18. Mukherjee, D., Multimeric proteins: its adaptation and regulation of biological activities. Ph D thesis, Jadavpur University, Kolkata, India, 2012.
19. Cheeseman, C. I. and O'Neill, D., Isolation of intestinal brush-border membranes. *Curr. Protoc. Cell Biol.,* 2006, **30**, 3.21.1–3.21.10.
20. Bhattacharya, R., Fruit and stem bromelain from pineapple (*Ananas comosus*): stabilization and biochemical characterization of the enzymes. Ph D thesis, Jadavpur University, Kolkata, India, 2009.
21. Sarath, G., Motte, R. S. D. L. and Wagner, F. W., Protease assay methods. In *Proteolytic Enzymes: A Practical Approach* (eds Beynon, R. J. and Bond, J. S.), IRL Press, Oxford University Press, Oxford, UK, 1996, pp. 25–55.
22. Soto, C., Sigurdsson, E. M., Morelli, L., Kumar, R. A., Castano, E. M. and Frangione, B., β-Sheet breaker peptides inhibit fibrillogenesis in a rat brain model of amyloidosis: implications for Alzheimer's therapy. *Nature Med.*, 1998, **4**, 822–826.
23. Kuipers, B. J. H. and Gruppen, H., Prediction of molar extinction coefficients of proteins and peptides using UV absorption of the constituent amino acids at 214 nm to enable quantitative reverse phase high-performance liquid chromatography–mass spectrometry analysis. *J. Agric. Food Chem.*, 2007, **55**, 5445–5451.
24. Shearman, M. S., Hawtin, S. R. and Tailor, V. J., The intracellular component of cellular 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) reduction is specifically inhibited by β-amyloid peptides. *J. Neurochem.*, 1995, **65**, 218–227.
25. Caughey, B. and Lansbury, P. T., Protofibrils, pores, fibrils, and neurodegeneration: separating the responsible protein aggregates from the innocent bystanders. *Annu. Rev. Neurosci.*, 2003, **26**, 267–298.
26. Chimon, S., Shaibat, M. A., Jones, C. R., Calero, D. C., Aizezi, B. and Ishii, Y., Evidence of fibril-like β-sheet structures in a neurotoxic amyloid intermediate of Alzheimer's β-amyloid. *Nature Struct. Mol. Biol*., 2007, **14**, 1157–1164.
27. Hoshi, M., Sato, M., Matsumoto, S., Noguchi, A., Yasutake, K., Yoshida, N. and Sato, K., Spherical aggregates of β-amyloid (amylospheroid) show high neurotoxicity and activate tau protein kinase I/glycogen synthase kinase-3β. *Proc. Natl. Acad. Sci. USA*, 2003, **100**, 6370–6375.
28. Lambert, M. P. *et al.*, Diffusible, nonfibrillar ligands derived from Aβ_{1-42} are potent central nervous system neurotoxins. *Proc. Natl. Acad. Sci. USA*, 1998, **95**, 6448–6453.
29. Banks, W. A., Characteristics of compounds that cross the blood–brain barrier. *BMC Neurol*., 2009, **9**, S1–S3.
30. Hamley, I. W., Peptide fibrillization. *Angew Chem. Int. Ed*., 2007, **46**, 8128–8147.
31. Attali, R. S. *et al.*, Complete phenotypic recovery of an Alzheimer's disease model by a quinine–tryptophan hybrid aggregation inhibitor. *PLoS ONE*, 2010, **5**, 1–15.
32. Crone, C., The blood-brain barrier – facts and questions. In *Ion Homeostasis of the Brain* (eds Siesjo, B. and Sorensen, S.), Munksgaard, Copenhagen, Denmark, 1971, pp. 52–62.
33. Witt, K. A. and Davis, T. P., CNS drug delivery: opioid peptides and the blood–brain barrier. *AAPS J*., 2006, E76–88; http://www.aapsj.org
34. Kim, S., Nollen, E. A., Kitagawa, K., Bindokas, V. P. and Morimoto, R. I., Polyglutamine protein aggregates are dynamic. *Nature Cell Biol*., 2002, **4**, 826–831.
35. Lecerf, J. M. *et al.*, Human single-chain Fv intrabodies counteract *in situ* Huntington aggregation in cellular models of Huntington's disease. *Proc. Natl. Acad. Sci. USA*, 2001, **98**, 4764–4769.
36. Yang, F. *et al.*, Curcumin inhibits formation of amyloid beta oligomers and fibrils, binds plaques, and reduces amyloid *in vivo*. *J. Biol. Chem*., 2005, **280**, 5892–5901.
37. Karuppagounder, S. S., Pinto, T., Xu, H., Chen, H. L., Beal, M. F. and Gibson, G. E., Dietary supplementation with resveratrol reduces plaque pathology in a transgenic model of Alzheimer's disease. *Neurochem. Int*., 2009, **54**, 111–118.
38. Yamada, K., Tanaka, T., Han, D., Senzaki, K., Kameyama, T. and Nabeshima, T., Protective effects of idebenone and alpha-tocopherol on beta-amyloid-(1-42)-induced learning and memory deficits in rats: implication of oxidative stress in beta-amyloid-induced neurotoxicity *in vivo*. *Eur. J. Neurosci.*, 1999, **11**, 83–90.
39. Cao, C. *et al.*, Caffeine suppresses amyloid-β levels in plasma and brain of Alzheimer's disease transgenic mice. *J. Alzheimers Dis*., 2009, **17**, 681–697.
40. Das, S. and Bhattacharyya, D., Destabilization of human insulin fibrils by peptides of bromelain derived from *Ananas comosus* (pineapple). *J. Cell. Biochem.*, 2017, **118**, 4881–4896.
41. Bhattacharjee, P. and Bhattacharyya, D., Factor V activator from *Daboia russelli russelli* venom destabilizes β-amyloid aggregate, the hallmark of Alzheimer disease. *J. Biol. Chem*., 2013, **288**, 30559–30570.

ACKNOWLEDGEMENTS. The research was supported by Cognition Science Initiative programme of DST, New Delhi awarded to D.B. (SR/CSI/07/2009). D.B. was also partly supported by DBT-Visiting Research Fellowship for development of North-East India. D.M., P.B. and R.B. were supported by fellowships from DST, UGC-NET and CSIR-SRF, New Delhi respectively. We thank Namrata Singh, CSIR-IICB for help with the figures and Prof. Subrata Pal (Department of Life Sciences and Biotechnology, Jadavpur University, Kolkata) for providing cell culture facility.

Received 15 December 2017; revised accepted 3 August 2018

doi: 10.18520/cs/v115/i11/2133-2141

Performance analysis of South-Indian mushroom units: imperative policy implications for their preparedness for global competitiveness

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A highly specialized six-dimensional performance index was designed to comprehensively analyse complex mushroom enterprises having components and estimates, viz. scale/size of the enterprise (4.225), infrastructure/machinery employed (4.539), social capital indicators (4.696), efficiency indicators (6.346), good mushroom cultivation practices (5.246) and incremental expansion (3.597). Sixty edible mushroom growing enterprises of Karnataka were selected for

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this study which concludes that four out of six components showed poor performance. Along with an urgent need to work-out economically optimum size of mushroom units with suitable infrastructure and machinery requirements, the paper presents important policy implications for making Indian mushroom industry globally competitive.

Keywords: Global competitiveness, mushroom enterprises, performance index, policy implications.

MUSHROOMS are proven to have immunomodulating, antioxidant, genoprotective, antitumour, hypocholesterinemic, antidiabetic, hepatoprotective and other medicinal properties[1–3]. Besides medicinal properties, they are a rich source of dietary fibre, many bioactive molecules and valuable enzymes with around 126 therapeutic effects[2,3]. Because of their nutritional and medicinal properties, mushrooms are in demand globally. Worldwide, the mushroom industry has grown more than 25-fold during the last 35 years (1 billion kg production in 1978 to 27 billion kg in 2012), against 1.7 times growth in human population (4.2 billion in 1978 to 7 billion in 2012)[4]. Based on FAOSTAT 2013 triennium ending (TE) data, the annual average per capita mushroom production in India and China was 33.2 g and 2.5 kg respectively. However, there is tremendous inconsistency in this data globally. The ICAR-Directorate of Mushroom Research (Solan) with very high degree of conviction claims that India annually produced on an average about 85 g mushrooms per capita during this period. On the other hand Chinese agencies associated with mushroom R&D claim that China annually produced 14.7 kg per capita mushrooms during that period. However, with the advantages of diverse climate, huge quantity of agricultural residues and abundant labour force, Indian mushroom industry has much higher potential to grow.

Business enterprises are a vital component in economic development[5,6] which is even more relevant for agribusiness enterprises in an agro-based country like India. Subsistence agriculture has rapidly transformed to an intensive commercialized entrepreneurship in the process of economic development[7]. Mushroom entrepreneurship, a grossly untapped business opportunity, has tremendous potential to address many problems plaguing rural India, viz. malnutrition, diminishing land holdings, declining soil fertility, un-employment and inadequate livelihood leading to widespread poverty. Mushroom is one of the rare crops which do not compete for scare cultivable land resources; hence potential of this crop in mitigating food and nutritional insecurity is much larger than field crops. The proportion of stunted children in Indian rural areas in the age of 6 to 35 months (40.70%) indicates widespread nutritional deficiency, especially protein, whereas the proportion of stunted children in the state is higher than the national average[8]. Hence mushroom enterprises in Karnataka have tremendous potential to grow. Increasing import demand for mushrooms from developed nations gives Karnataka state an added advantage of seizing this opportunity due to its proximity to seaports. However, before suggesting any large scale expansion, a comprehensive financial health check-up of existing enterprises becomes important. Hence, this study was carried out in Karnataka to assess the business robustness of mushroom enterprises in southern India and to develop and standardize a procedure to measure the performance of mushroom units in India.

Mushroom business, being very complex due to its socio-economic dimensions, needs a highly specialized methodology for measuring performance of its enterprises. A methodology suggested by Guilford[9], was adopted to develop performance index having six dimensions, viz. scale/size of the enterprise (SSE), infrastructure/machinery employed (IME), social capital indicators (SCI), efficiency indicators (EI), good mushroom cultivation practices (GMCPs) and incremental expansion (IE) for measuring performance of mushroom units. The methodology has been explained in the following five steps.

Based on a detailed review of literature and mushroom experts' inputs, six broad performance dimensions (D_1–D_6), viz. SSE, IME, SCI, EI, GMCP and IE of mushroom enterprises were identified. Relevant statements were written under each of these dimensions to bring forth the variability in the performance scores of the mushroom units.

Experts from the field of mushroom science, horticulture, agricultural extension, economics and management were asked to indicate their rating on the relevancy of each of the statement listed under the above mentioned dimensions of performance index, regarding their utility to measure a particular dimension of performance of mushroom unit. The experts were asked to indicate the relevancy on a Likert's scale of five point continuum ranging from 'not relevant' (1) to 'most relevant' (5). The 'relevant' (R), 'somewhat relevant' (SWR) and 'least relevant' (LR) were assigned the values of 4, 3 and 2 respectively. Thirty out of 130 experts responded to the relevancy analysis. Relevancy weightage (RW) was worked out using following formula

$$\mathrm{RW} = \frac{\mathrm{MR} * 5 + \mathrm{R} * 4 + \mathrm{SR} * 3 + \mathrm{LR} * 2 + \mathrm{NR} * 1}{\text{Maximum possible scores} * \text{No. of Judges}}.$$

Statements rated as relevant with RW of 0.75 or more (worked out on the basis of summated scores of all the judges responded) were considered for measuring the dimensions.

The variation in contribution of each dimension for the performance of an enterprise must be represented by assigning different weights to each dimension. Experts' input was relied upon to obtain the scale values for each dimension of performance ranked in the order of importance as perceived by them. The ranks given by 30

Table 1. Calculation of scale values of all the dimensions of performance based on the experts' ranking

R_i	R_{i_2}	SSE	IME	SCI	EI	GMCP	IE	P	C
1	6	2	4	4	15	1	4	91.67	6
2	5	2	4	6	5	11	2	75.00	6
3	4	6	11	0	6	4	3	58.33	5
4	3	9	0	9	4	8	0	41.67	5
5	2	6	9	7	0	6	2	25.00	4
6	1	5	2	4	0	0	19	8.33	4
$\sum f_{ji}$		30	30	30	30	30	30		
$R_j = \sum f_{ji}C$		143	147	149	170	156	135		
$R = R_j/\sum f_{ji}$		4.767	4.900	4.967	5.667	5.200	4.500		
R_c*		4.225	4.539	4.696	6.346	5.246	3.597		

judges were converted into rank values using the following formula

$$R_i = (n - r_i + 1),$$

where R_i is the rank value, n the number of items ranked and r_i is the rank given by the expert for each dimension. The centile position values (P) were arrived for each rank by the normalization of ranks approach using the formula

$$P = [(R_i - 0.5) \times 100]/n.$$

Deduction of 0.5 from the rank value is to get the middle of the area for the dimension so ranked.

P represents area under normal distribution below the median of interval assigned to the object. From the normal curve tables we find the corresponding z values to represent linear distances from the mean on the baseline. Since z values are awkward numbers to use, we make a linear transformation to values of a convenient type[10]. For this purpose, Hull[10] proposed a C scale of 10 units covering a range of 5 standard deviations. Following similar procedure, the C values were approximated to ranks in the order of rank value.

The procedure followed in arriving at the scale values for all the six dimensions of performance is presented in Table 1.

For all the relevant statements, a questionnaire was prepared to elicit appropriate variability for performance. The response categories for each dimension varied depending upon the variability inherent in each of the dimensions (D_1–D_6) of performance measurement. For IME, one score was given for each of the facility or machine listed under substrate/compost preparation, spawn production, cropping rooms and post-harvest handling/processing. For SSE of mushroom entrepreneurship, five point continuum was designed for all the six statements with a linear scoring pattern of 1 for the smallest and 5 for the biggest. For the remaining four dimensions (SCI, EI, GMCP and IE of the units), the responses were obtained on three point continuum. This instrument was pre-tested with 30 mushroom growing units from non-sample area to ascertain its ability to measure the intended variable.

Table 2. Dimensions of performance index and their respective scale values and ranks

Sl no.	Dimensions	Scale values	Rank
D_1	Scale and size of enterprise (SSE)	4.225	V
D_2	Infrastructure/machinery employed (IME)	4.539	IV
D_3	Social capital indicators (SCI)	4.696	III
D_4	Efficiency indicators (EI)	6.346	I
D_5	Good mushroom cultivation practices (GMCP)	5.246	II
D_6	Incremental expansion (IE)	3.597	VI

The performance index (PI) was calculated for all the individual mushroom growers**.** The mean score (raw score/maximum possible score) obtained by each mushroom growing unit for different dimensions was multiplied with the scale values of respective dimension. The summation of values obtained for all the dimensions gives the composite index measuring the performance of the mushroom growers. The formula used in arriving at PI values for all the units is given below

$$\text{PI} = \frac{\sum_{i=1}^{6} \frac{\text{Actual score of } D_i * \text{scale value of } D_i}{2} \times 100}{\sum \text{Scale value of } D_i}.$$

Reliability and validity of the scale were established by the pilot test conducted for a sample of 30 mushroom growing units randomly drawn across 13 different states of India. The coefficient of stability (test–retest method) and the coefficient of equivalence (split-half method) were employed to measure the reliability of the scale. The correlation coefficient (r) by test–retest method and split half method were found to be 0.981 and 0.968 respectively, suggesting high reliability of the scale. Validity of the scale was ensured by analysing content validity. Since the statements were based on extensive review of literature and relevancy analysis by the judges, the content validity was ascertained. The internal consistency was tested through construct validity by using correlation matrix technique with individual dimensions of the scale.

All the correlation coefficients were above 0.70 suggesting high construct validity.

Data were collected from randomly selected 60 mushroom enterprises growing any edible mushroom across Karnataka. Of these, 52 units produced tropical mushrooms and 8 produced white button mushrooms. The distribution of units on the dimensions of performance index was grouped into low, medium and high categories using mean and standard deviation. Since the scale developed on performance index was a ratio scale, the classification of units was done based on score range of equal interval distance. Based on the Sturges' rule, six classes were arrived and the units were categorized accordingly.

Six dimensions of performance index of mushroom units assumed values varying from 3.59 to 6.34. EI received highest scale value (6.346), followed by GMCP (5.246), SCI (4.696), IME (4.539), SSE (4.225) and IE (3.597) (Table 2).

EI was the most important dimension (highest scale value of 6.346) contributing to the successful performance of mushroom growing units. The physical productivity (quantity of fresh mushroom/100 kg straw), the economic productivity (returns to per rupee investment), efficiency in quality production (ratio of good quality mushrooms to total quantity produced), keeping quality (number of days) and marketability/saleability of fresh mushrooms (percentage of fresh mushroom sold at three different prices) were included as the indicators of efficiency. All these criteria have formidable role in the performance of the mushroom unit as more or less same criteria of quality were described by Griensven[11]. Hence, the efficiency attaining the highest weightage confirms its long established role in contributing to the performance of mushroom units.

Mushroom units growing button mushrooms have the facility to produce compost by short method or indoor method which gives higher efficiency compared to compost prepared by long method of composting[12]. Similarly the substrate used and method employed to pasteurize the substrate affect the productivity of mushrooms in other varieties like *Pleurotus*, *Calocybe*, *Volvariella* and others. Therefore, it can be said that efficiency parameters starting from compost quality to mushroom quality and efficient marketing will decide the performance of the mushroom unit to the highest level.

Analogous to good agriculture practices (GAP), GMCPs are emphasized to succeed in mushroom entrepreneurship. The second highest scale value (5.246) for GMCPs underscores the importance of good cultivation practices to influence performance of mushroom enterprises. Among many GMCPs, the most important practices like diversification of mushroom varieties, selectivity and homogeneity of compost, hygiene, temperature, relative humidity, maintenance of farm records, physical and cultural measures of pest and disease management were included as determinants of GMCPs. Equal weightage has been given to all GMCPs.

Energy being the critical input, cutting down this cost by growing different mushroom varieties suitable to natural conditions is an important good cultivation practice[13]. China cultivates nearly 30 commercial mushroom varieties (according to growing conditions) for medicinal and food purpose[14], whereas in India predominantly (>80%) the *Agaricus bisporus* (button-mushroom) with negligible quantity of *Pleurotus* spp. (oyster), *Volvariella volvaceae* (paddy-straw) and *Calocybe indica* (milky) are grown.

Selectivity and uniformity of compost are highly critical, technical and scientific issues[15] having crop devastating potential if mishandled. Hence, these two aspects attain imperative importance in overall GMCPs. The statement of Klaver and Van Gils[16], 'mushroom growing is an agricultural activity where hygiene is written up everywhere in capital letters' establishes the significance of hygiene in mushroom cultivation. Proper farm record maintenance is another important component for improving performance in mushroom cultivation because reliable record of several operations like monitoring of temperature, moisture/humidity, aeration, etc. during composting, spawning, cropping, harvesting are crucial determinants of cultivation.

SCI received third rank among the six dimensions of performance of mushroom enterprises. Mushroom being a non-traditional crop in India, this dimension has special significance for a variety of reasons like sharing knowledge regarding advances in cultivation technology and market information, etc. Further, imperfect market conditions for input (machines and spawn) and consultation services make this aspect very important. The mushroom sector because of the low level of organization of sales, has always been an insignificant sector in the horticultural industry[17]. Demand for mushrooms largely emerges from selected section of urban society which is handled by few market intermediaries; hence the growers have to exploit these channels to materialize their sales. Higher social capital (networking with fellow entrepreneurs and market functionaries) is rated among the important performance dimensions. Overall, the role of ecological concerns and social capital will be crucial in performance assessment of sustainable technology development[18].

IME significantly influences the performance of mushroom enterprises, as in developed countries, IME is a major factor deciding the performance of mushroom units. In the present study, the combined opinion of experts placed it at fourth place among the six dimensions with a scale value of 4.539. Relatively lower rating could have been on account of small and medium mushroom growers cultivating *Pleurotus* and *Calocybe* varieties (with family labour), outnumbering few large growers cultivating *Agaricus* sp. However, the importance of IME in mushroom enterprises is likely to further increase in the near future on account of higher need of standardization of business

Table 3. Distribution of mushroom growing units/spawn unit according to different dimensions of performance indicators (n = 60)

Dimensions	Category	Number	Percentage
Infrastructure/machinery employed (IME)	Low	28	46.67
	Medium	21	35.00
	High	11	18.33
Scale and size of enterprises (SSE)	Low	25	41.67
	Medium	22	36.67
	High	13	21.67
Social capital indicators (SCI)	Low	30	50.00
	Medium	10	16.67
	High	20	33.33
Efficiency indicators (EI)	Low	23	38.33
	Medium	12	20.00
	High	25	41.67
Good mushroom cultivation practices (GMCP)	Low	23	38.33
	Medium	13	21.67
	High	24	40.00
Incremental expansion (IE)	Low	23	38.33
	Medium	16	26.67
	High	21	35.00
Overall performance score	Low	22	36.67
	Medium	21	35.00
	High	17	28.33

Table 4. Distribution of units according to performance index (based on Sturge's rule) (n = 60)

Category	Score range	Number	Percentage
Very low	33.09–41.39	14	23.33
Low	41.39–49.69	18	30.00
Lower medium	49.69–57.99	13	21.67
Upper medium	57.99–66.29	10	16.67
High	66.29–74.59	3	5.00
Very high	74.59–82.89	2	3.33

processes and depletion of farm labour supply as a result of rural development and employment guarantee schemes like Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS).

SSE with a scale value of 4.225 is fifth in the order of importance among the six dimensions. Though SSEs themselves are major determinants of success especially in *Agaricus* mushroom cultivation, their lower scale value is an insinuation of experts cumulative opinion suggesting higher scale and size as a lower priority for achieving higher performance. Moreover, the EI (with highest scale value) and IME dimensions also embed within themselves the scale and size parameters. Yet, the importance of SSE of mushroom enterprises for their being globally competitive needs to be realized at policy, industry and enterprise level.

The IE placed at the bottom among all the dimensions is selected to assess the performance of mushroom entrepreneurship. The IE lists the expansion in the first five dimensions of the unit. Hence, any growth accompanied by the five dimensions will obviously transcend into growth in the IE dimension. Second, the performance and growth do not necessarily coincide in all cases as some entrepreneurs, even with better performance could be averse to expanding the unit for several reasons including lack of scope for expansion, contentment with the current performance, diversification in other enterprises, etc. However, for the industry being globally competitive, we need to stress heavily upon IE dimension of mushroom enterprises through much needed and rather overlooked policy support.

With the exception of EI and GMCPs, higher proportion of units was under low performance category on remaining four dimensions (Table 3). On the IME dimension, the highest number of respondents was in the low category, followed by medium and high. Similar trend was noticed on SSE with slight variation in the percentage of respondents in each category. On SCI, half of the responding units belonged to low category followed by one-third of the respondents in the high category and the remaining in the medium category. Large numbers of farmers were high on their EI parameters, followed by low category and medium category of efficiency. Similar trend was noticed for GMCP also. The IE dimension which reflects the growth of first five dimensions over a period of time showed that a large number of units belonged to low category, followed by high and medium.

The performance index with the same criteria revealed that the majority were low performers followed by medium and high. However, the same respondents were categorized on the basis of their performance based on Sturge's rule with six classes (Table 4). Higher number of respondents was low on performance index followed by very low. More than half of the respondents were very low to low on performance index. Both the medium categories accounted for 38.34% of respondents, whereas

only 8.33% of respondents showed high to very high level of performance.

As overall conclusion, the mushroom entrepreneurs in the study area had low performance due to sub-optimal use of machinery and infrastructure, sub-optimal size of units and lower level of social capital. Even on the efficiency and good cultivation practices, majority were in the medium level of performance. These determinants and low incremental expansion resulted in overall lower performance index. Karnataka, having nearby seaports, possesses great export potential of high-value processed mushrooms in addition to augmentation of meagre per capita annual mushroom production in India. Strong Indian mushroom industry will mitigate rural unemployment, inadequate livelihood, migration and unplanned urbanization. Mushroom cultivation being independent from availability of scarce cultivable land deserves higher attention for adequately tackling the domestic nutritional insecurity. The following points need adequate attention of the policy makers and agencies involved in mushroom R&D in India.

- There is an urgent need for working out an economically optimal size of mushroom units under different socio-environmental conditions and individual firm's goals and aspirations.
- The inadequate use of infrastructure and machinery by a majority of mushroom enterprises suggests depressed sentiment amongst these entrepreneurs that needs to be elevated. Such enterprises seek adequate government support and attention for making them globally competitive, especially with Chinese enterprises.
- Adequate support from policy level and mushroom R&D agencies, in terms of proper training to mushroom growers and enabling smooth availability of inputs till the industry attains take-off stage is very crucial.
- Another glaring weakness of mushroom enterprises in the study area was the low level of incremental expansion and realization of expansion significance by the studied enterprise. It becomes imperative for policy makers to incentivise mushroom growers through credit and electricity provisions equivalent to general agriculture.

The performance measurement approach developed to analyse the performance of mushroom units in the study area will serve as a useful tool to study not only mushroom units in other parts of the country but also the performance of industrial enterprises working on other commercial crops.

Application of discriminant analysis based on dimensions of performance will reveal the discriminant factors behind the success of mushroom enterprises.

1. Badalyan, S. M., Antitumor and immune-modulating activities of compounds from several basidiomycetes. *Probl. Med. Mycol.*, 2000, **2**, 23–28.
2. Wasser, S. P., Medicinal mushroom science: history, current status, future trends and unsolved problems. *Int. J. Med. Mushrooms*, 2010, **12**, 1–16.
3. Badalyan, S. M., Edible ectomycorrhizal mushrooms. In *Edible Ectomycorrhizal Mushrooms. Soil Biology Series* (eds Zambonelli, A. and Bonito, G.), Springer, Verlag, 2012, vol. 34, pp. 317–334. ISBN: 978-3-642-33822-9.
4. Royse, D. J., A global perspective on the high five: Agaricus, Pleurotus, Lentinula, Auricularia and Flammulina. In Keynote Address, VIII International Conference on Mushroom Biology and Mushroom Products, New Delhi, 2014, vol. 1, pp. 1–5.
5. Schumpeter, J. A., *Capitalism, Socialism, and Democracy*, Herper, New York, 1950.
6. Reynolds, P., Storey, D. J. and Westhead, P., Cross national comparisons of the variation in new firm formation rates. *Reg. Stud*., 1994, **28**, 443–456.
7. Mukherjee, A. and Maity, A., Public-private partnership for convergence of extension services in Indian agriculture. *Curr. Sci*., 2015, **109**(9), 1557–1563.
8. Bhavani, V. B., Anuradha, G., Gopinath, R. and Velan, A. S., Report of the State of the Food Insecurity in Rural India. M.S. Swaminathan Research Foundation and World Food Programme, FAO, MSSRF Report 27, pp. 39–42.
9. Guilford, J. P., *Psychometric Methods*, Tata McGraw-Hill, New Delhi, 1954.
10. Hull, C. L., *Aptitude Testing*, Yonkers, New York, 1928.
11. Griensven, L. J. L. D., Kwaliteit van champignons (Mushroom Quality). *De Champignon Cultuur*, 1985, **29**, 147–155.
12. Vijay, B., Methods of compost preparation for white button mushroom. In *Mushrooms Cultivation, Marketing and Consumption* (eds Singh, M. *et al.*), Directorate of Mushroom Research, Solan, 2011, pp. 56–57.
13. Singh, M., Mushroom production: an agribusiness activity. In *Mushrooms Cultivation, Marketing and Consumption* (eds Singh, M. *et al.*), Directorate of Mushroom Research, Solan, 2011, 1–10.
14. Dai, Y. C., Yang, Z. L., Bao, K. C. and Zhou, L. W., Species diversity and utilization of medicinal mushrooms and fungi in China. *Int. J. Med. Mushrooms*, 2009, **11**(3), 287–302.
15. Fermor, T. R. and Wood, D. A., Degradation of bacteria by *Agaricus bisporus* and other fungi. *J. Gen. Microbiol.*, 1981, **126**, 377–387.
16. Klaver, J. S. and Van Gils, J. J., Construction and equipment. In *Cultivation of Mushrooms* (ed. van Griensven, L. J. L. D.), Darlington Mushroom Laboratories, 1988, p. 125.
17. Schaper, P. M., de Vlieger, L. J. and van Griensven, L. J. L. D., Sales. In *Cultivation of Mushrooms* (ed. van Griensven, L. J. L. D.), Darlington Mushroom Laboratories, 2014, p. 23.
18. Kesavan, P. C., Shaping science as the prime mover of sustainable agriculture for food and nutrition security in an era of environmental degradation and climate change. *Curr. Sci.,* 2015, **109**(3), 488–501.

ACKNOWLEDGEMENTS. We acknowledge the cooperation extended by all the entrepreneurs in sharing the required information and valuable judgment of experts in the scale development process. We also thank ICAR-DMR, Solan for providing the opportunity to conduct this study.

Received 7 March 2016; revised accepted 27 August 2018

doi: 10.18520/cs/v115/i11/2141-2146