Morels can first fructify as pioneers on recently disturbed soils. For e.g. they become visible in the first spring following mechanical disturbance of the soil, after application of certain herbicides, after a deposition of vegetative wastes, after forest fires and even following volcanic devastation (Kaul *et al*., 1981). Under these conditions the production of ascocarp declines rapidly in the years following the disturbance (Buscot & Roux 1987; Miller *et al*., 1994). These observations reinforce the hypothesis that under these conditions morels are saprotrophic. The second case is the production of ectomycorrhiza with higher plants (Buscot & Kottke 1990; Buscot, 1992). Morels are observed in association with trees in undisturbed habitats, where only a few ascocarps are produced each spring over a period of several years (Buscot & Roux 1987; Buscot & Kottke 1990). So, the various environmental factors (for e.g. temperature, pH and rain) can affect the growth or production of *Morchella esculenta* mushroom.

MATERIALS AND METHODS

The literature was reviewed from the various available resources such as articles, thesis, book, abstracts, opinion from academic publisher, online repositories and web sites.

RESULTS AND DISCUSSION

The results of this study indicate that the *Morchella esculenta* is a wild edible mushroom and one of the most expensive mushroom throughout the world due to its high nutritional and medicinal value. Due to its high price it plays a very important role in the economy of country. It contains carbohydrates, proteins, fibers, all important vitamins, minerals and aromatic compounds. Morels are appreciated worldwide for their savory flavor. *Morchella esculenta* have a great effect of climate on its distribution from few past years. Most of the research work is done on the active constituents and nutritional aspects of *Morchella esculenta.* But there is rare research work done on the climate change effects on the *Morchella esculenta*. Earth's climate is changing. Due to the changed climatic conditions the morels are not produced in large quantity in forest habitats. In India, *Morchella esculenta* occurs primarily in the north-west Himalayan region of Himachal Pradesh and Jammu and Kashmir. India is one of the major producing country of dry morels throughout the world.

Morchella usually grows in clod temperature from March to July but nowadays due to the global warming the climate changes and there is no increase in the production of this mushroom. A good heavy rain is also responsible for the poping up of the morels because rain moisturizes the soil. *Morchella esculenta* needs about 5°C temperature to grow. These are some of the most desirable edible mushroom known in the Himalayan region. Fructifications of bodies of morel fungi are highly valued for their medicinal and nutritional qualities. Investigation has shown that there is a stage in the life cycle of morels called sclerotium. It is also demonstrated that sclerotia are essential in production of fructifications under controlled conditions. A wide range of environmental factors influence the timing and development of fruit bodies, including nutritional factors, gaseous regime, pH, light, microclimate, disturbance, and inter and intra-specific mycelia interaction. Many ascomycete species require exposure to light before they will fruit. So, the various environmental factors can affect the growth or production of *Morchella esculenta* mushroom.

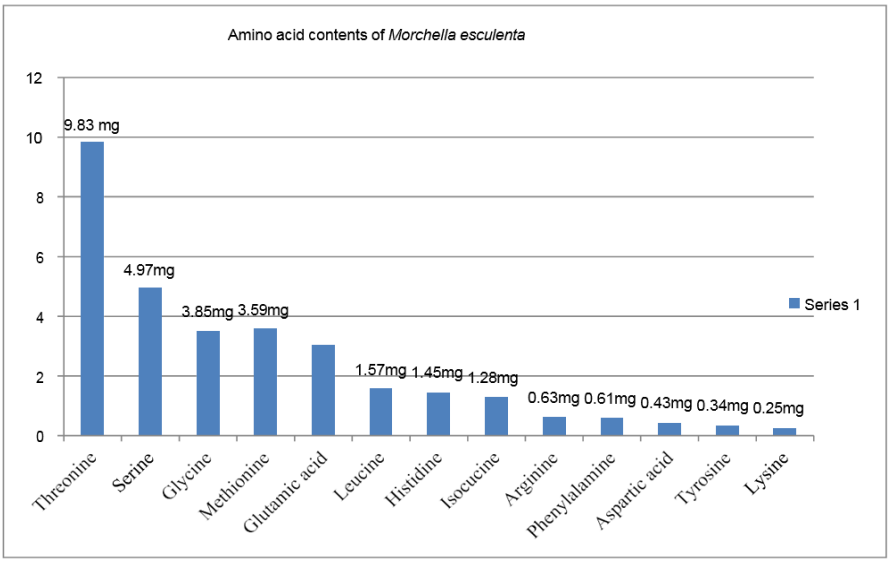


Fig. 8. Graph showing the amino acids contents of *Morchella esculenta* (L.) Pers. mushroom (mg/g of dry weight).

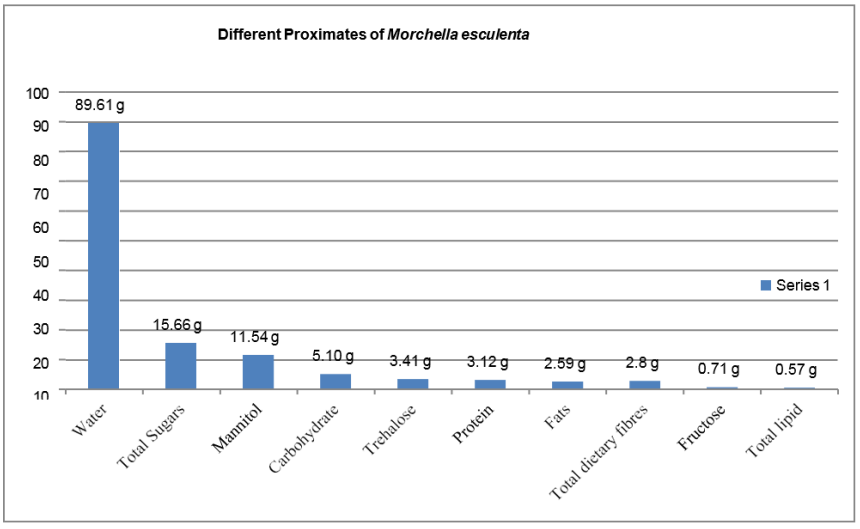


Fig. 9. Graph showing the different proximates of *Morchella esculenta* mushroom per 100 g of dry weight.

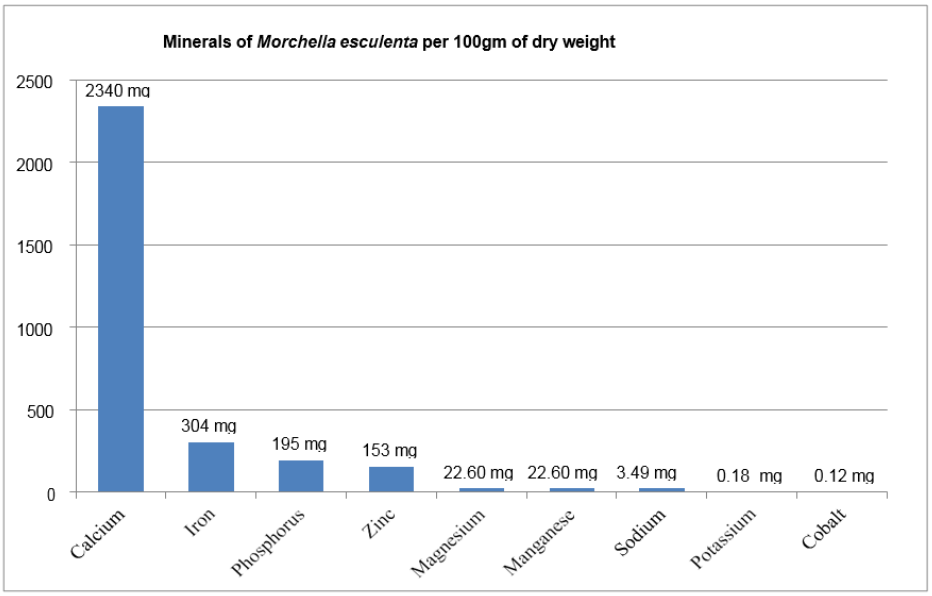


Fig. 10. Graph showing the minerals of *Morchella esculenta* mushroom per 100 g of dry weight.

In comparison of all six species of genus *Morchella*, it is concluded that all six species needed low temperature (below 7-10℃) for their growth (Table 13). And *Morchella esculenta* is most common species found in Himachal Pradesh as compare to the other species. Usually the species of *Morchella* genus is found in the temperate region but from past few years (2-3 years) *Morchella esculenta* is also found in the tropical or sub-tropical regions of Himachal Pradesh due to the climate change. From the past few years the habitat of *Morchella esculenta* shifted toward the sub-tropical and tropical zones due to climate change. There is a stage in the life cycle of morels called sclerotium. Sclerotia are essential in the production of fructifications of *Morchella*. In some regions of Himachal Pradesh there are some districts where the fructifications of morels are possible in sub-tropical and tropical regions instead of temperate region due to the climate change conditions. In fact, for the first time Indian Council of Agriculture Research-run Directorate of Mushroom (DMR), Solan, has successfully cultivated the world's costliest *Morchella* mushroom.

Given its potential, Dr. VP Sharma, Director, DMR, assigned the challenge to Dr. Anil Kumar in 2019, who prepared a project "Standardisation of cultivation technique for *Morchella* mushroom". Under continuous rigorous in vitro trails on the induction of fruit bodies in gucchi, three small ascomata of 0.5 to 1cm were obtained. They are performing their project work under greenhouse conditions. Since the experiment is still in progress, Dr. Anil is hopeful that the fruit bodies of Gucchi would keep on appearing at his experimental site till April. Gucchi is also reported from the Mount Abu, Rajasthan at a height of 1253.6 m and the temperature was 26±2°C. *Morchella* sp. has been reported from district Faizabad which lies between the parallels of 26°47'N to 26°78'N lataitude and 82.08°E to 82.13'E longitude having an average elevation of 97 m above the sea level. A wide range of environmental factors influence the timing and development of fruit bodies, including nutritional factors, gaseous regime, pH, light, microclimate, disturbance, and inter and intra-specific mycelia interaction. Many ascomycete species require exposure to light before they will fruit. *Morchella* spp. usually found at the high altitude but due to various climate changes, *Morchella* spp. also found to give fruits at lower altitude. So, the *Morchella* can also grow in the sub-tropical and tropical zones due to the various climatic changes.

Table 13. Comparison Between Six Species of Genus *Morchella* Found in Himachal Pradesh

Sr. No.	Comparison factors	Species					
		***Morchella esculenta* (L.) Pers.** (Common morel)	***Morchella conica* (Pers.) Fr.** Syn. *M. Elata* Fr. (White morel)	***Morchella deliciosa* Fr.** (Delicious morel)	***Morchella angusticeps* Peck** (Black morel)	***Morchella crassipes* (Vent.) Pers.**	***Morchella semilibera* DC.**
1.	**Temperature range needed**	About 5℃	About 7℃	About 3℃	About 4℃	About 5℃	About 7℃
2.	**Habitat**	Usually in or near lightly burned grassy areas and swampy ground.	On soil, in open forest, often a year or two after a forest fire.	On the ground in grassy places, usually at the edge of woods, widely distributed but rare.	On sandy soils in woods. Widely distributed and often associated with *Populus* spp.	On the ground in open places, at the edge of woods.	On the ground in oak or beech woods and usually fruiting about a week before the larger morels appear.

3.	**Morphological features**	Pileus not distinctly longitudinally ridged, upto 7-9 cm long and 4-5 cm wide, pits rounded, irregular or at times longitudinally elongated, yellowish, becoming light brownish when dry, edges rounded, lighter than the pits; stipe only slightly enlarged at the base.	Pileus can be up to 4-10cm but may occasionally be larger; cone is spindle-shaped with pronounced vertical ridges with cross-connections, producing a series of rectangular hollows up to 1cm long; honey coloured with ridges darkening to brown with age; stipe 2-4 cm, hollow, circular, often enlarged at base or top.	Pits or depressions of the pileus grey to fuscous, ridges pallid; fruit bodies typically small. Pileus 2-3 cm long, pit elongated, ridges much lighter than the pits, irregularly anastomosing; stipe up to 2/3 times as thick as the pileus, often enlarged at the base and somewhat lacunose, whitish or yellowish.	Pileus 1-5 cm high, narrowly conic, pallied to greyish young but the borders of the pits darhening finally to black. Heads with greatly elongated pits; stipe equal, nearly as thick as the head, pallid to buff in large forms, the pits blackish like the ribs by maturity.	Pits large and shollow, ridges thin; stipe enlarged and at times lacunose at the base. Pileus sub-conic, usually elongated and 6-12 cm long and 5-6 cm broad or at times larger; pits roundish or irregularly elongated; ribs irregularly anastomosing, edges sharp; stipe stout, upto 10-11 cm long, 4 cm at apex and 5-7 cm at base, yellowish or whitish.	Pileus with conspicuous ridges and in age obtusely conic with a flaring margin, pits elongated, dull yellowish brown, the ribs of the pits discolouring darker than the depressions; stipe 8-10 cm long, 1-2 cm thick at apex, in age clavate and up to 4 cm thick at the base, pallid to yellowish, at times with pinkish discolouration in age.

SUMMARY AND CONCLUSION

Morchella esculenta is an edible fungus. It is one of the most highly priced mushrooms found in the world. It is found at altitude of 2500-3500 m in forest habitat. The growing season of *Morchella esculenta* is from March to July. In this study the climate change effects on *Morchella esculenta* in Himachal Pradesh were reviewed. Because usually *Morchella* is found in the temperate zones mostly. But recently the habitat of the *Morchella esculenta* and other *Morchella* species are shifted toward the tropical zones. *Morchella esculenta* is the most important and precious fungal plant which plays an important role in the economy and the price depends upon the quality. It has been consumed and appreciated for its nutritional value as well as medicinal properties. For centuries, *Morchella esculenta* has been consumed and appreciated for its nutritional value as well as medicinal properties. Morels have adapted to a wide range of unusual habitats and environmental conditions, including river bottoms, dunes, garbage dumps, abandoned coal mines, cellars and basements, saw mills, wood piles, sand bars in rivers, road cuts, excavations, deer trails, orchards, bomb craters and limed soils. It contains all the important nutrients, from carbohydrates, proteins, polyunsaturated fatty acids, secondary metabolites like phenolic compounds, etc.

There are various studies done on the active constituents and nutritional aspects of *Morchella esculenta*. But there are very few studies done on the climate change effects on *Morchella esculenta*. Fruiting body of *Morchella esculenta* contains a broad range of active constituents which include carotenoids, tocopherols, phenolic compounds and organic acids. Carotenoids contain β-carotene and Lycopene. Morel species are reported to minimize oxidative damage in organisms that occurs in several chronic diseases. Previous studies have reported the antioxidant activity of mushrooms specially *Morchella esculenta.* Mycelia of *Morchella esculenta* possess beta-carotene and linoleic acid which exhibit antioxidant activities. Mycelia of *Morchella esculenta* contain antimicrobial properties. Powder of *Morchella esculenta* can be used as an antiseptic to heal the wounds and used for the treatment of stomach ache. Anti-inflammatory activity of morels was reported, showing significant dose-dependent inhibition of both acute and chronic inflammation. Polysaccharides extracted from *Morchella esculenta* are potentially tumor resistant. *Morchella esculenta* also acts as immune stimulant due to the presence of various active constituents. *Morchella esculenta* is also low in fat and contain low calories. *Morchella esculenta* contains 38% carbohydrates, 32.7% protein, 17.6% fibre, 9.7% ash and 2.0% fat. Morels are consumed worldwide as food, and in Tibet and India are cooked with vegetables and considered as nutritious as meat or fish. Protein obtained from the mycelia of *Morchella esculenta* are comparable to vegetative protein and can be used as a good source of protein supplement. It is rich in protein which can be more easily digested than other vegetables.

Morels are cold tolerant and have been found to give fructification at temperature less than 5.6°C. Morels are widely distributed in the temperate zones but from past few years morels are reported from the tropical zones. There are also some news reports on Gucchi reported from sub-tropical and

tropical regions. Some reports (research reports) on gucchi at different temperature are also discussed in review of literature. A wide range of environmental factors influence the timing and development of fruit bodies, including nutritional factors, gaseous regime, pH, light, microclimate, disturbance, and inter- and intra – specific mycelia interaction. Mycorrhizal fungi can be affected indirectly via effects of elevated CO_2 on plant physiology and on fixed carbon entering soil from roots. The shady location, higher altitude and western aspect gave the idea that *Morchella* specifically requires less sunlight and cool climate.

The one of the major finding are that the *Morchella* is also reported from some sub- tropical and tropical zones due to climate change. Because usually the *Morchella* is found in the temperate zones but now the *Morchella* spp. are also found in the tropical regions. *Morchella esculenta* is one of the most highly prized edible mushroom in the world. This edible fungus grows on soil rich in organic matter, in loamy soil and is found in various habitats such as coniferous forests, apple orchards, grassy places, etc. It contains a wide range of active constituents which include tocopherols, carotenoids, organic acids, polysaccharides and phenolic acid which exhibit a wide range of medicinal and pharmacological properties including anti-microbial, anti-inflammatory, immunostimulatory, antitumor and antioxidant. Nutritionally, it contains carbohydrates, proteins, fibers, all important vitamins, and minerals. This fungus is very expensive, hence called “growing gold of mountains” and it contributes a major role in country’s economy. There are very few studies done on the climatic effects on *Morchella esculenta*. There are various environmental factors which affects the fungal fruiting. Environmental factors such as organic matter amount, pH, metal concentration in soil and fungal factors such as species of mushroom, morphological part of fruiting body, development stages and age of mycelium, biochemical composition, and interval between the fructifications affects the metal accumulation in macro fungi. Effects of climate change on fungal distribution and activity are hard to predict because they are mediated in many different ways, including: fungal physiology, reproduction and survival, host physiology, spatial and temporal distribution of hosts and resource availability, and outcome of competitive interspecific interactions. Fructification of bodies of morel fungi are highly valued for their medicinal and nutritional qualities. Investigations have shown that there is a stage in the life cycle of morels called the sclerotium. It is also experimentally demonstrated that sclerotia are essential in production of fructifications under controlled conditions. A wide range of environmental factors influence the timing and development of fruit bodies, including nutritional factors, gaseous regime, pH, light, microclimate, disturbance, and inter and intra-specific mycelia interaction. Many ascomycete species require exposure to light before they will fruit. Due to the various changes in environment, morels are also found in tropical or sub tropical zones. The fruiting body of *Morchella esculenta* are low in fat and calories but rich in protein. So mushroom is one of the best plant to study and to gain knowledge about especially *Morchella esculenta* because there are very few studies done on the climatic effects on *Morchella esculenta* and on other *Morchella* species.

There is a wide range of scope in the future on this topic i.e. climate change induced shift in distribution of *Morchella esculenta* (L.) Pers. in Himachal Pradesh. There are many studies on the *Morchella esculenta* like active constituents of *Morchella esculenta* and nutritional aspects of *Morchella esculenta* but there are very few studies on the climate change effects on *Morchella esculenta*. So, there is still need to study about the various climatic factors that affects the *Morchella esculenta*. This is a very interesting topic and this topic also have a great research scope in the future.

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