

Species and region-wise mushroom production in leading mushroom producing countries - China, Japan, USA, Canada and India

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ABSTRACT

There has been rapid growth in mushroom production worldwide reaching 43 million tonne in 2018-19. The subsequent two years have been a difficult period for all economies of the world as COVID-19 has impacted all the sectors including mushroom output. Despite the rapid increase in mushroom production in this century, the production is highly localized. In all major mushroom producing countries, there are specific regions of concentrated production. In countries producing different types of mushrooms such as China, Japan and India, there are localized regions of production for different species. Species and region-wise production in major mushroom producing countries has been presented here for 2018-19. These data may serve as a bench mark to analyse the changes in mushroom production in the post-COVID era.

Keywords: China, Japan, USA, Canada, India region-wise production, pre-COVID mushroom production

Humans have been collecting and consuming mushrooms since long time ago but their cultivation is a relatively recent development. Commercial cultivation of mushrooms in the world picked up only after world war II (Singh et al., 2017). In the 60s, the button mushroom was the most commonly available cultivated mushroom. Over time, a number of other mushrooms have been cultivated and the contribution of different mushroom species to world mushroom production has changed over time (Singh et al. 2018). Five mushroom genera viz., *Lentinula*, *Pleurotus*, *Auricularia*, *Agaricus*, and *Flammulina* accounted for 90% of the global mushroom production in 2013 (Royse 2014). World production increased to 43 million tons in 2018-19 (Singh et al. 2020) and may surpass 50 MT by 2025.

The Corona pandemic has divided our times into a pre-covid and post-covid era and covid has impacted the growth of economies across the globe. Here we

report species and region-wise mushroom production in major mushroom producing countries viz., China, Japan, USA, Canada and India during pre-covid period i.e. 2018/19 that may serve as benchmark for post-covid analysis of regional growth of the mushroom industry. In fact data from USA for the year 2020 indicated that both production and productivity was impacted, particularly in California region (Singh et al., 2020).

China

China is the world's largest producer of mushrooms. They are the fifth most important crop after grains, vegetables, fruits and oil crops accounting for 5% of production and they have higher production than cotton, sugar or tobacco. Around 1789 edible fungi and 798 medicinal fungi have been reported from China (Kew, 2018). Over 200 species have been successfully cultivated in the laboratories, 100 species

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Table 1. Species-wise mushroom production (million kg) in China 2010-2019 (CEFA)

Species	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<i>1. Lentinula edodes</i>	4312	5018	6355	7103	7691	7667	8983	9865	10432	11159
<i>2. Auricularia auricula</i>	2896	3461	4754	5564	5791	6337	6795	7519	6740	7018
<i>3. Pleurotus ostreatus</i>	5599	5633	5330	5948	5458	5902	5381	5464	6435	6865
<i>4. F.filimormis (velutipes)</i>	1849	2493	2401	2729	2513	2614	2669	2479	2576	2590
<i>5. A.bisporus</i>	2207	2462	2184	2377	2301	3380	3352	2895	2483	2314
<i>6. Pleurotus eryngii</i>	426	523	729	673	1254	1365	967	1597	1956	2035
<i>7. Auricularia polytricha</i>	1259	1435	1262	1309	1526	1826	1834	1686	1899	1683
<i>8. Agrocybe aegerita</i>	407	424	499	626	684	0	714	778	886	919
<i>9. Pholiota nameko</i>	582	637	756	960	677	540	1771	653	562	588
<i>10. Tremella fuciformis</i>	314	333	360	385	431	451	496	543	526	542
<i>11. Hypsizygyus marmoreus</i>	25	44	154	146	128	239	360	391	270	300
<i>12. P. geesteranus</i>	212	202	273	202	371	408	344	325	266	320
<i>13. Volvariella volvacea</i>	331	301	294	276	253	249	213	239	202	234
<i>14. Dictyophora indusiata</i>	53	46	59	55	62	57	57	200	188	217
<i>15. Ganoderma lucidum</i>	91	110	109	83	104	117	124	137	168	186
<i>16. Coprinus comatus</i>	358	342	276	235	239	204	193	189	149	139
<i>17. Gastrodia elata</i>	102	89	21	78	103	70	93	96	106	127
<i>18. Agaricus blazei</i>	29	20	33	41	45	66	49	103	101	121
<i>19. Cordyceps militaris</i>	4	56	5	14	15	74	17	80	91	83
<i>20. Wolfiporia cocos</i>	0	0	0	0	0	367	81	74	80	177
<i>21. Boletus spp</i>	13	11	2	31	37	32	48	62	65	79
<i>22. Hericium erinaceus</i>	127	151	197	123	91	134	171	89	61	63
<i>23. Stropharia rugosoannulata</i>	47	42	54	29	53	43	42	29	57	143
<i>24. Pleurotus ferulae</i>	324	310	165	142	119	88	93	69	56	58
<i>25. Pleurotus citrinopileatus</i>	1	4	1	0	3	3	7	7	52	49
<i>26. Grifflola frondosa</i>	11	5	15	21	23	21	24	26	29	36
<i>27. Morchella spp</i>	0	0	0	2	3	4	6	10	25	73
<i>28. Tricholoma matsutake</i>	4	1	0	4	5	5	5	7	7	9
<i>29. Russula vinosa</i>	0	0	0	0	0	0	0	3	4	3
<i>30. Tricholoma lobayense</i>	4	7	49	47	50	53	3	9	3	2
Others	428	1556	1945	2492	2673	2451	1074	1496	1418	1210
Total	22012	25717	28280	31697	32701	34763	35967	37120	37890	39339

have been domesticated and more than 60 species have been commercially cultivated (Li, 2021). In the 70s there was very little production. But there has been exponential growth in the last century. In last few years the production is stabilizing. Production of different species in 2019 is presented in Table 1. Seven species are contributing over 1000 million kg with shiitake contributing 11159 million kg. Thirteen species contribute between 100 to 1000 million kg. Five species contributed between 50 to 100 million kg each. Cultivation of genera of medicinal mushrooms like *Cordyceps* and novel mushrooms like *Morchella* is contributing to the growth and their contribution is likely to be much more in the coming decades. Initial cultivation of different species as a seasonal activity with a subsequent shift to mechanisation and automation for industrial cultivation, development of varieties and policy support has contributed to the success of the mushroom industry in China.

Growth in *Pleurotus ostreatus* production has been only marginal since 2010 and as a result its position from number one in 2010 has become number three in 2019. There has been maximum growth in shiitake followed by increasing production in *Auricularia auricula* and their position from second

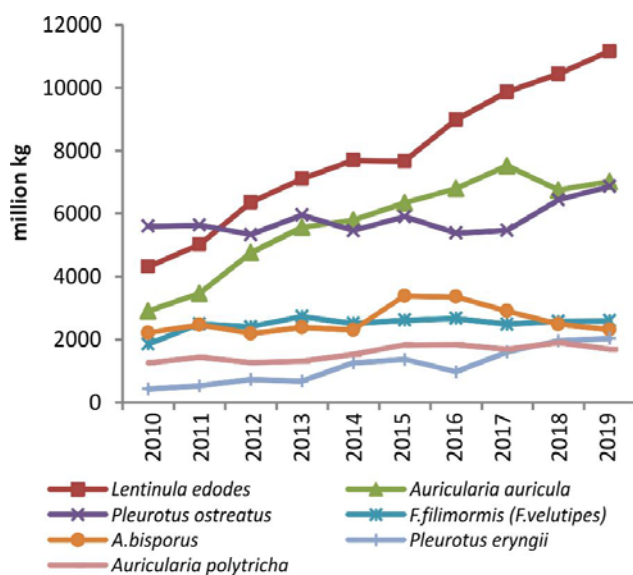


Fig. 1. Trends in mushroom production of seven major species in China in last decade

to third in 2010 has become first and second respectively. There is stability in growth in other species except button mushroom that showed increase in growth in 2015 but has decreased recently. *Pleurotus eryngii* has increased steadily in production (Fig 1).

Despite the high production, mushroom cultivation is not at same level in all the provinces. In 2019 five provinces out of over 30 regions viz., Henan, Fujian, Shandong, Heilongjiang and Hebei accounted for 50% of the total production. About 25% was contributed by five other provinces viz., Jilin, Jiangsu, Sichuan, Hubei and Jiangxi (Fig 2; Table 2).

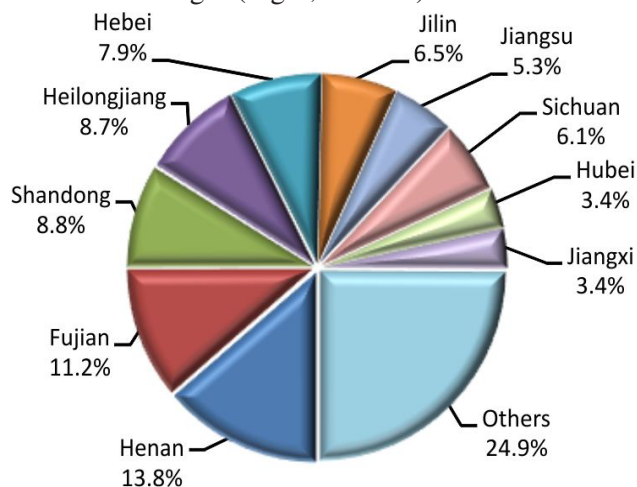


Fig. 2. Contribution of different regions of China in mushroom production during 2019

From Table 2 it can be seen that production of different species is localized. For each species three provinces contributed more than 50% in all major mushrooms except *Pleurotus ostreatus* that seems to be widely cultivated. Cultivation of *Auricularia* spp. is highly localized to a few provinces only, particularly *A. polytricha* where three provinces accounted for 91% of production (Table 2).

Most of the mushroom producing areas are concentrated in the East. As we move from South to North on the eastern side of China we can see a shift in major mushrooms under cultivation (Fig. 3). In 2018, the total output of mushrooms in China was 37890

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Table 2. Species and region-wise mushroom production in China in 2019 (CEFA)

Provence	Production (ton)	% share	Cumulative % age
<i>Lentinula edodes</i>			
Henan	3123620	28.0	28.0
Hebei	1774589	15.9	43.9
Fujian	1213857	10.9	54.8
Hubei	959203	8.6	63.4
Shaanxi	760639	6.8	70.2
Others	3327511	29.8	100.0
Total	11159419		
<i>Auricularia auricula</i>			
Heilongjiang	3195312	45.5	45.5
Jilin	1710000	24.4	69.9
Fujian	710980	10.1	80.0
Shaanxi	288578	4.1	84.1
Zhejiang	226672	3.2	87.4
Others	886603	12.6	100.0
Total	7018145		
<i>Pleurotus ostreatus</i>			
Shandong	1157790	16.9	16.9
Henan	1152635	16.8	33.7
Jilin	685000	10.0	43.6
Hebei	610134	8.9	52.5
Sichuan	551425	8.0	60.6
Others	2707738	39.4	100.0
Total	6864722		
<i>Flammulina velutipes</i>			
Shandong	704216	27.2	27.2
Jiangsu	550104	21.2	48.4
Henan	275734	10.6	59.1
Hebei	182898	7.1	66.1
Fujain	117460	4.5	70.7
Others	759217	29.3	100.0
Total	2589630		

Provence	Production (ton)	% share	Cumulative % age
<i>Agaricus bisporus</i>			
Jiangsu	498912	21.6	21.6
Henan	483826	20.9	42.5
Fujian	385355	16.7	59.1
Guangxi	226249	9.8	68.9
Shandong	166357	7.2	76.1
Others	552841	23.9	100.0
Total	2313540		
<i>Pleurotus eryngii</i>			
Jiangsu	685933	33.7	33.7
Fujian	298881	14.7	48.4
Henan	191520	9.4	57.8
Hebei	189539	9.3	67.1
Shandong	96650	4.8	71.9
Others	571989	28.1	100.0
Total	2034512		
<i>Auricularia polytricha</i>			
Sichuan	921491	54.7	54.7
Shandong	530115	31.5	86.2
Guangxi	89487	5.3	91.5
Jangxi	45133	2.7	94.2
Henan	27540	1.6	95.9
Others	69648	4.1	100.0
Total	1683414		
Total Mushroom Production			
Henan	5409444	13.8	13.8
Fujain	4407981	11.2	25.0
Shandong	3463802	8.8	33.8
Heilongjiang	3428700	8.7	42.5
Hebei	3100223	7.9	50.4
Jilin	2564882	6.5	56.9
Jangsau	2101216	5.3	62.2
Sichuan	2402788	6.1	68.3
Others	12459698	31.7	100.0
Total	39338734		



Fig. 3. Major regions of production of some important mushrooms in China

million kg, and the export of mushrooms was 703.1 million kg. China imported less than 10 million kg of mushrooms. In 2018, the population in mainland China was 1.39538 billion. According to these data, the annual mushroom consumption per person in China comes to be 27 kg per person per year in 2018.

Japan

Lentinula edodes, *Pholiota nameko*, *Flammulina velutipes*, *Hypsizygus ulnarius*, *Grifola frondosa* and *Pleurotus eryngii* are six

Table 3. Species-wise production in Japan from 2010 to 2019

Species	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<i>Lentinula edodes</i>	101.7	97.1	92.4	92.4	89.1	86.3	88.2	86.8	88.2	88.0
<i>Pholiota nameko</i>	27.3	25.4	25.8	23.4	21.8	22.9	22.9	23.5	23.4	23.9
<i>Flammulina velutipes</i>	141.0	143.2	134.1	133.6	135.9	131.7	133.3	135.7	140.2	129.1
<i>Pleurotus ostreatus</i>	2.5	2.1	1.9	2.3	2.3	3.3	3.4	3.8	4.0	3.9
<i>Hypsizygus ulnarius</i>	110.5	118.0	122.3	117.4	115.8	116.2	116.3	117.7	118.0	118.6
<i>Grifola frondosa</i>	43.4	44.5	43.3	45.5	49.5	48.9	48.5	47.7	49.7	51.1
<i>Pleurotus eryngii</i>	37.5	38.1	38.2	40.2	39.6	39.7	40.5	39.1	39.4	37.6
<i>Auricularia auricula</i>	0.3	0.6	0.8	0.8	0.9	1.2	1.3	1.7	2.3	2.3
<i>Tricholoma matsutake</i>	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0
Total	464.3	469.0	458.7	455.6	455.0	450.1	454.5	456.2	465.2	454.5

major species under cultivation in Japan. The total production has stabilized around 460 million kg though there has been some decline in production of Shiitake over the years (Table 3). Even though mushrooms are cultivated in all of Japan, there are specific regions of production of different mushrooms. Cultivation of shiitake for drying is more common in southern parts like Oita and Miyazaki prefectures whereas the cultivation of fresh shiitake is distributed in other regions with maximum production in Tokushima followed by Hokkaido (large province in extreme North). This is a manifestation of log cultivation vs bag cultivation that is more popular at present. About 20 percent of the shiitake production is dried. For

other mushrooms like *Pholiota nameko*, *Flammulina velutipes*, *Pleurotus ostreatus*, *Hypsizygus ulnarius*, *Grifola frondosa* and *Pleurotus eryngii* Nagano and Niigata were among the major producers and these two prefectures (provinces) out of 47 accounted for 55.6% of total production (Fig. 4 & 5; Table 4).

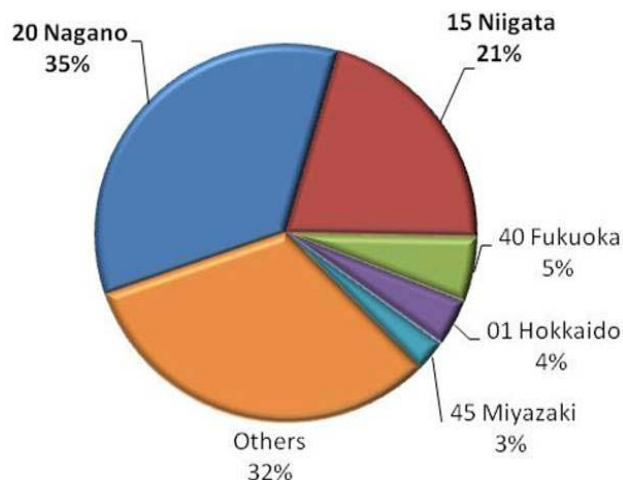


Fig. 4. Mushroom production by prefectures in Japan in 2018

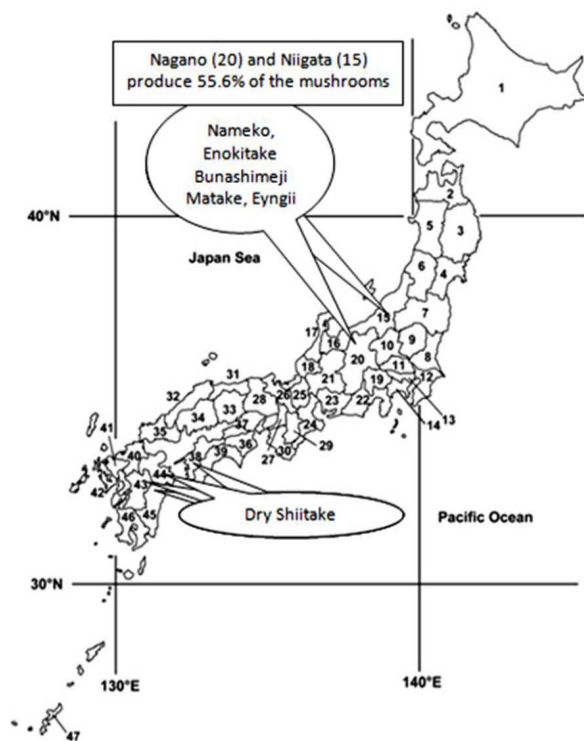


Fig. 5. Major mushroom producing prefectures of Japan

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Table 4. Region-wise production of different species in 2018 in Japan

Provence	Production (ton)	% share	Cumulative
Dried shiitake (<i>Lentinula edodes</i>) mushrooms (as fresh wt)			
Oita	7268.1	39.4	39.4
Miyazaki	3338.3	18.1	57.5
Kumamoto	1461.6	7.9	65.4
Ehime	1143.1	6.2	71.6
Iwate	830.2	4.5	76.1
Others	4400.9	23.9	100.0
Total	18442.2		
Raw (Fresh) shiitake (<i>Lentinula edodes</i>)			
Tokushima	8110.7	11.6	11.6
Hokkaido	7239.7	10.4	22.0
Iwate	4194.7	6.0	28.0
Gunma	3988.8	5.7	33.7
Akita	3549.2	5.1	38.8
Others	42671.0	61.2	100.0
Total	69754.1		
Nameko (<i>Pholiota nameko</i>)			
Niigata	4969.3	21.8	21.8
Yamagata	4391.2	19.3	41.0
Nagano	3880.7	17.0	58.1
Fukushima	1464.2	6.4	64.5
Hokkaido	1362.1	6.0	70.4
Others	6741.4	29.6	100.0
Total	22808.9		
Enokitake (<i>Flammulina velutipes</i>)			
Nagano	87940.6	62.8	62.8
Niigata	19704.8	14.1	76.9
Miyazaki	5705.9	4.1	80.9
Fukuoka	5196.4	3.7	84.7
Hokkaido	3493.8	2.5	87.1
Others	17996.0	12.9	100.0
Total	140037.5		
Hiratake (<i>Pleurotus ostreatus</i>)			
Niigata	1393.9	34.8	34.8
Fukuoka	806.2	20.1	55.0
Nagano	690.1	17.2	72.2
Ibaraki	298.0	7.4	79.7
Mie	162.3	4.1	83.7
Others	650.8	16.3	100.0
Total	4001.3		
Bunashimeji (<i>Hypsizygus ulnarius</i>)			
Nagano	48826.3	41.4	41.4
Niigata	22999.8	19.5	60.9
Fukuoka	14038.8	11.9	72.8
Kagawa	5099.1	4.3	77.1
Miyagi	3075.6	2.6	79.8
Others	23876.6	20.2	100.0
Total	117916.2		
Matake (<i>Grifola frondosa</i>)			
Niigata	32505.4	65.4	65.4
Shizuoka	5180.2	10.4	75.9

Provence	Production (ton)	% share	Cumulative
Nagano	2620.1	5.3	81.1
Hokkaido	2288.4	4.6	85.8
Gunma	1179.9	2.4	88.1
Others	5896.3	11.9	100.0
Total	49670.3		
Eringi (<i>Pleurotus eryngii</i>)			
Nagano	15995.7	40.6	40.6
Niigata	12759.5	32.4	73.0
Fukuoka	1756.1	4.5	77.4
Kagawa	1431.5	3.6	81.0
Nagasaki	1053.1	2.7	83.7
Others	6417.0	16.3	100.0
Total	39412.9		
Matsutake (<i>Tricholoma matsutake</i>)			
Nagano	42.1	74.8	74.8
Iwate	9.0	16.0	90.8
Kyoto	1.3	2.3	93.1
Okayama	1.2	2.1	95.2
Wakayama	0.8	1.4	96.6
Others	1.9	3.4	100.0
Total	56.3		
Dried Wood ear (<i>A. auricula</i>) (as fresh wt)			
Hokkaido	268.6	25.0	25.0
Kagoshima	86.9	8.1	33.1
Shizuoka	84.0	7.8	40.9
Yamaguchi	49.3	4.6	45.5
Oita	49.2	4.6	50.0
Others	537.0	50.0	100.0
Total	1075.0		
Wood ear fresh (<i>Auricularia auricula</i>)			
Gifu	356.4	28.9	28.9
Kumamoto	158.6	12.9	41.7
Ibaraki	124.2	10.1	51.8
Kagoshima	82.2	6.7	58.5
Niigata	64.5	5.2	63.7
Others	448.0	36.3	100.0
Total	1233.9		
Other mushrooms			
Kyoto	807.5	36.2	36.2
Nagano	476.1	21.4	57.6
Hokkaido	358.9	16.1	73.7
Gunma	92.4	4.1	77.8
Yamagata	77.1	3.5	81.3
Others	417.4	18.7	100.0
Total	2229.4		
Total of all mushrooms			
Nagano	162174.2	34.8	34.8
Niigata	97149.6	20.8	55.6
Fukuoka	26097.1	5.6	61.2
Hokkaido	18619.0	4.0	65.2
Miyazaki	12465.9	2.7	67.8
Others	150132.2	32.2	100.0
Total	466638.0		

USA

Mushroom production in the USA has stabilized around 400 million kg in the last decade (Table 5). In 2019/2020 season (i.e. July 2019 to June 2020) there was decline in productivity, particularly in California that could be attributed to COVID (Singh *et al.*, 2020). Like other countries, there are localized centres of production. Around 66% of the production is in Pennsylvania (Fig. 6) and within it Chester County accounted for 48% of production of USA. Contribution of species other than button is around 2-3% and is showing increasing trends (Table 6).



Fig. 6. Mushroom production in USA in different states

Table 5. Region-wise button mushroom production (million kg) (USDA)

	California	Pennsylvania	Others	Total US
2010/11	53.5	248.7	81.5	383.7
2011/12	55.1	248.4	96.5	400.0
2012/13	53.6	247.4	93.5	394.5
2013/14	46.1	259.5	94.5	400.1
2014/15	48.0	265.1	98.4	411.5
2015/16	49.8	266.7	100.4	416.9
2016/17	46.0	260.1	105.1	411.2
2017/18	43.2	259.7	101.5	404.4
2018/19	42.1	251.4	75.0	368.5
2019/20	51.1	239.0	71.5	361.5

Canada

Mushroom production in Canada is concentrated in two provinces. Ontario accounted for 50.5% while British Columbia had 42.7% of the total production in 2018/2019 (Fig. 7, Table 7). Other regions contributed less than 7%. The button mushroom is the major contributor and other mushrooms account for 2 to 3% of the total production (Table 8). One immediate impact of the start of COVID in 2019-2020 was an increase in canning (Singh *et al.* 2020).

India

In India too production is localized and different mushrooms are grown in different regions. Button mushroom dominates in the North-West, milky mushroom is mainly grown in South India and paddy straw mushroom is mostly localized to the coastal

Table 6. Species wise mushroom production (million kg) in USA from 2010/2011 to 2018/2019

Mushroom	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
White button	321.5	333.7	325.6	331.0	338.6	341.9	330.0	319.4	285.2
Brown button	62.3	66.3	68.8	69.1	72.9	74.9	81.2	84.9	83.4
Total button	383.7	400.0	394.5	400.1	411.5	416.9	411.2	404.3	368.5
Shiitake	3.32	3.63	3.75	4.06	4.20	4.59	4.90	4.59	3.05
Oyster	3.51	3.19	3.16	3.25	3.50	4.54	5.03	4.92	3.91
Others	1.24	1.40	1.53	0.74	1.66	1.95	2.21	2.29	1.77
Total	391.8	408.2	402.9	408.2	420.9	427.9	423.4	416.1	377.3

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Table 7. Region-wise mushroom production (tonne)

	British Columbia	Ontario	Others	Total
2014	46,603	64,445	11,009	1,22,057
2015	46,833	58,360	9,489	1,14,683
2016	46,894	61,083	10,735	1,18,711
2017	47,325	63,103	9,825	1,20,253
2018	47,352	69,196	9,017	1,25,565
2019	56,424	66,687	9,003	1,32,114



Fig. 7. Mushroom production in Canada in different states in 2019

regions of Odisha (Fig. 8). Oyster mushrooms are more popular in the North-East, Chhattisgarh and

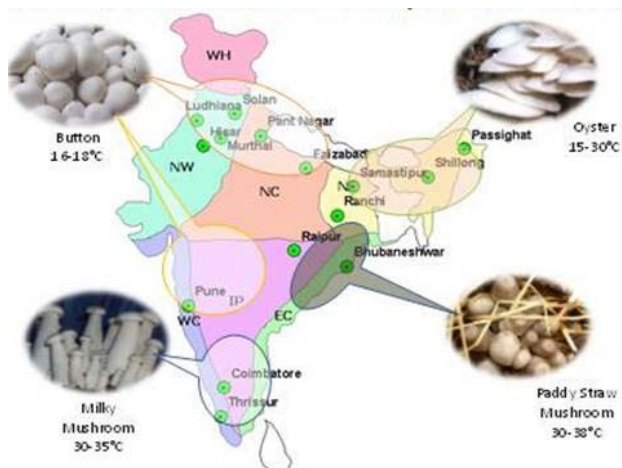


Fig. 8. Mushroom cultivation in different regions of India

Table 8. Species-wise approximate production (million kg) (based on Beaulieu-Fortin Simon, 2019)

	Button	Others*	Total
2008	112.9	3.5	116.4
2009	111.0	3.4	114.5
2010	110.3	4.6	114.9
2011	118.5	3.7	122.2
2012	122.3	2.5	124.8
2013	117.8	2.4	120.2
2014	119.6	2.4	122.1
2015	112.4	2.3	114.7
2016	116.3	2.4	118.7
2017	117.8	2.4	120.3

* Oyster, shiitake and others account for 2-3% of total

Bihar although they are cultivated on a small scale in almost all regions of the country. Mushroom production in 2019 surpassed 200 million kg (Fig. 9).

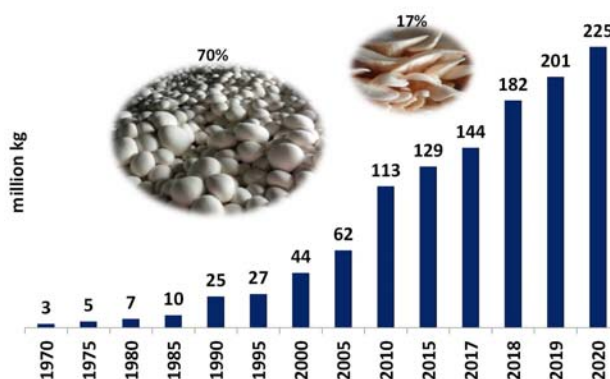


Fig. 9. Total mushroom production in India from 1970-2020

Even within a state there are regions of concentration. For example in Haryana state mushroom production is localized around National Highway 1 and only two districts, Sonipat and Panipat account for more than half of the production of Haryana state (Fig. 10). Likewise, in Punjab, mushroom production is more in the Eastern districts (Fig. 11).

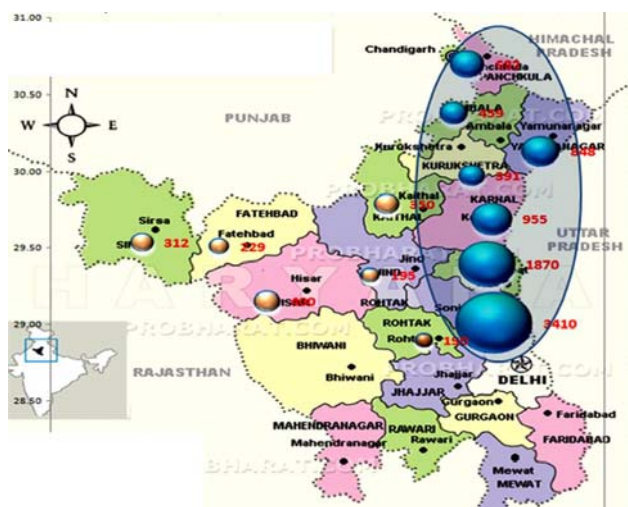


Fig. 10. Mushroom production in Haryana in 2016 (spheres indicate the amount of mushroom production)

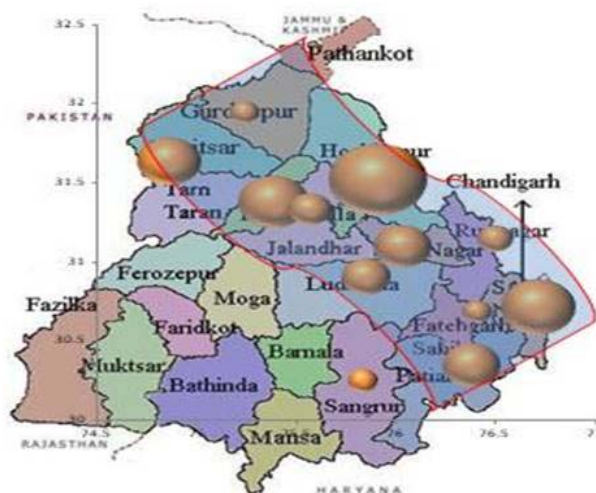


Fig. 11. Mushroom Production in Punjab in 2016 (spheres indicate the amount of mushroom production)

It is evident that in all major mushroom producing countries, there are specific regions of production. In countries producing different types of mushrooms such as China, Japan and India, there are localized regions of production of different species. There was problem of labour availability as well as marketing of the produce during 2020-2021. Alternatively, during COVID people developed interest in mushroom consumption and many experimented with cooking of mushrooms during lockdown. This impacted both production, processing and consumption. These data should serve as a benchmark for understanding changes in mushroom production and location and trends of species diversity spread of mushrooms in post-COVID period.

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