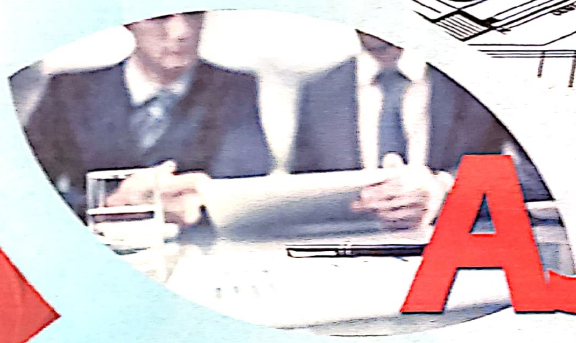
Peer Reviewed Refereed and
UGC Listed Journal
(Journal No. 40776)






AJANTA

ISSN 2277 - 5730

AN INTERNATIONAL MULTIDISCIPLINARY QUARTERLY RESEARCH JOURNAL



Volume - X, Issue - I,
January - March - 2021
English

IMPACT FACTOR / INDEXING
2019 - 6.399 www.sjifactor.com

Ajanta Prakashan

ISSN 2277 - 5730

AN INTERNATIONAL MULTIDISCIPLINARY
QUARTERLY RESEARCH JOURNAL

AJANTA

Volume - X Issue - I January - March - 2021

ENGLISH

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ज्ञान-विज्ञान विमुक्तये

IMPACT FACTOR / INDEXING

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www.sjifactor.com

❖ EDITOR ❖

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M.Drama (Acting), M.Drama (Prod. & Dir.), M.Ed.

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Ajanta Prakashan

Aurangabad. (M.S.)

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31. Self Reliant Industrial Sector by Atmanirbhar Bharat Abhiyan

Dr. Parmeshwar Sambhaji Kamble
HOD, Banking & Finance, Amruteshwar Arts, Commerce & Science, College, Vinzar, Pune.

Abstract

The paper goals to explore the changing role of Atmanirbhar Bharat abhiyan in MSMEs in making India. MSMEs it is backbones of self-relent Indian Industry. this research study explores the new significance within the Industry and self-relent India.

Key note - MSMEs

Introduction

The journey of economic development of India is very interesting, very important invectives by government with 1991 reforms in India. After that so many small level reforms taken by government of India.

India has been a visionary country taking measures to improve the economy and the governance. This has been indicated by the annual growth rate of Gross domestic Product, as provided by the world Bank (See Exhibit 1below)

Exhibit: GDP Growth (%) India

1995	2000	2005	2010	2015
7.5%	3.8%	7.9%	8.5%	8%

Source: The world Bank Data (WB, 2019) (3)

Concept of Atmanirbhar India

Atmanirbhar Bharat, which means 'independent India', is the vision of the Prime minister of India (with mission of) making India "a greater and more significant aspect of the worldwide economy". This will be accomplished by seeking after arrangements that are effective, serious and strong, and acting naturally supporting and self-creating.

Objectives of the Study

- To study of vireos aspects of Atmanirbhar Bharat abhiyan
- To study of significance of MSMEs an Atmanirbhar Bharat abhiyan.

- To study of steps about Atmanirbhar Bharat abhiyan.

Methodology of study

The Researcher research and analysis his Paper study is depend on secondary data base. information collects from various sources such as recently published research paper, articles, government of India report published in time to time, newspaper, etc.

Importance and value of study

This Research paper study covered to some of the options that may be considered or implemented in the context of MSMEs. With significant contribution from the MSMEs sector in the country's GDP and employment generation.

Vision and mission of Atmanirbhar India

Atmanirbhar Bharat abhiyan upholds Indian economy in battling against Covid-19. The clarion call given by the Honble Prime Minister to utilize these difficult occasions to become Atmanrbhar has been very generally welcomed to empower the resurgence of the Indian economy (govt.2020)(8). It rests on five components viz. the Economy, infrastructure system. Vibrant Demography and Demand. As one of the elements of Atmanirbhar Bharat, micro, small and medium enterprise area in India can assume a significant function by standing, vigorous on all the five aspects, in this manner accomplishing the vision of confident India (Sood, 2020)(9). In view of this, strengthening of the MSMEs is the key to realize the vision of Atmanirbhar Bharat Abhiyan.

Significance of Atmanirbhar and MSMEs

It may be noted that the role of MSME sector has been changing over the years. Earlier it I to provide the support to the economy. Now with this Atmanirbhar mindset, MSME will become the backbone of the economy as conveyed by our Hon'ble Prime Minister by promoting the concept "vocal for local'. Therefore. As mentioned earlier the concept 'vocal for local' calls from strengthening of the industry sectors of required goods and services whiting the country making it self sufficient country , It might be noticed that after farming MSME is the second biggest sector in India.

Industry sectors suitable to MSMEs

When we look at the import export list of items for India, the import export balance is not uniform and is heavily skewed towards imports. Imports are dominating the exports. This needs to be changed to become 'Self Reliant' it is reality.

Inclusion of MSMEs in Building of self-reliant India

It is required to strengthen the MSMEs by fixing the various issues that they are facing since last two decades. These are critical aspects for the success of MSMEs and are as listed below (sood,2020)

In this context, India can plan to promote its manufacturing and trade with the help of MSMEs. According to (Srivastav, 2020(12), there could be followings ways to encourage the MSMEs:

- Providing assurance of quality workforce.
- Making Financial Credit easily accessible so as to have financial stability.
- Providing Branding and Promotion support to enhance the market visibility of MSMEs and their products in domestic markets.

Good reforms towards 'reduction input costs' will benefit MSMEs and make India an attractive place to do business. This will ensure domestic value addition which will make MSME attractive and competitive.

With 'Make in India' agenda, support MSMEs get access to such resource such as design studios, innovation labs, and strengthening of standards and quality infrastructure.

Findings of the Study

The Researcher after the analysis of all data and related works of self-reliant Indian Industry systematic framework is required to include MSMEs in making a reality. It may be advised that there is need to understand our strengths and accordingly to bring-up and support the industry. Artisans and craftsmen are using natural resources for making their products. Providing and technology to artisans and craftsmen will definitely enhance their business prospects. Another sector is healthcare which will offer opportunity for MSMEs to provide a range of products and services for the masses. services making use of artificial intelligence.

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CONTENTS OF ENGLISH PART - I

7. A Study of Food Consumption Behaviour at the Time of Covid-19 Pandemic in India

Dr. Parmeshwar Sambhaji Gadkar
Asist. Professor Dept. of Economics, Amruteshwar Arts, Commerce & Science College, Vinzar, Pune.

Abstract

The Covid-19 pandemic India undertakes a fully lockdown for almost more than three months. All of a sudden, the lives of Indians were forced to shift in accordance with the regulations issued by government. This change in the lives of Indians can be mirrored by an adjustment in food consumer behaviour that, consequently, brought about a transition in the whole supply chain. This paper gives an overview of the recent changes in consumption patterns that occurred due to the Indian lockdown, and how evolutions in behaviour are intertwined with the evolution of the main food supply chains. Many of the events here depicted are likely to last far beyond the crisis and affect the subsequent evolution of food consumption in India. The Indian retail supply chain successfully adapted to the big shift in consumption. Despite purchases for essential items having increased, no stockout harmed the food security of Indians. Out-of-home consumption moved inside houses giving space to home meal preparation and comfort food. Home delivery has been the most important element in this context, as it boomed during this period, helping laggard consumers fill the digital divide, as it was mostly mediated by e-commerce platforms and instant messaging. It was also the leverage that allowed small retailers and small producers regain their space. This crisis calls for a more sustainable food system that will be increasingly oriented to moving goods rather than people, which will also have relevance in the coming years

Key words: consumption, lockdown, food, behaviour

Introduction

The disruptions in the supply chain occur due to natural calamities and crises. COVID-19 has resulted not only in the global tragedy for human deaths but also touches the economic sectors and activities, including manufacturing, supply chain logistic, etc. (World Health Organization, 2020). Significant consideration has aimed at the strength of the food supply

network at the time of disasters. Food supply requires to adjust to changes in food criteria, any supply chain interference due to transportation and supply network, shortage of labour. Following the influenza virus (H1N1) in 1918, (H2N2) in 1957, (H3N2) in 1968, pandemic flu (H1N1) in 2009; COVID-19 is different because of the economic situation arises for shuttering the commercial and economic activity, disruption of personal routine, work, home (e.g., closure of the school, work from home, social distancing, the response of retail sectors and food service). To reduce the COVID-19 impact among food workers, proper response plans were established for providing direction in the operations of the food supply chain at the time of the outbreak.

Objectives of Study

- To study of food consumption pattern in lockdown period.
- To study of consumption behaviour in lockdown period.
- To study of how to changing consumption pattern in lockdown period.

Methodology of the Study

The research paper depends on the primary as well as secondary data. researcher has collected information about the food consumption use of questioners from the across of Maharashtra. the researcher has collected data of food consumption from 500 household's throw-out the Maharashtra use of google form and analysis by exile and anoia technics. researcher also use of secondary data for the study as like published research paper, news, articles etc. The survey asks a number of questions related to how food consumption behaviours have been altered during the pandemic, including changes in food shopping, preparation, and consumption practices. The questionnaire consisted of 27 one-option, multiple-choice, and open questions and was structured into three sections: (1) socio-demographics (10 questions): citizenship, gender, household income, education level, etc.; (2) food purchase and consumption behaviour (15 questions): food shopping behaviour, food-related behaviours, food-related activities, extent of household food waste, etc.; and (3) emotions (2 questions). To assure the quality of the survey data, the questionnaire was pretested with 20 respondents. This step ensured that the questions were clear and comprehensible, and respondents can understand and answer them. Based on the feedback obtained from the pretexts, the questionnaire was adjusted and administered. Internal consistency was demonstrated with the coefficient alpha of 0.705. A total of 500 answers were collected. The data, collected through Survey Monkey, were downloaded into the Statistical Package for Social Sciences (SPSS) version 25.0 for analysis. Means, variation ratio,

frequencies, and percentages were calculated for descriptive data. The variation ratio, or Freeman index (VR), is a simple measurement of statistical dispersion in qualitative variables, while standard deviation is used for continuous data. It is the simplest measure of qualitative variation. It is defined as the proportion of cases, which are not in the mode category based on the equation. In particular, the Mann–Whitney U test was running whenever we had dichotomous categorical variables as independent variables (e.g., stocking up food—Yes = 1 or No = 0; citizenship—Qatari or non-Qatari) and the Kruskal–Wallis test was used for multi-choice responses as independent variables (e.g., occupation). In addition, statistical significance was set a priori at a p-value of 0.05.

Review of Literature

On the 31st of December 2019, the Municipal Health Commission of Wuhan (China) reported to the World Health Organization (WHO) a cluster of pneumonia cases of unknown disease in Wuhan City, in Hubei province. On the 9th of January 2020, the Chinese Centre for Disease Control and Prevention reported that a novel coronavirus (SARS-CoV-2) had been detected as the cause of the easily transmissible respiratory disease, later named Covid-19 (Ministry, 2020). On 11th March 2020, WHO declared the disease a pandemic (WHO, 2020). In the attempt to limit the outbreaks and contain the spread of the disease, many countries have adopted an emergency lockdown strategy. Lockdown measures have consisted of quarantines and restrictions such as borders closures, travel restrictions, limitations on personal freedom closure of educational establishments, smart working at home (except for all strategic sectors), ban on public gatherings, social distancing, closure of all but essential commercial activities. Amongst Western countries, the lockdown measures implemented in Italy have been considered one of the most restrictive closure schemes. On the 8th of March 2020, the Italian government imposed rigorous measures to its population, and the country became the first in the Western hemisphere to limit people to their homes. Leaving dwellings was possible only for a very limited range of activities such as food shopping, exercise, and dog walks, all within the vicinity of places of residence. This strict lockdown was maintained up to the 3rd of May 2020, after which citizens gradually were allowed to conduct their lives as normal, maintaining some minor precautions. The purpose of the study is to shed light on the changes in the food paradigm, presenting an overview of the main effects of the Italian lockdown on consumption habits as well

as on the corresponding psychological effects on consumers. In particular, the present study aimed to provide a categorization of the main changes in food purchasing

Results of the Study

Sociodemographic Characteristics of the Participants Table 01 & 02 indicates that 62.91% of the respondents were, 61.32% were women, 50.36% were married with children, 60.03% were active professionally, and 83.7% were highly educated. Further, most of the respondents were middle aged (53.89% of them were 25 to 45 years old). This was related to the mode of administration bias as mainly young and educated people have access to the internet and social media, which were used for the dissemination of the survey. Moreover, 62.05% of the respondents' households earn the same income as most other households in lockdown. Food Behaviour and Consumption Habits During COVID-19 Pandemic The results regarding food consumption during the COVID-19 pandemic in Maharashtra suggest clear changes in consumers' behaviour related to food shopping. According to Study, 35.35% of the respondents (including "moderately more" and "much more") indicated that they ordered more groceries online. At the same time, 29.14% of the respondents indicated that they never ordered Sustainability 2020, 12, 6973 7 of 18 groceries online. In addition, 29.30% of respondents indicated that they ordered much less food online from a full-service or fast-food restaurant or by a delivery application. Further, 33.79% of the respondents (including "moderately more" and "much more") indicated that they increased their purchase of local food products. Regarding eating and drinking habits during the COVID-19 pandemic, interestingly, 32.4% of the respondents increased their consumption of fruits and vegetables, 32.3% ate much more healthy foods, and 44.6% drank more water (all by including "moderately more" and "much more"). Meanwhile, by including "slightly less" and "much less", 44.5% of the respondents have decreased their consumption of unhealthy foods, such as fast food, 32.4% of respondents have decreased their consumption of unhealthy snacks, and 28.7% have eaten less candy, cookies, cakes, and pastries. The Study highlights some changes in food-related activities. In particular, by including "moderately more" and "much more", 42.90% of the cohort stated that they are eating more with family members, 49.20% are cooking and preparing food much more frequently, and 54.5% are spending a lot of time cooking.

Table 01. Change of food consumption related activities during the COVID-19 pandemic

Item	Percentage							Mean	VR
	Never	First Time	Much Less	Slightly Less	About the same	Moderately More	Much More		
Coking food	**4.08**	**0.70**	**1.0**	**1.41**	**26.50**	**16.79**	**48.20**	**4.92**	**0.51**
Eating with family members	3.70	0.20	2.10	3.10	37.30	9.90	42.89	4.71	0.57
Spending a time cooking	10.10	0.70	2.40	5.19	26.79	27.0	27.49	4.28	0.73
Eating between meals	4.70	0.50	6.79	7.31	45.49	23.30	12.01	4.06	0.55
Making easy meals	16.80	0.30	8.89	8.0	36.49	18.59	10.80	3.46	0.63
Eating at home	22.40	1.20	14.21	7.9	29.41	8.19	16.20	3.08	0.71
Take away with deliveries	26.00	1.60	28.55	8.71	17.20	8.70	8.20	2.47	0.71
Eating at someone else's place	41.91	1.70	28.0	6.91	10.9	2.80	2.30	1.47	0.51
Eating out	52.30	1.00	31.59	4.40	6.79	1.60	1.00	1.18	0.46

Table 02. food consumption behavioural change during the COVID-19 pandemic

Item	Percentage							Mean	VR
	Never	First Time	Much Less	Slightly Less	About the same	Moderately More	Much More		
Purchas local food	**7.07**	**1.03**	**1.12**	**1.38**	**55.52**	**15.86**	**17.93**	**4.17**	**0.44**
Purchas food from a large supermarket	6.55	0.52	13.62	9.66	48.10	11.21	10.34	3.67	0.52
Purchas food from a small supermarket	19.31	1.21	18.62	12.24	34.48	8.62	5.52	2.89	0.66
Ordering groceries online	29.14	5.17	11.55	5.00	13.79	21.21	14.14	2.89	0.71
Having meal delivered directly to my home form a full service	21.20	1.20	29.30	11.60	13.10	11.70	11.90	2.77	0.71

Conclusion and Findings of the Study

This finding could be explained by several factors in the study: The absence of panic buying due to the numerous policies and strategies implemented by the Qatari government to mitigate the effects of the COVID-19 pandemic on food supply, as explained below. The consumption of local Qatari food products increased due to food safety concerns. With the COVID-19 pandemic, uncertainty around the spread of the virus remains and consumers increasingly want to know where the food they buy comes from. Consumers' unfounded perceptions, that imported food products could pose a safety risk, involved a preference for locally produced items. with barrier gestures, and social distancing becoming the norm, the coronavirus pandemic has transformed how consumers in Qatar get their food with a surge in online grocery shopping. This is due to lockdowns as well as to a general hesitation to visit large and often busy hypermarkets, a precautionary measure to prevent contracting the virus. Some demographic groups, such as young and educated adults, use the internet more frequently and used more frequently services such as online grocery shopping and meals delivery during the pandemic. With the absence of panic buying and food stockpiling, food waste dropped. Normally, many consumers consume at least one meal on average outside their home. The waste is significantly greater when we eat outside regarding stoking up food, we noticed some differences between Qatari and non-Qatari respondents. Non-Qatari respondents stocked up more food than Qataris. This could be explained by the socio-economic characteristics. The Central Bank declared a QAR 75 billion (USD 20.5 billion) stimulus package to the private sector, which will provide much-needed relief to various sectors that underpin the economy. With the absence of panic buying and food stockpiling, food waste dropped. Normally, many consumers consume at least one meal on average outside their home. The waste is significantly greater when we eat outside. With the restaurants and coffee shops closed, entertainment options became limited and eating with family and cooking turned into new entertaining activities. In fact, eating outside is an intrinsic part of the culture in Qatar and is a major form of entertainment.

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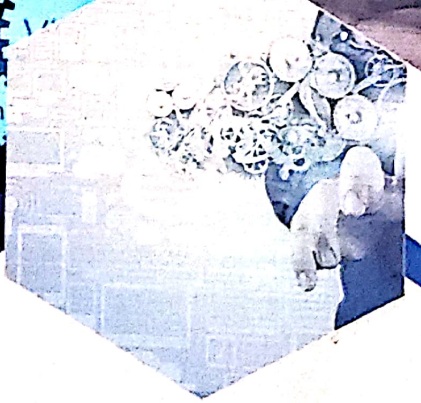

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CONTENTS OF ENGLISH PART - I

1. Impact of Covid-19 on India in Development Perspective

Prof. Dr. P. S. Kamble
Department of Economics, Shivaji University, Kolhapur, MS.

Abstract

The entire World is suffering from Corona pandemic, and India cannot be an exception. India has been suffering from Covid19 infection extensively as well as intensively. But the corona pandemic is a special and dangerous problem for India in many counts such as, it is highly populated, rural dominated, weak health sector especially public, demographic dividend availability, growing economy and many others. It is observed that Covid 19 infection is hard hitting the economic development of India and its sectors, sub sectors and individual economic activities also. The present research paper examines the impact of Covid19 pandemic on India in development perspective and probable policy direction for the revival of the economy and rehabilitation of the society especially labour class, and combating covid19 infection which is growing rapidly and extensively. The covid19 and its lockdown policy has imposed a heavy economic loss, burden, cost and damage to the Indian economy and its different productive sectors and sub sectors. A new economic stimulus package at least 5% of GDP which should be a sector specific like agriculture, industry, service, trade, labour, poor and so on, because the economic stimulus package of the government of India is just 1% of GDP according to the number of individual and institutional experts with more loan component and less proportion of direct transfer of income to the beneficiaries. Once again, the urgent need for development of public health and due cooperation and monitoring of the private health sector requires due and urgent attention by all the center, state and local governments. The citizens of India should behave responsibly and in a disciplined manner along with the honest and sincere implementation of the measures such as safe distancing, mask, face cover, hand wash, sanitizer.

Keywords: Corona Pandemic, Covid19 Infection, Development Impact, Economic Development and Growth, Gross Domestic Product (GDP), Economic Stimulus Package, Revival of Economy, Policy Direction

Introduction

The entire World is suffering from Corona pandemic. India cannot be an exception to this, as it is part and parcel of the globe with its close integration, association and connection. The policy of economic reforms in general and globalization in particular has further intensities and extensities the corona pandemic in India indicating a little bit chance of its exception. Consequently, India has been suffering from Covid19 infection extensively as well as intensively since March 2020 in the real sense of meaning. But the corona pandemic is a very special and dangerous problem and challenge for India in many counts and respects, such as it is highly populated, rapid urbanization, rural dominated, weak and inadequate health sector especially public, demographic dividend availability, growing economy and many others. It is observed that Covid 19 infection is very hard hitting to the economic growth of India and its sectors, sub sectors and individual economic activities also. It is not only this but it has also very severely affected social welfare and the society as a whole along with people of different strata in the society such as labour and migrants. This necessitates to analyse the impact of Covid 19 on Indian economy in development perspective and the probable policy direction which is urgently needed and will be useful and effective as well. Recently only, India is experiencing the second wave of Corona 19 infection especially March 2021 and highly rapid, extensive and intensive also, even in the use of two vaccines. It is against this background, the present research paper endeavours to examine the impact of Covid19 pandemic on India in development perspective and probable policy measures to achieve twin objectives; revival and recovery of the economy and rehabilitation of the society especially labour and at the same time combating covid19 infection which is growing rapidly and which is becoming extensive and intensive in India, across the states and districts.

Research Methodology

The Covid19 pandemic is a global phenomenon, problem and challenge, but is of greater intensity, extensive and gravity in the country like us. More importantly, it has posed two challenges at a time, one of weakening and failure of health sector, especially public health sector and a deep-rooted adverse impact on the economic development of the economy and its sub sectors and their collapse as well. Hence its research study was inevitable and urgently needed to take up. It is therefore the present study has been taken up. The prime and major objective of the present study is to assess the economic development impact of Covid19 lockdown policy on India and with useful policy direction. The present study is of analytical type, which analyses the economic development impact of Covid 19 on India and its sectors with

the help of data and the analysis of the data results. The study primarily depends on the secondary data for the nature and extent of Covid19 infection as well economic development indicated by the GDP and its sub sectors. The data has been collected from the WHO, Ministry of Health Government of India, Ministry of Finance, Ministry of Statistics and Programme Implementation, NSSO Reports, Economic Survey of India, Ministry of Agriculture, Ministry of Trade and Industry, Center for Monitoring Indian Economy (CMIE), research papers and articles and the newspapers like Economic times. The collected secondary data is not a time series but it is for the different points of time as per the availability and the necessity. The collected data was analysed by applying the simple statistical tools like growth, percentage share and others. The analysed of the data results have been interpreted and conclusions and inferences have been revealed. The data analysis has put forward problems, sub problems and weaknesses relating economic development, sectors, employment unemployment, and policy measures as a policy direction.

Extent of Covid-19 Infection In India

Covid19 is a World pandemic and about more than 172 countries have been suffering from its infection. On 21st July 2020 World has in all 14.68 million covid19 infected cases. Out of which 8.77 million cases have been recovered, but 609733 deaths have been taken place and all others are active cases. So far as India is concerned, the total number infected cases stood at 1127281, out of which 391727 cases are active, 27628 deaths have been taken place and 707926 cases have been cured. The analysis of Covid19 infection in India reveals that it is concentrated in a few states than all others namely Maharashtra, Tamil Nadu, Delhi, Karnataka and Andhra Pradesh, with 64% share in total number of infected cases. The state of Maharashtra is in a leading positon with 310455, which is followed by all others with 175678, 123747, 63772 and 49650 cases respectively. Delhi has the highest rate of recovery with 85%, which is followed by Tamil Nadu 69%, Maharashtra 55%, Andhra Pradesh 46% and Karnataka 36% respectively. The death rate is the highest in Maharashtra with 3.82%, which is followed by Delhi 2.96%, Karnataka 2.09%, Tamil Nadu 1.45% and Andhra Pradesh 1.29%. The further area wise analysis of Covid19 infection in India shows that it is prominently concentrated in a few cities and metropolitans, and Delhi is in leading position with 123747 cases, which is followed by Mumbai with 101388, Chennai 87325, Thane 75111, Pune 54624, Hyderabad 31929, Bangalore 31929, Ahmadabad, Kolkatta and Palghar respectively with their 49.55% share in total cases infected from covid19 virus. But this scenario is changing, recently with rising infected cases in rural areas and villages as well. For example, the infected cases in Kolhapur district are increasing

rapidly even in the recent lockdown in the urban areas like Kolhapur municipal corporation and Ichalkaranji municipal council, but the noteworthy thing is, the infected cases also have reached to all 12 tehsils and their villages of Kolhapur district is a thing of serious concern, to the real sense of meaning. In the last 3 to 4 days, the number of infected cases increasing rapidly at about more than 35000 cases daily and consequently has achieved a leading position across the countries in the World. This is showing extensive and intensive increasing a big challenge of Covid19 pandemic before the globe as well as India and the state like Maharashtra, which is in leading position from the beginning only.

On 28th July 2020, the total number of cases infected from Covid19 in the World stood at 16.46 million, out of which 653047 deaths have been taken place and 10.1 million cases have been recovered. According Ministry of Health government of India, as of today, the total infected cases were 1464990 with net addition of 52827 over previous day, out of which 496102 active cases with net addition of 18665, 33111 deaths and 935777 cured cases. The covid19 cases in India has been prominently contributed by 63.64% to total by only five states, which includes Maharashtra (375799) stood first, which is followed by Tamil Nadu (213723), Delhi (130606), Andhra Pradesh (96298) and Karnataka (96141) respectively. But Delhi is in leading position in recovery rate with 87.96%, followed by Tamil Nadu (73.24%), Maharashtra (56.74%), Andhra Pradesh (48.08%) and Karnataka (37.28%) respectively. But unfortunately Maharashtra has a highest death rate with 3.63%, which is followed by Delhi (2.93%), Karnataka (1.95%), Tamil Nadu (1.63%), and Andhra Pradesh (1.08%). Besides this, the extent and intensity of corona infection in India has been concentrated (44.39% share in total) in some cities and metropolitans, which comprises of Delhi with 130606 cases, which is followed by Mumbai (109161), Chennai (94695), Thane (86358), Pune (76203), Bangalore (45453), Hyderabad (35970), Ahmadabad (25692), Kolkatta (18201), and Raigad (14580) respectively. The salient feature of Covid19 infection is the bulk of infected cases are in the age group less than 40 years and 40 to 60 years. But the death rate is higher for the patients in the age group above 60 years which is 9% and it is about 2.6% for all others coupled with comorbidity of the diseases like blood pressure, heart problems, kidney problems and others also. Health sector of India as well as globe has failed in combatting infection because of domination of private sector, inadequate public sector, shortage of staff, equipment's, testing laboratories and other infrastructure as well as facilities.

It is about one year to be completed since the outbreak of the corona 19 infection, and it was in control after the passage of time. But recently its outbreak is found in the World as well as

in India in the muted form known as second form of Covid 19. And its infection is increasing especially in the foreign countries like USA, UK, Canada, Italy, Germany and others. Recently its infection also significantly in India also. As on 28th February 2021, the total number of new infected cases in India stood at 15510 with an average of 15199 in the last week period. The across the state analysis of the covid infected cases reveals that it is concentrated in a few states only such as Maharashtra, Kerla, Karnataka Andhra Pradesh and Tamil Nadu with 2.16M, +8,293 , 1.06M, +3,254 , 951K, +521 , 890K, +117 and 852K, +479 cases respectively. The present positon of the corona infected cases in the World reached to Total cases: 114M, Recovered: 64.4M, Deaths: 2.53M as on 28th February 2021. This is an adequate proof of still the risk and danger of corona pandemic and its adverse impact has not yet ended.

The second wave of covid 19 infection has been started from February 2021 in India and across the states and districts. It is very rapid and extensive compared to the first one. Hence it is of greater significance to consider the present position of covid19 infection in India. As on 18 April 2021 India had 2.34 lakh new infected cases, which is like epidemiological tsunami. The growth in infected cases is rapid from 11427 cases per day to 2.34 lakh in only 76 days adequately proves the rapidity of the infection in India. Across the state's analysis of the covid infection reveals that if March 1 to April 17, 2021 period is only considered, it is found that out of the total states and union territories in India 15 states and union territories have been hard hit by the very rapid infection by the covid. During this period, the share of cases registered in cumulative count Lakshadweep was the highest with 62%, which was followed by the Maharashtra 42%, Chhattisgarh 39.50%, Punjab 37.50%, Chandigarh 33.90%, Madhya Pradesh 32% Gujrat 29.90%, Dadra Nagar Haveli, Uttar Pradesh, Jharkhand, Himachal Pradesh, Haryana, Delhi, Rajasthan and Uttarakhand and the range of 18 to 27%. The noteworthy peculiarity of the second wave is its fatality or death rate is comparatively higher. The number of deaths in March 2020 was just 35, which rose to 33028 September 2020, after that it showed a declining trend with 11599 cases in December 2020, 5536 cases in January 2021, 2777 in February 2021, 5417 in March 2021, but rapidly shoot up 13181 cases in April 2021, which is very higher and rapid as well as compared to deaths in the previous months in the year 2021. This posed a very intensive and extensive problem and challenge before the Indian economy especially with acute shortage of hospitals, beds, staff and other facilities and infrastructure. The surprising thing is, this scenario is in the situation of covid vaccination in the county. Maharashtra state like that in first wave is in leading position with more than 60000 cases daily on an average. In Maharashtra, Mumbai, Pune, Amaravati, Yavatmal, Nagpur, Aurangabad and

Nanded districts are in leading positions showing a rapid growth in the infected cases. Kolhapur district of Maharashtra also is showing a rapid increase in the covid infected cases. On 17th April 2021, total number of infected cases in Kolhapur district was 452 with 12 deaths. Its decomposition reveals that in the area of corporation 192 cases, council 23, discharged 219, total deaths 1856, total infected 56135 and total corona free 51129 and active 3150. It is adequately proved that Kolhapur city has the maximum number of infected cases, which has registered a very rapid growth especially after 5th April 2021. On 1st April 2021 , total covid infected cases in Kolhapur city was just 45 , which increased to 114 on 5th April, 177 on 10th April and further very rapidly rose to 192 cases on 15th April 2021. Kolhapur city has in all five hot spot areas namely Yadavnagar, Phulewadi, Sadarbazar , Raviwar Peth and Rajarampuri are over crowded and congested areas. This gives a red signal of rapidly growing problem and challenge of covid 19 infection in India , especially in the state of Maharashtra with the districts like Mumbai, Pune, Kolhapur and others.

Impact of Covid-19 on India in Development Perspective

India has been implementing the measures such as use of sanitizer, hand wash, safe distancing, mask, face cover and prominently lockdown. As of now , no vaccine as well as medicine hence we are dominantly depending upon lockdown as a definite and assured measure and remedy on combating Covid19 infection spread and control. All economic activities and transactions were closed and shut down due to the policy of lockdown. But unfortunately, the policy of lockdown is very hard hitting the economic growth, its sectors and sub sectors, individual economic activities of India and across the states and areas. Hence it is of crucial importance to study and analyse the economic impact of Covid19 especially of the measure of lockdown on India. It has been hard hitting the economic growth of India, which was just haphazard and unplanned without any pre intimation and information. In general, it is observed that the lockdown policy did not succeed and become effective in controlling the spread of Covid19 infection extensively and intensively, but it is very adversely affecting economic growth of India. It did not succeed in controlling infection, deaths and increase in health infrastructure to the extent expected and desirable, but hampered the economic growth of India over all , sector wise and sub sector and activities wise also.

Even though the terms economic development and economic growth are used as synonymous terms, there is a little bit difference. Economic growth of a country is indicated by the GDP. The trends in GDP of India reveals that the GDP growth rate in the pre Covid19 crisis was 5.6% in January 2019 , which fell to 3.1% in the post covid19 period and it is showing

further and continuous fall. The quarter wise GDP growth in the pre and post lockdown reveals that it was 7.1%, 6.2%, 5.6%, 5.83% in the year 2019-20 respectively, which fell to 5.6%, 5.1%, 4.4% and 3% respectively in 2020-21 indicates how lockdown policy is affecting adversely the economic growth of India. In April 2020 Chief Economist of International Monetary Fund (IMF) Gita Gopinath has given a forecasted data, which shows that in the year 2020 the GDP of India will grow at the rate of just 1.9% , and it will be 1.2% for China, -6.1% for USA and -3% for the World economy. On 9th June 2020 the World Bank in its World Economic Outlook says in the Year 2020 the GDP growth rate of India will be -3.2% and for China it will be 1%, USA -7%, and World economy -5% respectively. Recently on 25th June 2020 the International Monetary Fund has released a revised data which indicates that in the year 2021 the World economy will grow at the rate of -4.9% and for India it will be 4.5% fall in GDP of India. According to India Rating and Research Agency the GDP growth rate of India in 2019-20 will be -5.3% and it will require to the growth at 5-6% rate for its recovery. The State Bank of India has forecasted that in the post Covid19 period, there will be a loss of 40% of GDP in April-June Quarter of 2020. According to Reserve Bank of India, the GDP growth rate of India will be zero in the year 2019-20 and it will be negative in 2020-21. On 23 July 2020 the ICRA has given a data that India will grow at -9.5% in the year 2021-22, which was forecasted at -5% previously. According to CARE the GDP growth rate of India will contract by -6.4% in 2020-21 which was previously estimated at -1.3%. The HDFC bank says India's GDP will grow at the rate of -6.5 to 6% in 2021-22, which was forecasted at 5%.

National Statistical Office (NSO), Ministry of Statistics and Programme Implementation has released the Second Advance Estimates of National Income, 2020-21 as well as Quarterly Estimates of GDP for the quarter October-December (Q3), 2020-21 in February 2021. Real GDP or Gross Domestic Product (GDP) at Constant (2011-12) Prices in the year 2020-21 is estimated to attain a level of □ 134.09 lakh crore, as against the First Revised Estimate of GDP for the year 2019-20 of □ 145.69 lakh crore, released on 29th January 2021. The growth in GDP during 2020-21 is estimated at -8.0 percent as compared to 4.0 percent in 2019-20. GDP at Current Prices in the year 2020-21 is estimated to attain a level of □ 195.86 lakh crore, as against □ 203.51 lakh crore in 2019-20, showing a growth rate of -3.8 percent. The Per Capita Income in real terms (at 2011-12 Prices) during 2020-21 is estimated to attain a level of □ 85,929 as compared to □ 94,566 in the year 2019-20, giving a growth of -9.1 percent during 2019-20, as against 2.5 per cent in the previous year. The Per Capita Income at current prices during 2020-21 is estimated to be □ 127,768, showing a decline of 4.8 percent, as compared to □ 134,186 during

2019-20. GDP at Constant (2011-12) Prices in Q3 of 2020-21 is estimated at □ 36.22 lakh crore, as against □ 36.08 lakh crore in Q3 of 2019-20, showing a growth of 0.4 percent. In the time of macroeconomic uncertainty, high fiscal deficit announced in Union Budget 2021 can be growth enhancing as it can catalyse public investment and reduce the output gap (Chakraborty, Lekha, 2021, p24).

This has further contributed in fall in employment generation and rapidly increasing unemployment in India, which has a benefit of demographic dividend. The rate of unemployment was just 6.2% in 2016-17, which very rapidly rose to 8.7% in March 2020, further to 23.5% in April 2020, 23.97% in May 2020 and it further increased rapidly and significantly in the post lock down period according to CMIE data. We have less than 10% formal employment and more than 90% informal employment. About 45 crore people are working in informal sector in India , with 40% migrant labours which suffered a lot due to loss of livelihoods and lives as well. In all 140 million people have lost their jobs in post lockdown period and in export sector alone 15 million jobs and in textile sector 3 million jobs have been lost. It did not recover to the desirable extent in the unlock policy period also. With the unlocking and opening up of the Indian economy employment generation is taking place, but not to the expected and desirable extent and pre corona pandemic level. Hence participation of workforce and unemployment level could not reach to the pre corona outbreak. According to CMIE, Mar 2020 in the unemployment rate for the nation was 8.75%, for urban area 9.41% and for rural rea it was 8.44%, it rapidly rose in May 2020 to 21.73%, 23.14%, and 21.11% respectively. It further changed in January 2021 to 6.53%, 8.08%, and 5.83% respectively. Recently on 3rd February 2021 the unemployment rate stood at 6.2% for the entire country, for Urban area 8.1% and for Rural area 5.4% respectively. The state wise analysis of the unemployment rate reveals that it was highest for Jammu & Kashmir at 21.9%, Tripura 18.1%, Haryana & Rajasthan, Tripura 18.1%, 17.7% , Goa 16.0% , Delhi 12.5% , Jharkhand 11.3% have the highest rate of unemployment. The shortcomings of the response, especially taking into consideration the curtailment of human mobility, which pushed migrants into enormous physical, psychological, and economic vulnerability, and the short-, medium-, and long-term measures provided by the government in order to alleviate them (Rajan, S Irudaya, 2020, p13).

The economic theory suggests that 3% is a natural rate of unemployment, which is affordable for any economy that exists due to changes in the policies, technologies and tastes and habits of the people in the country. According to SOC Children's Villages, two-thirds of people in India live in poverty: 68.8% of the Indian population lives on less than $2 a day. Over 30%

even have less than $1.25 per day available - they are considered extremely poor. This makes the Indian subcontinent one of the poorest countries in the world; women and children, the weakest members of Indian society, suffer most. The foregoing analysis reveals that the covid19 lockdown policy has very deeply and intensively adversely affecting economic growth of India as indicated by the trends in GDP analysed above because all productive sectors and economic activities were shut down as the part of lockdown policy. Even a gradual unlock is not effective and helping in the revival of the economy to the extent expected and again imposition of lockdowns frequently resulting in absence of desirable indicates planned efforts further.

The overall economic growth of the economy is contributed by three productive sectors namely agriculture, industry and service which have contributed by 16%, 30% and 54% respectively in the year 2018-19. This poses the urgent need for examining the impact of Covid19 especially on the productive sectors such as agriculture, industry and service also. Industry sector plays a very important role in the rapid and all round development of the economy. It is observed that the lockdown policy that India has adopted to control growing infection has very hard hit. According to the data given by Ministry of Statistics and Programme Implementation Government of India in the pre lockdown period the growth rate of Industry was 2.1% in January 2020 , which very rapidly fell to -18.3% in April 2020 and it showed a further and continuous fall thereafter, which indicates a rapid and significant adverse impact on the industry sector. When the trends in month to month industrial production are considered, it is observed the growth rate of industry sector fell from 2% in pre lockdown period to -10% post lock down period, which also registered a rapid and significant fall continuously thereafter as well.

National Statistical Office (NSO), Ministry of Statistics and Programme Implementation has released the Second Advance Estimates of National Income, 2020-21 as well as Quarterly Estimates of GDP for the quarter October-December (Q3), 2020-21 in February 2021. The agriculture sector grew at the rate of 4.3% at constant prices (2011-12) in 2019-20 , which fell significantly to 3% in 2020-21. During the same period mining & quarrying registered decline from -2.5% to -9.2% , manufacturing -2.4% to -8.4% , Electricity , gas , water supply , utility 2.1% to 1.84% , construction 1% to -10.3%, Trade, hotel, transport & communication 6.4% to -18% , Financial, real estate & Professional services 7.3% to -1.4% and Public administration, defence & other 8.3% to -4.1% respectively indicates except agriculture & allied activities and construction all other activities have registered a negative growth in the year 2020-21 over 2019-20 indicates activity or sub sector wise the negative impact of the covid19 pandemic and

lockdown policy adopted. As a result the Gross Value Added (GVA) in India during 2019-20 to 2020-21 shows a significant fall from 4.1% to -6.5%. The quarter wise analysis of growth in the afore mentioned activities or sub sectors reveals that in the first quarter of the year except mining and quarrying (-1.3%) all others have registered a positive growth with 5% for the year , but in the first quarter of 2020-21 except agriculture and allied activities (3.3%) all the activities and sub sector showed a higher level negative growth (e g ; manufacturing -35.9%, construction -49.4% and trade, hotel , transport & communication -47.6% with -22.4% GVA , which was further continued in the second as well as third quarter but with improvement.

According to Ministry of Trade and Industry in the post lockdown period compared to 2019 in 2020 a very large decrease in production of eight main industries is found. The production of Coal fell rapidly from 3.2% growth rate in April 2019 to -15.5% in April 2020. Likewise, Crude oil output grew at the rate -6.7% from -6.4% , Natural gas by -19.9% from -0.8%, Refinery products by -24.2% from 4.3%, Fertilisers by -4.5% from -4.4% , Steel by -83.3% from 13.3%, Cement by -86% from 23%, Electricity by -22.8% from 5.9%, registering a total fall by -38.1% from 8.2% , is a thing of serious concern. Further it is observed that in April 2020 core industry sector of India contracted by 38% with Cement 86%, Electricity 22.7%, Fertilisers 4.5%, and Crude oil 6.3% respectively. The analysis of industry wise impact of covid pandemic depicts that compared to the third quarter of 2019-20 in the year 2020-21 except coal production, steel consumption and purchase of private vehicles, manufacturing and electricity, all major industries and services such as crude oil production, cement production , cargo handled railway passengers, metallic minerals have registered a significant negative growth

We introduce India as an agricultural country, hence it is of crucial importance to examine the impact of Covid19 lockdown on agriculture sector of India. According to Ministry of Statistics and Programme Implementation GDP contributed by agriculture was Rs. 6098.83 lakh crore in January 2020 in pre lockdown which fell to Rs. 5306.26 lakh crore in April 2020 in post lock down period. In the year 2018-19 agricultural exports earned $38 billion, which was lost because of Covid19 lockdown in post lockdown period. About 700 million people in India depending on agriculture directly or indirectly as a source of livelihood suffered a lot during post lockdown due to close down of all agriculture and allied activities. More importantly, about 55% labours engaged in agriculture sector lost their livelihood in the corona pandemic period. About 45% workforce is cultivators which suffered a loss of income due to adverse impact of lockdown on agriculture. Actually, in this year the natural conditions were favourable and hence was expected a significant increase in production and the season was also good but due to lockdown

and no logistics and access to markets the farmers producing vegetables like tomato, cabbage, cauliflower, fruits like water melon, mango and food grains like paddy and wheat farmers suffered a huge economic loss, is a thing of concern. But unfortunately, due to limited supply of agricultural produce in the cities and metropolitans a significant rise in prices of agricultural commodities was observed. For example, during April 2019 to April 2020 the prices of cereals and products rose from 1.2% 2.8%, of milk and milk products from 0.4% to 9.4%, oil and fats from 0.7% to 10.8%, vegetables from 2.9% to 23.6%, pulses and products from -0.8% to 22.8%, which put additional economic burden on poor strata of the society in the urban areas, which can be described as Agricultural paradox or dilemma. According to the recent data in the year 2020-21 except agriculture (3%) and electricity, gas , water and utility (1.8%) all others have exhibited the negative growth only compared to the year 2019-20.

According to the quarter wise latest data also agriculture and allied activities have illustrated a positive growth of 3.9%, which was 3.4% in the third quarter during 2020-21 and 2019-20 . India is a service sector dominated economy so far as the economic growth of India is concerned. It is therefore very much needed to study the impact of Covid19 pandemic on service sector of the economy as well. The ease of doing business indicates state of service sector development and in the post lockdown period a significant fall is registered by the Ease of Doing Business Index from 63 in 2019 to 40 in 2020 and further continuous decline. Trade is a service and the balance of the trade indicates growth in international trade as well as the magnitude also, but the balance of trade of India has down turned from $ -15170 million in January 2020 to -6760 in April 20 and further to -3150 in the post lockdown.

The second wave of covid 19 infection has been started in India and across the states and districts. It is very rapid and extensive compared to the first one. India economy was recovered considerably but its development is being adversely affecting in the economy as well as its sub sectors because of restrictions and lock down policies have been adopted across the states and districts especially since February 2021 and restrictions and lockdowns have been started to implement. This is definitely going affect the development of India and its sub sectors and all other sectors and activities also. The adverse impact of this latest restrictions and lockdown policies have been forecasted by some the institutions and agencies, which is help in analyzing their adverse impact on the development of India. According to Economic Times poll of economists India's GDP will decline by 0.2 to 1% in Financial Year 2022. ICRA predicts that FY 22 growth at 10 to 10.5%. But Nomura forecasts the GDP growth of India to 12.6% from 13.5%, because of one-month lockdown and possibility of its further extension. Yes bank

projects the GDP growth of India for the FY 2022 27.5% for the first quarter of April to June. In addition to this, the data from the Index of Industrial Production (IIP) showed that the economy was still below levels seen in February last year , according to India Ratings and Research. The IIP has contracted by 3.6% in February 2021. India's Purchasing Managers' Index (PMI) touched a seven-month low of 55.4 in March. Bornali Bhandari of NCAER argues that, we are unsure of the actual situation before the second wave and now this has added to the uncertainty. Consequently, employment generation in India and across the states like Maharashtra is falling, which is resulting in rising unemployment and other evil consequences. This is an adequate and reliable proof of the corona pandemic has very hardly hit the Indian economy and its productive sectors and sub sectors. Even though a gradual unlocking and an economic stimulus package and measures & reforms coupled with the involvement of the RBI did not succeed to revive and improve the state of economic growth of the economy at even to pre-pandemic level. Hence we cannot think of economic supremacy of economy and it as a $ 5 trillion economy along with the doubling of farmers' income expecting at least a double digit growth rate. It is further continuing in the second wave of the covid 19 infection in India and more or less all the states, especially in the developed and industrialized states.

Policy Direction

The covid19 and its lockdown policy has imposed a heavy economic loss, burden and damage to the Indian economy and its different productive sectors and sub sectors as well. This demands a concrete and definite policy formulation and its sincere, honest and rigorous implementation. The necessary policy can be formulated and implemented by considering the following guidelines and policy inputs, which will be a policy direction in the post Covid 19 pandemic second wave period revival and improvement of the economy.

A new economic stimulus package at least 5% of GDP which should be a sector specific like agriculture, industry, service, trade, labour, poor strata of the society and so on because the stimulus package of the government of India is just 1% of GDP according to the number of individual and institutional experts with more loan content and less direct transfer of income portion. The financial package should have more direct transfer of income content than the loan component. Post covid19 lockdown has hit hard the poor and labour class in the society, they all should be covered under the basic universal income of at least Rs. 7500 per head per month till their rehabilitation and revival, which is being implemented across the countries in the globe. India has adequate stock of food grains with the Food Corporation of India which will be further added in by the production in the current year due to favourable natural conditions, hence food

grains should be distributed free of cost among the poor, migrant labours, informal labours and agricultural labours, handicapped and other deprived strata of the population. A pro employment growth strategy should be formulated and implemented to combat highly intensive and extensive unemployment problem during corona pandemic in India, which has the benefit of demographic dividend. The MGNREGA should be made extensive and intensive in rural areas coupled with its introduction in the urban areas also. The banking and financial sector should be made more liberal and open to meet credit demand of the different productive sectors and sub sectors. The health sector should be strengthened by assigning a status of social commodity or service and due coordination with the private sector also. Once again, the urgent need for development of public health and due cooperation and monitoring of the private health sector requires due and urgent attention by all the center, state and local governments. The citizens of India should behave responsibly and in a disciplined manner along with the honest and sincere implementation of the measures such as safe distancing, mask, face cover, hand wash, sanitizer. This policy direction will enable us in realizing twin objectives; that is revival of the deeply depressed Indian economy and its sectors & sub sectors and combating extensively and intensively growing Covid19 infection in India, across the states, districts and urban as well as rural areas.

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MARCH - APRIL, 2020

AMIERJ

AARHAT MULTIDISCIPLINARY INTERNATIONAL EDUCATION RESEARCH JOURNAL

ISSN: 2278-5655

A Peer Reviewed Multidisciplinary Journal
SJIF Impact Factor 6.236

Vol IX Special Issues II (Part A)

Editor : Prin. Dr. Nitin Ghorpade

INDEX

AMIERJ Volume–IX, Issues–II (Part -A) ISSN–2278-5655 March - April 2020

A STUDY OF WELFARE FACILITIES AND ITS EFFECT ON EMPLOYEE SATISFACTION

Prof. Anuja Gawade

Asst. Professor:

Amruteshwar Arts, Commerce and Science College, Vinzar, Tal,Velha Dist, Pune.

Introduction:-

"Employees welfare is comprehensive term including various services benefit and facilities offered to employees and by the employers. Through such generous fringe benefits the employers make life worth living for employees."

Life was hard for the working class at the beginning of the 20 century. In 1900 survey showed that between 15% and 20% of the population were living at subsistence level worse between 8% and 10% of population were living below subsistence level. Among all the resources of production employee is one of the most important functions of production. In it was possible that by hook and crook we can handle our work force, but today situation is totally different. Human being is not just like a machine, they have their emotions, feelings, likes and dislikes also. They do not work only for salary and wages. So satisfaction derived from their job as very important. Job satisfaction is one of the important aspects of HRM. Now days, so many organisation are giving welfare facilities to their employees. Because it is related to their satisfaction. If employees giving various welfare facilities their families is satisfied and overall employee satisfaction increasing. Motivated employees may do better.

The basic purpose of employee welfare is to enrich the life of employees and keep them happy and contented. Employee welfare measures motivate the employees for the better performance, it also improves the human relationship and thereby it increases the job satisfaction of the employees. Job satisfaction is a multifaceted concept. It is integral component of organisational climate and it is important element in the management of employee relationship. Therefore the research objective is to study the impact of employee welfare measures on job satisfaction.

Keywords: Employee Welfare, Job satisfaction, Organization

Meaning and Definition:

"Employee welfare is comprehensive term including various services, benefits and facilities offered to employees and by the employers. Welfare including anything that is done for the comfort and improvement of employees and provided over above the wages"

"Job satisfaction means a fulfilment or enjoyment that a person derives from their job". Employee welfare is very close relation to employee satisfaction because welfare helps in keeping the moral and motivation of the employees high so as to retain the employees for longer duration. Welfare include monetary but also many kind forms. Monitoring of working conditions creation of industrial harmony through infrastructure for Industrial relations and insurance against disease, accident and unemployment for the workers and their families.

Review of literature:-

"According to mark Columbus, in his study welfare facilities toward shoe makers in Chicago'1964.specifies that welfare measures is one of the most important factors for the overall well-being."satyanarayan and redid (2012) stated that the overall satisfaction levels of employees about welfare measures in the organisation cover is satisfactory .however a few are not satisfied with welfare measures provided by the organisation.therfore it is suggested that the existing welfare measures may be improved further. Such welfare measures enrich the

employee standard of living and their satisfaction levels. Employee satisfaction means employees are contented with their work and position. To be contented, they likely enjoy much of their work, they feel management is fair and cares about them, and they are comfortable in their work environment - both with other staffers, and with the resources they have available to complete their jobs.

Need of the study: -

"Government has passed many acts to provide facilities to the workers in factories. This study evaluates the extend of welfare facilities and satisfaction in this company. And what are actually effect of employee welfare and its effect on Employee satisfaction."

Objective of the study :-

1) To find out various welfare facilities and scheme of the employees.
2) To determine the relationship between welfare facilities and employee satisfaction.
3) To determine the various factor which influence job satisfaction?
4) To study the impact of welfare facilities on employee satisfaction.

Research methodology:-

1) The study is depends upon secondary data collection. E.g. Management books, journals, records, files, pamphlets, newspapers and internet.

Employee welfare divided by follows:

Statuary Welfare Schemes:- 1) Drinking Water 2) Facilities For Sitting 3) First Appliances 4)Lighting 5) Latrines And Urinals 6) Canteen Facilities 7) Spittoons Washing Place 8) Changing Rooms 9) Restrooms10) Health Services And Uniform.

Non-Statutory Welfare Scheme:- 1) Personal Health Care (Medical Check-Up) 2) Flexitime 3) Employee Assistance Program 4) Harassment Policy 5) Maternity And Adoption Leave 6) Medic-Claim Insurance Scheme 7) Gratuity 8) Pension 9) P.F. 10)Family Planning 11)Child Welfare12) Education 13) Housing Facilities 14) Recreational-Singing 15) Music 16) Sport Cultural Activities17) Fair Price Shops.

Related Acts:-

1) Factories Act-1948
2) Motor transport act-1961
3) Crèches-1931
4) Employees family pension scheme, 1971
5) Maternity benefit act, 1961
6) Employees Provident Fund and Miscellaneous Act, 1952.
7) Employees State Insurance Act, 1948
8) Employee's deposit-linked insurance scheme, 1976
9) The payment of Gratuity Act, 1972

Relevance of study:-

The Main purpose of the study is to know the impact of welfare facilities on job satisfaction and also to know about the satisfaction level of the employees. From the result of the survey the HR department can take the corrective actions to increase the satisfaction of the employees and thereby increase productivity.

Welfare facilities is very important factor every company because, it increase the moral of employees. It is very important to give satisfaction to our employees not in terms of salary or wages but also in terms of other welfare facilities. Because this leads not only to job satisfaction but also leads to overall satisfaction. A motivated employee can do better. They provide physical and mental health to workers and thus promote a healthy work environment. Facilities like housing schemes, medical benefits, and education and recreation

facilities for workers families help in raising their standards of living. This makes workers to pay more attention towards works and thus increases their productivity. Employees get stable labour force by providing welfare facilities, workers take their active interest in their jobs and work with a feeling of involving and participation. E.W. measures increase the productivity of org and promote healthy industrial relations there by maintaining industrial peace. Assisting employees with work place stress associated with financial problems. Keep their motivation level high. Employee are satisfied when their financial and safety need are satisfied for exp. Managing credit, debt, loan, insurance needs, tax planning and others. So it is very important what effect of Employee Welfare to employee satisfaction.

Conclusion and finding:-

From the study it is found that employee welfare facility has great impact on job satisfaction. They provide better physical and mental health to workers and thus promote healthy work environment. Facilities like housing schemes, medical benefits, and education and recreation facilities for workers' families help in raising their standards of living. This makes workers to pay more attention towards work and thus increases their satisfaction. Employers get stable labour force by providing welfare facilities. Workers take active interest in their jobs and work with a feeling of involvement and participation. Employee welfare measures increase the productivity of organization and promote healthy industrial relations thereby maintaining industries peace. Employees are very much satisfied with the increment policies which are provided by the organization. Employees are also happy with the working hours of the organization since there is no night shifts are encouraged. The social evils prevalent among the labours such as substance abuse, etc. are reduced to a greater extent by the welfare policies.

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Kanpur Philosophers
ISSN 2348-8301
International Journal of humanities, Law and Social Sciences
Published biannually by New Archaeological & Genological Society
Kanpur India

Vol. VIII, Issue I (Summer) 2021

Feminism and literature: A study of Anita Nair's 'Ladies Coupe'

Dr.Seema Ashok Bagul
Amruteshwar Arts Commerce and Science College,
Vinzar, tel. Velhe Dist –Pune
Dr.Anuja Vikram Gawade
Amruteshwar Arts Commerce and Science College,
Vinzar, tel. Velhe Dist –Pune

Abstract
There is very urgent urge which has to give more attention and that is the complexities of women's life in different cultures and social values and their struggle under the unfair mechanism of screwed society which is very nicely presented in the works of Anita Nair. Anita Nair paints her women as they are, with their defenses down, ready to open their heart to other women. The predicament of her characters is covered with a faint existential hue. They struggle for freedom, are aware of their absurd situation, feel stifled in it and try to find an answer to the very mystery of their existence in a society that does not understands them .They all finally come to their conclusions and feel at peace with themselves and their worlds.
The present research paper is an attempt to portray the woman of modern and current modern India as characterized in the novel 'Ladies Coupe' By Anita Nair who is devoted to raise feminist and social issues.
Key words: Social Justice, feminism, gender inequality, tradition, modernity.

Introduction:

Feminism is perhaps the most powerful movement that cleaned literary world in the second half of the twentieth century. It has been expressed differently in different parts of the world, and within India, by different women depending upon their class, background and the level of consciousness and understanding. Main focus of feminism stands for liberation and liberation of women from all forms of domination by the state, by society and by men. Anita Nair thoroughly testifies all the above-mentioned elements in her novels. Feminism is a progressive ideology, a mission and a movement that champions male and female equity. Feminism in India is not an artificial or duplicate of the west and feminist is not an anti-marriage, anti-men movement imported from the outside or any anti-social act which is against the society, but it is an art and science of the development of women in various challenging environment, it is fight for the existence of the women for the freedom and equal human rights. Feminism is a philosophy and an undertaking for ending all forms of domination. It is not against family and marriage. It is all about transforming these institutions to weed out their integral injustices. Indian feminism has thus its own elements and character which are developed as the times have passed with the more experience. (htt31)
The present research work attempts to explore and analysis of **Anita Nair's 'Ladies Coupe'**

Aims and objectives
1. To study critically Anita Nair's novel 'Ladies Coupe'
2.To Study the women characters portrayed by Anita Nair from feminist perspective.

Research methodology

The researcher has applied the following methods for her research paper

1. It is one of the descriptive, exploratory and interpretative by nature
2. The study material comprises the collection and thorough primary analysis of primary and secondary sources. i.e. Research papers, articles, literary reviews, journals etc.

As far as the research paper is concerned, the researcher has selected a novel by Anita Nair 'Ladies Coupe' for her research paper. All her novels mainly deal with the experiences of the women protagonists, who face traumatic situations in their family life. Subjugation of women in the predominantly patriarchal family life in India, Lesbianism, and rape are some of the issues she has projected in her fiction. Her Fiction mainly presents the ethos of the middle class Indian life.

The men and women in their fiction are influenced by the modernity. In an urban middle class life women find themselves entrapped in a male dominated world. They are assigned a secondary position in the family as a result of social customs and traditional values assigned to an ideal womanhood. .In a family life, essentially in India, a woman is forced to occupy secondary status even if she is an earning member of the family. It is not her feminity, but age old social traditions and the control of education by men which are the factors contributing to the subjugation of women in their family life and the society in general.

As per researcher in this novel, Anita Nair, the writer, mainly concentrated on a question through her protagonist, Akhila, is it possible for any women to stay single and be happy, or does she have to be dependent on any one for her identity?. Different solutions are provided by the women with whom she met in her journey on the train in the novel 'The Ladies Coupe'. Janki, the oldest woman in the group, from her experience from life, demonstrate the need of man, the husband, in woman's life. She is among those women who is taken care by their husband and then, after him, by their son. In Manu Smriti believes in this saying that a 'Woman is looked after first by the father, second then by the husband and after the death of the husband, at last by the son, and so she doesn't need freedom'. This is what Janki says *(Nair, 2001)**:*** **I am a woman who has always been looked after first there were my father and my brother, then my Husband. When my husband is gone, there will be my son, waiting to take off from where his father left off. Women like me end up being… fragile LC-(22)** (Nair)

Even Sheela, a teen age girl is sensitive enough to understand her grandma's desire to be well dressed even in her death, as she believed that a woman has to be physically attractive (htt30) Sheela understands the wishes of her grandmother, and in spite of the displeasure of her father and others, she dresses up the body of her grandmother. Sheela, through her action challenges male-controlled authority, and from her grandmother's example she learns that she has to look after her own wishes and pleasures in her life.

Margarate Shanti is presented as another victim of patriarchy. Her autocratic husband willfully frustrates her carrier by restraining her down to a job in the school and her household duties. He even makes her abort her child for his own pleasure. Margarate is given a secondary treatment in the presence of others. Being a modern woman and scholar in chemistry, she finds a way to escape the dictatorship of her husband, Paulraj. She starts feeding him rich food, which eventually deals his activity turning him into a fat, lazy man.

As per the researcher who has experienced gender inequality is a characteristic phenomenon everywhere and it is more observed in India. As the old customs and belief, the wife must try to please her husband and obey his wishes. Indian women, whose minds are influenced by the ancient traditions and myths like sati, savitri, cannot easily think of divorce. A divorced woman is looked down upon though she is not at fault. The narratives of Prabha Devi, Janki show how the birth of a girl child is glared upon by the father, which is the result of social practices in the Indian community especially in the middle-class families. (htt32)

Marikolanthu in 'Ladies Coupe' is an example of socially disregarded woman right from her teenage stage. She has to be a maidservant in the Chettiar House where she is maltreated by Murugan a male member of the aristocratic family. She is sexually exploited by the landlord and has also lesbian relationship with the lady of the house. Anita Nair presents her as a woman who finally arises as a strong woman and takes care of her unlawful son, who otherwise would have no future. Anita Nair has represented women from different social sections, but has shown how women everywhere are dominated and even maltreated in the Indian family life. Marikolanthu is sidelined not only as a woman, but also one who belongs to low section of the society. For no fault of her she is obsessed away from the Chettiar House. Her desire to learn further is overwhelmed, and even her brothers criticize and blame her.

Karpagam is represented as a strong woman determined for achieving self-recognition in a male-controlled social organization. She is a widow but contrasting other widows she applies the kumkum and wears colorful clothes. She is a bold woman, who disrupts the chain of patriarchy when she says,

I don't care what my family or anyone thinks. I am who I am. And I have as much right as anyone else to live as I choose. Tell me didn't we as young girls wear colorful clothes and jewelry and a bottu? It has nothing to do whether the girl is married or not and whether her husband is alive or dead. Who made these laws anyway? Some man who couldn't bear the thought that in spites of his death, his wife continued to be attractive to other men'' (LC-202) (Nair, Ladies Coupe)

Karpagam after the death of her husband did not lose hopes in her life she continued to fight for her rights in the society and was very brave in solving her own problem patiently. Even after facing such tough situation by Karpagam still she was happy and this was the most motivating factor for Akhila, who permitted her family to be dependent upon her for the expense, paying very less attention towards her own life. Karpagam advises Akhila to,

"--- live alone Build a life for yourself where your needs come first. Tell your family to go to hell or Whatever (LC-202) (Nair, Ladies Coupe)

Akhila absorbs from Karpagam the way to tackle the any tough situation coming in the way of her life, which guided Akhila in her future course of life. It was after this motivation by the Karpagam which helps her to take her long journey to Kanyakumari and met a variety of women in the Ladies Coupe.

Conclusion

The stories of women in 'Ladies Coupe' demonstrate how women in every section of the Indian society are demoted and even troubled by the male dominated society.

As far as Anita Nair's Novel 'Ladies Coupe' is concerned researcher has observed in Anita Nair's novel 'Ladies Coupe' that she has projected all her women characters revolt against the tradition destined old mode of life and try to rise above the male domination. As per researcher Anita Nair traces a variety of aspects related to feminism, deriving out of the family life of India. Gender inequality is one of the features, in 'Ladies Coupe'

The stories of women as illustrated in Anita Nair's 'Ladies Coupe' illustrate how women in every strata of the Indian society are marginalized and even oppressed by the patriarchal set up of the society. Even a woman who earns for livelihood of the family is subjected to the patriarchal norms

Though Anita Nair vary in her narrative techniques, and attitude towards feminism but her novel is centered on family and finally the idea of her protagonists journey from 'tradition to modernity who questions their existence in patriarchy and break the social order and make a silent war against it and succeed in keeping themselves within social conventions. The prominent thing is that her women at least realize that they are in dominance.

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Original Article: DTP/SiO_2: An Efficient and Reusable Heterogeneous Catalyst for synthesis of Dihydropyrano[3,2-c]Chromene-3-Carbonitrile Derivatives

Rahul D. Kamble[a] |Milind V.Gaikwad[b]* |Manojkumar R.Tapare[a] |Shrikant V.Hese[c] | Shuddhodan N. Kadam[d] | Ajay N. Ambhore[e] |Bhaskar S. Dawane[f]

[a]*Department of Chemistry, Amruteshwar ACS, College, Vinzar, Pune (MS) India-412213*
[b]*Department of Chemistry, D.Y. Patil ACS, College, affiliated; Savitribai Phule Pune University, Pimpri, Pune (MS) India-411018*
[c]*Department of Chemistry, DD Bhoyar College, Mouda, Nagpur (MS) India-441104*
[d]*Department of Chemistry, VidnyanMahavidhyalaya, Sangola, Solapur (MS) India 413307*
[e]*Department of Chemistry, PDVP College, Tasgaon, Sangali (MS) India 416312*
[f]*School of Chemical Sciences, SRTM University, Nanded (MS) India 431606*

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Citation R.D. Kamble, M.V.Gaikwad*, M.R. Tapare, S.V.Hese, S.N. Kadam, A.N. Ambhore, B.S. Dawane. **DTP/SiO_2: An Efficient and Reusable Heterogeneous Catalyst for synthesis of Dihydropyrano[3,2-c]Chromene-3-Carbonitrile Derivatives**. *J. Appl. Organomet. Chem.*, **2021**, *1*(1), 22-28.

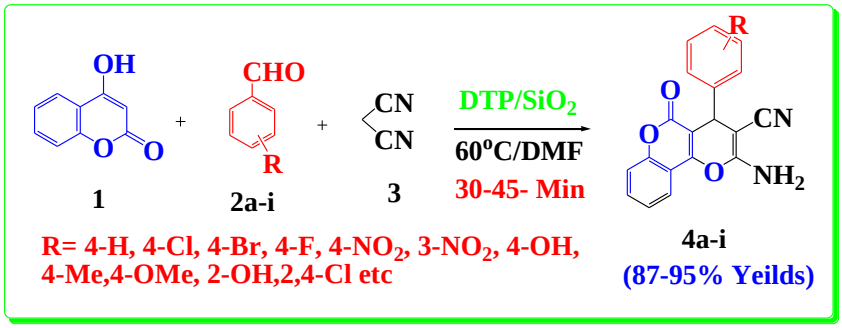
https://doi.org/10.22034/jaoc.2021.276239.1004

Article info:
Received: March 04, 2021
Accepted: March 26, 2021
Available Online: April 6, 2021
ID: **JAOC-2103-1007**
Checked for Plagiarism: **Yes**
Peer Reviewers Approved by:
Dr. SUNIL V. GAIKWAD
Editor who Approved Publication:
Professor Dr. Abdelkader Zarrouk

Keywords:
DTP/SiO_2, green synthesis, dihydropyrano[3,2-c]chromene-3-carbonitrile.

ABSTRACT

An efficient and convenient method has been developed for the synthesis of 2-amino-5-oxo-4-phenyl-4, 5-dihydropyrano[3,2-c]chromene-3-carbonitrile derivatives from a one-pot multi-component reaction between 4-hydroxy-2H-chromen-2-one. Aromatic aldehydes and malononitrile were catalyzed by DTP/SiO_2 as an efficient and reusable heterogeneous catalyst. The current method provides advantages over reported method viz simple operational procedure, easy isolation and recyclability of the catalyst, environmental benign, reduced reaction time and superior yield.



***Corresponding Author:** *Milind V.Gaikwad(mvg1976@rediffmail.com)*

Introduction

Silica-supported DTP/SiO_2 is simple to prepare and shows good acidic characteristics. The acidic properties of DTP/SiO_2 can be controlled by activation temperature and have shown significant catalytic activity [1]. DTP/SiO_2exhibits efficient heterogeneous catalytic properties for the synthesis of a wide variety of important organic building blocks such as α-aminophosphonate [2]. Moreover, it is successfully employed as catalyst for the many organic transformations *via* C-H activation and functionalization of nitrogen-containing aromatic heterocycles [3, 4], Fries rearrangement [5], Friedel-Crafts benzylation of anisole [6].

The pyrans are considered as an important building block for the synthesis of several natural products [7] and photochromic materials [8]. The heterocyclic entities containing pyrans ring show many medicinal and pharmacological properties and are involved in may biochemical reactions [8]. Furthermore, pyrans serve as important synthetic intermediates for the synthesis of biologically important compounds such as pyrano-pyridines [9], poly-azanaphthalenes [10], pyrano[2-c]pyrimidines [11], and pyridin-2-ones [12]. Hence, the synthesis of hetrocyclic compounds containing pyran nucleus has attracted the attention of many synthetic and medicinal chemists. Moreover, the heterocyclic compounds containingpyrano[3,2-c]chromene nucleus is a class of important heterocycle with broad spectrum of biological activities [13] involving spasmolytic, diuretic, anti-coagulant, anti-cancer and anti-anaphylactic activity [14]. The chromene building block with fused ring system has proved to expand the biological spectrum with superior anti-bacterial profile against numerous microbes such as bacteria and fungi [15]. The fused chromene containing heterocycles has shown the excellent biological properties vizantiproliferative [16], sexpheromonal [17], mutagenicitical [18], anti-tumor [19], anti-viral [20]and CNS depressant activities [21].

There are many methods available in the literature for the synthesis of dihydropyrano[3,2-*c*]chromene compounds via one-pot multi-component reaction (MCR) between 4-hydroxycoumarin with aldehydes and malononitriles such as $H_6P_2W_{18}O_{62}/18H_2O$ [22], sodium dodecyl sulfate (SDS) [23], DBU [24], Tetrabutylammonium bromide (TBAB) under solvent-free and in aqueous condition [25], ionic liquid [26], sulfonic acid functionalized silica (SiO_2PrSO_3H) [27], poly(N,N'-dibromo-N-ethyl-benzene-1,3-disulfonamide) [PBBS] and N,N,N',N'-tetrabromobenzene-1,3-disulfonamide [TBBDA] [28], trisodium citrate[29], Biguanide-functionalized Fe_3O_4/SiO_2magnetic nanoparticles [30], inorganic-organic hybrid magnetic nanocatalyst Fe_2O_3 [31] Ru(II) phosphine complexes [32], Silica-bonded n-propylpiperazine sodiumn-propionate [33], 2-hydroxyethylammonium formate (ionic liquid) [34], bleaching earth clay [35] etc. However, these reported methods have been found to be inadequate in terms of longer reaction time, lower practical yields, ease of handling of hazardous chemicals, isolation of the product, lack of catalytic reusability etc. Taking into account the limitation of the reported methods, we can still have a scope to develop new method for the synthesis of dihydropyrano[3,2-*c*]chromene derivatives. To address the shortcomings of reported methods, herein we reported DTP/SiO_2 as efficient, recyclable heterogeneous catalysts for the synthesis of dihydropyrano[3,2-*c*]chromene derivatives.

Experimental

General

All the physical constants were recorded in an open capillary tube and were uncorrected. The reagents, chemicals and solvents used were of synthetic grades and were used as obtained. The reactions were monitored by thin-layer chromatography on precoated sheets of alumina gel-G (Merk, Germany) using iodine vapours and or UV light for detection. The Infra-Red (IR) spectra were recorded on Schimadzu Spectrophotometer (KBr pellets). ^1H NMR (300MHz) and ^{13}C NMR (100 MHz) spectra

were recorded in DMSO-d6 or $CDCl_3$ using TMS an internal standard with an Avance spectrometer (Bruker, Germany). Mass spectra were determined on an EI-Schimadzu QP 2010+ GCMS system.

2.1. General procedure for the synthesis of 2-amino-5-oxo-4-phenyl-4,5-dihydropyrano[3,2-c]chromene-3-carbonitrile derivatives 4:

A mixture of 4-hydroxy-2H-chromen-2-one 1 (1 mol), aldehyde (2a–2n) (1.1 mol), malononitrile 3 (1.1 mmol), and DTP/SiO_2 (20 wt %) in DMF (10 mL) was heated to 60°C with stirring about 30-50 Minute (Table 2). The progress of reaction was checked by TLC. After completing the conversion of reactant into product (by TLC), the catalyst was filtered off and reaction mixture was allowed to cool at room temperature. To this cooled mixture, ice cold water (50 mL) was added and stirred mechanically for 5-10 min. The solid was separated out, filtered and recrystallized from ethanol to afford the pure products **4 a-n**.

2.1.1.Product 4a: Pale yellow powder; (purified by recrystallization with ethanol); IR (KBr) cm^{-1}: 3323, 3204, 2195, 1720, 1668, 1601, 1519, 1381, 1264, 1143, 1048, 761, 481; ^1H NMR (300 MHz, DMSO-d6 TMS) δ ppm; 4.40 (1H, s, pyran-CH), 7.21-7.30 (5H, m, arom.), 7.36 (2H, s, NH_2), 7.40-7.48 (2H, m, arom.), 7.69 (1H, t, J = 7.2 Hz, arom.), 7.86 (1H, d, J = 7.2 Hz, arom); ^{13}C NMR (100 MHz, DMSO-d6, TMS) δ ppm; 37.1, 57.9, 103.8, 112.9, 116.6, 119.2,122.5, 124.7, 127.2, 127.7, 128.6, 133.0, 143.4, 152.2, 153.5, 158.1, 159.6.

2.1.2. Product 4b: Grayish solid; (purified by recrystallization with ethanol); IR (KBr) cm^{-1}: 3319, 3310, 3195, 2196, 1718, 1676, 1608, 1377, 1057, 954, 757, 506; ^1H NMR (300 MHz, DMSO-d6 TMS) δ ppm; 2.21 (3H, s, CH3), 4.36 (1H, s, CH), 7.05-7.11 (4H, m, arom.), 7.34 (2H, s, NH_2), 7.39-7.47 (2H, m, arom.), 7.66 (1H, t, J = 9.0 Hz, arom.), 7.86 (1H, d, J = 9.0 Hz, arom.); ^{13}C NMR (100 MHz, DMSO-d6, TMS) δ ppm; 20.7, 36.7, 58.2, 104.2, 113.1, 116.6, 117.8, 119.3, 122.5, 124.7, 127.6, 129.1, 132.9, 136.3, 140.5, 152.2, 153.3, 158.0, 159.6.

2.1.3. Product 4c: White solid; (purified by recrystallization with ethanol); IR (KBr) cm^{-1}: 3370, 3290, 3182, 2191, 1709, 1671, 1605, 1571, 1507, 1459, 1379, 1319, 1251, 1178, 1111, 1052, 1026, 951, 834, 756, 564, 529; ; ^1H NMR (300 MHz, DMSO-d6 TMS) δ ppm; 3.68 (3H, s, OCH3), 4.35 (1H, s, CH), 6.82 (2H, d, J = 8.4 Hz, arom.), 7.13 (2H, d, J = 8.4 Hz, arom.), 7.33 (2H, s, NH_2), 7.38-7.47 (1H, m, arom.),7.63-7.69 (1H, m, arom.), 7.84 (1H, dd, J = 7.5 Hz, J = 1.2 Hz, arom.), 7.93 (1H, d, J = 9.0 Hz, arom.); ^{13}C NMR (100 MHz, DMSO-d6, TMS) δ ppm; 36.2, 55.1, 58.4, 104.3, 114.0, 115.3, 116.6, 119.4, 122.5, 124.8, 128.8, 132.9, 133.5, 135.5, 152.2, 153.1, 158.0, 159.6, 160.5.

2.1.4. Product 4e: Light yellow colored solid; (purified by recrystallization with ethanol); IR (KBr) cm^{-1}: 3402, 3323, 3204, 2197, 1714, 1670, 1604, 1509, 1379, 1264, 1143, 1047, 761, 481; ; ^1H NMR (300 MHz, DMSO-d6 TMS) δ ppm ; 4.46 (1H, s, CH), 7.23 (2H, d, J = 8.4 Hz, arom.), 7.43-7.50 (6H, m, NH_2 + arom.), 7.68-7.72 (1H, m, arom.), 7.88 (1H, d, J = 7.2 Hz, arom.); ^{13}C NMR (100 MHz, DMSO-d6, TMS) δ ppm; 36.4, 57.7, 103.6, 113.1, 116.6, 119.1, 122.6, 124.8,128.6, 129.6, 131.7, 133.1, 142.4, 152.3, 153.6, 158.1, 159.7.

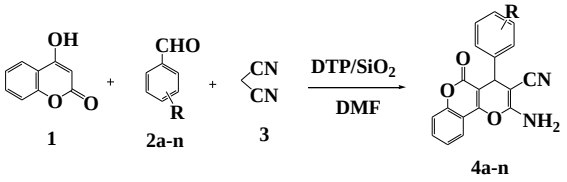
2.1.5. Product 4f: Yellow colored solid; (purified by recrystallization with ethanol); IR (KBr) cm^{-1}: 3385, 3305, 3188, 2191, 1712, 1674, 1606, 1375, 1060, 759, 510; ; ^1H NMR (300 MHz, DMSO-d6 TMS) δ ppm; 5.12 (1H, s, CH), 7.17-7.23 (3H, m, NH_2 + arom.), 7.34 (3H, t, J = 8.7 Hz, arom.), 7.46 (4H, t, J = 10.1 Hz, arom); ^{13}C NMR (100 MHz, DMSO-d6, TMS) δ ppm; 37.0, 56.6, 116.5, 116.9, 119.5, 120.7, 124.8, 125.1, 125.8, 129.8, 130.4, 131.9, 134.5, 142.5, 150.3, 154.1, 159.0.

2.1.6. Product 4j: Yellow colored solid; (purified by recrystallization with ethanol); IR (KBr) cm^{-1}: 3390, 3212, 3179, 2197, 1662, 1575, 1465, 1409, 1260, 1227, 746, 548; ^1H NMR (300 MHz, DMSO-d6 TMS) δ ppm: 4.64 (1H, s, CH), 7.44 (2H, t, J = 7.5 Hz, arom.), 7.49-7.54 (2H, m, arom.), 7.57 (2H, s, NH_2), 7.69 (1H, t, J = 7.5 Hz, arom.), 7.87 (1H, d, J = 7.5 Hz, arom.), 8.14 (2H, d, J = 8.4 Hz, arom.); ^{13}C NMR (100 MHz, DMSO-d6, TMS) δ ppm; 22.3, 36.9, 43.9, 56.9, 102.9, 113.0, 116.7, 118.9, 122.7, 123.8, 124.8, 129.2, 133.2, 146.7, 150.8, 152.4, 154.0, 158.1, 159.6.

2.1.7. Product 4k: Yellow colored solid; (purified by recrystallization with ethanol); IR (KBr) cm^{-1}; 3382, 3235,3179, 2193, 1728, 1663, 1600, 1416, 1298, 1173, 1119, 1010, 753, 472; ^1H NMR (300 MHz, DMSO-d6 TMS) δ ppm: 4.69 (1H, s, CH), 7.42 (1H, d, J = 8.7 Hz, arom.), 7.48 (1H, d, J = 7.8 Hz, arom.), 7.52 (2H, s, NH_2), 7.59 (1H, t, J = 7.8 Hz, arom.), 7.68 (1H, dt, J = 8.0 Hz, J = 8.0 Hz, J = 1.4 Hz, arom.), 7.76 (1H, t, J = 7.8 Hz, arom.), 7.87 (1H, d, J =7.2 Hz, arom.), 8.08 (2H, d, J = 7.8 Hz, arom.), ^{13}C NMR (100 MHz, DMSO-d6, TMS) δ ppm; 22.3, 36.8, 43.9, 57.1, 103.0, 113.0, 116.7, 119.0, 122.5, 124.8, 130.2, 133.2, 134.8, 145.6, 148.0, 152.4, 154.0, 158.3, 159.7.

Result and Discussion

To pursue our work towards the development of efficient methods for the synthesis of important heterocyclic compounds adopting MCRs [35], herein we became interested in developing an environmental friendly method involving use of DTP/SiO_2 as an efficient, recyclable heterogenous catalyst for the synthesis of 2-amino-5-oxo-4-phenyl-4, 5-dihydropyrano[3,2-c]chromene-3-carbonitrile derivatives through a one-pot multi-component condensation reaction of 4-hydroxyquinolin-2(1H)-one, aldehydes, and malononitrile. By a preliminary experiment, we found that this three-component condensation reaction catalyzed by DTP/SiO_2 worked very well. Hence, inspired by the preliminaryexperiments, herein we have reported an efficient one-pot multi-component synthesis of 2-amino-5-oxo-4-phenyl-4, 5-dihydropyrano [3,2-c] chromene-3-carbonitrile derivatives in excellent yields (Scheme 1).



Scheme 1. Synthetic route of 2-amino-5-oxo-4-phenyl-4, 5-dihydropyrano[3,2-c]chromene-3-carbonitrile derivatives

Initially, we investigated the three-component condensation reaction of 4-hydroxy-2H-chromen-2-one **1**, benzaldehyde **2a**, and malononitrile **3** in the presence of various catalyst; the results are tabulated in Table 1.

Table 1. Comparison of catalytic activity of various catalysts for synthesis of pyrano[3,2-c]chromene-3-carbonitrile derivatives

Entry	Solvent	Catalyst	Yield%
1	Methanol	DTP/SiO_2	60
2	Ethanol	DTP/SiO_2	64
3	DCM	DTP/SiO_2	70
4	Acetonitrile	DTP/SiO_2	75
5	DMF	DTP/SiO_2	94
6	Water	DTP/SiO_2	N R
7	DMF	20%DTP/SiO_2	94
8	DMF	30%DTP/SiO_2	94

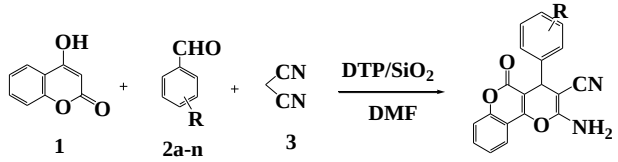
[a]Isolated yields

In order to optimize the reaction condition viz. catalyst loading and solvent, a model reaction was studied by varying the range of solvents including polar and non-polar solvents. In order to find out the appropriate solvent for the synthesis, the model reaction was carried out by using solvents such as methanol, ethanol, dichloromethane (DCM), acetonitrile, Dimethylformamide (DMF). However, the DMF solvent gave the preferred pyrano[3,2-c]chromene-3-carbonitrile product in good yield (Table 1, entry 8), whereas methanol, ethanol, DCM and acetonitrile, respectively gave moderate yield (Table 1, entries 1–4). The formation of the preferred product was not observed using water as the solvent (Table 1, entry 6). This indicates that the solvent plays a key role in the activity and performance of the catalyst. The above observations indicate the reaction using polar protic solvent that shows

an astonishing effect on the yield of the product. Thus, with the reaction in the presence of polar protic solvent, there was a negligible possibility for the substrate to come in contact with catalyst therefore, the yield of the product was found to be low, and reaction in polar aprotic solvent showed the highest yield. The promising results were observed using DMF as a solvent over a DTP/SiO_2 catalyst, which allowed us to further optimize the DTP/SiO_2 catalyst loading. The results in Table 1 (entry 7) reveal that the catalyst with 20 mole % of DTP/SiO_2 loading is excellent. Considering the catalyst using 30 mole % DTP/SiO_2 tested, there was no considerable rise in the yield of the product (Table 1, entry 8). The optimized reaction condition for the given reaction was found to be using 20 mole% DTP/SiO_2 in DMF solvent. These results motivated us to explore the scope of the pyrano[3,2-c]chromene-3-carbonitrile derivatives synthesis from substituted 4-hydroxyquinolin-2(1H)-one, aldehydes, and malononitrile in the presence of a DTP/SiO_2 catalyst at optimized reaction conditions.

A series of aromatic aldehydes were selected to undergo the condensation in the presence of DTP/SiO_2 catalyst. As shown in Table 2, aromatic aldehydes 2 carrying either electron-donating or electron-withdrawing substituent reacted efficiently and gave excellent yields (Table 2, entries 1–14). The possible mechanism is depicted in scheme 2 in the supplementary file.

Table 2. DTP/SiO_2 catalyzed synthesis of pyrano[3,2-c]chromene-3-carbonitrile derivatives

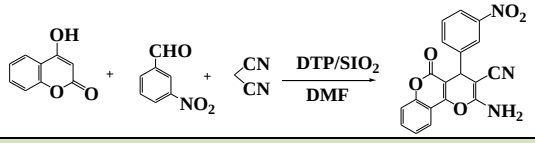


Product	Ar	Time (Min)	Yield[a] (%) Found(Reported)	MP◦C Found(Reported)
4a	C_6H_5 **2a**	30	94 (10)	254-256 (253-255)[31]
4b	4-$CH_3C_6H_4$ **2b**	32	92 (80)	210-220 (219-220) [32]
4c	4-CH_3O-C_6H_4 **2c**	35	90 (78)	220-222 (220-222) [31]
4d	4-F-C_6H_4 **2d**	30	95 (96)	260—262 (260-262) [26]
4e	4-Cl-C_6H_4 **2e**	35	92 (88)	257--259 (256-258)[27]
4f	4-Br-C_6H_4 **2f**	35	91(80)	247-248 (247-249)[23]
4g	3-CH_3O-4-HOC_6H_3 **2g**	30	94	228-230
4h	4-OH-C_6H_4 **2h**	30	87	258-260
4i	3-OH-C_6H_4 **2i**	30	89	263-265
4j	4-NO_2-C_6H_4 **2j**	40	90 (85)	177-179 (177-178)[32]
4k	3-NO_2-C_6H_4 **2k**	45	87 (84)	257-258 (257-258) [31]
4l	2-Cl-C_6H_4 **2l**	45	93 (84)	262-263 (263-266 [23]
4m	2,4-$Cl_2C_6H_3$ **2m**	45	90 (86)	256-258 (255-257) [22]
4n	2-OH-C_6H_4 **2n**	40	88	280-282

[a]Isolated yields.

Therefore, the nature of the substituents attached to the aromatic ring did not show a significant effect in this conversion. The experimental operations involved efficient, eco-friendly, convenient, rapid properties and showed the ability to endure a variety of electron releasing and electron-withdrawing functional groups, such as methoxyl, nitro, hydroxyl, and halides. The recycling experiment revealed that the catalyst could be recycled for next 4-5 times without further purification of the catalyst. And it was observed that there was no significant loss in the yield of the product (Table-3).

Table 3. Catalytic activity of DTP/SiO_2.



Run	1st	2nd	3rd	4th	5th
Time (Min)	45	45	45	45	45
Yield	87	87	86	86	86

Conclusion

In summary, we have reported a simple, rapid, efficient one-pot multi-component condensation of 4-hydroxyquinolin-2(1H)-one 1, aldehyde 2, malononitrile 3 catalyzed by efficient heterogeneous catalyst DTP/SiO_2 to offer 2-amino-5-oxo-4-phenyl-4, 5-dihydropyrano [3,2-c] chromene-3-carbonitrile derivatives 4. The current method offers simple experimental procedure, easy isolation of catalyst, efficacy and reusability of the catalyst over the previously reported methods.

Acknowledgments

The author RDK thankful to BOD, Savitribai Phule Pune University, Pune for ASPIRE Research Grant (**18TCR000044**) and author MVG gratefully acknowledge to Savitribai Phule Pune University, Pune for Minor Research Grant.

Orcid:

Rahul D. Kamble: https://orcid.org/0000-0003-4994-9818
Milind V. Gaikwad:https://orcid.org/0000-0001-5917-6455
Manojkumar R. Tapare:https://orcid.org/0000-0003-1968-9189
Shrikant V. Hese: https://orcid.org/0000-0002-5274-1148
Shuddhodan N. Kadam:https://orcid.org/0000-0003-3791-3498
Ajay N. Ambhore:https://orcid.org/0000-0002-0993-2440
Bhaskar S. Dawane:https://orcid.org/0000-0003-2359-9012

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Short communication

A Short Synthesis of Carbazole Alkaloids Murrayanine and Mukonine

Milind V. Gaikwad[1*], Rahul D. Kamble[2*], Shrikant V. Hese[3], Shuddhodan N. Kadam[4], Ajay N. Ambhore[5], Sunil V. Gaikwad[6], Ashok P. Acharya[7], Bhaskar S. Dawane[8]

[1]*Department of Chemistry, D.Y. Patil ACS College Pimpri, affiliated; Savitribai Phule Pune University, Pune (MS) India-411018*
[2]*Department of Chemistry, Amruteshwar ACS, College, Vinzar, Pune (MS) India-412213*
[3]*D.D. Bhoyar College of Arts and Science Mouda, Nagpur, 441104, MS, India*
[4]*Department of Chemistry, VidnyanMahavidhyalaya, Sangola, Solapur (MS) India -413307*
[5]*Department of Chemistry, PDVP College, Tasgaon, Sangli (MS) India -416312*
[6]*Department of Chemistry, Savitribai Phule Pune University, Pune (MS) India-411007*
[7]*Department of chemistry Mudhoji College, Phaltan- Satara(MS) India-415523*
[8]*School of Chemical Sciences, SRTM University, Nanded (MS) India -431606*

ARTICLE INFO

Article history

Submitted: 2021-05-12
Revised: 2021-05-14
Accepted: 2021-06-07
Manuscript ID: CHEMM-2105-1334
Checked for Plagiarism: **Yes**
Language Editor:
Dr. Behrouz Jamalvandi
Editor who approved publication:
Dr. Vahid Khakyzadeh
DOI: 10.22034/chemm.2021.131552

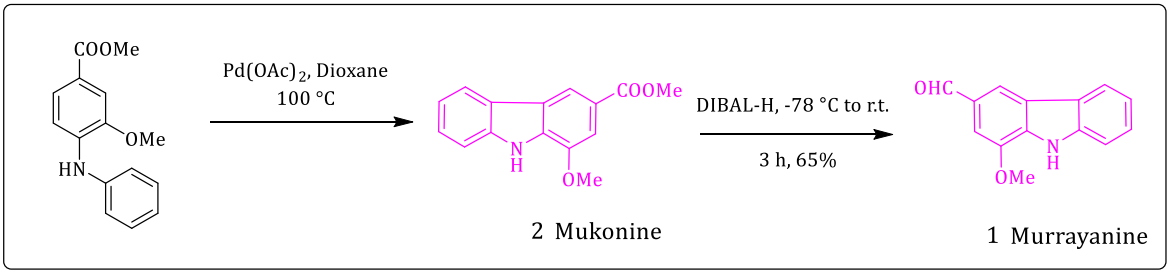
KEYWORDS

Carbazole alkaloids
Mukonine
Murrayanine
Buchard coupling

ABSTRACT

The short, easy and total synthesis of Murrayanine (1), Mukonine (2), carbazole alkaloids were elaborated, based on a regioselective buchwald coupling of methyl 4-bromo-3-methoxybenzoate with aniline and successive transformation into the corrsponding carbazole alkaloids by oxidative coupling followed by cyclization of the phenyl and aryl rings.

GRAPHICAL ABSTRACT



* Corresponding author: Milind V. Gaikwad & Rahul D. Kamble
✉ E-mail: mvgaikwad76@gmail.com; rdkamble143@gmail.com

Introduction

The carbazole alkalods which are pharmacutical importance nitrogen containing heterocycle have been isolated from various natural sources. The exhaustive effort has been made toward the new discovery and construct of natural product. In the recent decade, numerous synthesis methods have been reported globally [1]. In the early 1982, *Chakraborty et al.* studied the roots of *Murraya koenigii* Spreng and isolated the carbazole alkaloids Mukoline and Mukolidine [2] (Figure 1).

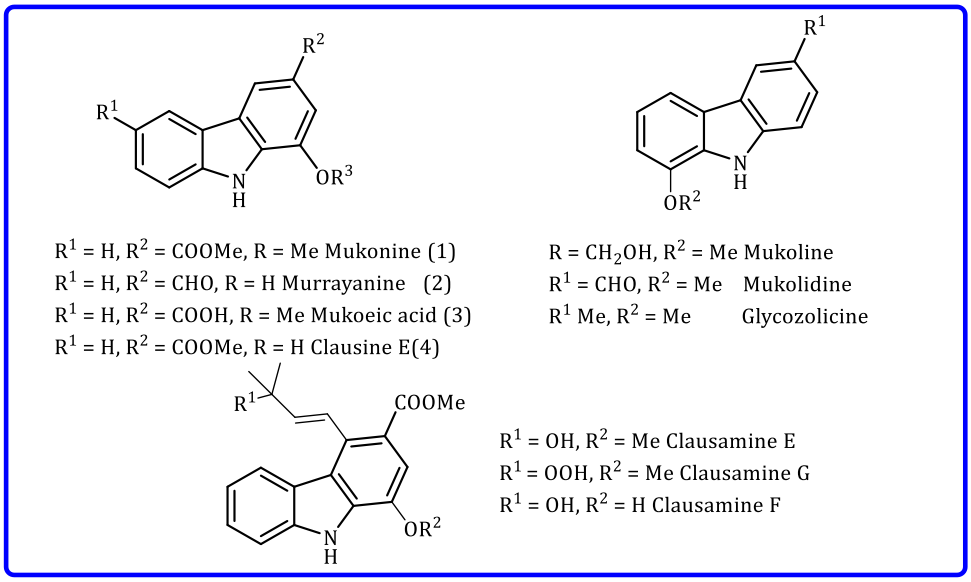


Figure 1: Naturally occurring carbazoles

In India, the *Murraya Koenigii* is the best source for the isolation of the carbazole alkaloids such as murrayanine which is commonly called kadi patta leaf and used day to day life in kitchen [3]. The alkaloids display wide-ranging range of pharmaceutical activity such as antitumor, anti-inflammatory, anti-histaminic, antioxidant, light emitting properties [4]. Because of extensive use of distinctive skeleton, physicochemical properties and pharmaceutical activities as mentioned above, the introduction of novel, simple and efficient route to prepare the carbazole moiety has considerable attention in the scientist community. The numerous synthetic methods are present for the preparation of murrayanine (1), mukonine carbazole alkaloids [5-6].

The diverse synthetic reports available in the literature include Fischer indolization [7] the iron metal catalyzed oxidative coupling with cyclization of arylamine tricarbonyl(cyclohexadiene) complexes [8-9], oxidative cyclization in the palladium(II)-catalyzed [10], the thermal cyclization of 1-phenyl benzotriazole [11] cyclization of biarylnitrenes to carbazole [12] and some others methods. Recently, Banwell et al. described a new procedure for the preparation of Mukonine carbazole alkaloids with 66% yield via a Pd-Catalyzed oxidative C-C bond formation followed by reductive coupling reaction [13]. Knoke et al. (1993) described the iron-promoted carbon-carbon, carbon-nitrogen bond formation followed by synthesis of koenoline, mukoeic acid, murrayafoliae A, murrayanine. murrayaquinone A, and mukonine natural product [14]. Subha et al. described the novel cross coupling reaction followed by reductive cyclization in the presence of triphenylphosphine that gives a range of carbazole alkaloids, including mukonine, murrayafoline A, mukoeic acid, clauszoline K, koenoline, murrayanine,glycoborine, mukoline, glycozolicine, mukolidine, and glycozoline alkaloids [15]. The natural product mukoline and mukolidine were produced by the reaction of aromatic amine with the exposure of palladium

(II) acetate and copper (II) acetate in the pivalic acid [16].

As a researcher, always interested to report a novel methodology for the construction of bioactive heterocyclic compound [17-23]. In this paper, we have described a new method for the total synthesis of murrayanine (1), mukonine via construction of desire scaffold via Buchwald coupling followed by $Pd(OAc)_2$ mediated oxidative coupling reaction to obtain desire molecule.

Material and methods

General

The experiment was performed in a dry glass apparatus and the required raw chemicals were bought from the national and international suppliers such as Spectrochem, Aldrich, Merck, Fisher and used directly. The dry reaction was carried out in the Argon gas atmosphere. The progress of reaction was checked on TLC. The synthesized compound purification was performed using column chromatography with Silica gel (60-120 Mesh) from Aura. The solvent was dried over A4 molecular sieves prior to use and the THF was dried over Na metal. The tetramethylsilane (TMS) used as internal standard at ambient temperature for the running of the ^1H NMR, ^{13}C NMR spectra over a Bruker 400, 500 MHz NMR machine. The FT-IR spectra were recorded over a Bruker- Perkin-Elmer model 683 B or 1605 spectrophotometer and absorptions were expressed in cm^{-1}. All Buchi 501 apparatus was used for the recording of melting points and Boiling Points of pure compounds and are uncorrected.

Synthesis of methyl 4-bromo-3-methoxybenzoate (5)

To a solution of 4-bromo-3-methoxybenzoic acid, 6 (1,00 g, 1 eq) in methanol (15 ml) H_2SO_4 (20 µL, 0.15 eq) was added. The reaction mixture was blended to reflux for 5 h. After completion of the reaction, the solvent was removed under reduced pressure and the crude mass was mixed in DCM $NaHCO_3$ and cold water. The organic layer was dried over sodium sulphate and concentrated under reduced pressure to afford the pure product 5 methyl 4-bromo-3-methoxybenzoate; white crystalline product, mp 54-56 °C.

Methyl 3-methoxy-4-(phenylamino)benzoate (3)

In a dry seal tube with magnetic stir bar, $Pd_2(dba)_3$, methyl 4-bromo-3-methoxybenzoate2 (g, mmol), aniline (g, mmol) was added, followed by xantphos (g, mmol) Cs_2CO_3 (g, mmol) in a dry 1,4-dioxane, the seal tube was then evacuated/backfilled with argon 3x with stirring. The seal tube was stirred vigorously at 110 °C for 48h. After completion of reaction (monitored by TLC), the reaction mixture was diluted with 5 ml ethyl acetate and filter over sintered glass funnel, the organic solution concentrate under vacuum and purified using column chromatography to afford white crystal with 58% yield.

^{1}HNMR (300MHz, $CDCl_3$); δ: 3.88(s, 3H), 3.96 (s, 3H), 6.54 (br, 1H), 7.06 (t, *J*= 7.4 Hz, 1H), 7.19-7.26 (m, 3H), 7.34 (t, *J*= 8 Hz, 2H), .7.52 (d, *J*= 1.5 Hz, 1H), 7.59 (dd, *J*= 1.4 Hz & 8.1 Hz, 1H)

^{13}CNMR (75 MHz, $CDCl_3$), δ: 51.7, 55.7, 59.8, 110.5, 110.6, 119.9, 120.8, 123.0, 123.5, 129.4, 132.2, 140.6, 146.5, 167.1.

Synthesis of methyl 1-methoxy-9H-carbazole-3-carboxylate; Mukonine (2)

In a dry seal tube with magnetic stir bar was added $Pd(OAc)_2$ and methyl 3-methoxy-4(phenylamino)benzoate 3 in a 1,4-dioxane the seal tube was fluxed with argon 3x with stirring. The seal tube was blended vigorously at 100 °C for 16h. The progress of reaction was checked using TLC and after completion of reaction the mixture mix with 10 mL Ethyl acetate.

After completion of reaction (monitored by TLC), the reaction mixture was diluted with 10 mL ethyl acetate and filter over sintered glass funnel, the organic solution concentrate under vacuum and purified using column chromatography with (ethyl acetate: hexane) to afford white solid.

Mukonine (5a): Yield (70%), mp 194-198 °C (lit. 4 mp 196 °C); ^{1}H NMR (300 MHz, $CDCl_3$): δ: 10.37 (s, D_2O exchange, 1H), 8.34 (s, 1H), 8.06 (d, *J*=6.2 and washed with the saturated solution of

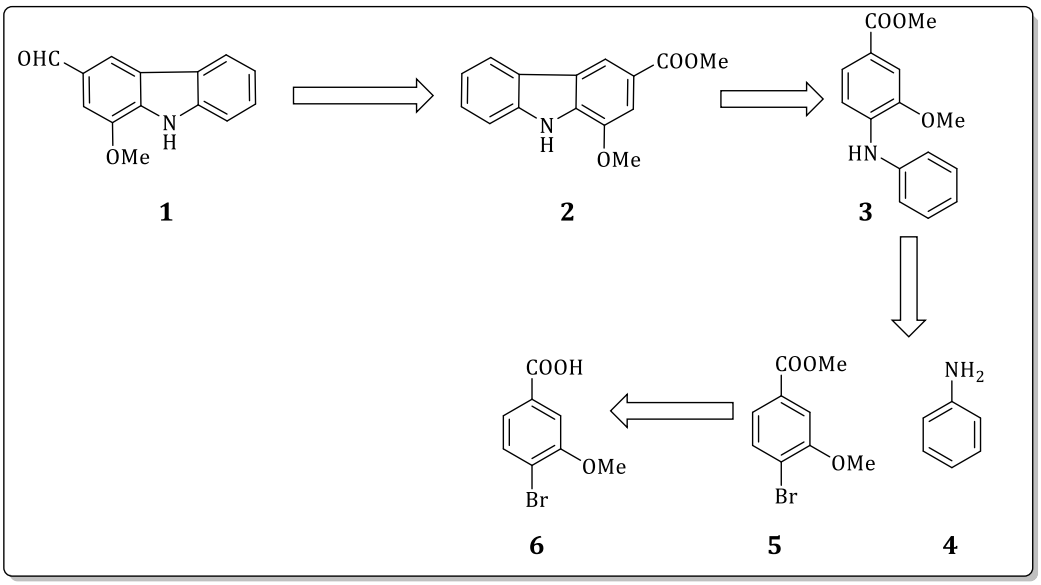
Hz, 1H), 7.61 (s, 1H), 7.51 (t, *J* = 9.1 Hz, *J* = 8.9 Hz, 1H), 7.40 (t, *J* = 8.8 Hz, *J* = 5.8 Hz, 1H), 7.09 (t, *J* = 6.2 Hz, 1H), 3.88 (s, 6H); ^{13}CNMR (75 MHz, DMSO-*d*$_6$): 167 δ 167.89, 146.01, 139.91 132.61, 126.02, 123.71, 123.83, 122.11, 120.22, 120.54, 116.21, 111.45, 107.23, 55.52, 55.01; The calculated HRMS for the molecular formula $C_{15}H_{13}NO_3$ [M+ H]$^+$, 256.0968 and observed 256.0970.

Synthesis of 1-methoxy-9H-carbazole-3-carbaldehyde; Murrayanine (1)

A solution of compound methyl 1-methoxy-9*H*-carbazole-3-carboxylate 0.500 mg in a 17 mL dry THF at -78 °C under the argon atmosphere di-isobutyl-aluminum hydride in THF was added drop wise and keep the vessel temperature below -65 °C. After completion of reaction, the reaction was quenched with 10 mL of 10% HCl, and extracted into 2 x 10 mL portions of ethyl acetate. The organic layer was also washed by using 10% HCl, solution and saturated sodium bicarbonate. The organic layer was dried over magnesium sulfate and concentration under reduced pressure gave desired 1-methoxy-9H-carbazole-3-carbaldehyde. Murrayanine (1): Colourless crystals, Yield (78%), mp 164-168 °C ; ^{1}H NMR (400 MHz, DMSO) δ: 11.68 (s, 1H), 8.78 (s, 1H), 8.20 (d, *J* = 7.9 Hz, 1H), 8.03 (dd, *J* = 8.3, 5.5 Hz, 2H), 7.66 (d, *J* = 8.3 Hz, 1H), 7.53 (t, *J* = 7.5 Hz, 1H), 3.95 (s, 3H).

Result and Dissection

The retrosynthesis analysis of murrayanine (1), mukonine (2), is shown in Figure-1. Our retrosynthetic analysis for the synthesis of the target molecule **1** murrayanine (1) and mukonine (2) carbazoles are expected to be obtained via Buchwald–Hartwig coupling followed by Pd catalyzed C-C coupling reaction (Scheme 2). The key precursor **5** has been required for the construction of murrayanine and mukonine carbazole alkaloids.



Scheme 1: Retro synthesis of murrayanine (1), mukonine (2), carbazole alkaloids

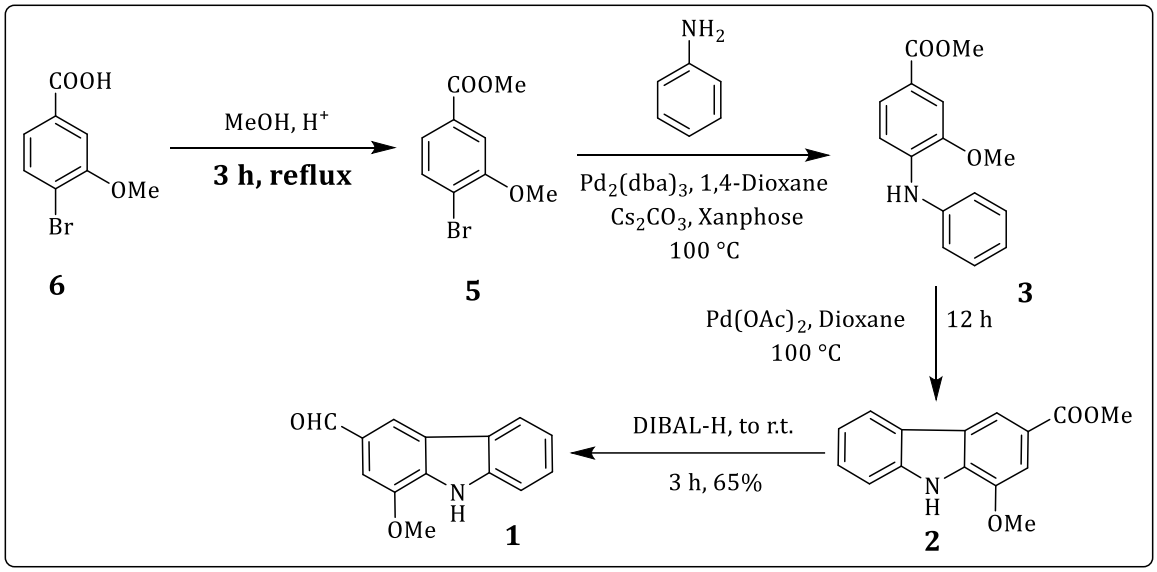
With the help of synthetic pathway as shown in Scheme 2, the optimization of **1** involves carbon–nitrogen coupling with Buchwald coupling the catalyzed coupling reactions of amines with aromatic halides followed by the C-C oxidative coupling cyclization of the phenyl and aryl rings are the key steps. We started our strategy as per our proposed strategy (Scheme 1). The precursor 5 has been prepared form the etherification of 4-bromo-3-methoxybenzoic acid in MeOH/ H$^+$ gives precursor 5. Then we moved towards the actual synthesis of desire precursor **3** from the

Buchwald coupling with 5 and amine 4 by using Xantphos, Cs_2CO_3 and *Pd*(tris)$_3$ [24] under the dry condition. At the beginning, we performed Buchwald coupling reaction by using various bases such as K_2CO_2, $CsCO_3$, KO*t*Bu. When the reaction was performed with the base K_2CO_3 at 100 °C to produce desired precursor, but very less yield, while in case of $CsCO_3$, t-BuOK yield was moderate to good (Table 1).

Table 1: Examination of the Pd-catalyzed Buchwald coupling reaction

Sr /No	Reagent	Ligand	Base	Time	Yield%
1	$Pd_2(dba)_3$	BINAP	K_2CO_3	24	20
2	$Pd(OAc)_2$	Xanphose	K_2CO_3	24	35
3	$Pd_2(dba)_3$	BINAP	KO*t*Bu	24	28
4	$Pd(OAc)_2$	Xanphose	KO*t*Bu	24	42
5	$Pd_2(dba)_3$	BINAP	Cs_2CO_3	24	30
6	$Pd_2(dba)_3$	Xanphose	Cs_2CO_3	24	69
7	$Pd(OAc)_2$	Xanphose	Cs_2CO_3	24	38

Based on the above observation, we decided to examine the synthesis intermediate 3 via Buchwald coupling reaction. Initially, we examined the Pd-catalyzed Buchwald coupling reaction using Ligand BINAP and Xanphose in the presence of base K_2CO_3, KO*t*Bu, Cs_2CO_3 (Table 1, entry 1). The treatment of 5 and 4 with $Pd(OAc)_2$ Pd-catalyst in the presence of ligand Xanphose and base K_2CO_3, Cs_2CO_3 and KO*t*Bu with dioxane solvent resulted in the formation of 3 with 35%, 38% and 42% yield (Table 1, entry 2, 4 and 7).



Scheme 2: Synthesis of murrayanine (1), mukonine (2), carbazole alkaloids

Based on the treatment of 5 and 4 with $Pd_2(dba)_3$ Pd-catalyst in the presence of ligand BINAP, Xanphose and base K_2CO_3, KO*t*Bu, Cs_2CO_3 with dioane solvent which resulted in the formation of 3 with 20%, 28%, 30% and 58% yield (Table 1, entry 1, 3, 5 and 6) from the above result, it can be concluded that the Buchwald coupling reaction occur by using $Pd_2(dba)_3$ reagent using Xanphose ligand with Cs_2CO_3 base in a 1,4-Dioxane solvent(table 1, entry 6). The desired compound 3 in our hand showed very good yield. Next, we embarked on the total synthesis of murrayanine (1) and Mukonine (2). The compound **3** were treated with Pd-catalyst and gave desired alkloids. Mukonine (2) was then prepared by oxidative coupling cyclization of the

phenyl and aryl rings of precursor 3 initiated by stoichiometric amount of $Pd(OAc)_2$ [25] in acetic acid solvent 7. Further, Mukonine (2) was converted to murrayanine (1) via reduction of ester group to aldehyde by using DIBAL-H in THF solvent with 78% yield.

Conclusion

We have described a new and concise synthesis method of Murrayanine (1) and Mukonine (2), by using the novel approach that involves a Pd-catalyzed Buchwald coupling followed by oxidative coupling cyclization of the phenyl and aryl rings using stoichiometric amount of $Pd(OAc)_2$.

Acknowledgement

The authors are thankful to Department of Chemistry Dr. D.Y. Patil A. C. S. College, Pimpri, Pune, 411018, India, Savitribai Phule Pune University for providing laboratory facilities for this research. The author RDK is thankful to BOD, Savitribai Phule Pune University, Pune for ASPIRE Research Grant (18TCR000044).

Authors' contributions

All authors contributed toward data analysis, drafting and revising the paper and agreed to be responsible for all the aspects of this work.

Conflict of Interest

We have no conflicts of interest to disclose.

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HOW TO CITE THIS ARTICLE
Milind V. Gaikwad, Rahul D. Kamble, Shrikant V. Hese, Shuddhodan N. Kadam, Ajay N. Ambhore, Sunil V. Gaikwad, Ashok P. Acharya, Bhaskar S. Dawane. A Short Synthesis of Carbazole Alkaloids Murrayanine and Mukonine, Chem. Methodol., 2021, 5(4) 341-347
DOI: 10.22034/chemm.2021.131552
URL: http://www.chemmethod.com/article_131552.html

NJC

PAPER

Cite this: *New J. Chem.*, 2021, **45**, 4632

Metal-free efficient thiolation of C(sp^2) functionalization *via in situ*-generated NHTS for the synthesis of novel sulfenylated 2-aminothiazole and imidazothiazole†

Shuddhodan N. Kadam,[a] Ajay N. Ambhore,[b] Rahul D. Kamble,[c] Mahesh G. Wakhradkar,[d] Priya D. Gavhane,[d] Milind V. Gaikwad,[d] Krishna Chaitanya Gunturu*[d] and Bhaskar S. Dawane *[d]

Received 3rd December 2020,
Accepted 4th February 2021

DOI: 10.1039/d0nj05904h

rsc.li/njc

A direct metal-free approach for the synthesis of novel sulfenylated 2-aminothiazole and imidazothiazole derivatives at room temperature is reported *via* an *in situ*-generated electrophilic thiolating agent. The present protocol provides mild and selective access for the insertion of C–S bond functionalization with good yield. The mechanistic path was justified *via* density functional theory (DFT) calculations, which explore the role of the solvent in the reaction mechanism.

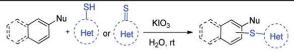
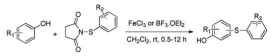
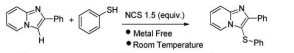
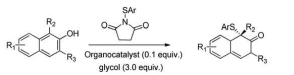
Introduction

The prevalent occurrence of organosulfur compounds in vital biological systems, drug architectures and natural products present themselves as versatile scaffolds in organic chemistry, medicinal chemistry and materials chemistry.[1–5] They constitute an active portion of commercially available drugs.[6,7] These consequences have led to an unending quest for a capable catalytic system, comprising a blend of carbon-sulfur bonds to create organosulfur compounds.[8–16] The majority of reported transformations for C–S bond coupling includes the synthesis of diaryl sulfides using imidazoheterocycles,[17–20] indoles[21–25] or aryl halides[26–30] by reaction with thiols or thiones. Several catalytic systems utilized for the cross dehydrogenative coupling reaction (CDC) of the C–S bond include the use of transition metals,[31–36] elemental sulfur,[37–39] and iodine.[40–44] Amongst these protocols, those capable of encountering direct metal-free regioselective C–S bond coupling in bifunctional motifs for the selective synthesis of heterocyclic organosulfur compounds are highly desirable.[45–52] Moreover, among numerous catalytic systems reported for the synthesis of organosulfur compounds, the use of *N*-halosuccinimides was proven to be a highly useful approach;[53–59] however, *N*-halosuccinimides have a general tendency to oxidise secondary alcohols to their corresponding ketones.[60,61] In recent years, the use of *N*-sulfanylsuccinimides for the direct sulfenylation of aromatic and heteroaromatic C–H bonds has become an interesting strategy.[62–73] Very few reports are available for the synthesis of catechol thioethers.[75–77] However, the selective synthesis of organosulfur compounds has not been reported hitherto *via in situ*-genarated *N*-(heteroarylthio)-succinimide (NHTS), by utilizing *N*-halosuccinimide and heterocyclic thiols such as 1H-benzo[*d*]imidazole-2-thiol, benzo[*d*]oxazole-2-thiol and 5-(pyridin-4-yl)-1,3,4-oxadiazole-2-thiol. The use of these heterocyclic thiols may impart advantages in the areas of small molecule syntheses as well as pharmaceuticals as imidazothiazole and thiazoles are considered to possess a broad spectrum of biological activity.[79,80] Consequently, the selective C-5 electrophilic sulfenylation of pseudo aromatic imidazothiazoles with secondary alcohols may provide a beneficial synthetic route for medicinal chemistry research. Jie *et al.* have reported the organocatalytic sulfenylation of β-naphthols using *N*-(arylthio)succinimide as the sulfur source, and they have observed that the dearomatization of β-naphthols takes place with the oxidation of an alcoholic group to a ketone (Scheme 1).[78]

Nevertheless, alcohols also possess the propensity to react with thiols to generate thioethers in the presence of certain catalytic systems.[81–86] These annotations and our previous study regarding the synthesis of bioactive compounds[87–89] have provoked us to focus on the development of a new catalytic system for the selective C(sp^2)–H bond thiolation of 2-aminothiazoles and imidazothiazoles using heterocyclic thiols and *N*-halosuccinimide.

[a] *Vidnyan Mahavidyalay Sangola, Solapur, MS 413307, India*
[b] *Padmabhushan Dr Vasantraodada Patil Mahavidyalay, Tasgaon Sangli, MS 416312, India*
[c] *Amruteshwar ACS College, Vinzar Pune, MS 412213, India*
[d] *School of Chemical sciences, Swami Ramanand Teerth Marathwada University, Nanded, MS 431606, India. E-mail: bhaskardawane@rediffmail.com, krishnachaitanya.gunturu@gmail.com*

† Electronic supplementary information (ESI) available. See DOI: 10.1039/d0nj05904h

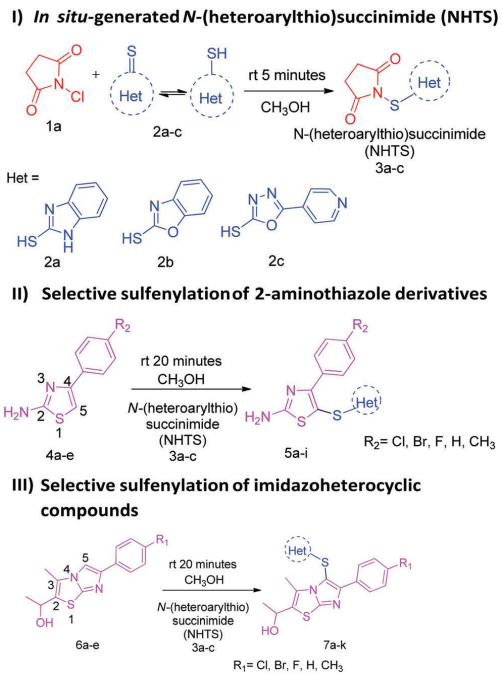
Sr. No.	Scheme	Time	Ref. No.
a)		15 h	72
b)		0.5 h	73
c)		30 min	74
d)		30 min	53
e)		75 h	78

Scheme 1 Earlier approaches for C–S bond coupling.

Results and discussion

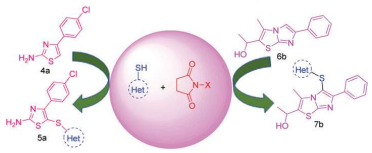
The hypothesized synthetic route commences with the reaction of *N*-chlorosuccinimide with aromatic thiophenols, as predicted by previous literature.[53] We have further demonstrated that further reaction of *N*-chloro-thiols smoothly allows the formation of C–S bonds.[53,74] When this halogenation-thiolation tandem strategy was first implemented, the formation of the product took place with poor yield and prolonged time of 10 h.

When we carried out the same reaction taking 1 equiv. of *N*-chlorosuccinimide with 1 equiv. of 1H-benzo[*d*]imidazole-2(3H)-thione using methanol as the solvent, we came across a curious observation that instead of introducing chlorination in heterocyclic thione, the construction of *in situ*-generated NHTS (Scheme 2I) takes place within 5 min by stirring at room temperature. A plausible reason for this observation may be that the resonance stability of heterocyclic thiols eventually supports the *in situ* generation of NHTS. When the same strategy was employed in the case of aromatic thiols, the generation of *N*-(arylthio)succinimide does not take place to such an extent. We investigated the utilization of NHTS for the sulfenyllation of substituted 4-phenylthiazol-2-amine **4a–e** (Scheme 2II) and 1-(3-methyl-6-phenylimidazo[2,1-*b*]thiazol-2-yl)ethanol **6a–e** (Scheme 2III) in the same reaction pot. The starting reactant **6a–e** was obtained by reducing 1-(5-((1H-benzo[*d*]imidazol-2-yl)thio)-6-(4-chlorophenyl)-3-methylimidazo[2,1-*b*]thiazol-2-yl)ethenone with $NaBH_4$.[90] For exploring the optimal reaction conditions, *N*-halosuccinimide and solvents were examined using 4-(4-chlorophenyl)thiazol-2-amine or 1-(3-methyl-6-phenylimidazo[2,1-*b*]thiazol-2-yl)ethanol as the standard reactant (Table 1). Initially, *N*-chlorosuccinimide (NCS) 1 equiv. was employed under dichloromethane (DCM) as the solvent yield was observed to decrease (Table 1, entry 1). When the amount of NCS was increased, the yield improved (Table 1, entry 2). Further improvement of the yield was seen when 1.5 equiv. of NCS was employed with 2 equiv. of the reactant (Table 1, entry 3). Optimized reaction conditions were found when methanol was used as the solvent with 1.5 equiv. of NCS and 2 equiv. of reactant



Scheme 2 Present work.

Table 1 Optimal reaction condition[a]



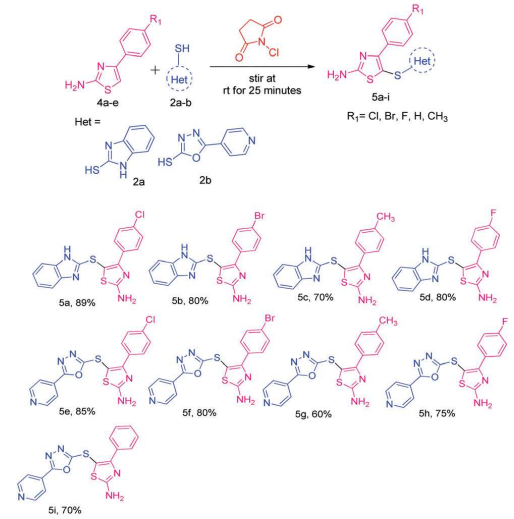
Entry	NXS equiv.	Heterocyclic thiols equiv.	Solvent (3 ml)	Yield[b] (%)
1	NCS (1.0)	1	DCM	43
2	NCS (1.5)	1	DCM	47
3	NCS (1.5)	2	DCM	52
4	NCS (1.5)	1	CH_3OH	71
5	NCS (2.0)	1	CH_3OH	64
6	**NCS (1.5)**	**2**	**CH_3OH**	**89**
7	NCS (1.5)	2	CH_3COOH	34
8	NCS (1.5)	2	Toluene	41
9	NCS (1.5)	2	CH_3CN	44
10	NCS (1.5)	2	DMF	31
11	NCS (1.5)	2	DMSO	51
12	NIS (1.5)	2	CH_3OH	58
13	NBS (1.5)	2	CH_3OH	78
14	—	2	CH_3OH	NR[c]
15	NCS (1.5)	2	No solvent	Trace

[a] Reaction conditions: *N*-halosuccinimide, heterocyclic thiols are stirred for 5 min at room temperature first and then reactant **4a** or **6a** was added and reaction mass was further stirred for next 20 min at room temperature. [b] Isolated yield. [c] NR = No reaction.

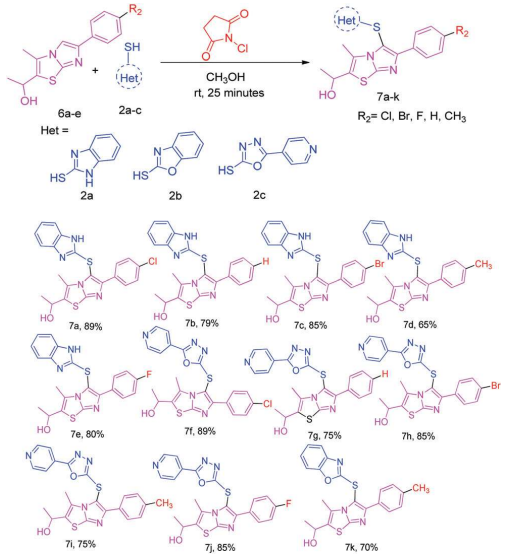
(Table 1, entry 6). The as-synthesized product was washed with cold ethanol. Column chromatography was not needed for purification. Further variation in the amount of the reactant and/or NCS using methanol as the solvent was shown to decrease the yield (Table 1, entries 7–11). The implementation of *N*-iodosuccinimide or *N*-bromosuccinimide was observed to diminish the yield (Table 1, entries 12 and 13). In absence of *N*-halosuccinimide the reaction did not proceed (Table 1, entry 14). Furthermore, the reaction was not observed under solvent-free conditions (Table 1, entry 15).

With this optimal set of reaction conditions (Table 1, entry 6), we proceeded to investigate the sulfenylation of 2-aminothiazole derivatives. While exploring the effects of the substrate scope of 2-aminothiazole derivatives, the unsubstituted 2-aminothiazole ring at the C-4 position was unable to furnish the product. Amongst the substituted 2-aminothiazole derivatives, those derivatives possessing electron withdrawing substituents at the para position of the aromatic ring successfully furnished the product with satisfactory yield (Scheme 3). Electron-donating groups were found to retard the yield (Scheme 3), while substituents at the meta position were unable to furnish the product.

Interestingly, the method achieves the selective C-5 sulfenylation of 2-aminothiazole derivatives, and no reactions were observed to give a nuclear sulfenylation product. We further proceeded to investigate numerous 1-(3-methyl-6-phenylimidazo[2,1-*b*]thiazol-2-yl)ethanol derivatives for their sulfenylation (Scheme 4). Subsequently, adding 1 equiv. of reactant **6a** in the same pot and stirring for 20 min at ambient temperature affords the synthesis of final products. Results obtained



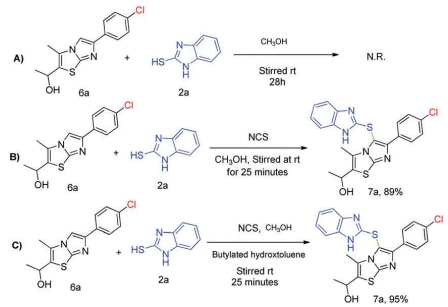
Scheme 3 Scope of substrate: variation of substituent on 2 aminothiazole[a,b]. [a]Reaction conditions: NCS (2.0 mmol) heterocyclic thiol (1.0 mmol), substituted 2-aminothiazole **4a–e** (1 mmol), CH_3OH (3 mL), reaction time (24–25 min). [b]Isolated yield.



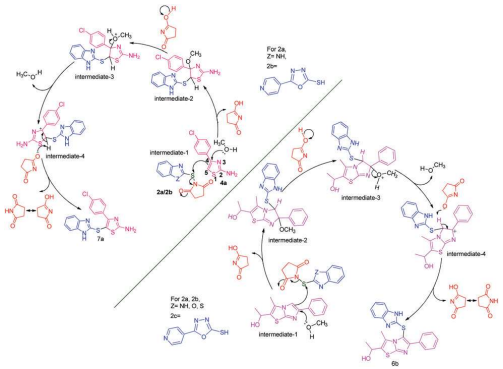
Scheme 4 Variation of substituent on imidazothiazole[a,b]. [a]Reaction conditions: NCS (2.0 mmol) heterocyclic thiol (1.0 mmol), substituted imidazothiazole **6a–e** (1 mmol), CH_3OH (3 mL), reaction time (24–25 min). [b]Isolated yield.

demonstrate that derivatives with electron-withdrawing groups on the aromatic ring at the para position provide the product with a satisfactory yield (Scheme 4), whereas with electron-donating groups such as the methyl group at the same position tend to decrease the yield of the product (Scheme 4). Electron-releasing substituents failed as exemplified by the reactant possessing the methoxy group at the same position. Variation in the heterocyclic thiol was not seen to alter the yield of the product. Interestingly, in each derivative selective sulfenylation was seen to take place at the C-5 position of imidazothiazole derivatives regardless of the pendant alcohol. Also, no derivatives were seen to give sulfenylation on an aromatic ring. The probable mechanistic path was further studied by taking other mechanistic pathways into account (Scheme 5). It came to our attention that the reaction does not proceed in absence of any catalyst or co-reagent after 28 h (Scheme 5A). The implementation of *in situ*-generated (NHTS) results decrease reaction time to 25 min, yielding 89% (Scheme 5B). When same protocol was carried out in presence of the radical quenching agent butylated hydroxtoluene BHT (2 equiv.), we were still able to get 95% yield (Scheme 5c), ruling out the possibility of free radical mechanistic path. Considering the observations of controlled experiments, optimized reaction conditions and (DFT) studies, the tentative mechanism of the reaction is given in (Scheme 6). The 4-(4-chlorophenyl)thiazol-2-amine (**4a**) derivative has been taken as the representative of all the derivatives.

The mechanistic path was studied by DFT calculations, as illustrated in (Scheme 6). The observations in Table 1 and



Scheme 5 Screening experiments.



Scheme 6 Plausible mechanistic path for the thiolation of substituted imidazothiazole and 2-aminothiazole.

Scheme 5 indicating the role of CH_3OH in the reaction is not only limited to the solvent effect but it also takes part in the mechanism as a reagent.[91–94] Initially, the reaction between (**4a**) and (NHTS) in presence of CH_3OH leads to an intermediate-1 with bond formation between C-5 of (**4a**) and -S of (NHTS). Here, methanol is found to be bonded at C-4 that induces the electronegativity of C-5 to facilitate C–S bonding. The release of succinimide is found during the formation of intermediate-2 with -H transfer from methanol. Subsequently, methanolate abstracts -H from succinimide (intermediate-3) and leaves to form intermediate-4. The disappearance of profound IR stretching frequency around 3210 cm^{-1} (Table S1, ESI†) indicates the formation of product (**5a**).

Conclusions

In summary, we have developed a metal-free, mild and selective protocol for the synthesis of novel sulfenylated 2-aminothiazoles and imidazothiazoles *via in situ*-generated (NHTS). Our study exemplifies that NHTS is acting as a co-reagent in the current procedure. The method adopted ensures chemoselectivity towards the C–H bond functionalisation in the presence of secondary alcohol in imidazothiazole, setting up the application of NHTS for the pharmaceutical and agrochemical arenas.

Conflicts of interest

There are no conflicts to declare.

Acknowledgements

Authors S. N. Kadam (F. No. 38/07/14) and A. N. Ambhore (F. No. 36/33/14) are grateful to the UGC for providing teacher fellowship. R. D. K. acknowledge S. P. P. U. Pune for aspire research grant.

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E-ISSN: 2788-9270
P-ISSN: 2788-9262
NJPS 2021; 1(1): 50-57
Received: 18-11-2020
Accepted: 21-12-2020

Ganesh C Nikalje
PG Department of Botany, Seva Sadan's R. K. Talreja College of arts, Science and Commerce, Ulhasnagar, Maharashtra, India

Zimare SB
Naoroji Godrej Centre for Plant Research (NGCPR), Satara, Maharashtra, India

Shelke DB
Department of Botany, Amruteshwar Art's, Commerce and Science College, Vinzar, Velha, Pune, Maharashtra, India

Correspondence
Ganesh C Nikalje
PG Department of Botany, Seva Sadan's R. K. Talreja College of arts, Science and Commerce, Ulhasnagar, Maharashtra, India

Effect of elicitors on plant cell suspension culture for the enhancement of secondary metabolite production

Ganesh C Nikalje, Zimare SB and Shelke DB

Abstract
In present era, different tissue culture techniques are applied to enhance secondary metabolites production by triggering stress response. These stresses include application of elicitors, biotransformation, change in environmental conditions, change in medium constituents, precursors, etc. Among them, elicitors are substances that induce defense responses in plants. Elicitors are introduced into various organ cultures and in cell suspension cultures to increase the stress tolerance. The present review focuses on secondary metabolite production in plant cell suspension culture. This will help in conservation of rare and endangered medicinally important plants and it will also provide increased secondary metabolite production with less time and low cost.

Keywords: Cell suspension culture, elicitor, secondary metabolite production.

Introduction
The extensive research work in the modern biological and chemical sciences have described the role of primary metabolites in vital life functions like cell division and growth, respiration, storage, and reproduction. The concept of secondary metabolite was first explained by Kossel [1]. He defined that secondary metabolites are opposed to primary ones. Later on, Czapek [2] have taken an important step and devoted an entire volume named "end product" to his 'plant biochemistry' series. As per Czapek, the secondary modification i.e. de-amination process in nitrogen metabolism gives rise to these end products. The secondary metabolites are often located at specific cell or organs and less than 1% of total carbon as compared to other main molecules. In the middle of 20th Century, advancement in different analytical techniques resulted in to identification and purification of several molecules which formed the basis of phyto-chemistry discipline. The paper chromatography revealed that some of the molecules are pigments. However, the possible role of these secondary metabolites in life cycle of plant is still mysterious as mentioned by Czapek as end product. Plant fitness is largely depending on production of secondary metabolites under environmental influence. Most of the secondary metabolites possesses bioactivities like antifungal, antibiotic, antiviral etc. Hence, they protect plant against pathogens and shows allelopathic effect which prevents germination of other species present in their vicinity. In addition, they possess UV absorbing compounds and prevents leaf damage from UV rays [3].
The classification of plant secondary metabolites is usually based on their biosynthetic pathways [4]. The secondary metabolites are grouped in to four families such as alkaloids, phenolics, steroids and terpenes. Among these phenolic family is widespread as its compounds are involved lignin synthesis and ubiquitous in higher plants. The alkaloids are sparsely distributed in plants and are specific to genus and species. Such narrow distribution of secondary metabolites forms basis of chemotaxonomy and chemical ecology. Because of the numerous biological activities of secondary metabolites, they have been used in traditional medicines for centuries.
In recent days, secondary metabolites correspond to value added products like cosmetics, fine chemicals or currently neutraceutics. Recent studies have well established that in pharmaceutical industries chemistry is said to be backbone, however about 25% molecule used in this industry have natural plant origin [5]. The secondary metabolite production requires large scale cultivation of medicinal plants. However, it is difficult to cultivate specific biotype away from their natural ecosystem. Sometime the common plants with pathogen sensitivity are unable to grow in large fields, for example anthracnose on *Arnica montana* and *Hypericum perforatum.* Due to this, plant cell, tissue and organ cultures become popular choice for production of secondary metabolites.

Different tissue culture techniques are being used for increase content of secondary metabolites by application of elicitors, alternation in environmental conditions and medium constituents etc.

Elicitors

An elicitor is a substance which, when introduced in small concentrations to a living cell system, it initiates or triggers the biosynthesis of specific compounds [6].

Classification of elicitors

Generally, elicitors are classified as physical or chemical, biotic or abiotic and complex or defined depending on their origin and molecular structure [6].

Biotic elicitors

Biotic elicitors are molecules of either pathogen or host origin that can induce defense responses (such as phytoalexin accumulation or hypersensitive response) in plant tissue. Often complex biological preparations have been used as elicitors, where the molecular structure of the active ingredients is unknown. Biotic elicitors can be classified on the basis of their exact molecular structure as follows: [7, 8].

A. Proteins and glycoproteins as elicitors

Proteins and enzymes are class of elicitors that trigger defense response e.g. in plant cell cultures. Cellulase causes rapid accumulation of phytoalexins, enhanced production of debneyol and capsidol in cell cultures of Nicotiana tabacum [9]. The glycoproteins are also involved in triggering of different phytoalexins in plant cell cultures. In cell cultures of *Plantanus acerifolia*, the coumarin concentration was increased due to application of glycoprotein in its native conformation extracted from a fungus *Ceratocystis fimbriata* cell suspension culture [10].

B. Oligosaccharides as elicitors

The oligosaccharides have shown to induce defense responses in plant cells. Like proteins, carbohydrates also act as chemical trigger i.e. elicitor to enhance the secondary metabolite production in cell suspension culture of plants. In Soybean cell cultures, the role of carbohydrates elicitors in accumulation of phytoalexin was observed [12]. The partial acid hydrolysis of mycelium of *Phytophthora gasperma* revealed involvement of eight oligosaccharides in phytoalexin production [12]. The oligosaccharides showing enhancement of secondary metabolites in cell cultures of plants are enlisted in Table 1.

C. Plant hormones as elicitors

The hormones play an important role in plant defense mechanism against different environmental stresses. The plat hormones, Jasmonic acid (JA), salicylic acid (SA), derivatives and analogs of SA, Brassinosteroids act as elicitor and accumulates specific metabolites to trigger defense mechanism. They upregulate expression of plethora of defense genes in plants. The plant resistance to bacterial, fungal and viral pathogens is regulated by SA [14, 15]. while the resistance against insects is regulated by JA [16, 17]. JA derived elicitation results in to enhanced synthesis of various proteins via octadecanoic pathway [16, 17].

Abiotic elicitors

The abiotic elicitors have acquired less attention as compared to biotic elicitors [6]. They include different stress causing physical and chemical factors of abiotic origin like salt, metal etc. Treatment of rare earth metal lanthanum to *Taxus sp.* cell cultures resulted in tremendous increase in taxol content (280%) [18]. The other abiotic factors like salinity, heat, drought, mechanical wounding, UV irradiation also shown increased content of secondary metabolites in plants. For example, exposure of cell cultures of *Vaccinium corymbosum* enhanced production of non-volatile phenolic compounds [19].

Cell suspension cultures

Initially, it was stated that the undifferentiated cells like callus or cell suspension cultures will not be able to synthesize secondary products [20]. However, Zenk and co-workers demonstrated that the cell cultures of *Morinda citrifolia* yields about 2.5 g of anthraquinones [21]. This finding opened the door to a large community of *vitro* culturists who extensively studied the possible use of plant cell cultures for the production of secondary compounds of industrial interest (mainly pharmaceutics and dyes). For the establishment of *in vitro* cell lines promising individual plants are selected and callus culture established for them. Once calli are established then they can undergo somaclonal variation during subculture cycles. After a period of time (from several weeks to several years) genetic stability occurs and each callus can be considered as homogeneous cell aggregate, just as if it was derived from single cell cloning.

When genetic stability is reached, it is necessary to screen the different callus lines according to their aptitudes to provide an efficient metabolite production. Hence, each callus must be assessed separately for its growth speed as well as intracellular and extracellular metabolite concentrations i.e. growth and production kinetics. This allows an evaluation of the productivity of each cell line (mg of products g^{-1} of cell day^{-1} or mg of products l^{-1} day^{-1}) so that only the best ones will be taken to cell suspensions and reactor studies. The cell growth kinetics is usually in exponential curve; however, the secondary metabolites are produced during stationary or plateau phase. This meager production in initial stages is a result of allocation of more carbon for cell structure building and respiration i.e. primary metabolism when cells growth is very active. On the contrary, when cell growth reaches to stationary phase, the carbon flow is diverted from primary metabolism to secondary metabolism and enhances the process of secondary metabolites synthesis. During lag or log phases, the enzyme activities are generally absent or less but in plateau phase they start appearing. These observations lead researchers to predict possible biochemical differentiation of cell in plateau phase [5]. But, some secondary products like betalains and carotenoids are associated with growth of undifferentiated cells.

The cell suspension is the best biological material to study biosynthetic and metabolic pathways. As compared to callus, the recovery of individual cells in large quantities for isolation of enzymes is easier [22]. The studies on biosynthetic pathways helps to restrict enzyme activities (or expression of associated genes) in synthesis of potent metabolites. Such restriction steps can be altered by feeding the cells suspension cultures with a precursor compound of desired product. This phenomenon also has high risk of activation of feedback inhibition at other places on the pathway [23]. Among multiple traditional strategies employed for increased production of secondary metabolites, the elicitation is one of the most successful technique. The

elicitor compounds impose physical or chemical stresses on cell suspension cultures which triggers production of stress induced secondary metabolites which are not produced under normal conditions. This elicitation of cell suspension cultures involves both biotic and abiotic factors. The fungal and bacterial attacks are most efficient to trigger elicitation process and increase in content of secondary metabolites. Immobilization is also used in liquid culture system for enhancing metabolite production [24]. In this technique, plant cells are encapsulated with polymers like alginate, carrageenan's etc. which improves yield of desired metabolites [25]. This may be due to possible effect of polymers around the cell which may mimic tissue organization between cells. This is supposed to give rise to the so-called biochemical differentiation which favors the synthesis of secondary products [26]. The present review aimed to summarize information of different elicitors used for enhancement of secondary metabolites in cell suspension cultures.

Table 1: List of plants and their elicitors used to enhance secondary metabolites

No.	Plant name	Product	Elicitors	Reference
1	*Abrus precatorius*	Glycyrrhizin	*Aspergillus niger* and *Rhizopus stolonifer*	[27]
2	*Agrostis tenuis*	Jasmonic acid	Fungal Elicitor	[28]
3	*Ammi majus*	Scopoletin	*Enterobacter sakazaki*	[29]
4	*Ammi majus*	Coumarin Umbelliferon	*Phytophthora megasperma*, *Alternaria carthami*	[6]
5	*Apium graveolens*	Furocaumarin	*Sclerotinia sclerotiorum*	[30]
6	*Apium graveolens*	Furocaumarin	*Erwinia carotovora*	[31]
7	*Apium graveolens*	Furocaumarin	UV, CuSO4	[32]
8	*Arabidopsis*	Indoleglucosinolates, Camalexin	Thaliana fungal elicitor, Methyl Jasmonate, Salicylic acid	[33]
9	*Arabidopsis thaliana*	Indole-glucosinolates, camalexin	*Erwinia carotovora*	[33]
10	*Arabidopsis thaliana*	Anthocyanin	Jasmonic acid	[34]
11	*Arabidopsis thaliana*	Indole-glucosinolates and anthocyanins	Jasmonic acid	[35]
12	*Arabidopsis thaliana*	Anthocyanins	Jasmonic acid	[36]
13	*Arabidopsis thaliana*	Aliphatic glucosinolates	Jasmonic acid	[37]
14	*Arabidopsis thaliana*	Camalexin	Jasmonic acid	[38]
16	*Artemisia annua*	Artemisinin	Jasmonic acid	[39]
17	*Azadirachta indica*	Azadirachtin	*Anabaena* sp. and *Nosto carneum*	[40]
18	*Azadirachta indica*	Azadirachtin	Jasmonic acid, salicylic acid	[41]
19	*Azadirachta indica*	Azadirachtin	Cyanobacterial elicitor	[42]
20	*Boswellia serrata*	boswellic acid	PVP. *Fusarium*, Penicillin, *Mucor sp*. and yeast extract, NaCl, NaSO4, UV-C, light intensity	[43]
21	*Brugmansiasu aveolens*	Tropane alkaloids	*Spodoptera frugiperda*, Methyl jasmonate	[44]
22	*Calendula officinalis*	Oleanolic acid	*Trichoderma viride*, Pectin, Chitosen	[45]
23	*Camptotheca acuminate*	Indol alkaloid	Methyl Jasmonate	[46]
24	*Carthamus tinctorius*	A-tocopherol and pigment	*Trametes varsicolor*, *Mucor sp*., *Penicillium notatum*, *Rhizopus stolonifer*, and *Fusarium oxysporum* and abiotic (NaCl, $MgSO_4$, $FeSO_4$,and $FeCL_3$)	[47]
25	*Catharanthus roseus*	5'diesterase	*Alteromonas acleodii*, Alginate oligomers	[48]
26	*Catharanthus roseus*	Indol alkaloid	Methyl Jasmonate	[49]
27	*Citrus aurantium*	Chitin oligomers	Chitin	[50]
28	*Citrus grandis*	Limonene, Linalool	Chitosan	[51]
29	*Coleus blumei*	Rosmarinic acid	Yeast Elicitor	[52]
30	*Coleus forskolin*	Methyl jasmonate	Forskolin	[53]
31	*Cupressus lusitanica*	B-thujaplicin	Oligosaccharide, Methyl Jasmonate	[54]
32	*Dacus carota*	Methoxymellein, 4-hydroxybenzoic acid	Fungal elicitor	[55]
33	*Datura stramonium*	Alkaloids (tropane)	*Phytopthora megasperma*	[56]
34	*Daucus carota*	*Pythium aphanidermatum*	6-Methoxymellein; 4-hydroxybenzoic acid	[56]
35	*Daucus carota*	Furocaumarin	Unknown	[57]
36	*Digitalis lanata*	Flavonoids	Copper sulphate	[58]
37	*Dioscorea zingiberensis*	Diosgenin	*Fusarium*	[59]
38	*Drosera burmanii*	Plumbagin	Methyl jasmonate, yeast Extract and chitosan	[60]
39	*Eschscholzia californica*	Benzophenanthridines, sanguinarine	Methyl Jasmonate, Fungal Elicitor Puccinia	[61]
40	*Eschscholzia californica*	Benzo-phenanthridine	Fungal elicitor	[62]
41	*Eschscholzia californica*	Alkaloids	Yeast extract	[63]
42	*Euphorbia pekinensis*	Terpenoids	*Fusarium*	[64]
43	*Eurycoma longifolia*	Alkaloids	Chitosan, polyvinylpyrrolidone	[65]
44	*Ganoderma lucidum*	Ganoderic acid and Ganoderma polysaccharides	Fungal	[66]
45	*Ginkgo biloba*	Bilobalide and ginkgolides	Biotic	[67]
46	*Glehnia littoralis*	Furanocoumerin	Yeast extract	[68]
47	*Glehnia littoralis*	Furocaumarin	*Pseudomonas cichorii*, UV	[69]
48	*Glycine max*	Glyceollins, Apigenin, Genistein, luteolin	Glucan, Methyl Jasmonate	[70]
49	*Glycine max*	Lignin	Fungal Elicitor	[71]

50	*Glycyrrhiza glabra*	Soyasaponin, 5-deoxyflavonoid	Methyl Jasmonate	[72]
51	*Gossypium arboretum*	Gossypol	Jasmonic acid	[73]
52	*Gymnema sylvestre*	Gymnemic acid	*Aspergillus niger*	[74]
53	*Helianthus tuberosa*	Insulin	*Aspergillu sniger* and *Saccharomyces cerevisiae;*	
54	*Hyoscyamus muticus*	Solavetivone, rishitin, lubimin, Scopolamine	Salicylic acid	[76]
55	*Linum album*	Podophyllotoxin	Ag, Pb, Cd, Yeast	[77]
56	*Lithospermum erythrorthizon*	Shikonin, Rosmarinic acid	Polysaccharides, fungal elicitor, Methyl Jasmonate	[78, 79]
57	*Lycopersicon esculentum*	Scopoletin	Fungal elicitor, Methyl Jasmonate	[61]
58	*Medicago truncatula*	Beta-amyrin	Yeast elicitor	[80]
59	*Morinda citrifolia*	Anthraquinone	Chitin, Pectine	[81]
60	*Nicotiana attenuata*	Volatile terpenes	Jasmonic acid	[82]
61	*Nicotiana benthamiana*	Nicotine	Jasmonic acid	[83]
62	*Nicotiana plumbaginifolia*	Nicotine	Cellulase, Methyl Jasmonate	[84]
63	*Nicotiana tabacum*	Capsidiol, Debneyol, Scopolatin, Nicotine	Cryptogein	[85]
64	*Nicotiana tabacum*	Sesquiterpenecyclise, Chitinase, Proteinase inhibitor	Algal Elicitor	[86]
65	*Nicotiana tabacum*	Nicotine	Jasmonic acid	[87]
66	*Nicotiana tabacum*	Phenylpropanoids	Jasmonic acid	[88]
67	*Nicotiana tabacum*	Capsidol	Fungal elicitor	[89]
68	*Oryza sativa*	Momilactones, Sakuranetin, Phytocassans	N-acetylachitoheptaose, Methyl Jasmonate	[90, 91]
69	*Panax ginseng*	Saponins	Low energy ultrasound	[92]
70	*Panax ginseng*	Saponin	Oligogalacturonic acid Low energy ultra sound	[93, 94]
71	*Panax ginseng*	Ginsenosides	Methyl Jasmonate	[95]
72	*Panax ginseng*	Saponin	Chitosan	[94]
73	*Papaver somniferum*	Sanguinarine	Methyl jasmonate, Phenidone, Fungal elicitor	[96]
74	*Pastinaca sativa*	Furocaumarin	*Ceratocystis fimbriata*	[97]
75	*Pastinaca sativa*	Furocaumarin	*Phomacompanata*	[98]
76	*Phaseolus vulgaris*	Phaseolin	Fungal elicitor	[99]
77	*Pinelli aternata*	Alkaloids	*Pseudomonas sp., Enterobacter sp*.	[100]
78	*Pinustaeda*	Flavonoids and isoprenoids	Jasmonic acid	[101]
79	*Psoralea cinerea*	Furocaumarin	CuSO4	[102]
80	*Rhodiola sachalinensis*	Salidroside	*Aspergillus niger*	[103]
81	*Rubia tinctorum*	Anthraquinone	Fungal polysaccharides, Salicylic acid, Gibbrelic acid	[104]
82	*Ruta graveolens*	Furocaumarin	UV, *Rhodotula rubra*	[105]
83	*Ruta graveolens*	Furocaumarin	NaCl	[106]
84	*Salvia miltiorrhiza*	Ditepenoidtanshinones	Yeast elicitor	[107]
85	*Silybum marianum*	Silymarin	Yeast extract	[108]
86	*Solanum tuberosum*	Hydroxy-cinnamoyltyramins	*Phytophthora infestans*	[109]
87	*Taxus baccata*	Taxol	Vanadyl sulphate	[110]
88	*Taxus chinensis*	Trifluoroethyl salicylate	Taxuyunnanine C (Tc)	[111]
89	*Taxus chinensis*	Taxol	Fungal elicitation	[112]
90	*Taxus chinensis*	Taxol	Nitric oxide	[113]
91	*Taxus chinensis*	Taxane	Methyl jasmonate, Salicylic acid	[114]
92	*Taxus unnanensis*	Taxane	Oligogalacturonides	[115]
93	*Vaccinium corymbosum*	Nonvolatile phenolic compounds	UV B radiation	[19]
94	*Vanilla planifolia*	Vanillin	Acetone dried red (Beetperoxidase)	[116]
95	*Vitis vinifera*	Stilbene, resveratrol, Anthocyanins	Methyl Jasmonate, Ethylene	[117]
96	*Vitis vinifera*	Anthocyanin	Salicylic acid, Abscisic acid, Jasmonic acid, Manitol	[118]
97	*Eschscholzia Californica*	Macarpine	Salicylic Acid	[119]
98	*Lithospermum erythrorhizon*	Rosmarinic acid	Yeast extract, Methyl jasmonate	[120]
99	*Taxus chinensis*	Paclitaxel	Chitosan	[121]

Conclusion

Plants are well known source of pharmaceuticals but due to low yield, they are not economically feasible. In biodiversity conservation point of view, it is necessary to avoid destruction of medicinally important plants. To overcome these obstacles, cell suspension culture is one of the potential *in vitro* tissue culture techniques to get these metabolites in less time and high amount. In addition, it is proving that applications of biotic and abiotic elicitors can enhance production of these metabolites. Elicitation in plants has opened up opportunities for better understanding of the pathways leading to the production of novel plant metabolite and overproduction of defense compounds useful in the protection against plant pathogens. However, the mechanism involved in elicitation process is not yet fully understood. To unravel the potential elicitation process, the future efforts must consider all the aspects of biochemistry, molecular biology, microbiology, phytochemistry, pharmacognosy, and fermentation technology associated with secondary metabolite production.

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Mankar GD *et al.* (2021)
Notulae Scientia Biologicae
Volume 13, Issue 2, Article number 10936
DOI:10.15835/nsb13210936
Research Article

Morphological, physiological, and biochemical responses to NaCl-induced salt stress in mungbean (*Vigna radiata* L.) varieties

Ganesh D. MANKAR[1], Uttam R. WAYASE[1], Deepak B. SHELKE[2], Tukaram D. NIKAM[3], Rajkumar B. BARMUKH[1]*

[1]*Modern College of Arts, Science and Commerce (Autonomous), Post Graduate Research Centre, Department of Botany, Shivajinagar, Pune-5, Savitribai Phule Pune University, Pune-7, MS, India; gdmbotany@gmail.com; botanica5050@gmail.com; barmukhbotany@moderncollegepune.edu.in (*corresponding author)*
[2]*Department of Botany, Amruteshwar Arts, Commerce and Science College, Vinzar, Velha, Pune- 412213, MS, India dpk.shelke1@gmail.com*
[3]*Savitribai Phule Pune University, Department of Botany, Pune 411 007, MS, India; tdnikam@unipune.ac.in*

Abstract

Seventeen mungbean varieties [*Vigna radiata* (L.) R. Wilczek] were subjected to 100-400 mM salinity stress at the germination stage, and the indices of seed germination and early seedling growth were analysed. With the increasing salinity, seed germination and seedling growth attributes were affected in all varieties. Principal component analysis and hierarchical cluster analysis of varietal responses on the germination and seeding growth attributes at 400 mM NaCl separated seventeen varieties into four distinct clusters. Principal component analysis at lower salt stress levels indicated that the attributes of germination and early seedling growth are reliable to identify salt-tolerant mungbean varieties. In contrast, only germination attributes are reliable at higher salinity levels. Two salt-susceptible and salt-tolerant varieties were further assessed for NaCl-induced physiological and biochemical changes. Levels of proteins, secondary metabolites, osmolyte, and antioxidants were increased at lower salt concentrations but reduced at higher salt concentrations. Photosynthetic pigments decreased and membrane damage increased under salinity. Varieties that showed tolerance to salt stress can be used in salinity-affected agriculture fields after validating their salt tolerance in field experiments.

Keywords: antioxidants; germination; NaCl; osmolytes; photosynthetic pigments; secondary metabolites

Abbreviations: DW: dry weight; DPPH: 2,2-Diphenyl-1-picrylhydrazyl; FGP: final germination percentage; FW: fresh weight; GI: germination index; GRI: germination rate index; HCA: hierarchical cluster analysis; MCA: multiple correlation analysis; MDA: malondialdehyde content; PCA: principal component analysis; PC: proteins content; RL: root length; STI: salt tolerance index; SL: shoot length; SR: secondary roots; SV: seedling vigor; TGI: Timson germination index; %TWC: percent tissue water content; TPC: total phenolics content; TFC: total flavonoids content; PRC: total proline content; TSC: total sugars content; TFAA: total free amino acid content.

Received: 28 Mar 2021. Received in revised form: 04 Jun 2021. Accepted: 09 Jun 2021. Published online: 23 Jun 2021.
From Volume 13, Issue 1, 2021, Notulae Scientia Biologicae journal uses article numbers in place of the traditional method of continuous pagination through the volume. The journal will continue to appear quarterly, as before, with four annual numbers.

Introduction

Mungbean is an economically important pulse crop grown in many parts of the world. It is an important protein source rich in fibbers, amino acids, fatty acids, vitamins, and minerals. Salt stress is one of the major abiotic stress in mungbean production, which results in a decrease in growth and productivity (Nair *et al.*, 2019). Cations such as Na^+, Ca^{2+}, and Mg^{2+} and anions such as Cl^-, $SO4^{2-}$ and HCO^{3-} are the most common ions present in saline soil. Since the soils deteriorate due to Na^+ in particular and Na^+ and Cl^- both are toxic to plants, NaCl is considered the most critical salt (Yadav *et al.*, 2011). Excess NaCl in the surroundings and inside the cell impairs germination, morpho-physiological, photosynthetic, and biochemical processes and culminates in a threat to the plant's growth and survival (Sehrawat *et al.*, 2019).

Seed germination is an important agronomic and ecological process that determines the growth and productivity of higher plants. Screening of mungbean varieties at seed germination and early seedlings stage for stress tolerance is practical because plants are more susceptible to environmental stresses at the initial stages (Vibhuti *et al.*, 2015). Salinity adversely affects cellular and metabolic processes like photosynthesis, synthesis of proteins, nucleic acids, lipids, and carbohydrates, mechanisms detoxifying reactive oxygen species (ROS), and the levels of secondary metabolites (Parida and Das, 2005). Sustained seed germination, improved root and shoot growth, levels of photosynthetic pigments, and biochemical parameters confer salt tolerance during the initial phase of stand establishment. The crop varieties that are likely to have the mechanisms to avoid or tolerate salinity are precious and required for such harsh environments. Since mungbean varieties have performed differently under salinity stress (Nawaz *et al.*, 2020), a plant-based solution demands a thorough screening of tolerant crop varieties for better yield under a saline environment.

In light of this, the present investigation was undertaken with two objectives- i) identify mungbean varieties tolerant to salt stress during seed germination, and ii) analyse effects of NaCl salt stress on key physiological and biochemical parameters during seed germination and early seedling growth of salt-tolerant and salt-susceptible varieties.

Materials and Methods

Seed collection, growth, and treatment conditions

Healthy seeds of the following seventeen certified varieties of mungbean were procured: 'VBN(Gg)2' and 'VBN(Gg)3' (National Pulses Research Centre, Tamil Nadu Agricultural University, Vamban), 'IPM 401-3', 'IPM 302-2', 'IPM-2K-14-9', 'IPM 2-3', 'IPM 2-14', and 'IPM 99-125' (Indian Institute Of Pulse Research, Kanpur), 'PKU-AKM-4', 'PKU-AKM 12-28', 'PKU-AKM 8802', and 'PKV Greengold' (Pulses Research Unit, Akola), 'DGGV-2' (ICAR-Indian Institute for Pulses Research Regional Research Center, UAS Campus, Dharwad, Karnataka). The seeds of 'Utkarsha', 'Samrat', 'SML 668', and 'Swati 4' were collected from the local market.

Seeds were surface sterilized with 0.1% $HgCl_2$ for three min and subsequently washed five times with distilled water. Ten Seeds were set to germinate on a double-layered germination paper placed in sterile Petri plates (90 mm). The germination paper was moistened with 10 ml of 100 to 400 mM of NaCl solutions. The control was set by moistening the germination paper with 10 ml of distilled water. Petri plates were incubated in the dark at 25±2 °C for ten days. The experiment was performed in triplicate, and each replicate had ten seeds, and germination counts were taken on each day.

Germination attributes

After the germination run of ten days, seed germination was analysed by computing: final germination percentage (FGP), germination rate index (GRI), and germination index (GI) by following Kader (2005) and Timson germination index (TGI) as per Timson (1965).

Growth attributes

Five seedlings were randomly selected on the 11th day. Their growth was measured in terms of shoot length (SL), root length (RL), number of secondary roots (SR), fresh weight (FW), dry weight (DW), percent tissue water content (%TWC) as described by (Shelke *et al.*, 2017), and seedling vigour (SV) as per Abdul-Baki and Anderson (1973).

The multivariate analysis tools such as PCA and HCA are used to differentiate samples having different biological statuses, quality, and origin (Chunthaburee *et al.*, 2015). Therefore, PCA and HCA were used to identify stress-tolerant mungbean varieties. This analysis grouped seventeen varieties into clusters based on their responses under NaCl salt stress. STIs of attributes were subjected to PCA and HCA to evaluate the salt tolerance level in seventeen mungbean varieties. The salt tolerance indices (STIs) were calculated by dividing the value observed on an attribute under a given salinity level by the weight on the same attribute in control (Chunthaburee *et al.*, 2015).

Selection of varieties for photosynthetic and biochemical analysis

The most tolerant and susceptible varieties were selected for photosynthetic and biochemical analyses based on germination and growth attributes in all varieties. IC50 is the inhibitory concentration of salt at which the seed germination is inhibited by 50%. The IC50 treatment of salt stress in the most susceptible variety was used for further experiments along with one concentration below and above the IC50 concentration. Seeds were surface sterilized with 0.1% $HgCl_2$ for three min and subsequently washed five times with distilled water. Ten Seeds were set to germinate on a double-layered germination paper placed in sterile Petri plates (90 mm). The germination paper was moistened with 10 ml of 75, 100, and 125 mM NaCl solutions. The control was set by moistening the germination paper with 10 ml of distilled water. Seedlings were allowed to grow under controlled conditions (25±0.5 °C and 16:8 h Light: dark photoperiod) for up to ten days. After ten days, five seedlings were selected, and the shoots and roots of seedlings were harvested separately for further analysis. The experiment was performed in triplicate, and each replicate had ten seeds.

Photosynthetic pigments and biochemical analysis

The photosynthetic and biochemical parameters were estimated spectrophotometrically on a microprocessor-based UV-Vis spectrophotometer (Bioera, India).

Chlorophyll content was estimated by Arnon's (1949) method. The carotenoid content was estimated by Maclachlan and Zalik's (1963) method. The anthocyanins were estimated by Mancinelli's (1984) method. Protein content was estimated by the Lowry *et al.* (1951) method with bovine serum albumin (BSA) as a standard protein. Malondialdehyde (MDA) (nmol/g dry weight) was estimated by Heath and Packer's (1968)method. Total phenolics were estimated by Swain and Hillis's (1959)method, and gallic acid was used as a standard phenol. Total flavonoids were estimated by the Balbaa *et al.* (1974)method, and rutin was used as a standard flavonoid. The proline content was estimated by the Bates *et al.* (1973)method. Total amino acid content was estimated by Lee and Takahashi's (1966)method, and L-Serine was used as a standard amino acid. Total sugar content was estimated by Scott and Melvin's (1953) method, and D-glucose was used as a standard sugar. The radical scavenging activity (%RSA) was estimated using the Blois (1958) DPPH method.

Statistical analysis

All the experiments were performed with three replicates in a completely randomized block design (CRD). Each replicate had ten seeds. The data were analysed by one-way analysis of variance (ANOVA) using SPSS software version 20. Mean values of treatments were compared using Duncan's multiple range test (DMRT) at $P \leq 0.05$. The data were presented as a mean ± standard deviation. The PCA of salt tolerance indices (STIs) was performed using the PAST statistical package (Hammer *et al.*, 2001). Parameters that showed a higher contribution to PCA were subjected to HCA. Ward's complete linkage clustering method and squared Euclidean distance were used for HCA performed in SPSS software version 20.

Results and Discussion

Effect of salt stress on seed germination

The increasing salt concentration affected all the seed germination attributes (FGP, GI, GRI, and TGI) in all varieties. At 100 mM NaCl, FGP, GI, GRI, and TGI were reduced drastically in 'VBN(Gg)' up to 54%, 56%, 61%, and 56%, respectively. Relatively lesser reductions were observed in all germination parameters in 'IPM 401-3', 'IPM 302-2', 'IPM 99-125', 'PKU-AKM 12-28', 'PKV Greengold', 'DGGV-2', 'PKU-AKM 4', 'PKU-AKM 8802', and 'Samrat'. These varieties showed the highest FGP (100%). 'PKV Greengold' had the highest GRI, GI, and TGI (100%) among those varieties that germinated at 100 mM NaCl. At 200 mM NaCl, 'VBN (Gg)3' showed a significant reduction of 84.61%, 90.47%, 94.49%, 90.47% in FGP, GI, GRI, TGI, respectively. However, 'PKV Greengold', 'PKU-AKM 4', 'PKU-AKM 8802', 'IPM 302-2', and 'Swati-4' showed less reduction without any significant difference. At 300 mM, more than 50% reduction in germination was observed in 'IPM 2-3', 'DGGV-2', 'PKU-AKM 4', 'Swati 4', 'IPM 99-125', and 'VBN(Gg)2'. The highest germination (FGP) was observed in 'PKU-AKM 8802' (96.66%), followed by 'PKU-AKM 12-28' (76.66%). These two varieties showed the highest GI, GRI, and TGI. At 400 mM NaCl, only seed germination indices were calculated. 'VBN(Gg)2' and 'VBN(Gg)3' did not germinate at this highest salt-stress level. Less reduction in FGP was observed in 'PKU-AKM 8802' (46.6%), followed by 'PKU-AKM 12-28' (50%). GI and TGI were reduced by 70.66% in 'PKU-AKM 12-28' and 64.66% in 'PKU-AKM 12-28'. A higher reduction in GI and TGI was observed in all other varieties.

FGP, GI, GRI, and TGI are helpful to analyse the effects of stress on seed germination (Kader, 2005). Reduced seed germination resulted in weak growth and development in 'VBN(Gg)3' and 'VBN(Gg)2' and reflected a crucial determinant for salinity tolerance. Salinity affects water and nutrient uptake during seed germination by creating osmotic and ionic imbalances that reduce germination potential (Pandey and Penna, 2017). Podder *et al.* (2020) have reported a similarly reduced mungbean germination under salinity. Decreased seed germination with increased salt concentration was also reported in wheat (Bagwasi *et al.*, 2020) and rice (Öner *et al.*, 2020). Therefore, germination attributes are the most critical and valuable attributes that reflect time, rapidity, uniformity, and synchronization in seed germination under salt stress.

Effect of salt stress on seedling development

Salt stress causes a detrimental effect on root growth as roots are directly in contact with salt. Root growth directly correlates with other seedling growth attributes such as shoot length, secondary root, and biomass production. Early seedling growth parameters such as SL, RL, SR, SV, FW, DW, and %TWC are helpful attributes for screening salt-tolerant varieties since these attributes are also affected by salinity (Shelke *et al.*, 2017). Various early seedling growth parameters such as SL, RL, SR, SV, FW, DW, TWC% were affected by salt stress. At 100 mM NaCl, SL was reduced by more than 50% in all varieties screened, but a severe reduction was observed in 'IPM 401-3', 'IPM-2K-14-9', and 'Swati-4'. The RL was more reduced in 'PKU-AKM 4' than 'PKV Greengold'. Seedling vigor was dramatically reduced by more than 70% in 'VBN (Gg)3' and 'IPM-2K-14-9', and up to 34% reduction was observed in 'PKV Greengold' and 'IPM995'. SR was reduced by nearly 70% in I'PM 2-14' and 'Swati-4'. More than 50% reduction in FW was observed in almost all varieties. Moreover, a more significant reduction in FW and DW was noted in 'DGGV-2'. TWC was reduced by 2-7%.

At 200 mM NaCl, 84 to 94% reduction in SL was observed in all varieties. 'VBN (Gg)3', 'IPM 2-3', and 'IPM 2-14' showed more than 83% reduction in root length than other varieties. More than 80% reduction in SV was observed in all varieties; however, 'VBN (Gg)3' showed the highest reduction (98%). Secondary roots were not developed in 'VBN(Gg)2', 'VBN(Gg)3', 'IPM 401-3', 'IPM 2-3', 'IPM 2-14', 'PKV Greengold', 'PKU-AKM 4', and 'Samrat'. FW was reduced up to 84-96%. Among these varieties, 'DGGV2' had the least, and 'Swati-4' had a maximum reduction in FW. DW was reduced by 68-91%, with a greater reduction in 'Swati-4' among all varieties screened. TWC% was less reduced in 'DGGV2' than other varieties. A greater reduction in TWC% was observed in 'Swati-4'. At 300 mM NaCl, all the varieties screened showed SL and RL reduced by

up to 90%. There was not a significant difference in SL and RL in all the varieties. However, SV was less reduced in 'PKU-AKM 8802' and 'PKU-AKM 12-28' compared to other varieties. At 300 mM, FW was reduced to 95-97% in all varieties without significant differences in FW. The DW was reduced by 7-11% in all varieties. TWC% was reduced between 80-94% except in Utkarsha, which showed up to 66% reduction. At 400 mM NaCl, SL, RL, and SV were not measurable due to poor seedling growth, and only germination indices were the key parameters. At 400 mM NaCl, FW, DW, and TWC% could not be calculated.

These results corroborate those by (Rahneshan *et al.*, 2018) in *Pistacia vera*. The number of secondary roots (SR) differed in different varieties at low salt concentrations. SR was poorly developed in a few varieties with the increased salt concentration. In few varieties, SR was not developed at and above 300 mM NaCl salt stress. The number of secondary roots decreased with increased salinity in soybean varieties and was a deterministic feature under salinity (Shelke *et al.*, 2017). SV was reduced in all varieties at low salinity levels. However, it was reduced by more than 70% in all varieties at 200 mM NaCl. At higher salt concentrations, the differences in the reduction observed in all the varieties were negligible. The highest reduction was observed in 'VBN(Gg)3'. A similar decrease in SV was observed in rice varieties subjected to salt stress (Datir *et al.*, 2020). Seedling fresh weight, dry weight, and tissue water content reduced with increasing salt concentration. The reduction in these attributes affects the absorption of water and essential minerals. It also reduces root pressure, water, and mineral flow, and their transport from root to shoot, and thus the growth and development of plants (Liu *et al.*, 2020). Our results are in line with Rahman *et al.* (2016), who have reported a variety-dependent reduction in SL, RL, DW, FW, and SV with increased salinity. These, therefore, appear to be deterministic features in mungbean varieties as well. A similar result was reported in rice (Datir *et al.*, 2020) and soybean (Shelke *et al.*, 2017).

In summary, a stepwise increase in salinity caused a progressive reduction in seed germination and affected early seedling growth parameters in all mungbean varieties screened in the present investigation. These varieties showed varied responses to salinity stress from low to high salinity levels. For example, at 100 mM NaCl, the 'Samrat' variety was resistant, but it was salt-susceptible at a higher level of 400 mM NaCl. At 100 mM and 200 mM NaCl, germination parameters such as FGP, GI, TGI, GRI, and early seedling growth parameters such as SV, RL, SL, SR, FW, DW, and %TWC are vital parameters to assess salinity responses in different varieties and can be used alternatively. However, at higher salinity levels of 300 mM and 400 mM, only germination parameters such as FGP, GI, TGI, and GRI are critical to assess salt-tolerance response because of poor SL and RL in seedlings. Further, SL, RL, FW, DW, SV were reduced by more than 80% at and above 200 mM NaCl, and SR was absent at and above 300 mM NaCl in all varieties. 'VBN(Gg)3' was highly susceptible at all salinity levels, and it did not germinate at and above 300 mM NaCl. Likewise, 'VBN(Gg)2' also did not germinate at 400 mM NaCl. PKU-AKM 12-28 showed the highest tolerance at all salinity levels.

The results showed significant differences in germination indices across varieties subjected to 400 mM NaCl stress (Table 1). PCA and HCA analyses were performed using germination indices of seedlings of seventeen mungbean varieties exposed to 400 mM NaCl (Table 2) to discriminate them based on their tolerance levels. FGP, GRI, GI, and TGI are essential to understand time, rapidity, uniformity, rate, and synchronization of seed germination (Kader, 2005). The higher the FGP, the higher is the population size. Higher GI is shown by seeds having a greater germination percentage and also a high rate of germination. Thus, if seed germination is higher and faster, it results in a better GRI (Kader, 2005). The Timson germination index (TGI) is an important and widely used parameter to assess the seed germination rate (Timson, 1965). 'VBN(Gg)3' and 'VBN(Gg)2' did not germinate at this salt stress level, and hence their germination indices were zero, while 'PKU-AKM 12-28' and 'PKU-AKM 8802' showed the highest germination indices due to their salt-tolerant nature.

Table 1. Seed germination parameters in seventeen mungbean varieties under control and 400 mM NaCl stress

Variety	NaCl (mM)	FGP (%)	GI	GRI	TGI
'VBN(Gg)2'	0	86.67 ± 5.77	41.67 ± 3.06	7.83 ± 1.04	83.33 ± 6.11
	400	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
'VBN(Gg)3'	0	86.67 ± 5.77	42.00 ± 1.73	8.07 ± 0.12	84.00 ± 3.46
	400	0.00 ±0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
'IPM 401-3'	0	100.00 ±0.00	43.00 ± 0.58	7.17 ± 0.00	86.00 ± 0.00
	400	33.33 ± 5.77	13.00 ± 1.73	1.56 ± 0.10	26.00 ± 3.46
'IPM 302-2'	0	100.00 ±0.00	50.00 ± 0.00	10.00 ±0.00	100.00 ± 0.00
	400	33.33 ±15.28	11.33 ± 4.93	1.36 ± 0.63	22.67 ± 9.87
'IPM-2K-14-9'	0	90.00 ±10.00	42.33 ± 4.16	8.36 ± 0.55	84.67 ± 8.33
	400	33.33 ± 5.77	8.67 ± 2.08	1.00 ± 0.22	17.33 ± 4.16
'IPM 2-3'	0	100.00 ±0.00	47.67 ± 0.58	8.83 ± 0.29	95.33 ± 1.15
	400	23.33 ±11.55	4.67 ± 2.31	0.58 ± 0.29	9.33 ± 4.62
'IPM 2-14'	0	100.00 ±0.00	46.67 ± 2.52	9.08 ± 0.52	93.33 ± 5.03
	400	30.00 ±10.00	7.33 ± 0.58	0.95 ± 0.14	14.67 ± 1.15
'IPM 99-125'	0	100.00 ±0.00	44.67 ± 0.58	7.33 ± 0.29	89.33 ± 1.15
	400	33.33 ±15.28	14.00 ± 2.65	2.08 ± 0.14	28.00 ± 5.29
'PKU-AKM 12-28'	0	100.00 0.00	50.00 ± 0.00	10.00 ±0.00	100.00 ± 0.00
	400	50.00 ±17.32	14.67 ± 4.04	1.75 ± 0.50	29.33 ± 8.08
'PKV Greengold'	0	100.00 ±0.00	50.00 ± 0.00	10.00 ±0.00	100.00 ± 0.00
	400	13.33 ± 5.77	5.67 ± 2.89	0.94 ± 0.77	11.33 ± 5.77
'DGGV-2'	0	100.00 ±0.00	50.00 ± 0.00	10.00 ±0.00	100.00 ± 0.00
	400	36.67 ± 5.77	15.33 ± 2.08	2.22 ± 0.19	30.67 ± 4.16
'PKU-AKM-4'	0	100.00 ±0.00	5]0.00 ± 0.00	10.00 ±0.00	100.00 ± 0.00
	400	10.00 ± 0.00	4.33 ± 0.58	0.50 ± 0.00	8.67 ± 1.15
'PKU-AKM 8802'	0	100.00 ±0.00	50.00 ± 0.00	10.00 ±0.00	100.00 ± 0.00
	400	53.33 ±11.55	17.67 ± 5.77	2.03 ± 0.82	35.33 ± 11.55
'Utkarsha'	0	96.67 ± 5.77	39.00 ± 3.00	6.14 ± 0.76	78.00 ± 6.00
	400	30.00 ±10.00	6.67 ± 3.06	0.81 ± 0.34	13.33 ± 6.11
'SML 668'	0	100.00 ±0.00	48.00 ± 1.00	9.00 ± 0.50	96.00 ± 2.00
	400	20.00 ±10.00	4.67 ± 1.53	0.56 ± 0.21	9.33 ± 3.06
'Swati 4'	0	100.00 ±0.00	47.33 ± 0.58	8.67 ± 0.29	94.67 ± 1.15
	400	26.67 ± 5.77	5.33 ± 1.15	0.67 ± 0.14	10.67 ± 2.31
'Samrat'	0	100.00 ±0.00	49.67 ± 0.58	9.83 ± 0.29	99.33 ± 1.15
	400	6.67 ± 11.55	1.67 ± 2.89	0.23 ± 0.40	3.33 ± 5.77

FGP: final germination percentage, GI: germination index**,** GRI: germination rate index**,** TGI: Timson germination index. (Values represent mean± standard deviation)

The germination indices were converted to STIs (Table 2) subjected to PCA and HCA. The PCA (Figure 1) showed the discrimination of varieties. PC1 and PC2 described 95.42% and 3.82% of the variance. The eigenvalue of PC1 and PC2 constituted 3.82% and 0.15% of the variation, respectively. PC1 positively correlated with GI (0.99), TGI (0.99), GRI (0.97), and FGP (0.95). PC2 had a positive correlation with only FGP (0.31), and all other parameters showed a negative correlation. The 'PKU-AKM 8802', 'PKU-AKM 12-28', 'DGGV-2', 'IPM 99-125', and 'IPM 401-3' ranked positively with PC1 due to higher germination parameters, whereas 'VBN(Gg)3', 'VBN(Gg)2', and 'Samrat' ranked negatively where all the parameters were suppressed. The STIs of GI, TGI, GRI, and FGP ranged between 0.00 to 0.35, 0.00 to 0.35, 0.00 to 0.22, and

0.00 to 0.53, respectively. The 'VBN(Gg)2' failed to germinate at this NaCl concentration. The highest STIs for germination parameters were observed in 'PKU-AKM 12-28' and 'PKU-AKM 8802'.

Table 2. Stress tolerance indices (STIs) of seed germination parameters of seventeen mungbean varieties under 400 mM NaCl salt stress

Variety	FGP	GI	GRI	TGI
'VBN(Gg)2'	0	0	0	0
'VBN(Gg)3'	0	0	0	0
'IPM 401-3'	0.33	0.3	0.22	0.3
'IPM 302-2'	0.33	0.23	0.14	0.23
'IPM-2K-14-9'	0.37	0.2	0.12	0.2
'IPM 2-3'	0.23	0.1	0.07	0.1
'IPM 2-14'	0.3	0.16	0.1	0.16
'IPM 99-125'	0.4	0.31	0.28	0.31
'PKU-AKM 12-28'	0.5	0.29	0.18	0.29
'PKV Greengold'	0.13	0.11	0.09	0.11
'DGGV-2'	0.37	0.31	0.22	0.31
'PKU-AKM 4'	0.1	0.09	0.05	0.09
'PKU-AKM 8802'	0.53	0.35	0.2	0.35
'Utkarsha'	0.31	0.17	0.13	0.17
'SML 668'	0.2	0.1	0.06	0.1
'Swati 4'	0.27	0.11	0.08	0.11
'Samrat'	0.07	0.03	0.02	0.03

(FGP: final germination percentage, GI: germination index, GRI: germination rate index, TGI: Timson germination index)

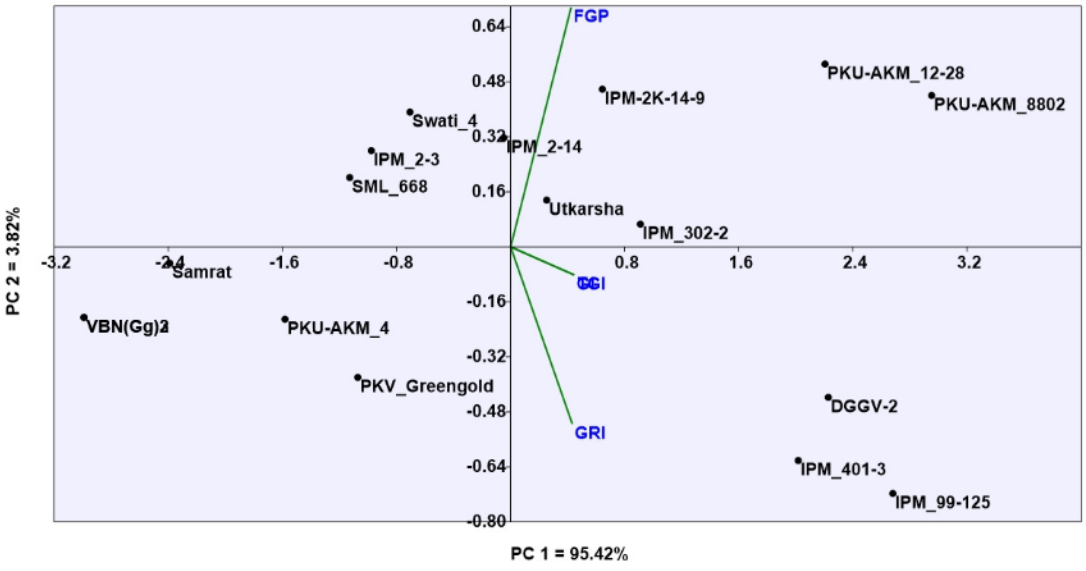


Figure 1. Biplot of principal components 1 and 2 of the PCA obtained from germination data on seventeen mungbean varieties exposed to 400 mM NaCl

FGP: final germination percentage, GI: germination index, GRI: germination rate index, TGI: Timson germination index.

PCA results were further confirmed by cluster analysis, which was performed on parameters responsible for most of the variation accounted for by PC1 and PC2. At 400 mM NaCl, SL, RL, and SV were not measurable due to poor seedling growth. Only germination indices were the key parameters to separate all varieties into four clusters at the highest salinity level (400 mM NaCl) (Fig 2). The 'VBN(Gg)2', 'VBN(Gg)3', and 'Samrat' from cluster I represent a highly susceptible group of varieties with low germination indices. 'IPM 2-14', 'Utkarsha', 'IPM 302-2', and 'IPM-2K-14-9' separated in cluster II represented moderately susceptible varieties. In contrast, 'IPM 2-3', 'SML 668', 'Swati 4', 'PKV Greengold', and 'PKU-AKM-4' separated in cluster III are moderately tolerant varieties. This separation is because of better germination indices in cluster II than cluster III. The 'PKU-AKM 12-28', 'PKU-AKM 8802', 'IPM 401-3', 'DGGV-2', and 'IPM 99-125' varieties separated in cluster IV represent salt-tolerant varieties with higher germination compared to all other clusters.

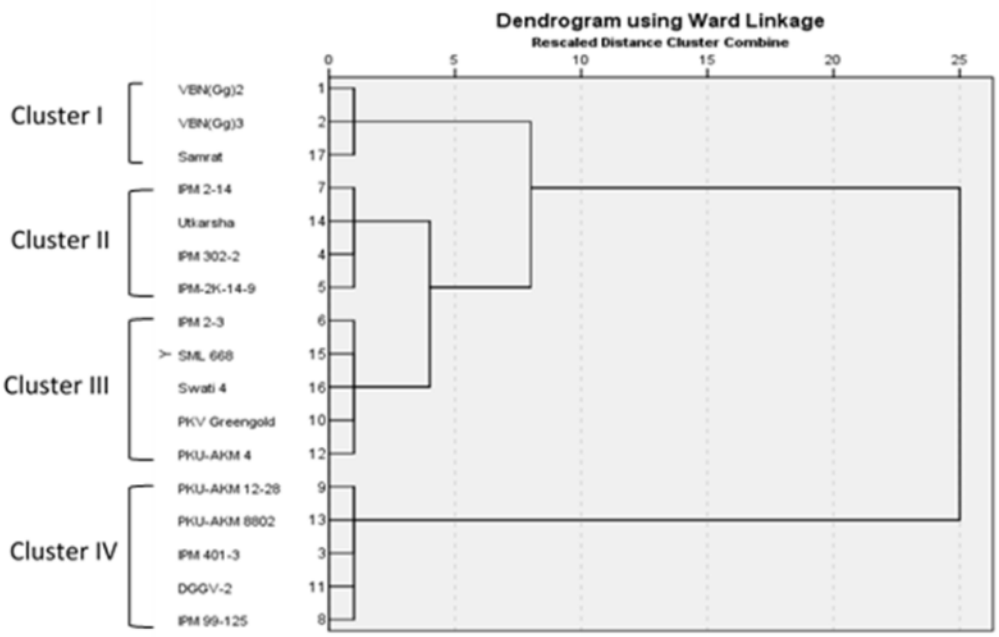


Figure 2. Hierarchical cluster analysis based on germination parameters on seventeen mungbean varieties subjected to 400 mM NaCl stress

Effect of salt stress on photosynthetic and biochemical attributes at early seedling growth in mungbean varieties

Two salt susceptible varieties ('VBN (Gg)3' and 'VBN (Gg)2') and two salt-tolerant varieties ('PKU-AKM 12-28' and 'PKU-AKM 8802') were selected to explore the salt-responsive photosynthetic and biochemical attributes at early seedling growth. These varieties were subjected to 75, 100, and 125 mM NaCl stress, and various photosynthetic and biochemical parameters in shoot and root biomass were measured.

Effect of salt stress on photosynthetic pigments

Salinity alters photosynthetic, biochemical, physiological, and metabolic processes, the extent of which varies with the level of stress and ultimately limits crop productivity (Shahid *et al.*, 2020). Plant growth is severely affected due to alteration in photosynthesis. Photosynthesis is hampered under salinity stress due to a reduction in chlorophyll contents or synthesis (Shin *et al.*, 2020).

In the present study, amounts of photosynthetic pigments, carotenoids, and anthocyanins were significantly reduced under salt stress (Figure 3A-3E). Damage to the photosynthetic pigments increased with the increasing salt concentration (Figure 3A-3E) and the 125 mM NaCl stress was the most damaging. These results corroborate those by Datir *et al.* (2020) in wheat and Regni *et al.* (2019) in olive. Low chlorophyll

content observed in mungbean plants under salinity may be associated with increased oxidative stress (Regni *et al.,* 2019) and the activation of chlorophyll degradation by the chlorophyllase enzyme (Datir *et al.*, 2020).

Salinity also affected carotenoid contents in mungbean varieties. Carotenoid levels were relatively less affected in 'PKU-AKM 12-28' at 75 and 100 mM NaCl concentration (Figure 3D). At the highest salinity stress level, the maximum reduction in carotenoids was observed in 'VBN(Gg)3'. Similar results were reported by Romanenko *et al.* (2017) in the alga *Acutodesmus dimorphus*. The enhanced carotenoid content improved salt tolerance in VBN(Gg)2. This result confirms carotenoid's potential role as antioxidants to detoxify ROS effects in plants during salinity stress (Verma and Mishra, 2005).

Literature is meager on anthocyanin levels in the vegetative tissue under salt stress. Anthocyanin content was marginally high in 'PKU-AKM 12-28' at 125 mM NaCl, whereas the other three varieties showed a 30-35% decrease in anthocyanin content (Figure 3E). High anthocyanin content was shown to induce an active protective response in *Oryza sativa* under salinity stress (Chutipaijit *et al.*, 2009). Eryilmaz (2006) had observed that chlorophyll content decreases, whereas anthocyanin content is elevated in different parts of seedlings under salinity. In sorghum, Jeon *et al.* (2020) have reported an increased anthocyanin production in salt-tolerant genotype 'Nampungchal' and reduced anthocyanin levels in the salt-susceptible 'Sodamchal' genotype. The mechanism of anthocyanin biosynthesis under salt stress is poorly understood and needs to be explored in detail (Eryilmaz, 2006).

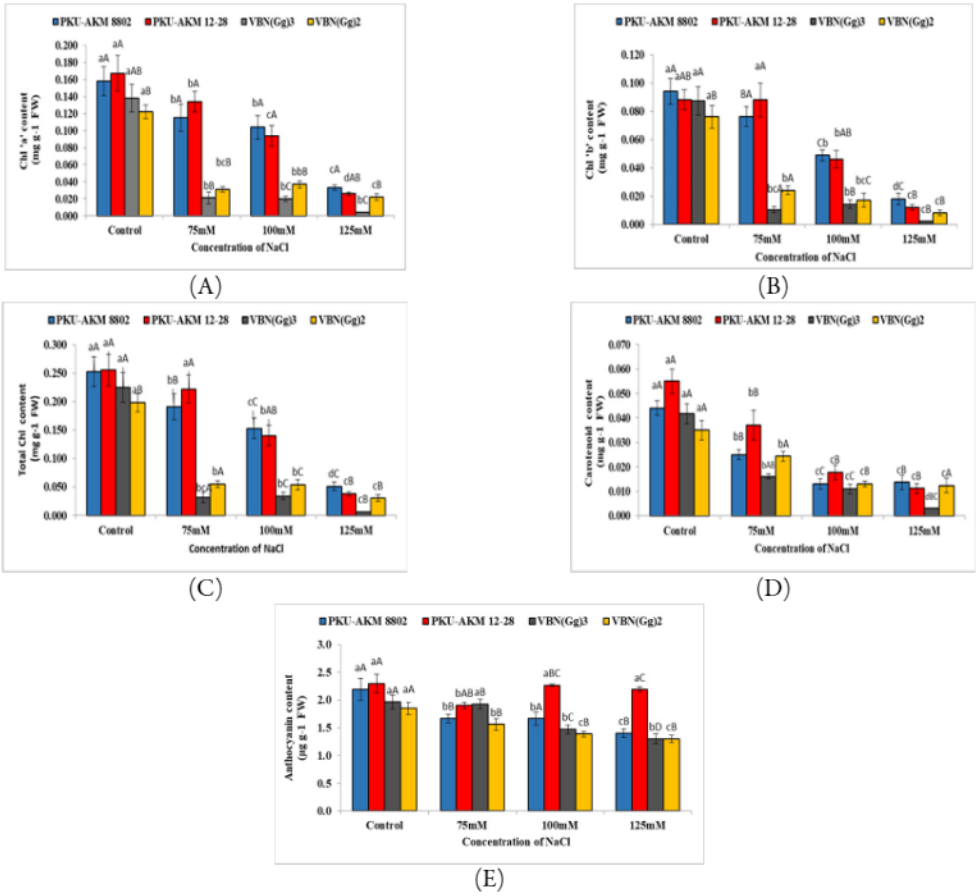
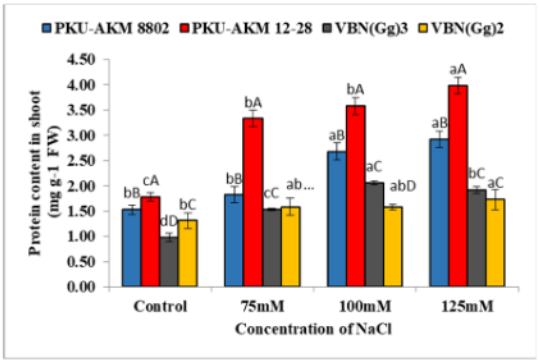


Figure 3. Effect of salt stress on plant pigments of 10-day old seedlings of *Vigna radiata* varieties
A) Chlorophyll 'a'; B) Chlorophyll 'b'; C) Total chlorophyll; D) Carotene and E) Anthocyanin content. Each value represents the mean of three replicates, and the vertical bar indicates the standard deviation. Small letters denote significant difference between treatments, and capital letters denote significant difference between varieties at a 0.05% significance level as per Duncan's Multiple Range Test (DMRT)

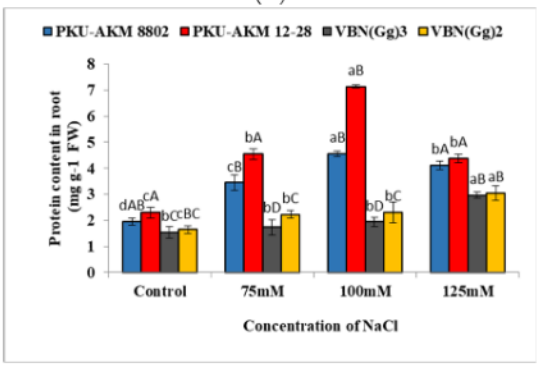
Effect of salt stress on protein content

The biochemical attributes were indeed influenced by increasing salt concentration in the selected four varieties. Protein content was increased upon exposure to salt stress in all varieties. Shoot protein content increased significantly under salt stress in 'PKU-AKM 12-28' (1.01-fold and 1.23-fold), followed by 'PKU-AKM 8802' (0.75 and 0.91-fold) at 100 and 125 mM NaCl concentration, respectively (Figure 4A). In 'VBN (Gg)2' and 'VBN (Gg)3', protein content increased relatively less compared to control at the highest salt concentration. In 'VBN (Gg)3', protein content increased at 100 mM NaCl but decreased at 125 mM NaCl.

Root protein was increased dramatically in 'PKU AKM 12-28' (2.1-fold) and 'PKU-AKM 8802' (1.32-fold) at 100 mM NaCl compared to 'VBN (Gg)2' (41%) and 'VBN (Gg)3' (0.26-fold) (Figure 4B). Protein content was high at all NaCl concentrations in 'PKU AKM 12-28' and 'PKU-AKM 8802'. The higher protein content in susceptible varieties could be due to enhanced detoxification pathways (Alharby *et al.*, 2019). Under salinity, plants significantly increase the levels of proteins such as photosynthetic pathway proteins, enzymes involved in scavenging ROS and osmolyte biosynthesis, late embryogenesis abundant proteins (LEA proteins), and membrane proteins, and carbohydrate and energy metabolism proteins (Arif *et al.*, 2020).



(A)



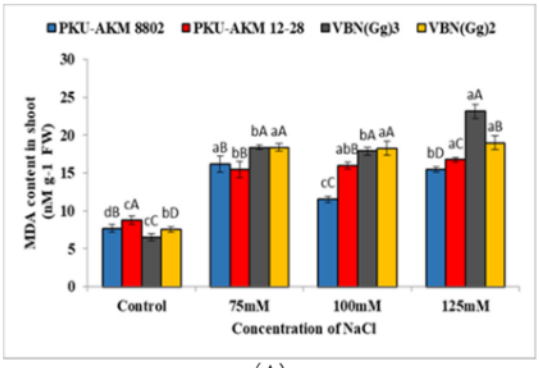
(B)

Figure 4. Effect of salt stress on the protein content of 10-day old seedlings of *Vigna radiata* varieties
A) Shoot protein content and B) Root protein content. Each value represents the mean of three replicates, and the vertical bar indicates the standard deviation. Small letters denote significant difference between treatments, and capital letters denote significant difference between varieties at a 0.05% significance level according to Duncan's Multiple Range Test (DMRT)

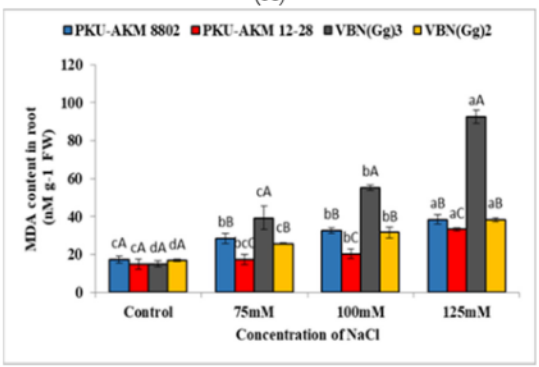
Effect of salt stress on lipid peroxidation

MDA, an output of oxidative stress and membrane damage, was used to measure the intensity of membrane damage in shoots and roots exposed to salinity stress (Campo *et al.*, 2014). Untreated normal seedlings have lower MDA content due to relatively less membrane damage caused by reactive oxygen species (ROS) generated as a by-product of plant aerobic metabolism. Various environmental stresses result in excessive ROS production, causing progressive oxidation of membranes (Sharma *et al.*, 2012), and therefore,

elevated MDA levels. Increased salt concentrations elevated the MDA content in mungbean, and it can be used as a vital biomarker to discriminate crop varieties. Membrane damage increased with increasing salt concentration from 75-125 mM NaCl. In the shoot, MDA content was significantly increased in 'VBN (Gg)2' by 1.43-fold and by 1.81-fold in 'VBN (Gg)3' as compared to 'PKU-AKM 12-28' (0.7-fold) and 'PKU-AKM 8802' (1.1-fold) at 75 mM NaCl. Further, it increased in 'VBN (Gg)3' by 2.53-fold than in 'PKU-AKM 12-28' at 125 mM NaCl (Figure 5A). In the root, the highest MDA content was found in 'VBN (Gg)3', which was increased by 5.14-fold compared to other varieties, which showed a nearly 1.2-1.3-fold increase in MDA at 125 mM NaCl (Figure 5B). Such an increase in MDA content with increasing salt concentrations was also observed more in the sensitive wheat genotype than the tolerant ones (Datir *et al.*, 2020).



(A)



(B)

Figure 5. Effect of salt stress on lipid peroxidation (in terms of MDA content) in 10-day old seedlings of *Vigna radiata* varieties

A) Shoot MDA content and B) Root MDA content. Each value represents the mean of three replicates, and the vertical bar indicates the standard deviation. Small letters denote significant difference between treatments, and capital letters denote significant difference between varieties at a 0.05% significance level according to Duncan's Multiple Range Test (DMRT)

Effect of salt stress on phenolics, flavonoids, and antioxidants

Natural antioxidants such as phenolic and flavonoid compounds play an essential role under stress. These metabolites have various biological functions in plants, the significant being protection from ROS generated under various environmental stresses such as salt stress (Khare *et al.*, 2020). The elevated levels of phenolics and flavonoids observed in the present investigation support the observations by (Bistgani *et al.*, 2019). These secondary metabolites act as antioxidants, mitigate oxidative stress, and scavenge the reactive oxygen species (ROS)(Selmar and Kleinwächter, 2013). Phenolic content in shoot and root was increased in 'PKU AKM 12-28' and 'PKU-AKM 8802' compared to 'VBN (Gg)2' and 'VBN (Gg)3' at 125 mM NaCl (Figure 6A). It was increased in the root of 'PKU AKM 12-28' and 'PKU-AKM 8802' by 24% and decreased in 'VBN (Gg)2' and 'VBN (Gg)3' by 38% and 63%, respectively, at 125 mM NaCl. However, 'VBN (Gg)3'

showed increased phenolic content at 100 mM NaCl in the root (Figure 6B). In the shoot, flavonoid content increased in 'PKU AKM 12-28' by 14% and 'PKU-AKM 8802' by 33% but decreased in 'VBN (Gg)2' by 53% and 'VBN (Gg)3' by 35% at 75 mM NaCl. However, it was decreased in all varieties at 125 mM NaCl by 41-52% (Figure 6C). In the root, flavonoid content increased in 'PKU-AKM 12-28' by 96% and decreased in 'VBN (Gg)2' by 57% at 100 mM NaCl. At 125 mM NaCl, it was significantly reduced in 'VBN (Gg)2' and 'VBN (Gg)3' compared to 'PKU-AKM 12-28' and 'PKU-AKM 8802' (Figure 6D). Such an increase in these secondary metabolites in salt-tolerant varieties was also reported by Chutipaijit *et al.* (2009) in salt-tolerant rice varieties than salt-sensitive ones.

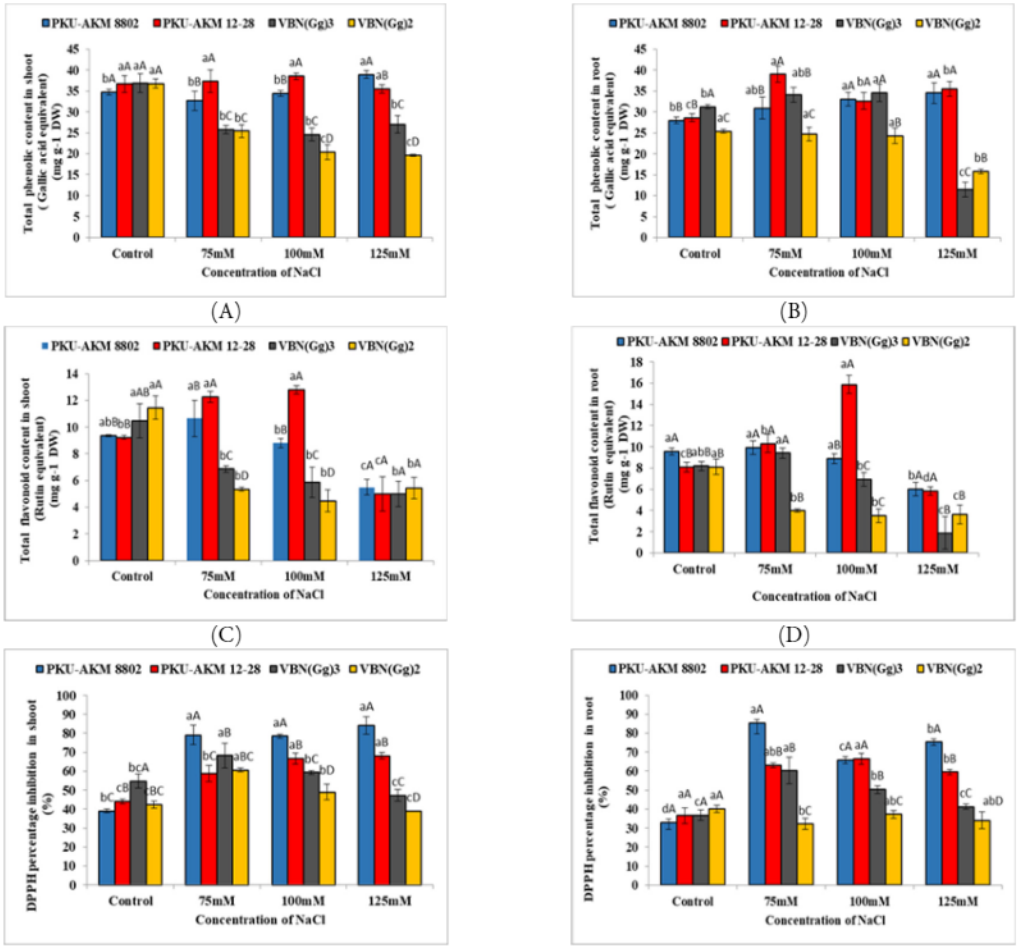


Figure 6. Effect of salt stress on phenol and flavonoid content and antioxidants of 10-day old seedlings of *Vigna radiata* varieties

A) Shoot phenolic content; B) Root phenolic content; C) Shoot flavonoids content; D) Root flavonoids content; E) Shoot DPPH radical scavenging activity and F) Root DPPH radical scavenging activity. Each value represents the mean of three replicates, and the vertical bar indicates the standard deviation. Small letters denote significant difference between treatments, and capital letters denote significant difference between varieties at a 0.05% significance level according to Duncan's Multiple Range Test (DMRT)

Where phenolic and flavonoid content correlates with antioxidant nature, DPPH assay is a nonenzymatic antioxidant activity which is a direct and sensitive method to investigate savaging of ROS by antioxidants (Golkar *et al.*, 2020). In the present study, DPPH radical scavenging activity significantly increased in both shoot and root as the salt concentration increased from 75-125 mM NaCl in 'PKU-AKM

12-28' and 'PKU-AKM 8802' (Figure 6E-6F). However, it was initially increased at 75 and 100 mM NaCl and later decreased at 125 mM NaCl in 'VBN (Gg)2' and 'VBN (Gg)3'. However, DPPH radical scavenging was higher in 'PKU-AKM 8802' than 'VBN (Gg)2' at all salt concentrations. In this regard, the increase in DPPH activity under salt stress corroborates with studies in chickpea (Kaur *et al.*, 2014).

Effect of salt stress on osmolyte accumulation

High accumulation of different osmolytes like proline, amino acids, and total sugars was observed in the mungbean varieties exposed to NaCl stress (Figure 8). In the shoot, proline content was significantly higher in 'PKU-AKM 12-28' and 'PKU-AKM 8802' than 'VBN (Gg)2' and 'VBN (Gg)3'. At 125 mM NaCl, the highest increase in proline content in the shoot was found in 'PKU-AKM 12-28' (by 5.48-fold) and in 'VBN (Gg)3' (by 1.25-fold) (Figure 7A). At 125 mM NaCl, proline content was significantly increased by 3.26-fold in the roots of 'PKU-AKM 12-28', whereas in the roots of 'VBN (Gg)2' and 'VBN (Gg)3', it increased by 0.4-fold and 0.27-fold respectively (Figure 7B). Proline content was significantly increased in root than shoot. Proline also acts as an antioxidant by stabilizing the membranes, scavenging free radicals, stabilizing proteins and protein complexes, and maintaining the osmotic balance (Muchate *et al.*, 2016).

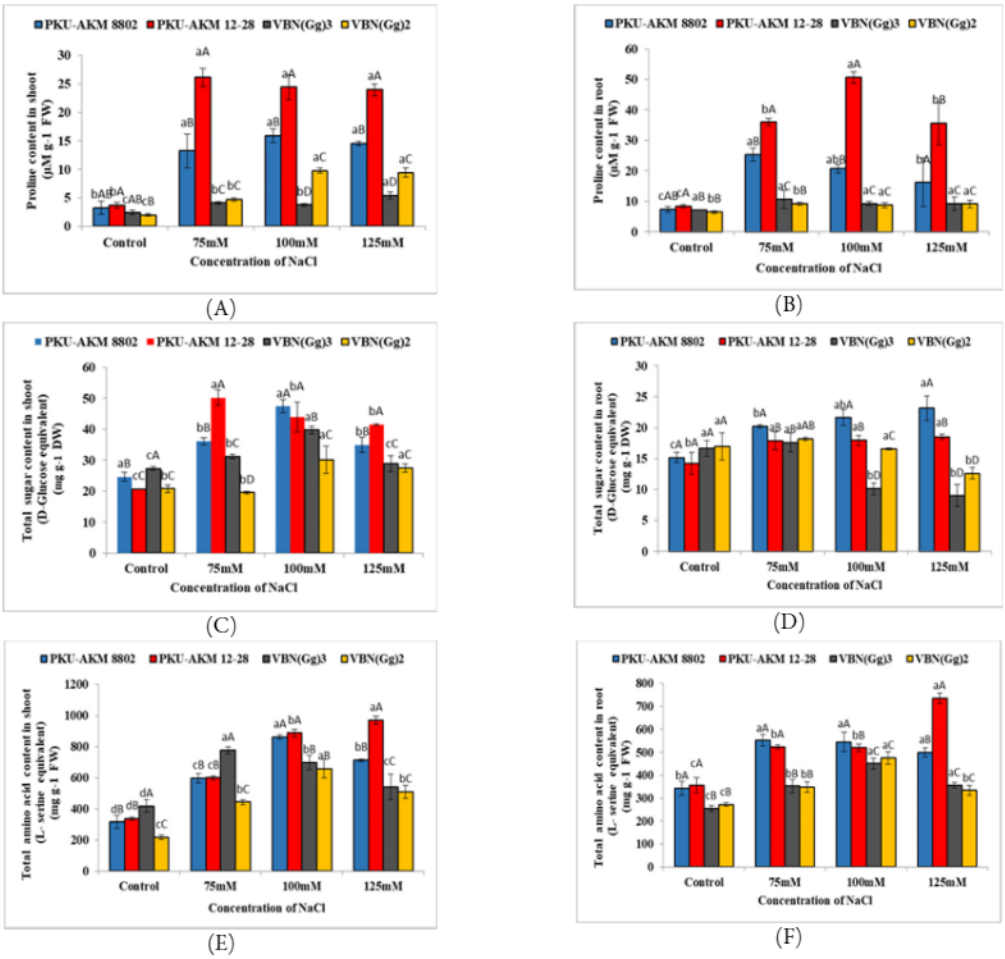


Figure 7. Effect of salt stress on osmolyte accumulation of 10-day old seedlings of *Vigna radiata* varieties A) Shoot proline content; B) Root proline content; C) Shoot total sugar content; D) Root total sugar content; E) Shoot amino acid content and F) Root amino acid content. Each value represents the mean of three replicates, and the vertical bar indicates the standard deviation. Small letters denote significant difference between treatments, and capital letters denote significant difference between varieties at a 0.05% significance level according to Duncan's Multiple Range Test (DMRT)

At 100 and 125 mM NaCl, 'VBN (Gg)2' and 'VBN (Gg)3' showed a remarkable decrease in sugar content than 'PKU-AKM 12-28' and 'PKU-AKM 8802' (Figure 7C-7D). The levels of sugars increase under salinity, and their role in osmotic adjustment has been validated (Marzec *et al.*, 2013; Ali *et al.*, 2018). At 75, 100, and 125 mM NaCl, amino acid content was significantly increased in the shoot and root of 'PKU-AKM 12-28' and 'PKU-AKM 8802' than 'VBN (Gg)2' and 'VBN (Gg)3' (Figure 7E-7F). Shahid *et al.* (2013) and Verma *et al.* (2018) have also reported increased amino acid content under salinity.

Conclusions

The present study concludes that the NaCl-induced salinity stress significantly affects the germination of seeds and early seedling growth in mungbean. Among the seventeen mungbean varieties, 'PKU-AKM 12-28' and 'PKU-AKM 8802' were the least affected by NaCl stress, whereas 'VBN(Gg)2' and 'VBN(Gg)3' were the most affected. These findings suggest that seed germination and growth attributes of mungbean seedlings can be used as traits for a rapid assortment of salt stress-tolerant varieties. Comparatively higher contents of photosynthetic pigments, proteins, secondary metabolite, osmolytes, antioxidants, and lower MDA content in the seedlings of 'PKU-AKM 12-28' and 'PKU-AKM 8802' suggest the salt-tolerant nature of these varieties. However, since this assessment of salt stress tolerance in the seventeen mungbean varieties is based on seeds germinated in Petri plates, field-based experiments are needed for validating the results. Further, studies on proteomics and genomics in these mungbean varieties would also be appropriate to know and validate genes and proteins conferring salt tolerance.

Authors' Contributions

GDM: Performed the experiments, collected and analysed the data, URW: Analysed data and prepared draft manuscript, DBS: Analysed data and prepared draft manuscript, TDN: Designed the experiments, and RBB: Designed the experiments, analysed the data, and finalized the manuscript. All authors read and approved the final manuscript.

Acknowledgements

We are grateful to Dr. Neeta M. Patil, Head, Department of Botany, and Principal Dr. R. S. Zunjarrao, for providing the necessary infrastructure required to conduct the research. The authors gratefully acknowledge all institutes and companies for providing seeds of mungbean varieties. This work was supported by the Council of Scientific and Industrial Research (CSIR), New Delhi, MS, India, through the CSIR-JRF fellowship to Mr. Ganesh Mankar (grant number- 08/658(0001)/2017-EMR-I).

Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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Journal of Experimental Biology and Agricultural Sciences

http://www.jebas.org

ISSN No. 2320 – 8694

TIME-DEPENDENT DETERMINATIVE BIOCHEMICAL TRAITS FOR SALT TOLERANCE MECHANISM IN MUNGBEAN (*Vigna radiata* (L.) R. WILCZEK)

Ganesh Deepak Mankar[1], Uttam Ramchandra Wayase[1], Deepak Bhaskar Shelke[2], Kiran Bharat Raskar[1], Tukaran Dayaram Nikam[3], Rajkumar Baban Barmukh[1*]

[1]Post Graduate Research Centre, Department of Botany, Modern College of Arts, Science and Commerce (Autonomous), Shivajinagar, Pune-5, Savitribai Phule Pune University, Pune-7, MS, India
[2]Department of Botany, Amruteshwar Arts, Commerce and Science College, Vinzar, Velha, Pune- 412213, MS. India
[3]Department of Botany, Savitribai Phule Pune University, Pune 411 007, MS, India

Received – February 07, 2021; Revision – April 10, 2021; Accepted – April 24, 2021
Available Online – April 25, 2021

DOI: http://dx.doi.org/10.18006/2021.9(2).152.171

KEYWORDS

Biochemical response

Cluster analysis

Discriminant analysis

Discriminant partial least squares analysis

Principal Component Analysis

Salt stress

ABSTRACT

Mungbean is one of the commercially valuable pulse crops. Time-dependent biochemical modulations in the mungbean varieties PKV AKM 12-28 and VBN (Gg)3 exposed to 75, 100, and 125 mM NaCl were estimated, and the results were concluded through multivariate modeling. The cluster analysis gave two fairly distinct clusters that had similar biochemical responses. Results on the principal component analysis suggested that protein content (PC), total phenolic content (TPC), total flavonoid content (TFC), DPPH radical scavenging activity, ABTS radical scavenging activity, proline content (PRC), total free amino acid (TFAA) content, and malondialdehyde (MDA) contents were dominant traits in the shoot as compared to the root. These can be taken as the primary indicators to assess the effect of salt stress on mungbean varieties. The discriminant analysis had identified TFC, MDA, and total sugar content (TSC) as discriminating variables between the roots and shoots. Further, MDA and TFC were identified as discriminating variables under different salt concentrations, and TSC was identified as a discriminating variable at different exposure durations. Discriminant partial least squares analysis further identified optimum biochemical modulations in the shoots of PKV AKM 12-28 and 75 mM NaCl. The salt treatment produced a strong biochemical modulation after 30 and 45 days, which helped plants survive under salt stress. The multivariate approaches efficiently interpreted time-dependent biochemical modulations in shoots and roots of mungbean varieties under salt stress.

* Corresponding author
E-mail: barmukhbotany@moderncollegepune.edu.in (Dr. Rajkumar Baban Barmukh)

Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

Production and Hosting by Horizon Publisher India [HPI] (http://www.horizonpublisherindia.in/).

1 Introduction

Soil salinity as abiotic stress has affected over one billion hectares of the global arable land. Such landmasses are increasing annually by ~10% due to natural causes and human-made causes such as substandard agricultural practices like improper irrigation and the extensive use of chemicals (Shrivastava & Kumar 2015; Soltabayeva et al., 2021). According to one estimate, salinity-affected soil is equivalent to more than 6% of the global landmass (Ding et al., 2018). The soil salinity is usually caused by excess sodium and chloride ions (Fall et al., 2018). Salinity reduces the growth and development of crops due to ionic, osmotic, and oxidative stresses (Arzani & Ashraf 2016; Abid et al., 2020). Salinity is known to affect many essential cellular and metabolic processes adversely.

Mungbean, *Vigna radiata* (L.) R. Wilczek (Fabaceae) is an important dietary pulse crop. It is commonly cultivated worldwide and in several Indian states like Maharashtra, Rajasthan, Andhra Pradesh, Madhya Pradesh, and Orissa (Ram & Singh, 1993). In India, 3.45 million hectares were under mungbean cultivation during the twelfth plan (2012-2017), which gave 1.59 million tons of produce (Kumar & Pandey, 2018). It is a significant source of proteins, vitamins, antioxidants, and minerals (Nair et al., 2019). It is also used as green manure, fodder, and in pharmaceuticals and cosmetics industries (Tang et al., 2014). However, soil salinity affects its physiology and biochemistry culminating in retarding its growth, development, and production (Saha et al., 2010; Ghosh et al., 2011; Ghosh et al., 2015; Sehrawat et al., 2019).

The effects of NaCl stress on plant metabolism are generally studied by monitoring the variations or changes in the plant's biochemical responses (Ghosh et al., 2015; Sehrawat et al., 2015; Muchate et al., 2016; Kalaria, 2017; Shelke et al., 2017; Rahneshan et al., 2018). However, it becomes challenging to interpret and to draw conclusions from the complicated nature of biochemical responses and their interrelationships through the conventional approach. Moreover, the conventional approach can only provide quantitative data characteristics. However, it cannot determine conceptual descriptions and underlying reasons for dependencies among data attributes (Michalski & Kaufman, 1998). Cluster analysis (CA), principal component analysis (PCA), discriminant analysis (DA), discriminant partial least squares (DPLS), and Pearson's multiple correlation analysis (MCA) are statistical tools that are used to analyze and interpret complex datasets accurately (Simeonov et al., 2003; Singh et al., 2004; Sinha et al., 2009a; Sinha et al., 2009b; Shelke et al., 2017; Mundada et al., 2020). These methods can adequately analyze, interpret, and draw conclusions from complex interrelationships among attributes used in different environmental, biological, chemical, and ecotoxicological studies (Mujunen et al., 1998; Singh et al., 2004; Sinha et al., 2009a; Sinha et al., 2009b; Chunthaburee et al., 2015; Sarabi et al., 2016; Shelke et al., 2017; Mundada et al., 2020). In the present study, the effects of NaCl stress on the biochemical responses in mungbean varieties were investigated through multivariate techniques (CA, DA, PCA, DPLS, and MCA) to interpret the results and the complex relationships among many such attributes.

2 Materials and methods

2.1 Plant materials, growth, and salt treatment

Certified and healthy seeds of mungbean varieties PKU-AKM 12-28 and VBN (Gg)3 were procured from Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, and National Pulses Research Centre, Tamil Nadu Agricultural University, Tamil Nadu, respectively. Plants were grown in the Botanical garden of the Modern College of Arts, Science and Commerce, Shivajinagar, Pune- 5. The potting mixture was prepared from the sandy clay loam soil collected from the village Charholi in the district Pune (MS). Plants were grown in non-perforated plastic pots of 35 cm × 20 cm size. Each pot contained a 15 kg mixture of soil and farmyard manure in a 3:1 ratio.

Fifteen seeds of each variety were sown per pot. Thinning of plants was done after fifteen days of sowing to maintain five plants per pot. The salinity stress was given to these 15 day-old seedlings through Hoagland nutrient medium Hoagland & Arnon (1950) containing 0, 75, 100, and 125 mM NaCl (equivalent to 0.3, 7, 8, and 9 dsm^{-2} EC, respectively). Three hundred ml respective solution was added to each pot on every alternate day to maintain the potting mixture's desired EC until the experiments were concluded. Each treatment was replicated in three pots. Data was collected, /analyses were performed on two plants per pot after 15, 30, and 45 days of salt stress treatments.

2.2 Biochemical analysis

All the biochemical parameters were estimated spectrophotometrically on a microprocessor-based UV–Vis spectrophotometer (Bioera, India).

2.2.1 Protein content (PC)

Lowery et al.'s (1951) method with the Bovine serum albumin (BSA) as a standard protein was used to estimate proteins. The suspension of one gram tissue homogenized in 3 ml of 100 mM potassium phosphate buffer was centrifuged at 15000 rpm for 20 min at four ºC. The supernatant was used for protein estimation, and the intensity of blue color developed was measured at 550 nm.

2.2.2 Malondialdehyde (MDA) content

MDA content was estimated by Heath & Packer's (1968) method. One gram plant material was homogenized and mixed with 2 ml of

20 % trichloroacetic acid containing 0.5 % thiobarbituric acid. This mixture in 3 ml of 0.1 % trichloroacetic acid was centrifuged at 5000 rpm. Two ml of the supernatant was incubated for 30 minutes at 95 °C, and the absorbance was read at 532 nm. The absorbance was also recorded at 600 nm to subtract nonspecific absorption.

MDA content (nmol/g dry weight)=

$$\frac{[(A_{532} - A_{600}) \times \text{total volume(ml)} \times 1000]}{[\text{Extinction coefficient} \times \text{sample volume(ml)}] \times \text{Weight of plant tissue (g)}}$$

Where, extinction coefficient = 155

2.2.3 Extraction of total phenolics, flavonoids, and antioxidants

The extract was prepared by refluxing 40 mg of dried plant material in 5 ml of 80 % methanol for one hr. The extract was filtered through Whatman no. 1 filter paper fitted on the Buchner funnel, and the filtrate was evaporated to dryness. The residue was dissolved in 10 ml 80 % methanol.

2.2.3.1 Estimation of total phenolics (TPC)

Total phenolics were estimated by Swain & Hillis' (1959) method. Half ml of the extract was evaporated to dryness, and the residue was dissolved in 0.5 ml distilled water, to which 0.5 ml of Folin-Ciocalteu Phenol reagent was added. After 5 minutes, 1 ml of a saturated sodium carbonate solution was added to this mixture and incubated for one h at room temperature. The absorbance was read at 760 nm. Gallic acid was used as a standard phenol.

2.2.3.2 Estimation of total flavonoids (TFC)

Total flavonoids were estimated by the Balbaa et al. (1974) method. Half ml of extract was evaporated to dryness, and the residue was dissolved in 1 ml 0.1 M methanolic aluminium chloride. The yellow color developed was read at 420 nm. Rutin was used as a standard flavonoid.

2.2.3.3 DPPH radical scavenging assay

A method by Blois (1958) was used to quantify antioxidants. A mixture of 200 µl extract and 1 ml DPPH (0.1 mM) was incubated in the dark for 30 min, after which its absorbance was recorded at 517 nm. The following formula was used to calculate the percentage radical scavenging potential.

$$\text{RSA (\%)} = (\text{Abs control} - \text{Abs sample} / \text{Abs control}) \times 100$$

2.2.3.4 ABTS radical scavenging assay

The method of Roberta et al. (1999) was followed for this assay. Two hundred µl extract was added to 1 ml of ABTS reagent (a mixture of equal volumes of 7 mM ABTS and 2.45 mM potassium persulphate incubated in the dark for 16 h at room temperature). After 10 min of incubation, the reaction mixture's absorbance was read at 734 nm. The following formula was used to calculate the percentage of radical scavenging activity

$$\text{RSA (\%)} = (A_{control} - A_{sample} / A_{control}) \times 100$$

2.2.4 Total proline content (PRC)

Proline content was estimated by Bates et al.'s (1973) method. Fifty mg of dry tissue sample was homogenized in 4 ml of 3 % sulfosalicylic acid, and the mixture was centrifuged at 3,000 rpm for 20 min, and the supernatant was collected. A mixture of 1 ml each of supernatant, ninhydrin, and glacial acetic acid was incubated in a boiling water bath for one h. The reaction was terminated by placing the test tubes in an ice bath. Four ml of toluene was added to the above mixture. The intensity of red color was read at 520 nm against toluene blank.

2.2.5 Total free amino acid content (TFAA)

Total amino acid content was estimated by Lee & Takahashi's (1966) method. One hundred mg tissue was homogenized in 3 ml of 80 % methanol. The homogenate refluxed for two h in a water bath was centrifuged, and the supernatant was collected. The residue was once again extracted with 3 ml of 80% methanol and centrifuged. The supernatants were pooled for further use. The mixture was evaporated in a water bath, and the residue was dissolved in 3.0 ml of 10% isopropyl alcohol. Two hundred µl of this sample was added to 3.8 ml of ninhydrin-citrate-glycerol reagent (a mixture of 1 ml of 1% ninhydrin in 0.5 M citrate buffer (pH 5.5), 2.4 ml glycerol, and 0.4 ml 0.5 M citrate buffer) and boiled for 12 min. The absorbance of the mixture was read at 570 nm. Glycine was used as a standard amino acid.

2.2.6 Total sugars content (TSC)

Total sugar content was estimated by Scott & Melvin's (1953) method. Twenty mg dry material was added in 1.25 ml 2.5 N HCl and incubated in a hot water bath for one h. Pinches of Na_2CO_3 were added to neutralize the acid, and the volume was adjusted to 25 ml with distilled water. To 1 ml of this solution, 4 ml of anthrone reagent was added and incubated in a hot water bath for 8-10 min. After cooling the contents to room temperature, the intensity of the dark green color developed was measured at 630 nm. D-glucose was used as standard sugar.

2.3 Statistical analyses

All the experiments were performed in triplicates and with a completely randomized block design (CRD). The data were presented as mean±SD. The root and shoot biochemical datasets for chemometric modeling consisted of nine variables subjected to

multivariate modeling. Multivariate modeling of these variables was performed through principal component analysis (PCA) and hierarchical cluster analysis (HCA) by using the PAST statistical package. The discriminant analysis (DA) was performed on the dataset by Statistica V 10.0 software by using the standard, forward stepwise and, backward stepwise modes. The dissimilarity-based partial least square analysis (DPLS) was performed in XL-Stat statistical software (Wunderlin et al., 2001; Singh et al., 2004; Sinha et al., 2009a; Sinha et al., 2009b). The correlations between the NaCl stressed plants' biochemical parameters at different NaCl concentrations and exposure durations were determined through Pearson's correlation method in SPPS statistical software version 20 (Chunthaburee et al., 2015; Shelke et al., 2017).

3 Results

Biochemical changes induced by NaCl concentrations and the exposure durations in the roots and shoots of PKU-AKM 12-28 and VBN (Gg)3 are presented in Tables 1 and 2. Cluster analysis (CA) was used to detect changes in the biochemical responses induced by NaCl stress. CA produced a dendrogram (Figure 1), where all the twelve combinations (four levels of NaCl concentrations and three exposure durations) for root and shoot tissues of PKU-AKM 12-28 and VBN (Gg)3 were grouped into two statistically significant clusters (susceptible and resistant). These were further divided into two subgroups (shoot and root) since the samples within these groups had similar characteristics concerning biochemical and physiological responses. Thus, the differences in the responses in root and shoots tissues of PKU-AKM 12-28 and VBN (Gg)3 under NaCl stress were observed. It also distinguished varieties based on the tolerance level.

The normalized dataset (combined roots and shoots) was subjected to the PCA analysis to evaluate (i) interactions between plant and NaCl stress, (ii) differential responses in root and shoot tissues subjected to different levels of NaCl stress, (iii) relationships among variables, and d. factors affecting these variables. The first three significant principal components (PCs) of PCA indicated 92.37% of the total variance. Figure 2 illustrates the loadings and scores of the first two PCs (PC1 vs. PC2). The first Two PCs represent 84.56% of the total variance and reflected the main groupings in the data set. The PC1 is determined mainly by PC, TPC, TFC, DPPH, ABTS, PRC, and TFAA with strong positive loadings, whereas in PC2, MDA alone showed high positive loading.

Differences between the responses in root and shoot tissues are presented in the plot's scores and were grouped into two distinct clusters. It may be noted that the shoot tissues differentiated prominently in terms of PC, TPC, TFC, DPPH, ABTS, PRC, and TFAA and MDA. It shows variations and differences in responses of root and shoot tissues of mungbean varieties on the dominance of the biochemical and physiological variables at all NaCl concentrations and exposure durations. The root and shoot tissues of the same variety or the same tissues of different varieties showed different response patterns. The shoot and root tissues of PKU-AKM 12-28 variety had high scores with PC1 compared to VBN (Gg)3, which indicates its high tolerance level to salinity stress.

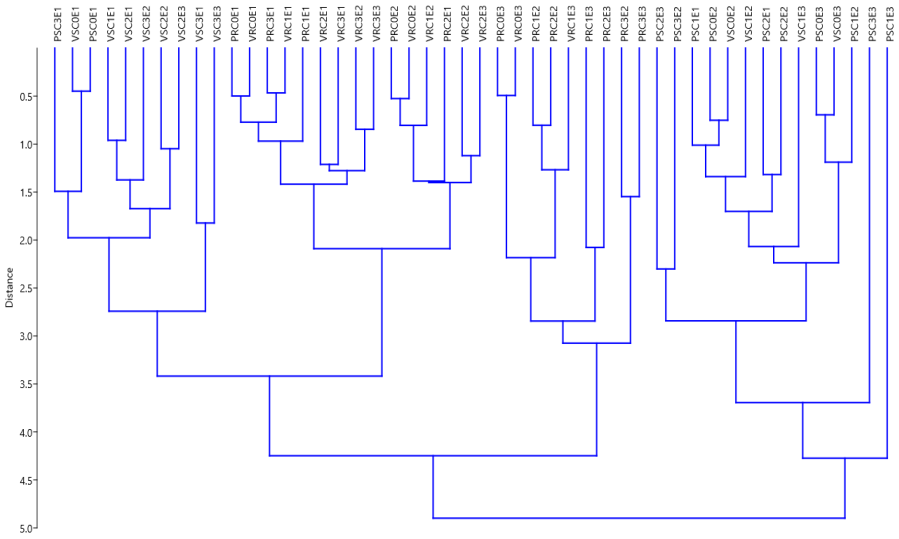

Figure 1 Dendrogram showing clustering of root and shoot tissue biochemical samples of the NaCl stressed plants of mungbean varieties

Table 1 Effects of NaCl stress on biochemical parameters in shoot tissue of *Vigna radiata* varieties PKU AKM 12-28 and VBN (Gg)3

variety	NaCl (mM)	Exposure duration (days)	Coding	Protein content (mg gm^{-1} FW)	MDA content (nmol gm^{-1} DW)	Total phenolic content (mg gm^{-1} DW)	Total flavonoid content (mggm^{-1} DW)	DPPH-RSA (Inhibition %)	ABTS-RSA (Inhibition %)	Proline content (µmol gm^{-1} DW)	Total sugar content (mg gm^{-1} DW)	Total free amino acid content (µmol gm^{-1} FW)
PKU AKM 12-28	0	15	PSC0E1	4.74 ± 0.40	170.32 ± 1.86	45.98 ± 1.55	5.72 ± 0.59	41.26 ± 2.13	42.44 ± 1.74	16.21 ± 1.08	91.63 ± 2.35	12.50 ± 0.73
		30	PSC0E2	5.59 ± 0.34	180.65 ± 4.59	51.03 ± 0.99	8.47 ± 0.64	58.54 ± 1.27	63.18 ± 1.21	24.20 ± 1.91	116.14 ± 2.65	13.80 ± 0.89
		45	PSC0E3	6.62 ± 0.36	189.76 ± 3.15	55.60 ± 0.96	10.14 ± 1.07	72.09 ± 1.16	79.65 ± 1.16	34.49 ± 2.21	157.21 ± 2.96	16.03 ± 0.07
	75	15	PSC1E1	5.57 ± 0.26	185.46 ± 5.57	59.84 ± 2.49	6.93 ± 0.43	5368 ± 2.02	57.56 ± 0.58	19.91 ± 1.41	117.49 ± 2.04	12.45 ± 0.89
		30	PSC1E2	6.08 ± 0.14	220.04 ± 2.93	66.67 ± 1.59	10.65 ± 0.33	64.85 ± 1.88	76.16 ± 1.74	29.00 ± 1.99	141.48 ± 2.91	14.99 ± 0.70
		45	PSC1E3	8.31 ± 0.90	250.32 ± 5.95	73.98 ± 1.56	13.40 ± 0.78	83.66 ± 0.78	90.31 ± 2.04	51.30 ± 1.28	202.95 ± 5.36	21.56 ± 1.60
	100	15	PSC2E1	6.98 ± 0.42	213.33 ± 6.87	51.25 ± 1.13	6.53 ± 0.31	46.40 ± 2.37	47.67 ± 2.10	22.06 ± 1.74	129.18 ± 2.95	15.26 ± 0.96
		30	PSC2E2	7.04 ± 0.13	244.82 ± 9.38	57.19 ± 1.19	8.88 ± 0.46	50.97 ± 0.92	55.04 ± 1.34	24.56 ± 1.44	164.62 ± 1.94	17.21 ± 0.49
		45	PSC2E3	7.53 ± 0.26	273.20 ± 7.75	65.27 ± 1.42	10.62 ± 1.03	61.53 ± 3.89	67.83 ± 1.46	21.17 ± 1.58	236.06 ± 2.61	18.54 ± 0.98
	125	15	PSC3E1	4.47 ± 0.23	236.22 ±12.17	38.82 ± 1.56	6.55 ± 0.40	38.07 ± 1.22	42.25 ± 1.68	24.14 ± 1.77	139.89 ± 1.37	10.42 ± 0.66
		30	PSC3E2	7.86 ± 0.28	259.44 ± 6.74	45.92 ± 1.45	8.02 ± 0.31	43.16 ± 2.49	49.61 ± 1.46	12.86 ± 1.35	201.84 ± 2.96	19.60 ± 0.60
		45	PSC3E3	5.51 ± 0.63	282.67 ± 9.92	37.27 ± 1.53	6.11 ± 0.43	31.88 ± 3.23	46.32 ± 2.62	9.16 ± 1.37	255.22 ± 3.68	12.48 ± 1.07
VBN (Gg)3	0	15	VSC0E1	4.54 ± 0.23	172.22 ± 9.12	44.17 ± 2.06	5.67 ± 0.60	38.96 ± 1.95	39.34 ± 2.93	19.83 ± 1.43	97.25 ± 2.78	11.30 ± 0.76
		30	VSC0E2	4.92 ± 0.25	172.56 ± 5.27	48.35 ± 1.04	7.77 ± 0.39	56.47 ± 1.70	53.49 ± 2.33	27.34 ± 0.95	123.03 ± 3.74	13.30 ± 0.85
		45	VSC0E3	5.88 ± 0.27	181.68 ± 7.74	58.19 ± 0.96	9.37 ± 1.01	75.04 ± 0.61	82.75 ± 3.20	30.83 ± 1.59	166.32 ± 3.06	14.45 ± 0.70
	75	15	VSC1E1	3.45 ± 0.31	215.91 ±14.98	44.08 ± 0.10	6.45 ± 0.59	38.15 ± 1.58	41.47 ± 2.62	3.41 ± 0.98	109.20 ± 2.50	8.31 ± 0.41
		30	VSC1E2	5.00 ± 0.13	246.02 ± 4.51	53.88 ± 1.50	9.75 ± 0.33	49.19 ± 0.92	64.73 ± 0.89	21.28 ± 1.45	130.63 ± 1.96	12.48 ± 0.77
		45	VSC1E3	5.65 ± 0.20	270.62 ± 6.05	49.29 ± 1.05	8.31 ± 0.44	57.61 ± 4.33	70.93 ± 2.66	9.56 ± 2.25	178.97 ± 3.41	14.34 ± 0.70
	100	15	VSC2E1	3.71 ± 0.34	246.19 ± 3.61	36.02 ± 1.60	5.05 ± 0.21	35.48 ± 2.26	37.79 ± 1.74	3.24 ± 1.00	87.74 ± 2.49	7.56 ± 1.41
		30	VSC2E2	4.56 ± 0.21	277.85 ± 6.45	45.97 ± 0.85	6.51 ± 0.31	42.60 ± 1.04	56.98 ± 1.16	4.23 ± 1.01	121.67 ± 1.76	11.22 ± 0.47
		45	VSC2E3	4.56 ± 0.19	300.39 ±10.73	42.32 ± 1.96	6.69 ± 1.06	36.69 ± 4.44	42.05 ± 3.20	5.02 ± 0.34	141.75 ± 2.61	11.10 ± 0.56
	125	15	VSC3E1	2.03 ± 0.17	262.54 ± 3.15	19.93 ± 1.39	3.63 ± 0.49	17.31 ± 2.43	27.71 ± 1.78	3.63 ± 0.22	62.65 ± 1.72	7.28 ± 0.46
		30	VSC3E2	3.53 ± 0.38	302.62 ± 6.37	29.31 ± 0.96	5.51 ± 0.42	36.41 ± 4.68	36.82 ± 4.12	1.46 ± 0.59	89.33 ± 2.07	10.55 ± 0.30
		45	VSC3E3	3.07 ± 0.28	336.00 ± 9.85	23.29 ± 1.24	4.51 ± 0.28	23.30 ± 0.97	27.33 ± 4.07	1.25 ± 0.14	126.20 ± 4.58	7.53 ± 0.58

Values represent mean±SD

Table 2 Effects of NaCl stress on physiological and biochemical parameters in root tissue of *Vigna radiata* varieties PKU AKM 12-28 and VBN (Gg)3

variety	NaCl (mM)	Exposure duration (days)	Coding	Protein content (mg gm^{-1} FW)	MDA content (nmol gm^{-1} DW)	Total phenolic content (mg gm^{-1} DW)	Total flavonoid content (mggm^{-1} DW)	DPPH-RSA (Inhibition %)	ABTS-RSA (Inhibition %)	Proline content (µmol gm^{-1} DW)	Total sugar content (mg gm^{-1} DW)	Total free amino acid content (µmol gm^{-1} FW)
PKU AKM 12-28	0	15	PRC0E1	1.95 ± 0.16	78.11 ± 5.20	17.92 ± 0.45	1.11 ± 0.128	16.63 ± 1.88	21.71 ± 2.62	4.62 ± 0.67	118.21 ± 2.06	4.25 ± 0.13
		30	PRC0E2	3.01 ± 0.13	80.86 ± 4.17	32.39 ± 2.05	1.21 ± 0.138	30.87 ± 2.25	43.80 ± 2.62	22.63 ± 1.75	135.49 ± 2.52	5.28 ± 0.09
		45	PRC0E3	3.84 ± 0.34	76.73 ± 7.30	46.01 ± 1.36	1.58 ± 0.060	76.70 ± 2.32	88.18 ± 1.46	35.49 ± 1.50	145.54 ± 1.39	5.75 ± 0.34
	75	15	PRC1E1	2.50 ± 0.27	77.76 ± 8.66	24.16 ± 2.07	1.49 ± 0.058	23.54 ± 1.16	29.84 ± 1.46	8.69 ± 0.98	131.58 ± 2.00	4.70 ± 0.14
		30	PRC1E2	3.29 ± 0.17	82.58 ± 1.79	54.02 ± 1.24	1.75 ± 0.078	56.39 ± 3.22	61.43 ± 3.20	25.07 ± 2.48	151.32 ± 3.04	5.39 ± 0.21
		45	PRC1E3	3.63 ± 0.17	86.37 ± 5.11	57.47 ± 2.03	2.08 ± 0.147	64.97 ± 1.62	72.87 ± 0.89	48.55 ± 2.11	213.01 ± 2.98	6.44 ± 0.21
	100	15	PRC2E1	3.01 ± 0.20	86.71 ± 2.73	32.65 ± 1.76	1.84 ± 0.080	32.04 ± 2.91	43.02 ± 1.74	4.48 ± 1.13	136.02 ± 2.62	5.31 ± 0.23
		30	PRC2E2	3.11 ± 0.10	98.75 ± 2.60	52.65 ± 1.10	1.84 ± 0.091	55.02 ± 1.15	57.17 ± 0.89	24.62 ± 1.03	184.58 ± 2.29	6.05 ± 0.18
		45	PRC2E3	2.17 ± 0.18	115.96 ± 2.19	46.91 ± 1.56	1.51 ± 0.012	52.39 ± 1.29	57.75 ± 1.46	66.59 ± 3.57	234.05 ± 3.26	4.49 ± 0.18
	125	15	PRC3E1	1.18 ± 0.11	98.41 ± 2.60	20.44 ± 1.41	0.95 ± 0.111	21.60 ± 2.03	24.03 ± 2.75	3.01 ± 0.48	132.15 ± 1.95	2.59 ± 0.22
		30	PRC3E2	2.77 ± 0.20	112.52 ± 5.75	36.88 ± 1.79	1.32 ± 0.102	41.59 ± 1.17	47.29 ± 3.78	34.72 ± 1.95	228.16 ± 3.62	4.92 ± 0.09
		45	PRC3E3	2.06 ± 0.13	132..82 ± 2.92	32.48 ± 1.54	1.13 ± 0.209	36.41 ± 4.79	40.70 ± 2.66	16.71 ± 0.90	254.23 ± 4.08	3.84 ± 0.16
VBN (Gg)3	0	15	VRC0E1	1.95 ± 0.21	76.04 ± 3.15	15.73 ± 1.52	1.00 ± 0.116	13.96 ± 4.31	28.88 ± 2.93	4.74 ± 1.49	108.29 ± 0.87	3.81 ± 0.50
		30	VRC0E2	2.55 ± 0.32	87.74 ± 6.77	35.46 ± 1.27	1.43 ± 0.079	33.17 ± 1.15	47.87 ± 1.46	25.61 ± 2.31	124.32 ± 3.24	5.17 ± 0.18
		45	VRC0E3	3.44 ± 0.31	81.20 ± 1.46	43.37 ± 1.32	1.74 ± 0.105	71.64 ± 1.94	84.30 ± 1.74	34.56 ± 0.88	153.90 ± 2.62	5.59 ± 0.26
	75	15	VRC1E1	1.79 ± 0.11	94.97 ± 1.03	19.72 ± 1.31	0.42 ± 0.030	20.63 ± 2.25	20.74 ± 2.93	2.40 ± 0.47	130.16 ± 2.22	3.81 ± 0.26
		30	VRC1E2	2.68 ± 0.21	105.29 ± 6.28	35.47 ± 1.03	0.82 ± 0.101	42.39 ± 1.58	45.54 ± 1.21	20.17 ± 1.42	120.42 ± 2.75	4.70 ± 0.26
		45	VRC1E3	2.97 ± 0.16	133.85 ± 4.38	38.71 ± 1.38	1.34 ± 0.071	51.78 ± 1.89	57.75 ± 4.36	24.20 ± 1.34	161.28 ± 1.70	4.93 ± 0.19
	100	15	VRC2E1	1.60 ± 0.16	102.19 ± 2.73	26.59 ± 0.92	0.77 ± 0.050	27.55 ± 4.13	32.36 ± 2.04	0.99 ± 0.10	92.87 ± 3.86	3.14 ± 0.20
		30	VRC2E2	2.02 ± 0.16	137.63 ± 3.63	28.68 ± 0.41	0.84 ± 0.025	32.89 ± 2.44	39.73 ± 0.34	17.48 ± 0.81	105.13 ± 3.63	4.14 ± 0.14
		45	VRC2E3	1.35 ± 0.12	154.84 ± 8.03	31.31 ± 1.27	0.86 ± 0.120	39.04 ± 1.29	44.19 ± 1.16	7.38 ± 0.67	134.33 ± 3.11	3.87 ± 0.12
	125	15	VRC3E1	0.90 ± 0.11	127.31 ± 4.65	16.61 ± 0.81	0.53 ± 0.056	19.90 ± 1.75	22.29 ± 2.62	0.56 ± 0.11	71.64 ± 2.62	1.78 ± 0.09
		30	VRC3E2	1.67 ± 0.09	152.09 ± 5.30	23.15 ± 1.03	0.81 ± 0.075	25.77 ± 1.52	31.59 ± 3.78	11.56 ± 1.23	97.47 ± 2.60	3.32 ± 0.22
		45	VRC3E3	1.08 ± 0.11	185.46 ± 1.46	19.29 ± 1.26	0.66 ± 0.053	21.84 ± 5.04	26.55 ± 2.42	7.29 ± 1.11	112.95 ± 2.66	2.26 ± 0.24

Values represent mean±SD

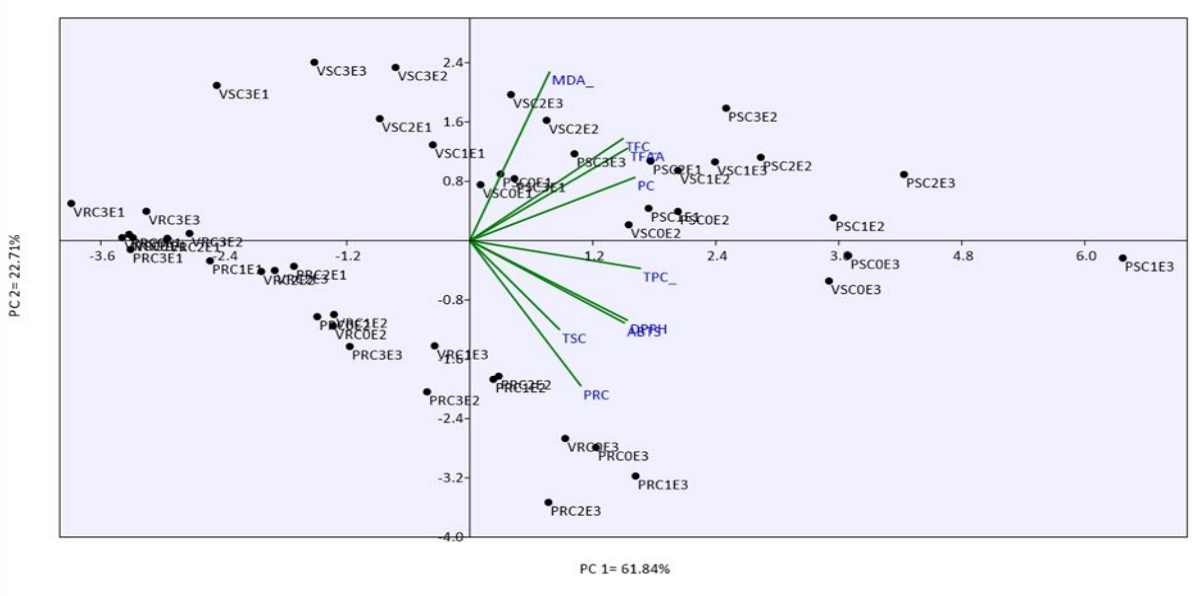

Figure 2 PCA scores and loadings of the first two PCs obtained from the shoot and root biochemical dataset of mungbean varieties

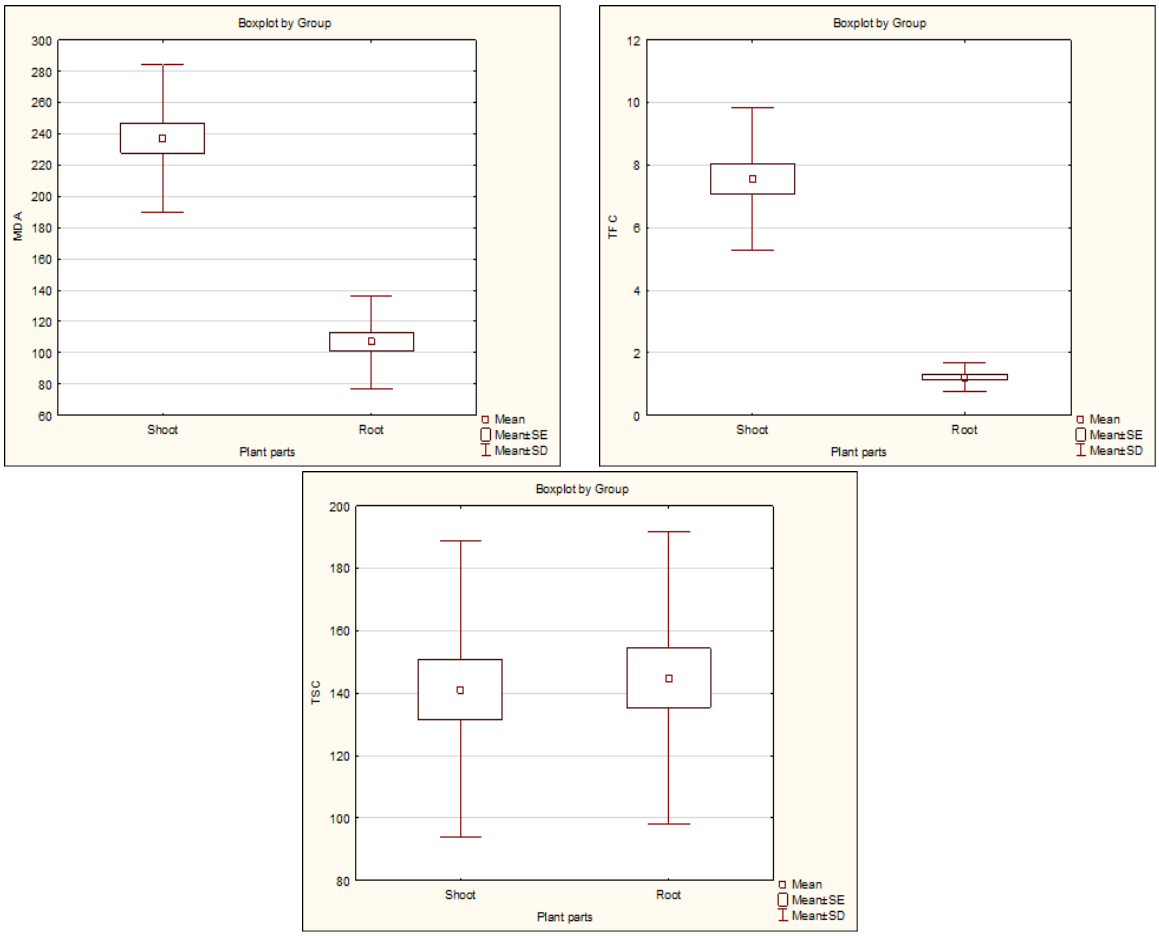

Figure 3 Box whisker plots-Variation in root and shoot biochemical samples a) MDA b) TFC c) TSC

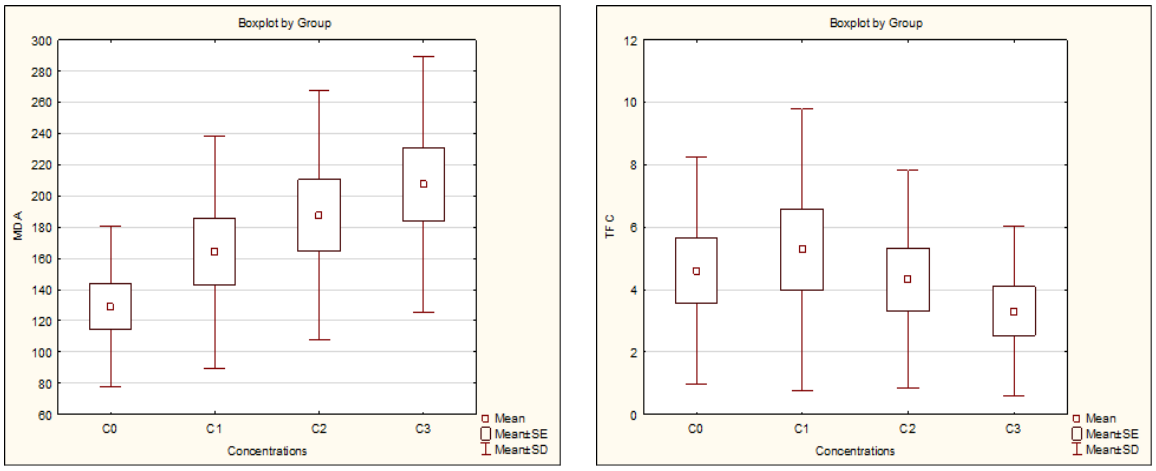

Figure 4 Box whisker plots-Variation induced by NaCl concentrations on biochemical samples a) MDA b) TFC

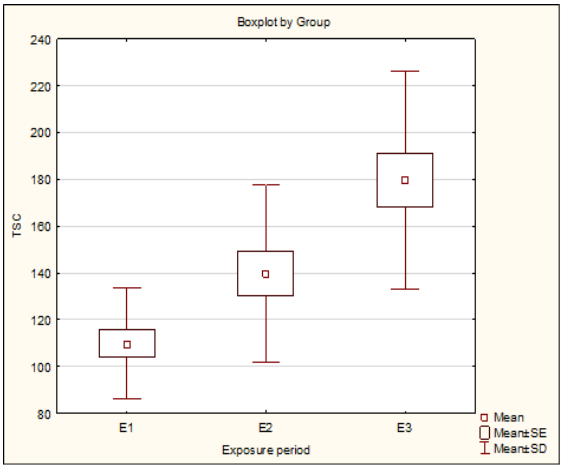

Figure 5 Box whisker plots-Variation induced by NaCl exposure duration in TSC

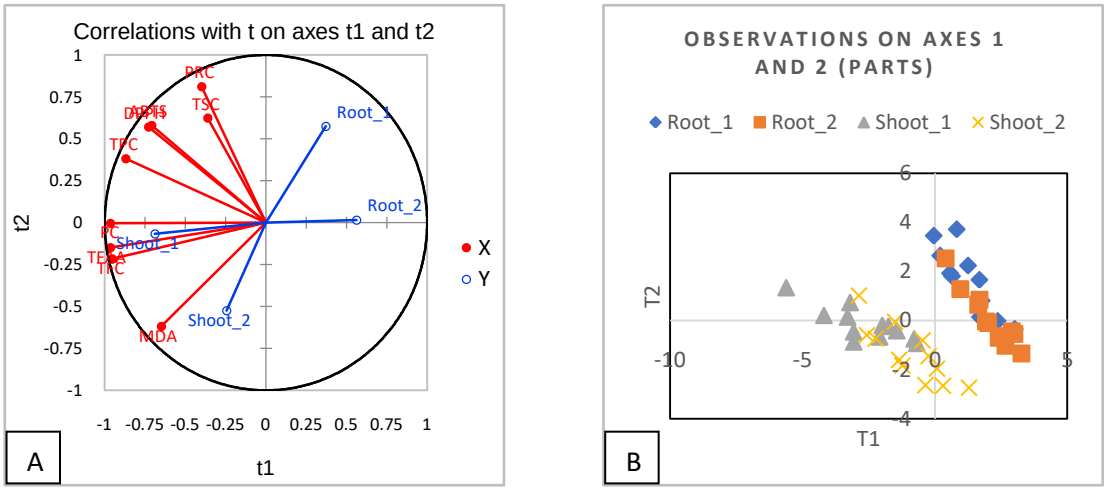

Figure 6 DPLS a) loadings and b) scores of the first two components obtained for the combined root and shoot data set (Where, Root_1: Root of PKU-AKM 12-28; Shoot_1: Shoot of PKU-AKM 12-28; Root_2: Root of VBN(Gg)3; Shoot_2: Shoot of VBN(Gg)3)

Table 3 a) Classification functions and b) Classification matrix for discriminant analysis of variation between the root–shoot biochemical samples of the mungbean

a)

	Linear Discriminant Functions for Groups Coefficients[a]	
	Shoot	Root
Standard DA mode		
PC	3.9285	0.7262
MDA	0.2779	0.1041
TPC	0.5569	0.4586
TFC	1.0462	-2.6927
DPPH	0.0017	-0.0002
ABTS	-0.1135	0.1292
PRC	-0.1019	-0.1783
TSC	-0.0931	0.0238
TFAA	0.2407	0.1149
Constant	-52.9722	-16.1920
Forward DA mode		
TFC	1.6812	-2.1738
MDA	0.2663	0.1021
TSC	-0.0839	0.0220
PC	4.9181	1.6464
ABTS	0.0524	0.2196
TFAA	0.2320	0.1003
DPPH	0.0028	0.0007
Constant	-49.4559	-13.4974
Backward DA mode		
MDA	0.1942	0.05870
TFC	4.1359	-0.09097
TSC	-0.0276	0.06046
Constant	-37.3836	-8.15575

[a]Discriminant function coefficient for shoot and root

b)

Monitoring groups	Correct assignations %	Groups assigned by DA	
		Shoot	Root
Standard DA mode			
Shoot	100.0000	24	0
Root	100.0000	0	24
Total	100.0000	24	24
Forward DA mode			
Shoot	100.0000	24	0
Root	100.0000	0	24
Total	100.0000	24	24
Backward DA mode			
Shoot	100.0000	24	0
Root	100.0000	0	24
Total	100.0000	24	24

Table 4 a) Classification functions and b) classification matrix for discriminant analysis of variation between NaCl concentrations and biochemical samples of the mungbean varieties under salinity

a)

	Linear Discriminant Functions for Groups			
	Coefficients[a]			
	C0	C1	C2	C3
Standard DA mode				
PC	-2.6069	-2.4868	-2.7521	-2.7702
MDA	0.0853	0.1172	0.1500	0.1700
TPC	0.7307	1.1376	1.1772	0.7568
TFC	-3.9099	-4.1047	-5.2000	-4.8061
DPPH	-0.2536	-0.2759	-0.2375	-0.0705
ABTS	0.2991	0.1840	0.1018	-0.0001
PRC	-0.2070	-0.3020	-0.2950	-0.2032
TSC	0.0317	0.0563	0.0675	0.0959
TFAA	1.4351	0.6108	1.0152	1.0674
Constant	-16.1155	-24.3347	-28.5462	-26.5231
Forward DA mode				
TPC	0.5963	0.9971	1.0462	0.6854
MDA	0.0902	0.1221	0.1550	0.1737
TFC	-3.4560	-3.6579	-4.7333	-4.4051
TSC	0.0343	0.0597	0.0694	0.0931
ABTS	0.0934	-0.0364	-0.0939	-0.0776
TFAA	0.3196	-0.4594	-0.1570	-0.0825
PRC	-0.2028	-0.3006	-0.2884	-0.1840
Constant	-15.4720	-23.6481	-27.9147	-26.1477
Backward DA mode				
MDA	0.03423	0.05008	0.07686	0.10176
TFC	-0.23513	-0.45302	-0.97984	-1.47946
Constant	-3.05324	-4.29882	-6.47752	-9.48695

[a]Discriminant function coefficient for different concentrations of NaCl

b)

Monitoring groups	Correct assignations %	Groups assigned by DA			
		C0	C1	C2	C3
Standard DA mode					
C0	91.6667	11	1	0	0
C1	50.0000	2	6	3	1
C2	75.0000	0	2	9	1
C3	100.0000	0	0	0	12
Total	79.1667	13	9	12	14
Forward DA mode					
C0	83.3333	10	2	0	0
C1	50.0000	2	6	3	1
C2	75.0000	0	2	9	1
C3	100.0000	0	0	0	12
Total	77.0833	12	10	12	14
Backward DA mode					
C0	83.33334	10	2	0	0
C1	16.66667	5	2	5	0
C2	33.33333	2	2	4	4
C3	50.00000	0	1	5	6
Total	45.83333	17	7	14	10

Table 5 a) Classification functions and b) classification matrix for discriminant analysis of variation between NaCl exposure duration and biochemical samples of the mungbean varieties under salinity

a)

	Linear Discriminant Functions for Groups Coefficients[a]		
	E1	E2	E3
Standard DA mode			
PC	-6.6606	-9.7591	-11.0212
MDA	0.1627	0.2068	0.2558
TPC	0.1025	0.0418	-0.3390
TFC	-4.8394	-6.1462	-6.2375
DPPH	0.0960	0.1013	0.4313
ABTS	0.7033	0.9848	1.1109
PRC	-0.1350	-0.1026	-0.1049
TSC	0.1374	0.1757	0.2517
TFAA	2.6701	3.9021	3.8457
Constant	-26.6541	-42.9207	-64.1950
Forward DA mode			
TSC	0.1505	0.1946	0.2714
ABTS	0.4540	0.6400	0.7656
TPC	-0.1978	-0.3131	-0.6998
MDA	0.1090	0.1399	0.1869
PC	-4.4178	-5.7326	-7.2157
DPPH	0.1748	0.2485	0.5769
Constant	-18.1337	-30.3862	-51.1537
Backward DA mode			
TSC	0.07841	0.09983	0.1283
Constant	-5.40130	-8.07316	-12.6247

[a]Discriminant function coefficient for different Exposure time to NaCl

b)

Monitoring groups	Correct assignations %	Groups assigned by DA		
		E1	E2	E3
Standard DA mode				
E1	87.50000	14	2	0
E2	81.25000	1	13	2
E3	87.50000	0	2	14
Total	85.41666	15	17	16
Forward DA mode				
E1	81.25000	13	3	0
E2	68.75000	3	11	2
E3	87.50000	0	2	14
Total	79.16666	16	16	16
Backward DA mode				
E1	62.50000	10	6	0
E2	25.00000	8	4	4
E3	56.25000	1	6	9
Total	47.91667	19	16	13

Discriminant analysis (DA) was used to investigate further NaCl-stress-induced variations in biochemical parameters in the root and shoot tissues. The entire data set was divided into two groups (shoot and root), and linear DA was performed. Tables 3a and 3b shows the DFs and CMs generated from DA. The standard, forward, and backward stepwise DA modes constructed DFs, including all 9, 7, and 3 parameters, respectively, and depicted the corresponding CMs assigning 100% cases correctly. Forward stepwise DA showed that TFC, MDA, TSC, PC, ABTS, TFAA, and DPPH were followed by three variables - TFC, MDA, TSC in the backward stepwise DA with the same number of correct assignations by the DA mode. Thus, the DA results suggest that TFC, MDA, TSC are the most significant parameters to distinguish between two plant tissues (roots and shoots) exposed to NaCl stress. It further suggests that these parameters account for most of the expected variations in the biochemical parameters. The TFC, MDA, and TSC play a crucial role in the classification of the two clusters. Both CA and DA identified significant differences in root and shoot responses concerning biochemical changes in the mungbean varieties exposed to NaCl stress. DA identified the presence of significant differences between the root and shoot responses expressed in terms of discriminating variables (TFC, MDA, and TSC). As identified by DA, box and whisker plots of selected parameters showing shoot and root responses are given in Figure 3a-3c. TFC and MDA showed variations in root and shoot tissues under salinity. However, TSC did not change much in root and shoot.

Table 6 Pearson's correlation in the physiological and biochemical parameters in the roots and shoots of the NaCl exposed plants of *Vigna radiata*

	SPC	SMDA	STPC	STFC	SDPPH	SABTS	SPRC	STSC	STFAA	RPC	RSMDA	RTPC	RTFC	RDPPH	RABTS	RPRC	RTSC	RTFAA
SPC	1																	
SMDA	-.140	1																
STPC	.813**	-.423*	1															
STFC	.833**	-.194	.897**	1														
SDPPH	.028	-.240	.212	-.044	1													
SABTS	.739**	-.305	.873**	.925**	.056	1												
SPRC	.766**	-.536**	.797**	.814**	.053	.776**	1											
STSC	.686**	.249	.470*	.584**	-.100	.512*	.347	1										
STFAA	.810**	.035	.640**	.665**	.004	.606**	.493*	.610**	1									
RPC	.758**	-.452*	.810**	.809**	.050	.873**	.761**	.419*	.610**	1								
RSMDA	-.388	.925**	-.614**	-.415*	-.217	-.461*	-.696**	.070	-.225	-.580**	1							
RTPC	.797**	-.022	.783**	.895**	-.137	.834**	.679**	.644**	.639**	.799**	-.251	1						
RTFC	.847**	-.353	.806**	.737**	.143	.745**	.813**	.517**	.633**	.835**	-.515**	.803**	1					
RDPPH	.669**	-.032	.666**	.824**	-.160	.858**	.619**	.607**	.605**	.785**	-.200	.906**	.698**	1				
RABTS	.677**	-.151	.680**	.813**	-.153	.873**	.677**	.560**	.560**	.833**	-.277	.877**	.743**	.977**	1			
RPRC	.747**	.014	.686**	.831**	-.119	.760**	.580**	.724**	.617**	.615**	-.149	.800**	.627**	.765**	.765**	1		
RTSC	.740**	.144	.503*	.574**	-.054	.459*	.371	.958**	.667**	.440*	-.056	.626**	.552**	.523**	.476*	.698**	1	
RTFAA	.808**	-.444*	.874**	.821**	.067	.831**	.752**	.441*	.597**	.949**	-.569**	.809**	.852**	.725**	.770**	.626**	.488*	1

**. Correlation is significant at p= 0.01 (2-tailed); *. Correlation is significant at p= 0.05 (2-tailed).

Where, SPC: proteins content in shoot , SMDA: malondialdehyde content in shoot, STPC: total phenolics content in shoot, STFC: total flavonoids content in shoot, SDPPH: 2,2-Diphenyl-1-picrylhydrazyl-Radicle scavenging activity in shoot, SABTS: (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid))- Radicle scavenging activity in shoot: SPRC: total proline content in shoot, STSC: total sugars content in shoot, STFAA: total free amino acid content in shoot, RPC: proteins content in root , RMDA: malondialdehyde content in root, RTPC: total phenolics content in root, RTFC: total flavonoids content in root, RDPPH: 2,2-Diphenyl-1-picrylhydrazyl-Radicle scavenging activity in root, RABTS: (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid))- Radicle scavenging activity in root: RPRC: total proline content in root, RTSC: total sugars content in root, RTFAA: total free amino acid content in root,

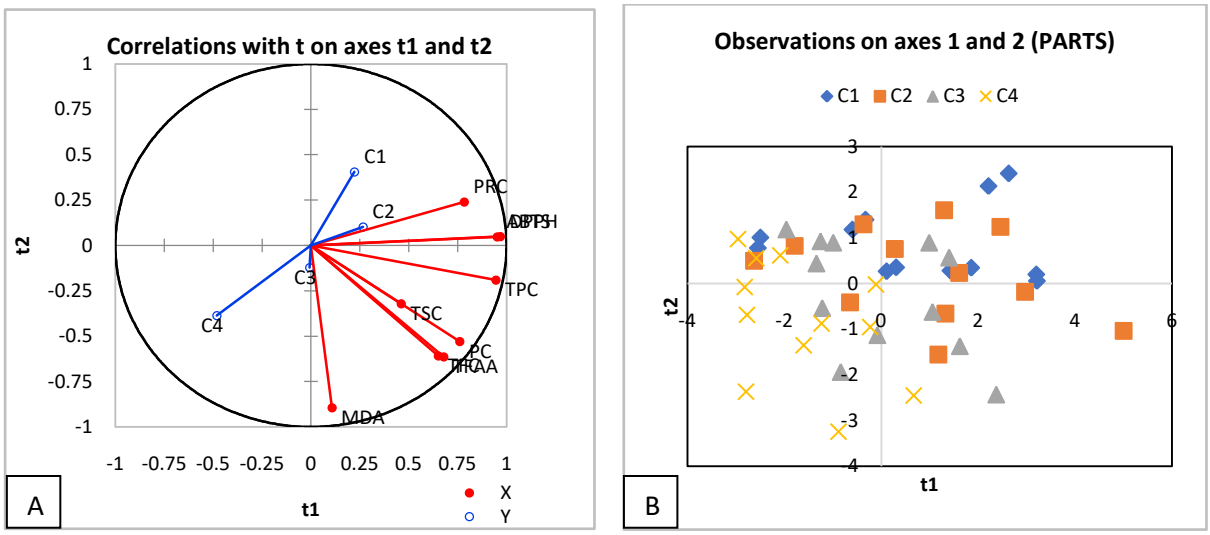

Figure 7 DPLS a) loadings and b) scores of the first two components obtained for concentrations of NaCl (Where, C1- 0 mM NaCl; C2- 75 mM NaCl; C3- 100 mM NaCl; C4- 125 mM NaCl)

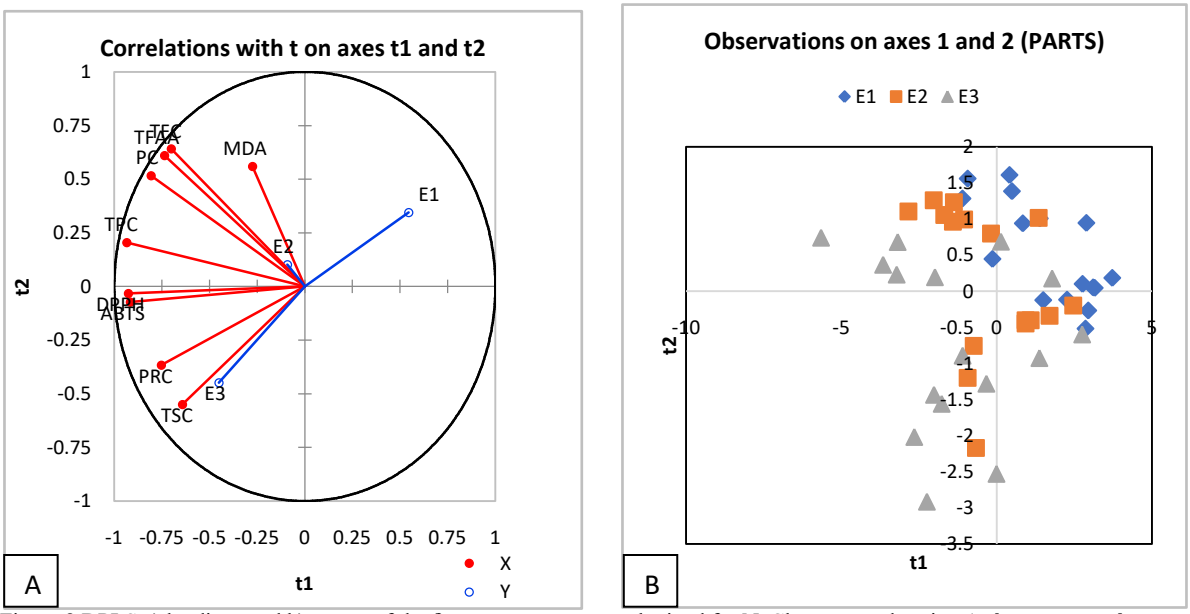

Figure 8 DPLS a) loadings and b) scores of the first two components obtained for NaCl exposure duration (Where, E1- 15 days; E2- 30 days; E3- 45 days of exposure period after salt treatment)

The effect of salt stress on the mungbean varieties was studied through DA performed on measured variables. The category variables (Y) were the four NaCl concentrations to which mungbean varieties were exposed. Table 4a shows the DFs and CMs obtained from modes of DA, viz., standard, forward stepwise, and backward stepwise. These DA modes constructed DFs, including all nine and two parameters, respectively, and rendered the corresponding CMs (Table 4b), assigning 79.17%, 77.08%, and 45.83% cases correctly. This result on DA suggests that MDA and TFC were significant parameters to differentiate the four sets of the plant responses corresponding to four NaCl concentrations. As identified by DA, box and whisker plots of selected parameters showing different NaCl concentration responses are given in Figure 4a-b. TFC and MDA showed variations in biochemical changes under salinity at different NaCl concentrations.

The effect of salt stress exposure duration in the mungbean varieties was also studied through DA performed on measured

variables. The category variables (Y) were the three exposure duration (E1, E2, and E3). The DA in standard and forward stepwise modes constructed DFs that included all 9 and 7 and 1 parameters for E1, E2, and E3, respectively (Table 5a), and produced corresponding CMs (Table 5b) assigning 85.41%, 79.16, and 47.91% cases correctly. Thus, the DA results revealed that TSC (Figure 5) is the most critical parameter to discriminate between the three sets of exposure durations.

Differences in responses of the NaCl-stressed mungbean varieties' root and shoot tissues were also studied through DPLS. The Score and loadings plots of the first two components (Figure 6a and 6b) illustrate the distribution pattern of response variables in the two sample groups. The PC, MDA, TFC, TPC, and TFAA dominated in the shoot compared to root in both verities. DPPH and ABTS activity are more dominated in shoot than the root of PKU-AKM 12-28 and root and shoot of VBN (Gg)3. PRC and TSC are more dominated in shoot and root of PKU-AKM 12-28. PC, TFC, TPC, DPPH, ABTS, and TFA were dominant in root and shoot of PKU-AKM 12-28 compared to VBN (Gg)3. However, MDA was more dominated in root and shoot of VBN (Gg)3 compared to (PKU-AKM 12-28).

The effect of NaCl concentrations on mungbean varieties was also studied through DPLS performed on measured variables. The score and loadings plot of the first two components are presented in Figure 7a and 7b. At higher NaCl concentration (C4=125 mM), PC, TPC, TFC, DPPH, ABTS, PRC, and TFAA showed more decline, and the MDA was increased more as compared to that observed at all other concentrations. At 75 mM (C2), PC, TPC, TFC, DPPH, ABTS, TSC, TFAA dominated more as compared to C1 (control), C3 (100 mM), and C4. Further, the effect of exposure durations on mungbean varieties' responses was also studied through DPLS performed on measured variables. The score and loadings plots of the first two components are presented in Figure 8a and 8b. These results suggest that at low exposure duration E1 (15 days), biochemical parameters are least affected. With increased exposure duration, parameters were affected more prominently at E2 (30 days) and E3 (45 days). The parameters were greatly influenced at E3 compared to E2.

It was observed that MDA variations were negatively correlated with all other parameters except PRC and TSC under salt stress. Variations in shoot MDA was positively correlated with root MDA ($r=0.92^{**}$). High ($r=0.90^{**}$) positive correlation was observed in variations among shoot TPC, TFC, DPPH, and ABTS. Moreover, nearly 70 to 80% positive correlation was observed among root and shoot TPC, TFC, DPPH, and ABTS. Variation in shoot PRC was positively correlated with root TFC ($r=0.81^{**}$). Variation in shoot and root TSC was positively correlated ($r=0.96^{**}$) with each other. Furthermore, PC in the root was positively correlated with TFAA in the root ($r=0.94^{**}$). TPC in the root was positively correlated with DDPH in the root ($r=0.90^{**}$). Finally, DPPH and ABTS activities in the root showed ($r=0.97^{**}$) a positive correlation with each other (Table 6).

4 Discussion

Salt stress affects the growth, development, and production of crops through osmotic and ionic stress (Liang et al., 2017; Zelm et al., 2020). In India, Mungbean is an economically important and significant dietary pulse crop cultivated, which is also susceptible to salt stress (Ghosh et al., 2015; Sehrawat et al., 2019). In the last decades, its production is reduced due to its susceptibility to different environmental stresses at different stages of its life cycle (Sehrawat et al., 2015). Soil salinity is one of the major stresses that has severely reduced its growth and global yield. Salt stress equivalent to 50 mM NaCl can cause a more than 60% reduction in the yield (Abd-Alla et al., 1998). Salinity alters biochemical processes such as protein synthesis (Alharby et al., 2019). lipid formation in plasma membranes (Datir et al., 2020), levels of secondary metabolites like phenolics and flavonoids (Isah, 2019), and antioxidant defense mechanism to scavenge reactive oxygen species (Taïbi et al., 2016) and synthesis of osmoprotectants like proline, amino acids, and sugars (Gupta & Huang 2014; Yang et al., 2020). Therefore, the current study examined PC, MDA, TPC, TFC, DPPH, ABTS, PRC, TSC, TFAA under 0, 75, 100 and 125 mM NaCl stress. Varieties of crops like soybean (Shelke et al., 2017), rice (Chunthaburee et al., 2015), and watermelon (Sarabi et al., 2016) showed different biochemical responses under salinity stress. Hence, in the present investigation, we compared the effects of salt stress in two mungbean varieties PKV AKM 12-28 and VBN (Gg)3.

HCA is an unsupervised pattern identification method that exposes the underlying behavior or intrinsic structure of datasets without any *a priori* assumption about the dataset to classify or separate objects of the system into different clusters or categories based on its similarity or nearness (Singh et al., 2004; Sinha et al., 2009a; Sinha et al., 2009b; Shelke et al., 2017; Pongprayoon et al., 2019; Dehnavi et al., 2020). It is the most common approach in which clusters are formed sequentially by pairing most similar objects and forming higher clusters. The similarity between the two samples is given by Euclidean distance, and this 'distance' is calculated based on the 'difference' between the analytical values of the two samples (Otto, 1998). HCA was performed to uncover similarities or dissimilarities in the root and shoot responses based on the biochemical and physiological changes under salinity.

The CA results suggest a diverse response to salinity stress at the variety level, as evident from the separate clusters of PKU AKM 12-28 and VBN (Gg)3. These findings agree with previous studies in Sorghum (Dehnavi et al., 2020) and rice (Chunthaburee et al., 2015). Thus, at the same stress level, shoot and root tissues may

show entirely different responses. The plants take up NaCl through their root system and translocate it to the shoot. Therefore, roots play a crucial role in the salt tolerance of plants since they are the first point of contact that controls the uptake and translocation of salts and nutrients. Despite the direct exposure of the roots to the saline environment, their growth is less affected due to salt than that of the shoots (Munns & Tester, 2002). The NaCl concentration gradient along the plant axis may induce different biochemical and physiological responses in root and shoot tissues.

In the PCA analysis of a combined dataset of root and shoot, a close association of PC, TPC, TFC, DPPH, ABTS, PRC, and TFAA was observed in PC1, which is indicative of enhanced synthesis of proteins, amino acids, osmoprotectants such as proline, antioxidant compounds and secondary metabolites to counteract NaCl stress. The protein content is considered one of the critical indicators under stress in plants since it increases under salinity due to enhanced activity of detoxification pathways (Alharby et al., 2019). Protein content in plants increased under salinity due to an increase in the proteins involved in photosynthetic pathways, osmolyte synthesis pathways, ROS scavenging mechanisms, carbohydrate, and energy metabolism (Arif et al., 2020). The phenolics are one of the main groups of secondary metabolites. They function to protect plants against UV light, defense against pathogens, and pigmentation to attract pollinators and protect from ROS. Phenolics accumulate in plants under various environmental stresses, such as salt stress (Isah, 2019; Khare et al., 2020). Chutipaijit et al. (2009) have reported increased flavonoid content under salt stress in salt-tolerant rice cultivar compared to the salt-sensitive one. Antioxidant defense mechanism plays a vital role under salinity. It protects plants from oxidative damage of biomolecules like DNA (Kaur et al., 2014). Our observation of an increase in phenolics and flavonoids under salinity is supported by Valifard et al. (2014) and Bistgani et al. (2019). The proline is also increased under salinity for scavenging ROS, maintaining membrane integrity, osmotic adjustment, and stabilizing protein complexes (Muchate et al., 2016; Abid et al., 2020). These results are in line with those reported by Shahid et al. (2013) and Verma et al. (2018), who have demonstrated an increase in the amino acid contents in various pea and ber cultivars subjected to salt stress, respectively. The elevated levels of amino acids reduced the damages caused by salinity stress (Ashraf & Harris 2004). The PC2 is positively correlated with MDA, which supports earlier work of Sairam et al. (2002), Ashraf and Ali (2008), and Datir et al. (2020), which showed increased plasma membrane lipid peroxidation under salinity. The score plot of the first two principal components (PC1 and PC2) of the combined dataset (shoot and root) reflect the pattern of variations and differences in root and shoot tissue in terms of biochemical parameters over the entire salinity stress used in the experiments. In our study, the shoot's MDA content was elevated more in VBN (Gg)3 than PKU AKM 12-28 at 30 and 45 days of exposure to NaCl. The salinity elevates MDA levels due to the excessive generation of free radicals, which disrupts cellular functioning, affects lipid metabolism, cell membrane properties, and ion transport (Nigam & Schewe 2000; Alzahib et al., 2021). Further, Bor et al. (2003), Chaparzadeh et al. (2004), Shi et al. (2007), Datir et al. (2020), and Alzahib et al. (2021) have also observed salinity elevated MDA levels in beet, marigold, cucumber, wheat, and tomato respectively. At lower salinity levels, the PKU AKM 12-28 showed higher protein content, which tended to decline with increasing salinity. On the contrary, the protein content in VBN (Gg)3 decreased at every salinity level. These results are supported by the observations of Gomathi et al. (2013) and Mohammad et al. (2019). These studies reported increased protein content under salinity in rice *and Tagetes minuta*, respectively, due to differential accumulation of proteins and enhanced expression of polypeptides.

The accumulation of the phenolics and flavonoids was induced at a lower salinity level (75 mM). However, their levels declined at moderate and high salinity levels (100 and 125 mM). Salinity-induced oxidative damage may occur through generating excess reactive oxygen species (ROS) that can attack DNA, proteins, lipids, and carbohydrates. The ROS may occur in non-radical forms ($^1O_2$ and H_2O_2) as well as free radical forms (OH•, $O_2^{\bullet -}$, RO•, and HO_2•) (Gill & Tuteja, 2010). Plants produce antioxidant phenolic compounds such as phenolics and flavonoids to eliminate these ROS (Navarro et al., 2006; Petridis et al., 2012; Isah, 2019). However, the accumulation of phenolics under salinity stress may vary in different varieties of the same plant, as Hichem et al. (2009) showed in maize and Ghosh et al. (2011) in rice. The present investigation corroborates these observations since the phenolic compounds were induced more in PKU AKM 12-28 compared to VBN (Gg)3. The mungbean showed a relative tolerance to 75 mM NaCl stress by increasing phenolic and flavonoid levels. With the increase in salinity level, the imbalance between ROS generation and antioxidants synthesis reduced the efficiency to scavenge ROS. The flavonoids can function as antioxidants under environmental stresses, including salinity (Babu et al., 2003; Tattini et al., 2006; Agati et al., 2012; Babaei et al., 2020). We observed that the change in antioxidant potential was almost similar to the changes in TPC. It indicates a close relationship between phenolics compounds levels and the antioxidant potential (Huang et al., 2006; Ben Taârit et al., 2012; Khare et al., 2020). The results of the present investigation are in line with those in buckwheat sprout (Lim et al., 2012), maize (Hichem et al., 2009), and few Chinese medicinal plants (Wong et al., 2006). A significant correlation was reported between the phenolic content and antioxidant capacity in these plants as well.

The DA results indicate TFC, MDA, and TSC to be the most significant parameters to discriminate between two different plant

tissues (shoot and root) under the same salt stress. These account for most of the variations in biochemical changes studied in the present investigation. MDA and TFC are significant parameters to differentiate four sets of plant responses corresponding to four concentrations of NaCl. These results also reveal the TSC as the most critical parameter to discriminate among the three levels of stress exposure durations.

DPLS models the relationship between the independent variable (X) and dependent variable (Y) simultaneously to identify latent variables (LVs) in X that will predict the latent variables in Y. To verify variables and directions in multivariate space, discriminant partial-least square (DPLS) analysis is used. It enables the determination of variables and directions in multivariate space, which discriminate against the known classes in the calibration set. The DPLS was applied to study the differences in the shoot and root tissues' responses under salt stress in mungbean plants. The DPLS grouped shoot and root tissues separately in different quadrants of loading plots, indicating dominant parameters in both groups. The PC, MDA, TFC, TPC, and TFAA were dominant in the shoot compared to the root. Variations in the dominance of parameters in shoot and root tissues at the variety level were also observed. DPLS analysis-inferred differences between root and shoot tissues' responses under salt stress were as per expected lines. The PC, TPC, TFC, DPPH, ABTS, TSC, TFAA are relatively more dominant at a lower salt concentration (75 mM) than moderate (100 mM) and higher (125 mM) salt concentrations. All the parameters are affected by salt stress given for longer durations. Multiple correlation analysis showed that the variation in most of the biochemical and physiological parameters in shoot and root positively correlated with each other except MDA content, which correlated negatively. The application of a multivariate modeling technique to analyze the effects of salt stress on biochemical attributes in the root and shoot tissues of two varieties of mungbean demonstrated the grouping of variables and their interrelationship between shoot and root tissues and identified significant variables responsible for differential behavior.

5 Conclusion

Multivariate modeling (CA, DA, PCA, DPLS, and MCA) was performed to investigate the effects of NaCl stress and subsequent biochemical changes measured in the mungbean varieties PKU-AKM 12-28 and VBN(Gg)3. This technique provided information on the differential pattern for changes in biochemical parameters in the root and shoot tissues of mungbean. This modeling approach further identified significant biochemical parameters responsible for discrimination between shoot and root sensitivity to salt stress. This analysis revealed variation patterns in biochemical responses and their interdependence under salinity stress. It also revealed the degree of salt-stress tolerance and suggested VBN(Gg)3 as salt susceptible and PKU-AKM 12-28 as salt-tolerant variety. The multivariate modeling approach can interpret results and successfully elaborate the biochemical information from a biological system and the complex relationships among many such attributes in plants.

Acknowledgment

We are grateful to Dr. N.M. Patil, Head, Department of Botany, and Principal Dr. R. S. Zunjarrao for providing the necessary infrastructure required to conduct the research. We thankfully acknowledge the Council of Scientific and Industrial Research, New Delhi, MS, India, for awarding the CSIR-JRF fellowship to Mr. Ganesh Mankar. The authors gratefully acknowledge all institutes and companies for providing seeds of mungbean varieties.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Bioactive Carbohydrates and Dietary Fibre 24 (2020) 100241

Contents lists available at ScienceDirect

Bioactive Carbohydrates and Dietary Fibre

journal homepage: http://www.elsevier.com/locate/bcdf

Hypoglycemic and anticataract activity of crude exopolysaccharides of medicinal mushroom *Phellinus badius* on streptozotocin-induced diabetic rats and goat eye lenses respectively

Hiralal Sonawane [a,*], Sagar Arya [b,c], Vikram Ghole [d], Kishori Apte [e], Deepak Shelke [f], Manohar Chaskar [a,g]

[a] PG Research Centre Botany, PDEA's Prof. Ramkrishna More ACS College, Akurdi, Pune, 411044, Maharashtra, India
[b] Teri-Deakin Nanobiotechnology Centre, Gurgaon, Haryana, 122001, India
[c] Center for Innovation, Research and Consultancy, Pune, 411018, India
[d] National Institute of Virology, Pashan, Pune, Maharashtra, India
[e] National Toxicology Centre, Pune, Maharashtra, India
[f] Department of Botany, Amruteshwar Arts, Commerce and Science College, Vinzar, Velha, Pune, 412213, India
[g] Faculty of Science and Technology, Savitribai Phule Pune University, Pune, Maharashtra, India

ARTICLE INFO

Keywords:
Phellinus badius
Exopolysaccharides
Hypoglycemic
Streptozotocin
Anticataract

ABSTRACT

Phellinus badius is one of the medicinal mushrooms used as folk medicine in Western Ghats of India. Traditionally, the *P. badius* is used in the treatment of diabetes, diarrhea, arthritis, toothaches, as well as tongue and throat related ailments. Therefore, we investigated the hypoglycemic and anticataract activity of *P. badius* crude exopolysaccharides (EPS) in streptozotocin (STZ) induced diabetic rats and Goat eye lens, respectively. The EPS obtained from the submerged mycelial culture of *P. badius* was used for the bioactivity studies. Among various concentrations of EPS administered to diabetic rats, 400 mg/kg dose showed significant hypoglycemic effects, such as the reduction in blood glucose (37.2 %) and increase in body weight (47.4 %) as compared to the control groups. Furthermore, reduction in triglycerides (23.4 %), cholesterol (23.4 %), as well as decrease in the activities of aspartate aminotransferase (33.8 %) and alanine aminotransferase (31.9 %) were also observed. The crude EPS retarded the progression of lens opacification and reduced the risk of cataract formation in sugar administered goat eye lenses. The results suggest that the crude EPS obtained from *P. badius* mycelia can be considered as a potential source for hypoglycemia and cataractogenesis. The LC/MS analysis revealed the metabolic profile of the crude EPS, which could be further evaluated based on bioassay guided fractionation to identity and characterize the active ingredients.

1. Introduction

Mushrooms are a part of traditional medicine in Asian countries since time immemorable, especially basidiomycetes, having diverse nutritional, medicinal and pharmacological properties (Nakamura et al., 2004). Various medicinal mushroom, their parts, cellular components and mushroom-derived secondary metabolites are reported for bioactive properties, such as immunomodulatory, anticancer, hepatoprotective, antidiabetic, hypolipidemic, etc., and are therefore explored for their pharmaceutical applicability (Liu et al., 2019; Rathore et al., 2019; Smith, Rowan, & Sullivan, 2002; Valverde et al., 2015; Wasser, 2002).

Phellinus is one such genus of medicinal mushrooms belonging to the family Hymenochaetaceae. Vaidya and Bhor (1991) have reviewed '*Phellinus*' and suggested that as many as twelve species of this poroid genus which are used in ayurvedic and traditional medicine. The fruiting bodies and exopolysaccharides (EPS) derived from *Phellinus* species have shown to have bioactive properties and are therefore explored for their pharmaceutical relevance (Hwang et al., 2007; Wang et al., 2015). For instance, they are used to treat allergy, arthritis, diarrhea, diabetes, hepatic disorders, toothaches and other throat-related issues (Kim, Yang, Hur, Das, Yun, Choi, & Song, et al., 2001, 2003, 2010; Sonawane et al., 2013; Zhu et al., 2008). Similarly, several studies demonstrated

* Corresponding author. PG Research Centre in Botany, Department of Botany, PDEA's Prof. Ramkrishna More ACS College, Akurdi, Pune, Maharashtra, 411044, India.
E-mail address: amolsbr@gmail.com (H. Sonawane).

https://doi.org/10.1016/j.bcdf.2020.100241
Received 23 April 2020; Received in revised form 7 August 2020; Accepted 14 August 2020
Available online 26 August 2020

the hypoglycemic potential of EPS obtained from medicinal mushrooms such as *Lentinus edodes, Agrocybe cylindracea, Auricularia polytricha, Cordyceps militaris, P. linteus, Cordyceps sinensis, P. baumii,* and *Tremella fuciformis* (Yamac et al., 2009). However, few species belonging to the genus *Phellinus* still need a scientific evidence to be used for their EPS for pharmaceutical evaluations. Among them is a medicinal mushroom *P. badius* found in the western ghats of India. The fruiting body of *P. badius* is widely used by the tribal and traditional practitioners for tooth-, tongue-, throat-related ailments, excess salivation in infants and diarrhea (Sonawane et al., 2013; Vaidya & Lamrood, 2000).

Globally, diabetes mellitus is one of the most common health crisis arising from fluctuation in blood glucose levels. At present, about 5–10 % of the world population is suffering from diabetes, and the number is increasing by 3 % annually (Zhang et al., 2017). Diabetes mellitus is symptomized by progressive destruction of β-cells and subsequent impairment in insulin secretion. Macrophages present such β-cells to specific auto-antigens of $CD4^+$ Th cells, which is generally considered as an onset of autoimmune diabetes (McDevitt, 2001). Various drugs are available to treat diabetes and the complications arising from it (Katarzyna et al., 2019). However these drugs have a range of side-effects associated them, and hence, it is essential to search for natural alternatives with little or no side-effects. Among many natural sources, use of medicinal mushroom could be an effective option. Owing to the hypoglycemic potential of exopolysaccharides (EPS) of medicinal mushrooms, there is an exponential increase in the interest toward them (Kim., Lim., Joo., Kim., Hwang, Choi., & Yun et al., 2005; Rosado et al., 2003; Xiao et al., 2004). Furthermore, reports also suggest that EPS can alleviated the side-effects of hyperglycemia such as cataractogenesis, which is a prime secondary complication of diabetes (Javadi & Zarei-Ghanavati, 2008). Therefore, cataract remains a leading cause of visual disability and blindness in diabetic patients. Biochemical changes in cataract include, loss of glutathione, protein thiol, ATP, impaired ionic equilibrium, altered mitotic rate, modification of protein and increase in unfolded polypeptides. Aging is another factor responsible for cataractogenesis and is followed by excess alcohol consumption, smoking, inappropriate diet, steroids, exposure to ultraviolet light, hypertension, etc. (McCarty & Taylor, 1996). In hyperglycemia, there is a marked increase in cellular and tissue glucose levels where the influx is independent of insulin, which includes lens, retina, kidney and peripheral nerves.

As per the traditional claims and previous reports on medicinal mushrooms, we aim to investigate the hypoglycemic and anticataract potential of *P. badius* mycelia derived crude EPS in Streptozotocin (STZ)-induced diabetic rats and goat eye lenses, respectively.

2. Material and methods

2.1. Culture of P. badius

The basidiocarps of *P. badius* were collected from the western ghats of Maharashtra, India. The *P. badius* culture was established on Petri plates containing potato dextrose agar (PDA) and was incubated at 27 ± 2 °C. The *P. badius* culture was then authenticated from and submitted to Microbial Type Culture Collection, Chandigarh, India with accession no. MTCC8449. The acclimatization of *P. badius* for submerged culture and scale-up was performed as per the procedure of Hwang et al. (2005) with slight modifications.

Briefly, the *P. badius* submerged culture was established in potato dextrose broth (PDB) (pH 5) and was kept at 28 ± 2 °C on an incubator shaker at 120 rpm for 14 days. Further to optimize the growth and maintenance, the mycelia from the 14 days old submerged culture (100 ml) was homogenized and inoculated in PMP medium (PDB 24 g/L, malt extract 10 g/L, peptone 1 g/l). The culture (pH 5) was incubated at 28 ± 2 °C on an incubator shaker at 120 rpm for 5 days. After acclimatization, the scale-up of submerged culture for EPS production was performed in stirred tank fermenter (5 L) with glucose 4 %, polypeptone 0.3 %, yeast extract 0.3 %, KH_2PO_4 0.05 % and Na_2HPO_4 0.05 %. The pH and temperature were maintained at 5.5 and 27 ± 2 °C, respectively. We further analyzed the influence of different temperature (20, 23, 26, 29, 32, 35 °C) and pH (4, 5, 6, 7, 8) conditions to maximize the yield of mycelia and exopolysaccharides stirred tank fermenter.

2.2. Separation of exopolysaccharides

The culture broth was filtered through Whatmann filter paper no. 2. The filtrate was mixed with 90 % ethanol in a ratio 1:4 (v/v) and the mixture was kept idle at 4 °C. The mixture was centrifuged at 10,000 rpm for 20 min and the pellet was mixed in distilled water followed by dialysis (MW cutoff, 8,000–14,000 Da) against distilled water. After dialysis, the dialyzed extract was centrifuge at 10,000 rpm for 10 min. The pelleted precipitate was freeze-dried and used as aqueous crude EPS for bioactivity studies.

2.3. Hypoglycemic activity

2.3.1. Animal studies

Animal studies were carried out at the National Toxicology Center (NTC), Pune, India. All the experiments were approved by the Institutional Animal ethical committee (IAEC). Wistar male rats (200 ± 20 g) were housed at NTC in controlled conditions. The temperature and humidity were maintained at 24 ± 2 °C and 60 ± 5%, respectively under 12 h light/dark period. The rats were fed with pelleted diet (Amrut rats pellet diet, India) and water throughout the experiment.

2.3.2. Induction of experimental diabetes mellitus

All the rats were subjected to overnight fasting and were made diabetic by injecting Streptozotocin (STZ) (Sigma, India) intraperitoneally. STZ was prepared by dissolving in 0.01 M citrate buffer (pH 4.5) at a dose of 50 mg/kg (Bolkent et al., 2000; Kim, Yang, Hur, et al., 2001). Blood glucose level was determined by glucometer (Contour TS) after 48 h of injection. Rats with blood glucose level >300 mg/dl were considered as diabetic and used for further study. Rats were randomly divided into six treatments with eight rats in each treatment, i.e. normal control (NC), diabetic control (DC); STZ + EPS 50 mg/kg, STZ + EPS 100 mg/kg, STZ + EPS 200 mg/kg and STZ + EPS 400 mg/kg. Rats were administered oral zoned dose for 14 days.

2.3.3. Biochemical assay

The blood samples of the test rats were collected and treated with EDTA (0.1 M) as an anticoagulant. The blood plasma was separated by centrifuging at 3,000 rpm for 10 min. Plasma triglycerides and cholesterol levels were determined by colorimetry-based enzyme assay kits (Merck. India). The alanine aminotransferase and aspartate aminotransferase levels were also determined using enzyme kits (Merck, India) based on the Reitman-Frankel method (Reitman & Frankel, 1957). Blood urea nitrogen (BUN) and albumin levels (ALB) were analyzed by using diagnostic kits (Merck Bioline RX Ltd.).

2.4. Anticataract activity

2.4.1. Collection of goat lenses and cataractogenesis

The anticataract activity was performed as per the procedure of Ganeshpurkar et al. (2011). Briefly, goat eyes were collected from a local slaughter house with prior approval from IAEC. The eyeballs obtained from a 6 months old male goat were transported to the laboratory in freezing conditions. The eyeballs were dissected by anterior approach and lenses were isolated within an hour of sacrificing animals. The lenses were rinsed with physiological saline and incubated at 37 °C in sterile culture media supplemented with antibiotics (100 μg/ml streptomycin and penicillin), which was filtered through 0.2 μ membrane filters (Millipore, India) (Suryanarayana et al., 2004; Zigler & Hess, 1985). Two pairs of lenses were incubated separately in 5 ml sterile

medium with either control (5.5 mM glucose) or test sample (100 mM glucose) and incubated at 37 °C for 12 days. To maintain the viability of lenses, the spent sterile medium was replenished with fresh medium aseptically after a regular interval of 48 h. *P. badius* crude EPS (1 mg/ml) was added to the medium when used along with the supra-physiological concentration of glucose i.e. 100 mM. Lenses incubated with 5.5 mM glucose (physiological concentration) served as control. The lenses were observed for haziness, opacities, intumescences, disruption and other morphological changes on everyday basis. After 10 days of incubation, lenses were removed and wet weight was recorded. Further, the lenses were homogenized in a buffer containing 25 mM Tris, 100 mM NaCl, 0.5 mM EDTA and 0.01 % NaN_3 at pH 8.0. The homogenate was centrifuged at 10,000 rpm at 4 °C for 30 min. The soluble fraction of the lens homogenate was stored at - 40 °C for further analysis.

2.4.2. Total protein and soluble protein estimation

The soluble fraction of the lens homogenate was used in protein estimation. The precipitated protein was dissolved in sodium hydroxide and aliquots were used for the estimation of total proteins. The homogenate prepared in double-distilled water supernatant was used in the estimation of soluble fractions of protein. The protein content was determined by the method of Lowry et al. (1951) using bovine serum albumin as the standard.

2.4.3. Estimation of malondialdehyde (MDA)

Lens homogenate MDA was estimated as TBA reactive substances (Bhuyan et al., 1981). Briefly, to 0.1 ml total protein, 1 ml of 20 % TCA was added and this homogenate was heated at 90 °C for 20 min. An aliquot of 1 ml supernatant was mixed with 0.5 ml of 0.5 % (w/v) TBA and boiled for 30 min, following which it was brought to room temperature and absorbance of pink-colored product was measured at 532 nm. The 1, 1, 3, 3-tetraethoxypropane (20 nmol/ml) was used as standard.

2.4.4. Protein carbonyl estimation

The measurement of protein carbonyl was carried out according to Uchida et al. (1988) . Briefly, 0.5 ml (0.5 mg) lens protein sample was incubated with 0.5 ml of 0.1 % of 2,4 dinitrophenylhydrazine (DNPH) in 2 N HCl for 1 h. After an hour, 0.5 ml of 20 % TCA was added and the precipitated proteins were washed three times with 1:1 ethanol/ethyl acetate. Finally, the precipitate was solubilized in a buffer containing 133 mM Tris, 13 mM EDTA buffer (pH 7.4) containing 8 M urea. Absorbance was recorded at 365 nm. The concentration of carbonyl groups was calculated using 365 nm = 21 mM^{-1} cm^{-1} as the extinction coefficient for aliphatic hydrazones. Protein content was estimated as per Lowry et al. (1951) using bovine serum albumin as a standard.

2.4.5. AGE fluorescence

Advanced glycation end product (AGE) fluorescence was measured in soluble protein 0.15 mg/ml protein in 0.05 M sodium phosphate buffer (pH 7.4). The fluorescence emissions were recorded from 400 - 500 nm with excitation at 370 nm as described by Monnier and Cerami (1981), on a RF-5301 spectrofluorometer (Shimadzu, Osaka, Japan).

2.4.6. Estimation of glycated proteins

In this study, 3 mg/ml of glycated lens protein was loaded on the phenyl boronate affinity column (7 × 1 cm) equilibrated with 5 column volumes of equilibration buffer (0.25 M ammonium acetate buffer (pH 8.5) containing 0.05 M $MgCl_2$. The unbound fraction of non-glycated proteins were washed with equilibration buffer. The bound glycated lens proteins were eluted using elution buffer (0.1 M Tris HCl, pH 7.5 containing 0.2 M sorbitol) with a flow rate of 0.3 ml/min (Fujita et al., 1998). The protein content in each fraction was determined spectrophotometrically by recording absorbance at 280 nm against distilled water as blank.

2.5. LC/MS analysis

LC/MS was performed to identify some of the dominant compounds present in the crude aqueous EPS. Briefly, the crude EPS obtained from mycelial culture of *P. badius* were mixed in 95 % methanol and the mixture was filtered through Whatman filter paper no. 1 pre-wetted in 95% methanol. The resultant filtrate was aliquoted after passing it through 0.2 μ membrane filters (Millipore, India). The bioactive compounds were then identified by performing Q-TOF LC/MS analysis of aliquoted crude EPS on Agilent Accurate-Mass 6200 Series TOF LC/MS systems (Agilent Santa Clara, California). The mass spectrometer was coupled to HPLC equipped with UV–vis detector. The compounds were separated using Zorbax SB C18 rapid resolution column (4.6 mm × 150 mm, 3.5 particle size). The solvent systems used were, formic acid (0.1%, v/v) (Solvent A), 90 % acetonitrile + 0.1 % formic acid (Solvent B). A gradient was used for solvent B at a 2–30 min of total run time. The flow rate was maintained at 0.3 ml/min with an initial injection volume of 3 μl/min. The ESI parameters both negative and positive ion mode with mass range 125–1000 m/z, spray voltage 1 kV, gas temperature 250 °C, gas flow 13 L/min, nebulizer 35 psi and mass were analyzed using Agilent technologies Mass-Hunter software.

2.6. Statistical analysis

The result analysis for statistical significance of eight replicates was done by one-way analysis of variance (ANOVA) test using the SPSS statistical program. The data was expressed as mean ± Standard Deviation (SD). Group means were compared by Duncan's multiple range tests at $p < 0.05$ significance level.

3. Results

3.1. Optimization and establishment of P. badius submerged culture

The pure culture of *P. badius* was sequentially acclimatized before optimization for scaled-up in stirred tank fermenters. Different physiological conditions, such as series of temperature and pH regimes were tried to maximize the biomass and EPS yield. The progressive increase in mycelial biomass and EPS content was recorded at regular intervals for a growth period of 24 days (Fig. 1). About 2.7 g/l EPS was obtained from 8.2 g/l mycelial biomass on 24 days. The analyzed data under various temperature and pH conditions demonstrate that the maximum growth of mycelial biomass and EPS was achieved at pH 5 (Fig. 2a) and 26 °C (Fig. 2b). The fermenter runs at 26 °C temperature yield 2 g/l EPS from 5.2 g/l mycelial biomass while fermenter runs at 5.0 pH yield 1.8 g/l EPS from 6.7 g/l mycelial biomass.

3.2. Hypoglycemic activity

The effect of crude aqueous EPS on the blood glucose level and other related parameters were observed in streptozotocin induced diabetic rats over a period of 14 days.

3.2.1. Blood glucose level

In this test, a continuous increase in blood glucose level was observed in STZ treated control rat group during the entire experimental duration (Fig. 3). However, the rat groups which were administrated with various concentrations of crude EPS showed a concentration depended reduction in blood glucose level as compared to the diabetic control group. The groups that received high concentrations of EPS such as 200 mg/kg and 400 mg/kg showed a significant reduction in blood glucose level by 27.5 % and 37.2 % respectively.

3.2.2. Food intake and body weight gain

The effect of PBE on the food intake and body weight gain in STZ-induced diabetic rats is presented in Fig. 4. A significant difference in

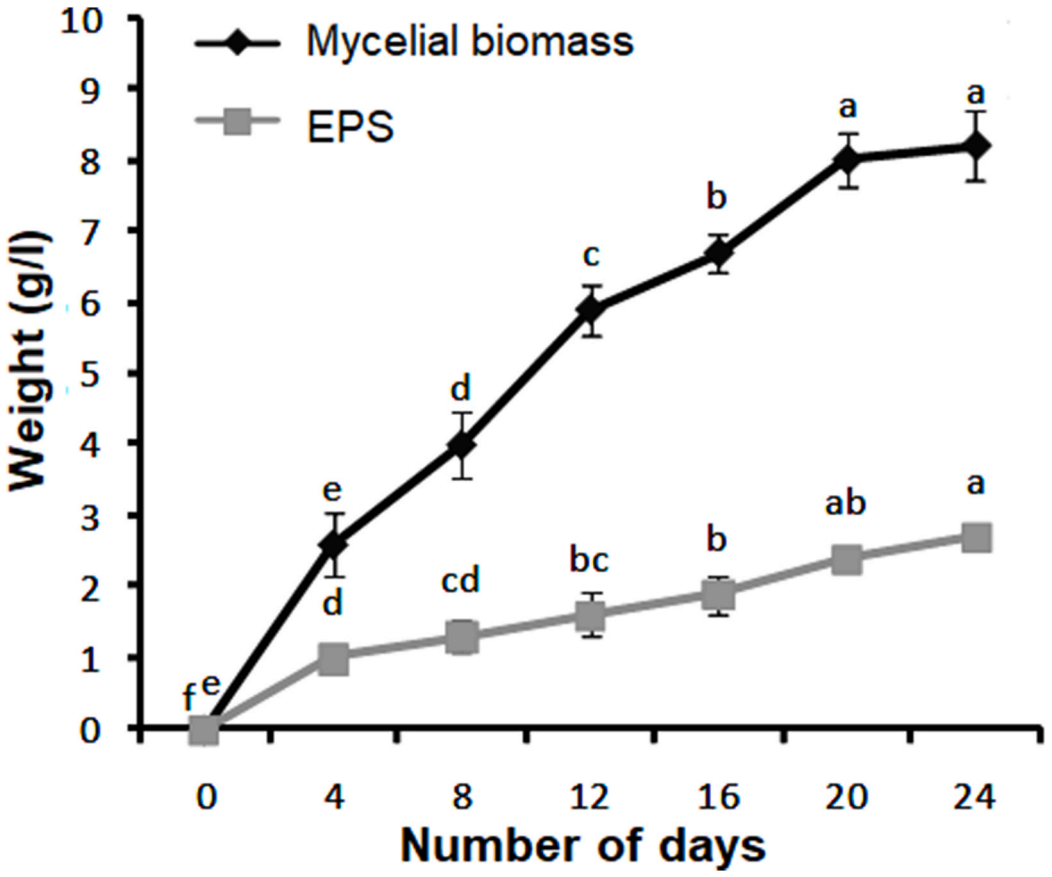

Fig. 1. Accumulation of mycelial biomass and exopolysaccharides (EPS) (g/l) in the submerged culture of *Phellinus badius* with respect to the number of days.

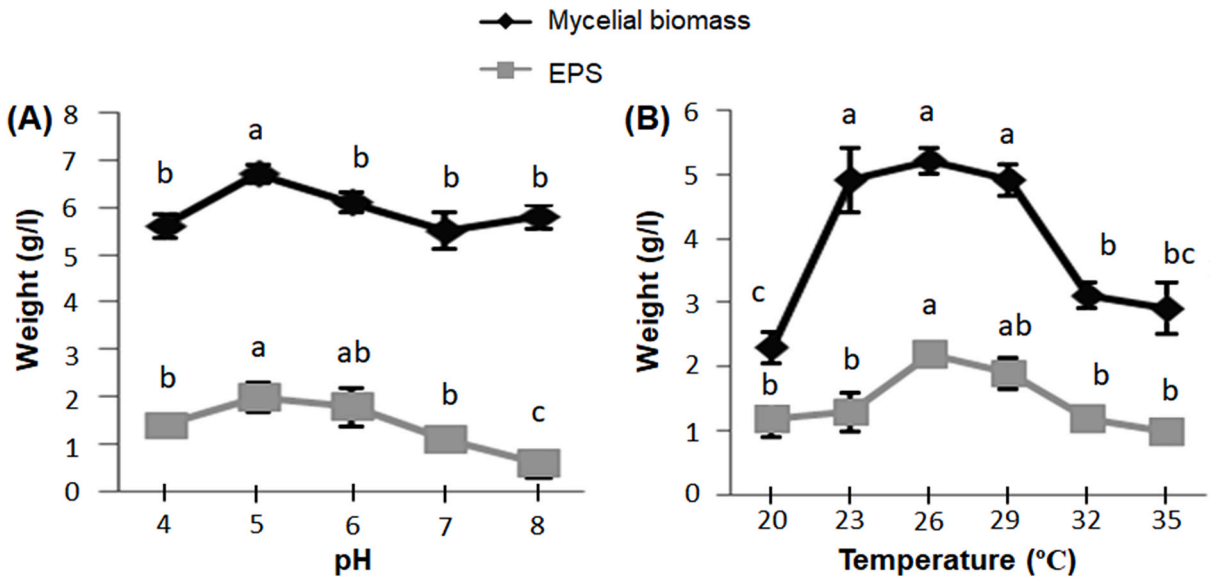

Fig. 2. Effect of (a) pH, and (b) temperature on the mycelial biomass and exopolysaccharides. (EPS) production in submerged culture of *Phellinus badius*.

food intake and body weight gain was observed between diabetic rat groups (DC – STZ-induced diabetic rats; and STZ + EPS – EPS administered diabetic rats) and normal control group (NC). The food intake of the DC increased by 12.34 %, whereas body weight gain was reduced by 55 % as compared to NC (Fig. 4). However, STZ + EPS group (50, 100, 200 and 400 mg/kg EPS) showed decrease in food intake, which was 27.2, 27.6, 15.9 and 21.5 % lower respectively than DC. Hence, EPS 50 and 100 mg/kg dose selected to be the most effective dose to control food intake in diabetic rats. Furthermore, a significant difference was observed in the body weights of STZ + EPS group as compared to DC and NC (Fig. 4). However, no significant difference between the body weights of STZ + EPS rats were observed. The STZ + EPS group showed a progressive increase of 47.4 % in body weight gain compared to DC (Fig. 4).

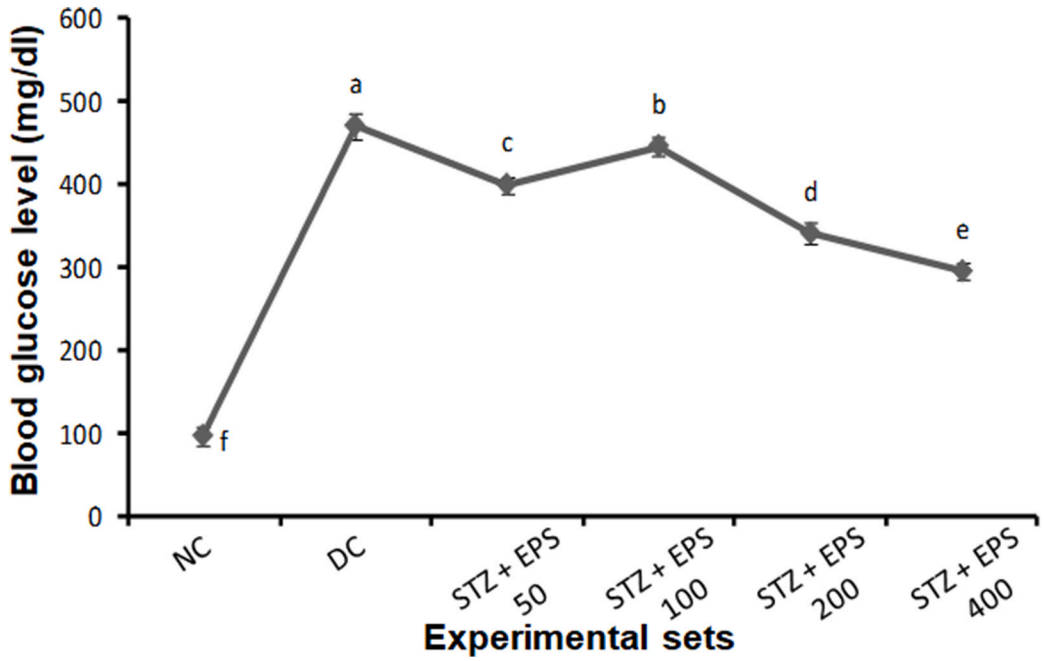

Fig. 3. Blood glucose levels of rats with no diabetes (normal control - NC), streptozotocin (STZ) induced diabetic rats (diabetic control - DC) and streptozotocin induced diabetic rats injected with various concentrations of *Phellinus badius* crude EPS i.e. (50, 100, 200 and 400 mg/kg EPS).

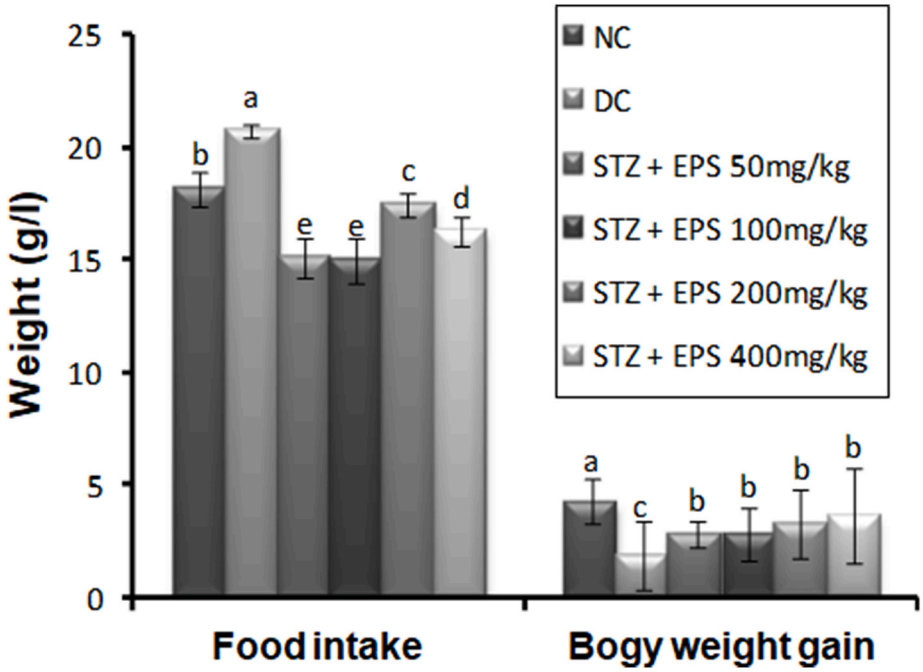

Fig. 4. The food intake and body weight gain in the rats with no diabetes (normal control - NC), streptozotocin (STZ) induced diabetic rats (diabetic control - DC) and streptozotocin induced diabetic rats injected with various concentrations of *Phellinus badius* crude EPS i.e. (50, 100, 200 and 400 mg/kg EPS). Values are means ± S. D., where n = 8, $p < 0.05$.

3.2.3. Triglyceride and cholesterol level

The triglyceride (39.4%) and cholesterol (29.8%) levels were significantly increased in DC compared to the normal control (Fig. 5). However, the plasma triglyceride level was markedly reduced in 50, 200 and 400 mg/kg EPS administered rats. Furthermore, the rats belonging to STZ + EPS groups significant and concentration dependent decrease in cholesterol levels as compared to NC and DC. In comparison to DC, the STZ + EPS (400 mg/kg) group showed 23.4 % and 27.9 % reduction in triglyceride and cholesterol levels respectively (Fig. 5).

3.2.4. Aspartate aminotransferase (AST) and alanine aminotransferase (ALT)

The crude EPS on the plasma AST and ALT activities in STZ-induced diabetic rats is shown in Fig. 6. A significant difference in both AST and ALT activities was observed between DC and NC. For instance, the AST and ALT activities of the DC increased by 50.1 % and 39.6 % compared to NC. Furthermore, a concentration dependent decline AST activity was observed in the STZ + EPS groups. However, maximum reduction in AST and ALT activities were observed in STZ + EPS (400 mg/kg) group,

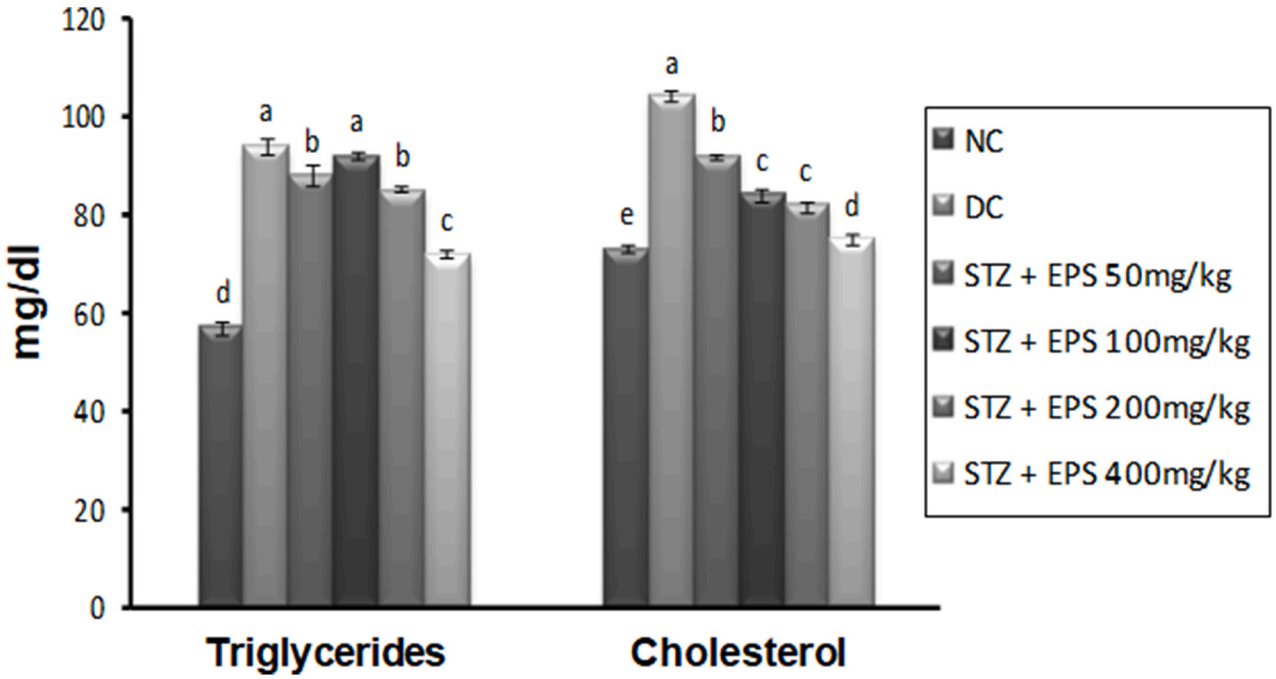

Fig. 5. The levels of plasma triglycerides and cholesterol in the rats with no diabetes (normal control - NC), streptozotocin (STZ) induced diabetic rats (diabetic control - DC) and streptozotocin induced diabetic rats injected with various concentrations of *Phellinus badius* crude EPS i.e. (50, 100, 200 and 400 mg/kg EPS). Values are means ± S.D, where n = 8, $p < 0.05$.

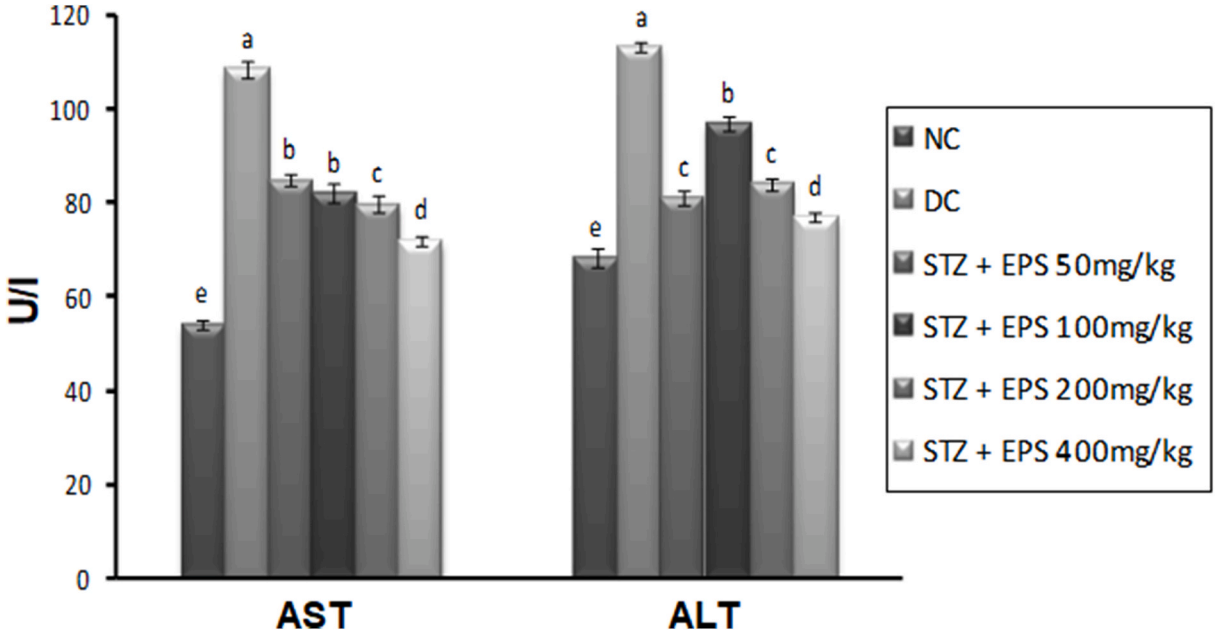

Fig. 6. The activities of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) in the rats with no diabetes (normal control - NC), streptozotocin (STZ) induced diabetic rats (diabetic control - DC) and streptozotocin induced diabetic rats injected with various concentrations of *Phellinus badius* crude EPS i.e. (50, 100, 200 and 400 mg/kg EPS). Values are means ± S.D, where n = 8, $p < 0.05$.

which was 33.8 % and 31.9 % respectively compared to DC.

3.2.5. Blood urea nitrogen (BUN) and albumin (ALB) levels

As shown in Table 1, the BUN and ALB levels of DC increased by 55.5 % and 23.1 % respectively, compared to NC. There was a significant difference between the BUN levels of DC and NC. Furthermore, the BUN levels for all the STZ + EPS groups showed a declining trend as compared to DC. Interestingly, a marked reduction of 51.4 % in the BUN level was observed in STZ + EPS (200 mg/kg) group, which was close to NC. Although there was a difference in the level of ALB in DC and NC, the STZ + EPS groups did not show any significant difference as compared to DC or among themselves.

3.2.6. Rat body organ weight

The variation in the body organ weight of all the experimental groups are presented in Fig. 7. There were no significant differences recorded in the weight of spleen, kidney and lung in between the studied groups. However, the weight of heart, liver and pancreas were increased

Table 1
The blood urea nitrogen (BUN), and albumin (ALB) levels of control (NC), streptozotocin (DC) and streptozotocin (STZ) + *P. badius* crude exopolysaccharides (EPS) treated rats.

Animals group	BUN (mg/dl)	ALB (g/dl)
NC	15.87 ± 1.09^{e}	3.56 ± 0.21^{c}
DC	35.67 ± 1.53^{a}	4.63 ± 0.25^{a}
STZ + EPS 50 mg/kg	24.00 ± 1.0^{b}	4.58 ± 0.10^{a}
STZ + EPS 100 mg/kg	21.33 ± 1.53^{c}	4.32 ± 0.10^{a}
STZ + EPS 200 mg/kg	17.33 ± 1.53^{d}	4.19 ± 0.06^{ab}
STZ + EPS 400 mg/kg	22.33 ± 3.21^{b}	4.20 ± 0.10^{ab}

Values are means ± S.D, where n = 8, $p < 0.05$.

and/or decreased in the DC as compared to the NC. The weight of heart, liver and pancreas of DC increased by 10.1 %, 10.8 % and 45.6 % respectively, as compared to NC. Two STZ + EPS groups administered with 100 and 200 mg/kg EPS showed reduction in heart weight by 32.8 % and 37.7 % respectively, as compared to DC. Furthermore, the STZ + EPS group administered with 100 mg/kg EPS showed a decrease in the weight of liver and pancreas by 46.8 % and 43.9 % respectively, as compared to DC. Generally, a similar trend was followed in almost all STZ + EPS groups, i.e. reduction in body organ weight at low concentration of EPS (50 and 100 mg/kg EPS) and an increase at higher concentrations (200 and 400 mg/kg). Unlike other experiments, the administration of higher concentration of EPS i.e. 400 mg/kg did not show any significant effect on the body organ weight as compared to DC.

3.3. Effect of crude P. badius EPS against cataractogenesis

The goat eye lenses were used to examine the effect against cataractogenesis and related parameters.

3.3.1. Lens morphology

The goat eye lenses incubated with physiological (5.5 mM glucose), supra-physiological concentration (100 mM glucose) and test sample i.e. (100 mM glucose + EPS) are presented in Fig. 8. Photographic examination suggests that the lenses kept at physiological concentration of glucose did not show any visual change throughout the experiment (Fig. 8a). Lenses incubated with supra-physiological concentration of glucose showed varying degree of cataractogenic changes, such as complete opacification after 10 days (Fig. 8b). However, the lenses treated with crude EPS showed a decline in the progression of lens opacification (Fig. 8c).

3.3.2. Lens total protein and total soluble protein

The homogenate of the lenses treated with 100 mM glucose showed significant reduction in total protein and total soluble protein as compared to lenses treated with 5 mM glucose (Table 2). However, the homogenate of the lenses treated with 100 mM glucose and crude EPS retained the total protein and total soluble protein concentration at significantly higher levels i.e. 36.3 % and 15.8 % respectively, as compared to the homogenate of the lenses treated with only 100 mM glucose.

3.3.3. Lipid peroxidation and protein carbonyl

The variation in the levels of lipid peroxidation and protein carbonyl of the control and test sample are given in Table 2. Lipid peroxidation measured in terms of malondialdehyde (MDA) levels showed a significant increase in MDA (40 %) of homogenate of the lenses treated with 100 mM glucose as compared to homogenate of lenses treated with 5 mM glucose. However, the homogenate of the lenses treated with 100 mM glucose and crude EPS showed a decrease of only 25 % in MDA levels as compared to the control i.e. 5 mM glucose. Likewise, significantly increased in protein carbonyl was observed in lenses incubated with 100 mM glucose i.e. 81.3 % as compared to the control lenses. Whereas the homogenate of the lenses treated with both 100 mM glucose and crude EPS showed significant decrease in MDA i.e. 76.4 % as compared to the 100 mM which was insignificant from the control i.e. 5 mM glucose treatment.

3.3.4. AGE fluorescence and glycated protein

The advanced glycation end product (AGE) fluorescence of control and test lenses are shown in Fig. 9. The test sample i.e. 100 mM glucose and crude EPS treated lenses showed a decreased in AGE fluorescence as compared to lenses treated with only 100 mM glucose. Furthermore, when soluble lens proteins from the lenses treated with 100 mM glucose were subjected to phenyl boronate affinity column (strong affinity towards glycated proteins), the column retained 30 % of the soluble lens proteins. However, the glycated proteins retained by phenyl boronate affinity column from the soluble proteins of the lenses treated with 100 mM glucose and crude EPS were negligible as compared to that of the glycated protein retained by the column with the soluble protein of lenses incubated with only 100 mM glucose (Fig. 10).

3.4. LC/MS profile of P. badius crude EPS

The LC/MS profiling of *P. badius* crude EPS showed the presence of some well-characterized bioactive compounds (Table 3). Some of the dominant compounds identified are arecoline, gliquidone, indole-3-carboxylic acid, thymoquinone, hydrocodone, naloxone, maprotiline, khivorin, artemisinin, dihydroartemisinin, anastrozole, flutamide, diltiazem, capsaicin and naphthalene dihydrodiol. In addition, other

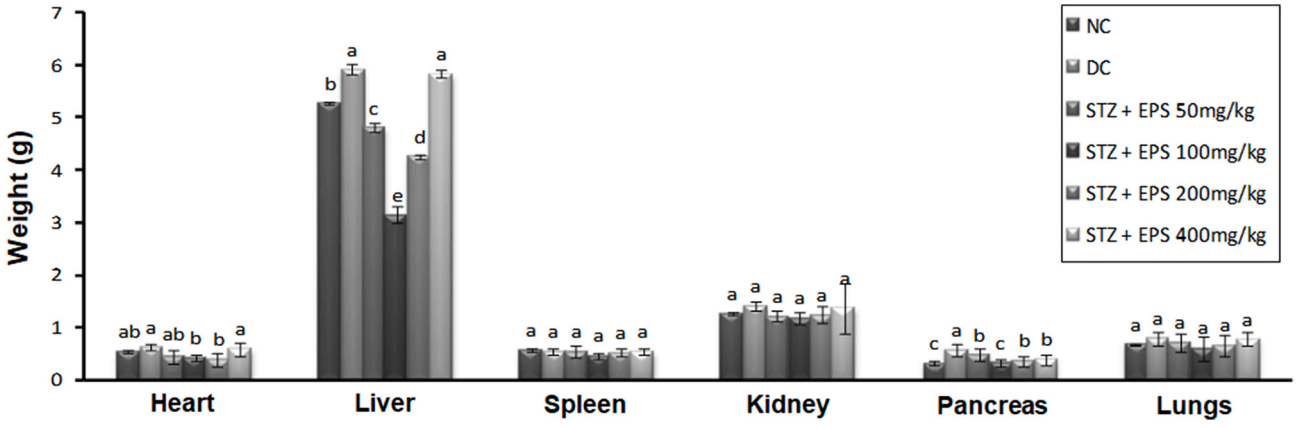

Fig. 7. The body organ weight/100 g of rats with no diabetes (normal control - NC), streptozotocin (STZ) induced diabetic rats (diabetic control - DC) and streptozotocin induced diabetic rats injected with various concentrations of *Phellinus badius* crude EPS i.e. (50, 100, 200 and 400 mg/kg EPS). Values are means ± S.D, where n = 8, $p < 0.05$. Values are means ± S.D, where n = 8, $p < 0.05$.

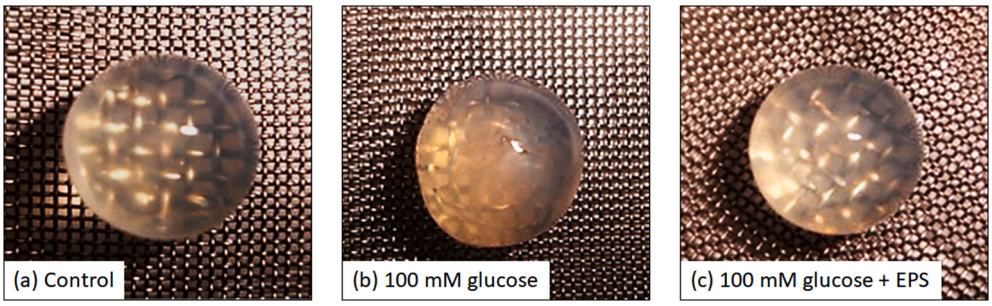

Fig. 8. Goat eye lenses treated with (a) Control (5 mM glucose), (b) 100 mM glucose, and (c) 100 mM glucose + crude EPS under *in vitro* conditions.

Table 2
The total protein, total soluble protein, MDA and protein carbonyl content of Goat eye lenses treated with either glucose (5 mM and 100 mM) or glucose (100 mM) and *P. badius* crude exopolysaccharides (EPS).

Treatment	Total protein (μg/ml)	Total soluble protein (μg/ml)	MDA (μM/g)	Protein carbonyl (nM/mg protein)
Control (5 mM glucose)	192.2 ± 6.4^{a}	96.3 ± 5.2^{a}	0.36 ± 0.01^{c}	3.4 ± 0.6^{b}
100 mM glucose	112.7 ± 8.2^{c}	71.2 ± 3.6^{c}	0.6 ± 0.04^{a}	18.2 ± 2.8^{a}
100 mM glucose + EPS	176.8 ± 7.7^{b}	84.6 ± 2.4^{b}	0.45 ± 0.01^{b}	4.3 ± 2^{b}

Values are means ± S.D, where n = 8, $p < 0.05$.

compounds with potential bioactivities were also reported, for instance, indospicine, tropine, sulfabenzamide, o-hydroxyaniline, etc. (Table 3).

4. Discussion

P. badius is a medicinal mushroom widely used as folk medicine in western ghats of Maharashtra, India. The fruiting body of *P. badius* is reported to have antioxidant, antifungal and glucose lowering properties, however, very less is known about the exopolysaccharides (EPS) by the mycelial biomass (Sonawane et al., 2013). Also, though the fruiting body has bioactivities and is traditionally used, it is not feasible to employ it for pharmaceutical and industrial application owing to the complicated extraction process and nonuniformity in the extracted chemical compounds. Therefore, it is more reasonable to use EPS obtained *in vitro* grown *P. badius* mycelial biomass than the fruiting body of mushrooms. Hence, to investigate the traditional claims of the glucose lowering potential, we investigated the hypoglycemic and anticataract activity of EPS obtained from *in vitro* culture of submerged *P. badius* mycelia. Initially we analyzed the influence of physiological conditions such as temperature and pH on the growth and yield of *P. badius* mycelial biomass and exopolysaccharide (EPS) respectively for a period of 24 days. As reported in other studies, these parameters greatly influenced the growth in mycelial biomass and EPS yield (Kim, Lim, et al., 2005; Park et al., 2001; Xiao et al., 2004). The temperature (26 °C) and pH (5) that gave maximum output can be correlated to the average annual temperature of western ghats i.e. 20 °C to 26 °C, and the pH is close to the physiological pH of higher plants on which it grows i.e. 5.5 to 6.5.

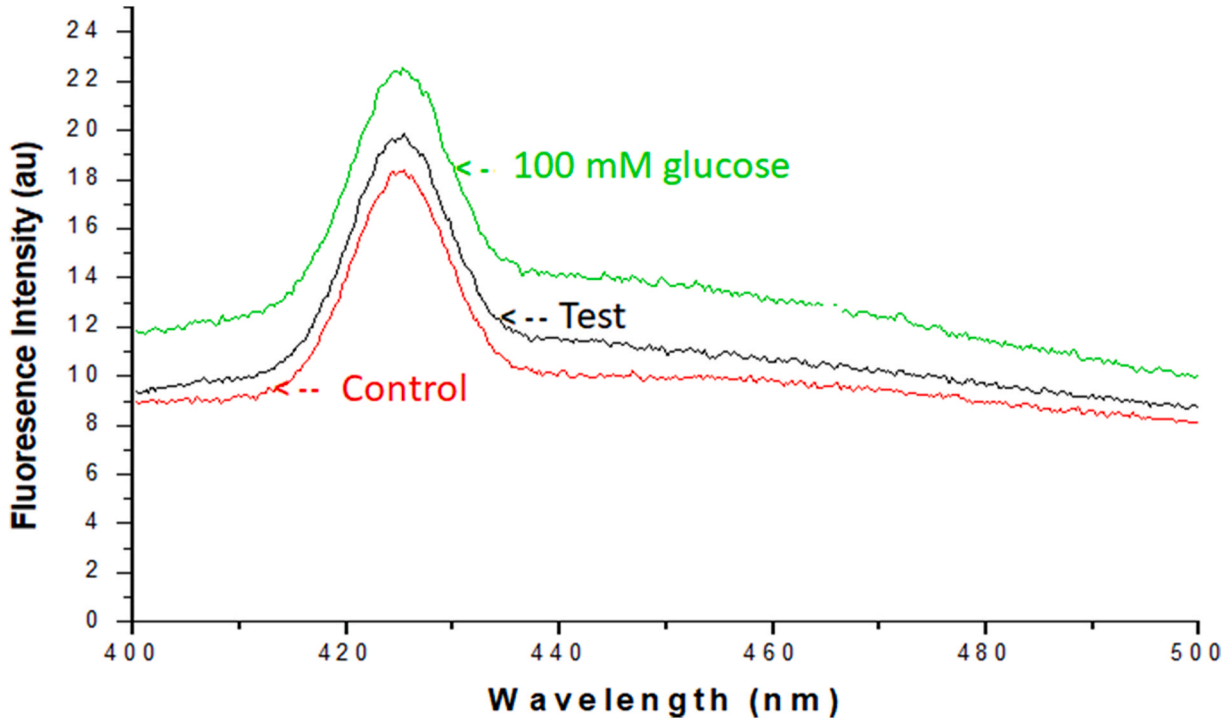

Fig. 9. Advanced glycation end product (AGE) fluorescence of the soluble protein of goat eye lenses treated with (a) Control (5 mM glucose), (b) 100 mM glucose, and (c) 100 mM glucose + crude EPS (Test) under *in vitro* conditions.

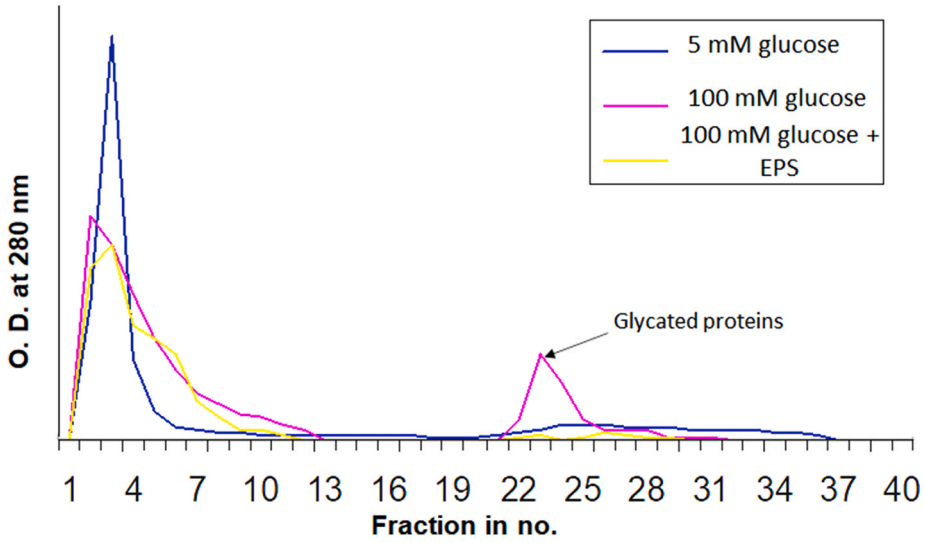

Fig. 10. Phenyl boronate affinity chromatogram of soluble protein from the lenses cultured with glucose applied to column. Control (5 mM glucose), 100 mM glucose and 100 mM glucose + EPS.

After optimizing the physiological parameters, the crude EPS was isolated from the mycelial biomass of *P. badius* and were used for bioactivity studies. The EPS derived from medicinal mushrooms such as *Lentinus edodes*, *Tremella fuciformis*, *Coprinus comatus*, *Lenzites betulina*, *Cerrena unicolor* and many others have been studied for their hypoglycemic potential (Cho et al., 2007; Hwang et al., 2005; Yamac et al., 2009; Yang et al., 2002). Moreover, EPS from one of the closely related species to *P. badius* i.e. *P. baumii* is also reported to have hypoglycemic activity (Hwang et al., 2005). Furthermore, the EPS from their fruiting bodies or *in vitro* cultured mycelial biomass also alleviated the side effects associated hyperglycemia. Therefore, some of these mushrooms and their EPS were regarded as ideal choices for their pharmaceutical evaluation to treat hyperglycemia (Yamac et al., 2009). In our study, a broad spectrum antibiotic Streptozotocin (N-nitroso derivative of glucosamine) was used to inhibited insulin secretion by selective destruction of β-cells of islets of Langerhans and artificially induce hyperglycemia in rats i.e. type-I diabetes mellitus. The diabetic rats initially showed an increase in food intake of diabetic rats was a result of insulin deficiency and decreased muscle tissue sensitivity to insulin. Also, decrease in weight was observed which may be due to the damage caused to the muscle and adipose tissue by the decline in insulin level (Chen et al., 2018; Liu et al., 2019). Further, these diabetic rats were given different doses of aqueous crude EPS (50, 100, 200, 400 mg/kg i.e. EPS/wt. of rats).

The crude EPS injection to the diabetic rats resulted in a significant decrease in the blood glucose level (Fig. 3), and its side-effects in a concentration dependent manner. As discussed earlier regarding the selective destruction of β-cells by STZ, we can assume that *P. badius* mycelia derived EPS could play a crucial in repairing the damaged β-cells and promoting insulin secretion, thereby reducing the blood glucose level. Gray and Flatt (1998) suggested that the extract of *Agaricus campestris* fruiting body could reduce diabetes by regulating plasma glucose levels. Other possible mechanism for EPS might be increase blood glucose utilization by stimulating pancreas and promoting insulin secretion. Zhang and Lin (2004), observed that polysaccharides derived *Ganoderma lucidum* could promote the insulin release from the pancreatic islets by facilitating Ca^{2+} inflow to the pancreatic h-cells.

The blood glucose-lowering effect of crude EPS showed a direct correlation to the behavioral, physiological and molecular changes in the diabetic rats. For instance, reduction in food intake and increase in overall body weight (Fig. 4). Also, the level of plasma cholesterol and triglycerides, and the activities of AST and ALT enzymes also showed a decline as compared to DC (Figs. 5 and 6). Similar results were observed with the EPS of *P. baumii* (Hwang et al., 2005), suggesting that compounds in EPS can influence the food intake and body weight ratio. Numerous other reports suggest that the EPS administration to diabetic rats can influence the food utilization efficiency and body weight ratio (Furuse et al., 1993; Hwang et al., 2005; Kiho et al., 2001; Kim, Yang, Jeong, Hur, Das, Yun, Choi, Lee, & Song et al., 2001; Yang et al., 2002). The reduction in plasma cholesterol and triglycerides, and rise in the activities of AST and ALT may be the result of liver damage and related metabolic changes caused by STZ. The EPS could also exert hepatoprotective effect and reduce the high-fat-emission by liver as evidenced from the study performed on the EPS of *Termitomyces albuminosus* (Zhao et al., 2017). There was no clear distinction between the body organ weight of EPS administered rats, however, a trend was followed i.e. decrease at lower (50 and 100 mg/kg) and increase at higher (200 and 400 mg/kg) EPS concentrations (Fig. 7).

The BUN level is indicative of the normal functioning of the kidneys and liver. The BUN concentration of EPS treated diabetic rats showed a significant decrease as compared to diabetic rats (Table 1). Reduction in the BUN level suggests a corrective role of EPS towards kidney and liver functioning (Yang et al., 2002). However, not much variation was observed in the ALB levels of EPS treated and diabetic rats (Table 1).

For the first time we report *in vitro* anticataract activity of EPS obtained from *P. badius* mycelia. The lenses incubated with supra-physiological glucose concentration and EPS showed a decrease in the level of total protein and total soluble protein as compared to control lenses (Table 2). It is reported that during cataractogenesis large amount of soluble proteins are converted to insoluble proteins (Aziz et al., 2015). However, decrease in soluble protein was significantly prevented in the lenses incubated in the medium containing EPS. Furthermore, the rise in MDA and protein carbonyl content was significantly reduced in the EPS treated lenses (Table 2). The level of MDA and protein carbonyl are considered as markers for oxidative stress. Thus, the decrease in MDA and carbonyl protein level suggest that EPS inhibits oxidative stress (Uchida et al., 1998).

The reduction in the characteristic fluorescence of AGE suggests that EPS interferes in the process of glycation as well as the formation of AGE (Fig. 9), suggesting the antiglycation potential of EPS. The excess of glucose results in protein glycation, which can be measured as AGE fluorescence. Also, the level of total glycated proteins measured using phenyl boronate affinity column chromatography showed that the EPS has protected the lens proteins from excess glycation (Fig. 10). Incubation of goat lenses with supra-physiological concentrations of glucose (100 mM) led to the loss in the transparency, however, the treatment of

Table 3
Compounds identified by LC/MS profiling of *P. badius* crude exopolysaccharides.

Compound name	RT	Mass	Formula	DB diff (ppm)
Norcotinine	0.805	162.0745	C9 H10 N2 O	29.62
Sulfabenzamide	0.817	276.0551	C13 H12 N2 O3 S	6.5
4-Hydroxybenzyl cyanide	0.978	133.0516	C8 H7 N O	8.58
L-2-Aminoadipic acid	1.092	161.0678	C6 H11 N O4	6.05
Tropine	1.119	141.1144	C8 H15 N O	6.95
L-Homophenylalanine	1.212	179.0935	C10 H13 N O2	6.19
Neuraminic acid	1.217	267.0954	C9 H17 N O8	0.12
Indospicine	1.269	173.1154	C7 H15 N3 O2	6.17
4-(3-Pyridyl)-3-butenoic acid	1.301	163.0624	C9 H9 N O2	5.9
o-Hydroxyaniline	1.402	109.0545	C6 H7 N O	−16.17
Arecoline	1.514	155.0955	C8 H13 N O2	−5.91
9-amino-nonanoic acid	1.751	173.1403	C9 H19 N O2	7.53
2-Methylene-5-(2,5-Dioxotetrahydrofuran-3-YL)-6-oxo-10,10-Dimethylbicyclo [7: 2: 0] Undecane	2.836	304.1639	C18 H24 O4	11.7
13-amino-tridecanoic acid	3.205	229.2027	C13 H27 N O2	6.34
Gliquidone	3.742	527.2001	C27 H33 N3 O6 S	16.93
Indole-3-carboxylic acid	3.898	161.0467	C9 H7 N O2	5.94
p-Hydroxymethylphenidate	3.979	249.1373	C14 H19 N O3	−3.33
4-(3-Pyridyl)-3-butenoic acid	4.102	163.0624	C9 H9 N O2	5.98
Letrozole	4.746	285.0989	C17 H11 N5	8.85
4-Hydroxyquinazoline	4.82	146.0471	C8 H6 N2 O	6.46
Naphthalene dihydrodiol	4.916	162.0672	C10 H10 O2	5.72
Meperidine N-oxide	5.211	263.1529	C15 H21 N O3	−2.8
Thymoquinone	5.269	164.0829	C10 H12 O2	5.22
hydrocodone	5.287	299.1505	C18 H21 N O3	5.57
Naloxone	5.421	327.1459	C19 H21 N O4	3.48
Maprotiline	5.422	277.1893	C20 H23 N	−22.68
Khivorin	5.855	586.2728	C32 H42 O10	8.59
Artemisinin	5.857	282.1453	C15 H22 O5	5.1
5,7,9,11,13-tetradecapentaenoic acid	5.859	218.1297	C14 H18 O2	4.33
Tegaserod	6.066	301.1872	C16 H23 N5 O	10
Anastrozole	6.203	293.1638	C17 H19 N5	0.82
Oxyquinoline	6.461	145.0521	C9 H7 N O	4.8
Dihydroartemisinin	6.589	284.1611	C15 H24 O5	4.48
amiloxate	6.589	248.1403	C15 H20 O3	3.74
3,6,8-dodecatrien-1-ol	6.589	180.153	C12 H20 O	−8.71
Nabumetone alcohol	6.589	230.1297	C15 H18 O2	4.18
1H-1,2,4-Triazole-1-propanoic acid, 4,5-dihydro-3- (1-hydroxyethyl)-5-oxo-4-(2-phenoxyethyl)-	7.234	321.1311	C15 H19 N3 O5	4.16
Metaxalone	7.343	221.1046	C12 H15 N O3	2.8
Methsuximide	7.347	203.0939	C12 H13 N O2	3.56
Spaglumic Acid	7.376	304.0908	C11 H16 N2 O8	−0.57
Flutamide	7.379	276.0665	C11 H11 F3 N2 O3	20.61
Matricin	7.425	306.1434	C17 H22 O5	10.82
Naloxol	7.482	329.1628	C19 H23 N O4	−0.21
6beta-Naltrexol	7.596	343.1769	C20 H25 N O4	4.27
Diltiazem	7.606	414.1553	C22 H26 N2 O4 S	14.62
Capsaicin	7.719	305.2	C18 H27 N O3	−3
Helenine	9.226	232.1451	C15 H20 O2	5.32
gamma glutamyl ornithine	9.39	261.1357	C10 H19 N3 O5	−12.44
Dihydrodeoxystreptomycin	10.127	567.2863	C21 H41 N7 O11	0.19
Sulfamethazine	11.098	278.085	C12 H14 N4 O2 S	−4.52
Homatropine	11.385	275.1506	C16 H21 N O3	5.48
2R-aminohexadecanoic acid	15.597	271.2494	C16 H33 N O2	6.37
3-Deoxo-3beta-Acetoxydeoxydihydroge Dunin	19.283	512.2779	C30 H40 O7	−1.01
12beta-Hydroxy-3-oxo-5betacholan-24-oic Acid	20.795	390.275	C24 H38 O4	5.25
Anhydroeschscholtzxanthin	22.781	530.397	C40 H50	−10.82
levmetamfetamine	26.517	149.1194	C10 H15 N	6.91
Dextroamphetamine	26.518	135.104	C9 H13 N	5.65
2,4,6-Trimethylacetophenone imine	26.522	161.1194	C11 H15 N	6.48

EPS (0.5 mg/ml) preserved the transparency and protected the lenses from supra-physiological concentration of glucose. This result indicates a positive effect of the EPS on the cataractous lenses.

In addition to the above findings, the LC/MS of crude EPS showed the presence of arecoline, gliquidone, indole-3-carboxylic acid, thymoquinone, hydrocodone, maprotiline, artemisinin, dihydroartemisinin, anastrozole, dextroamphetamine, capsaicin, and naphthalene dihydrodiol as predominant ones. These compounds are well-documented and known for their blood glucose regulatory activity (Bule, Nikfar, Amini, & Abdollahi, 2019; Choudhary et al., 2011; Guo et al., 2018; Kevin & Alvin, 2013; Malaisse, 2006; Meng et al., 2019; Saha et al., 2015; Suresh et al., 2012; Tigran et al., 2019; Zhang et al., 2017). The compound naphthalene dihydrodiol is also reported to reduce cataractogenesis (Xu et al., 1992). Therefore, the presence of these compounds in the EPS supports hypoglycemic and anticataract activity shown by the EPS of *P. badius*.

Moreover, some of the compounds are also reported to have pharmacological potentials such as cardio-protection, anti-parasitic, anti-inflammatory, anticancer, hepatoprotection, anti-microbial, antidepressant, antimalarial, antitumor, antiviral, antifungal, antiarthritic, and hypolipidemic (Liu et al., 2016; Goyal et al., 2017; Meng et al.,

2019; Guo et al., 2018; Suresh et al., 2012; Sharma, Vij, & Sharma, 2013). Therefore, further bioassay guided fractionation is required to identify the active ingredients of EPS that are responsible for the hypoglycemic and anticataract activity. *P. badius* might become a multipotential and promising natural alternative to treat diabetes mellitus and cataractogenesis.

This study shows that *P. badius* have the potential to work as a hypoglycemic agent. The viscosity of EPS may delay carbohydrate absorption and improving the control of hyperglycemia, hyperinsulinemia, impaired glucose and insulin resistance in diabetic mice (Hwang et al., 2007; Kim, Kim, Choi, & Lee et al., 2005). Exopolysaccharides can restore the immune-modulative imbalance caused by diabetes or it may even increase the activities of hepatic glucokinase, hexokinase, and glucose-6-phosphate dehydrogenase (Zhang & Lin, 2004). The no variances in.

5. Conclusion

Our study suggests that *P. badius* EPS plays a crucial role in blood sugar regulation and against cataractogenesis in diabetic rat and goat eye lenses, respectively. The result encourages us to believe that the *in vitro* culture of *P. badius* mycelia can become a potential source of hypoglycemic and anticataract agents in the future. However, as revealed by LC/MS analysis we need further study to identify the active fractions or pure compounds responsible for the bioactivities.

CRediT authorship contribution statement

Hiralal Sonawane: Formal analysis, Writing - original draft, Data curation, Investigation. **Sagar Arya:** Formal analysis, Writing - original draft, Data curation. **Vikram Ghole:** Data curation, Investigation, Supervision. **Kishori Apte:** Data curation, Investigation, Supervision. **Deepak Shelke:** Formal analysis, Writing - original draft. **Manohar Chaskar:** Supervision.

Declaration of competing interest

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bcdf.2020.100241.

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Journal of Interconnection Networks
Vol. 21, No. 2 (2021) 2150007 (7 pages)

DOI: 10.1142/S0219265921500079

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A Note on Conditional Edge Connectivity of Hypercube Networks

J. B. Saraf* and Y. M. Borse†

Department of Mathematics
Savitribai Phule Pune Univeristy
Pune 411007, India
**sarafjb@gmail.com*
†*ymborse11@gmail.com*

Received 5 December 2018
Accepted 29 March 2021

Let G be a connected graph with minimum degree at least n and let h be an integer such that $0 \leq h < n$. The conditional h-edge (h-vertex) cut of G is defined as a set F of edges (vertices) of G whose removal disconnects G leaving behind components of minimum degree at least h. The characterization of a minimum h-vertex cut of the n-dimensional hypercube Q_n is known. In this paper, we characterize a minimum h-edge cut of Q_n. Also, we obtain a sharp lower bound on the number of vertices of an h-edge cut of Q_n and obtain some consequences.

Keywords: Hypercube; conditional connectivity; edge cut.

1. Introduction

An interconnection network with high fault tolerance capacity is preferable for practical implementation. The fault tolerance capacity of the given network is closely related to the connectivity of the underlying graph. Harary [5] introduced the concept of conditional edge (vertex)-connectivity, which measures the fault tolerance capacity of a network more accurately. Let $h,\ n$ be integers such that $0 \leq h < n$ and G be a connected graph with minimum degree at least n. An *h-edge (h-vertex) cut* of graph G is a set F of edges (vertices) of G such that the graph $G - F$ is disconnected and each component of it has minimum degree at least h. The *conditional h-edge (h-vertex) connectivity* of G is denoted as $\lambda^h(G)$ ($k^h(G)$) and is the minimum cardinality $|F|$ of an *h-edge (h-vertex) cut* F of G. Clearly, $h = 0$ gives traditional connectivities. The conditional connectivities for various networks have been studied in the literature, see [8,9,11–13,15]. These connectivities are also known as R_g-connectivities [14].

The *Cartesian product* of two graphs $G_1 = (V_1, E_1)$ and $G_2 = (V_2, E_2)$ is denoted by $G_1 \square G_2$. It is the graph with vertex set $V_1 \times V_2$ and edge set $\{(x_1, y_1)(x_2, y_2) :\ x_1 =$

x_2 and $y_1y_2 \in E_2$, or $y_1 = y_2$ and $x_1x_2 \in E_1\}$. Let n be a positive integer. The n-dimensional hypercube, denoted by Q_n, is the Cartesian product of n copies of the complete graph K_2. It is an n-regular, n-connected graph having 2^n vertices and $n2^{n-1}$ edges. The hypercube network is one of the most widely used interconnection networks due to its beautiful properties [7] such as regularity, high connectivity, vertex-transitivity, low dimension, recursive structure etc.

For the hypercube Q_n, the conditional h-vertex connectivity and conditional h-edge connectivity are determined by Oh and Choi [9], and Xu [13], respectively and both the connectivities are equal to $(n-h)2^h$. These connectivities are also obtained for some hypercube variants such as augmented cubes [12], hypercube-like networks [8, 15] and multidimensional tori [11].

The problem of characterizing a minimum h-vertex cut S of the hypercube Q_n is considered in [6, 10, 14]. Usually, such characterization is given by characterizing a smallest component (i.e. a component with a minimum number of vertices) of the graph $Q_n - S$. It seems that a smallest component of $Q_n - S$ is isomorphic to Q_h. Ramras [10] proved that this holds when $h = 0$ while Latifi [6] proved it for $1 \leq h \leq [n/2]$. However, Yang and Meng [14] established that the case $h = n - 3$ is an exception.

Theorem 1.1 ([14]) *Let h, n be integers with $1 \leq h \leq n-2$ and S be a minimum h-vertex cut of Q_n and Y be a smallest component of $Q_n - S$. Then*

(i) *Y is isomorphic to Q_h if $h \leq n-4$ and $n \geq 5$, or $h = n-2$ and $n \geq 3$;*
(ii) *Y is isomorphic to Q_h or $Q_{h-1}\Box K_{1,4}$ if $h = n-3$ and $n \geq 4$.*

In this paper, we characterize a minimum h-edge cut F of the hypercube Q_n. Note that an $(h+1)$-edge cut of Q_n is also an h-edge cut. However, we see that this does not hold for minimum h-edge cuts except for $h = n-2$. We characterize a smallest component of $Q_n - F$ in the following theorem. Note that the hypercube Q_0 of dimension zero is a graph consisting of only one vertex and no edge.

Theorem 1.2. *For integers h, n with $0 \leq h \leq n-1$, let F be a minimum h-edge cut in the hypercube Q_n and Y be a smallest component of $Q_n - F$. Then*

(i) *Y is isomorphic to Q_h if $0 \leq h \leq n-3$ and $n \geq 3$, or $h = n-1$ and $n \geq 1$;*
(ii) *Y is isomorphic to Q_h or Q_{h+1} if $h = n-2$ and $n \geq 2$.*

We prove this theorem in Sec. 2. In Sec. 3, we obtain a sharp lower bound on the number of vertices of an h-edge cut of Q_n and prove some interesting consequences of this result about removable regular subgraphs.

2. Minimum h-Edge Cut

In this section, we prove Theorem 1.2.

For a subgraph Y of a graph G, let $E_G(Y)$ be the set of edges of G between Y and $G - V(Y)$, that is, $E_G(Y) = \{xy\colon x \in V(Y),\ y \in V(G) - V(Y)\}$. For a set F of

edges of G, let $V(F)$ be the set of end vertices of edges belonging to F. Let e be any edge of Q_n. We can write Q_n as $Q_n = Q^0_{n-1} \cup Q^1_{n-1} \cup M$, where Q^0_{n-1} and Q^1_{n-1} are vertex-disjoint copies of Q_{n-1} and M is the perfect matching of Q_n between these two copies with $e \in M$.

The following result shows every the smallest h-regular subgraph of Q_n is isomorphic to Q_h.

Lemma 2.1 ([1]) *For positive integers h, n with $h < n$, let Y be a subgraph of Q_n of minimum degree at least h. Then Y has at least 2^h vertices. Moreover, if Y has exactly 2^h vertices, then it is isomorphic to Q_h.*

We also need the following results.

Lemma 2.2 ([1]) *For positive integers h, n with $h < n$, let Y be a subgraph of Q_n isomorphic to Q_h. Then any vertex of Q_n, which is not in Y, has at most one neighbour in Y.*

Lemma 2.3 ([13]) *For positive integers h, n with $h < n$, let Y be a connected subgraph of $Q_n = Q^0_{n-1} \cup Q^1_{n-1} \cup M$ for which $E_{Q_n}(Y)$ is an h-edge cut of Q_n. If $Y_i = Q^i_{n-1} \cap Y$, then Y_i is a subgraph of Q^i_{n-1} such that $E_{Q^i_{n-1}}(Y_i)$ is an $(h-1)$-cut of Q^i_{n-1} for $i = 0, 1$.*

Lemma 2.4 ([13]) *For positive integers h, n with $h < n$, $\lambda^h(Q_n) = (n-h)2^h$.*

Thus a minimum h-edge cut of Q_n has cardinality $(n-h)2^h$. Note that $\lambda^{n-1}(Q_n) = 2^{n-1} = \lambda^{n-2}(Q_n)$. Hence a minimum $(h+1)$-edge cut is also a minimum h-edge cut of Q_n for $h = n-2$. However, this does not hold if $h \neq n-2$.

In the following lemma, we provide a minimum h-edge cut of Q_n.

Lemma 2.5. *For integers h, n with $0 \leq h < n$, let Y be a subgraph of Q_n isomorphic to Q_h. Then the edge set $E_{Q_n}(Y)$ is a minimum h-edge cut of Q_n.*

Proof. Let $F = E_{Q_n}(Y)$. Then $Q_n - F$ is disconnected and Y is one of its components. By Lemma 2.2, any vertex $x \in V(Q_n) - V(Y)$ has at most one neighbour in Y. Hence the minimum degree of $Q_n - V(Y)$ is $n-1 \geq h$. This shows that F is an h-edge cut of Q_n. By Lemma 2.4, $|F| = (n-h)2^h = \lambda^h(Q_n)$. Thus F is a minimum h-edge cut of Q_n. □

The case $h = 0$ of Theorem 1.2(i) follows from the following result of Ramras [10].

Lemma 2.6 ([10]) *For $n \geq 3$ and $h = 0$, if F is a minimum h-edge cut of Q_n, then $Q_n - F$ is a disconnected graph with an isolated vertex.*

We now prove Theorem 1.2.

Proof of Theorem 1.2. Suppose that F is a minimum h-edge cut of Q_n and Y is a smallest component of $Q_n - F$. By Lemma 2.4, $|F| = (n-h)2^h$. Then $Q_n - F$ has

two components, each of minimum degree at least h. Hence, by Lemma 2.1, each component has at least 2^h vertices.

Case (i). Suppose $h = n - 1$.

Then each component of $Q_n - F$ has exactly 2^{n-1} vertices as Q_n has 2^n vertices. Therefore Y is a subgraph of Q_n of minimum degree at least $n-1$ on 2^{n-1} vertices. By Lemma 2.1, Y must be isomorphic to Q_{n-1}.

Case (ii). Suppose $0 \leq h \leq n-3$ and $n \geq 3$.

We proceed by induction on n. If $h = 0$, then Y is isomorphic to $K_1 = Q_0$ by Lemma 2.6. Hence the result holds for $h = 0$ and so it holds for $n = 3$. Suppose $n \geq 4$ and $1 \leq h \leq n-3$. Assume that the result is true for the $(n-1)$-dimensional hypercube. Since the minimum degree of Y is $h \geq 1$, it contains an edge, say e. Write $Q_n = Q^0_{n-1} \cup Q^1_{n-1} \cup M$, where M is the perfect matching of Q_n between Q^0_{n-1} and Q^1_{n-1} containing e. Let $Y_i = Y \cap Q^i_{n-1}$ and $F_i = E_{Q^i_{n-1}}(Y_i)$ in Q^i_{n-1} for $i = 0, 1$.

Then both Y_0 and Y_1 are non-empty as $e \in M$. By Lemma 2.3, F_i is an $(h-1)$-edge cut of Q^i_{n-1}. Therefore, by Lemma 2.4, $|F_i| \geq (n-h)2^{h-1}$ for $i = 0, 1$. Since F_0 and F_1 are disjoint subsets of F, we have $(n-h)2^h = |F| \geq |F_0| + |F_1| \geq (n-h)2^{h-1} + (n-h)2^{h-1} = (n-h)2^h$. Thus we have $|F_0| = |F_1| = (n-h)2^{h-1} = \lambda^{h-1}(Q_{n-1})$. This shows that $F = F_0 \cup F_1$ and so, F does not contain any edge of the matching M. By Lemma 2.4, F_i is a minimum $(h-1)$-edge cut of Q^i_{n-1} for $i = 0, 1$. Hence $Q^i_{n-1} - F_i$ has two components, one of which is Y_i. Let Z_i be its other component. By induction, Y_i or Z_i is isomorphic to Q_{h-1}. As Y is a smallest component of $Q_n - F$, we have $|V(Y)| \leq |V(Q_n)| - |V(Y)| = |V(Z_0)| + |V(Z_1)|$. Therefore we may assume that $|V(Y_0)| \leq |V(Z_0)|$. Hence Y_0, being a smaller component of $Q^0_{n-1} - F_0$, is isomorphic to Q_{h-1}. As the degree of each vertex of Y_0 is at least h in Y, every vertex of Y_0 has a neighbour in Y_1. Therefore $|V(Y_1)| \geq |V(Y_0)| = 2^{h-1}$. Assume that $|V(Y_1)| > |V(Y_0)|$. Then there exists a vertex x in Y_1 which has no neighbour in Y_0. However, x has a unique neighbour, say x', in Q^0_{n-1}. Thus x' must be in Z_0. Hence x' is not a vertex of Y. This shows that the edge $f = xx'$ of the matching M also

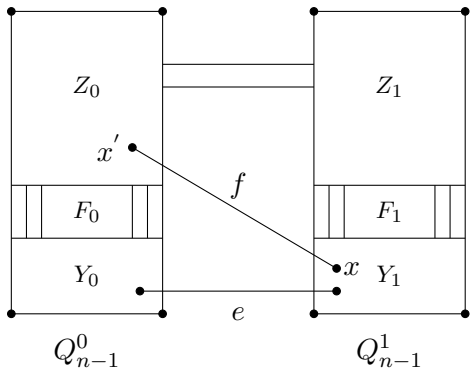

Fig. 1. The h-edge cut F of Q_n.

belongs to F as shown in Fig. 1, a contradiction. Thus $|V(Y_1)| = |V(Y_0)| = 2^{h-1}$. Since the minimum degree of Y_1 is at least $h-1$, Y_1 is isomorphic to Q_{h-1} by Lemma 2.1. It follows that Y is isomorphic to Q_h.

Case (iii). Suppose $h = n-2$ and $n \geq 2$.

Suppose $n = 2$. Then $h = 0$ and Q_n is just a 4-cycle. Obviously, any minimum edge cut F of a 4-cycle consists of two edges that either form a matching or are incident to a vertex. Thus the smallest component of $Q_n - F$ is $K_1 = Q_0$ or $K_2 = Q_1$. Hence the result holds for $n = 2$.

Suppose $n \geq 3$. Assume that the result holds for Q_{n-1}. As in the proof of Case (ii), split Q_n along an edge e of Y as $Q_n = Q^0_{n-1} \cup Q^1_{n-1} \cup M$. If $Y_i = Y \cap Q^i_{n-1}$, then $F_i = E_{Q^i_{n-1}}(Y_i)$ is a minimum $(n-3)$-edge cut of Q^i_{n-1} with Y_i as a component of $Q^i_{n-1} - F_i$ for $i = 0, 1$. Further, $F = F_0 \cup F_1$. This implies that all neighbours of Y_0 present in Q^1_{n-1} are in Y_1 and vice versa. Since a component of a graph is its vertex-induced subgraph, Y_i is a vertex-induced subgraph of Q^i_{n-1}. It follows that Y_1 is the subgraph of Q^1_{n-1} corresponding to Y_0. Thus $Y = Y_0 \square K_2$. As Y is a smallest component of Q_n, Y_0 is also a smallest component of $Q_{n-1} - F_0$. By induction, Y_0 is isomorphic to Q_{n-3} or Q_{n-2}. Hence Y is isomorphic to $Q_{n-3} \square K_2 = Q_{n-2}$ or $Q_{n-2} \square K_2 = Q_{n-1}$. □

Corollary 2.1. *For integers h, n with $n \geq 3$ and $0 \leq h \leq n-1$, let F be a minimum h-edge cut in the hypercube Q_n. Then*

(i) $F = E_{Q_n}(Q_h)$ *if* $h \neq n-2$;
(ii) $F = E_{Q_n}(Q_h)$ *or* $E_{Q_n}(Q_{h+1})$ *if* $h = n-2$.

3. Removable Regular Subgraphs

In this section, we obtain a sharp lower bound on the number of vertices of an h-edge cut of the hypercube. We prove several consequences of this result about removable regular subgraphs.

For a subgraph Y of Q_n let $N[Y] = N(Y) \cup V(Y)$, where $N(Y)$ is the set of all neighbours Y in $V(Q_n) - V(Y)$. Ye and Liang [15] proved the following result.

Lemma 3.1 ([15]) *If h, n are integers with $0 \leq h \leq n-1$ and Y is a subgraph of Q_n with minimum degree at least h, then $|N[Y]| \geq 2^h(n-h+1)$.*

In the following theorem, we prove that $2^h(n-h+1)$ is also a lower bound on the number of vertices of an h-edge cut of Q_n.

Theorem 3.1. *If h, n are integers with $0 \leq h \leq n-1$ and F is an h-edge cut of Q_n, then $|V(F)| \geq (n-h+1)2^h$.*

Proof. We prove the result by induction on n. The graph $Q_n - F$ is disconnected. Since Q_n is n-connected, F consists of at least n edges and so, $|V(F)| \geq n+1$.

Hence the statement holds for $h = 0$. Therefore it also holds for $n = 1$. Suppose $1 \leq h \leq n-1$ and $n \geq 2$. Assume that the result holds for the $(n-1)$-dimensional hypercube. Let Y be a smallest component of $Q_n - F$. Then $|V(Y)| \leq 2^{n-1}$ as Q_n has exactly 2^n verticees. Write $Q_n = Q^0_{n-1} \cup Q^1_{n-1} \cup M$ so that the perfect matching M contains an edge e of Y. Let $Y_i = Y \cap Q^i_{n-1}$ and $F_i = E_{Q^i_{n-1}}(Y_i)$ for $i = 0, 1$. Then both Y_0 and Y_1 are non-empty as $e \in M$. The minimum degree of Y_i is at least $h-1$. As $|V(Y_0)| + |V(Y_1)| = |V(Y)|$, we have $|V(Y_i)| < 2^{n-1}$ and so, Y_i is a non-spanning subgraph of Q^i_{n-1}. Hence $Q^i_{n-1} - F_i$ is disconnected. This shows that F_i is an $(h-1)$-edge cut of Q^i_{n-1} for $i = 0, 1$. By induction, $|V(F_i)| \geq 2^{h-1}((n-1)+1-(h-1)) = 2^{h-1}(n+1-h)$. Hence $|V(F)| \geq |V(F_1)| + |V(F_0)| \geq 2.2^{h-1}(n+1-h) = 2^h(n+1-h)$. □

A subgraph H of a connected graph G is *removable* if $G - E(H)$ is connected. In particular, a cycle C in G is *removable* if $G - E(C)$ is connected. The existence of removable cycles in graphs is well studied; see [3, 4]. It follows from Theorem 3.1 that *every* smaller regular subgraph of Q_n is removable.

Corollary 3.1. *For integers h, n with $1 \leq h < n$, every h-regular subgraph of Q_n with less than $(h+1)2^{n-h}$ vertices is removable.*

Corollary 3.2. *Every cycle of length less than $3(2^{n-2})$ in Q_n is removable.*

Corollary 3.3 ([1]) *A non-perfect matching in Q_n is removable.*

Remarks. (1) The lower bound given in Theorem 3.1 is sharp as, by Lemma 2.5, $E_{Q_n}(Q_h)$ is a minimum h-edge cut of Q_n with exactly $(n-h+1)2^h$ vertices.

(2) The upper bound given in Corollary 3.1 is sharp for $h \leq (n+1)/2$. We construct an h-regular subgraph H of Q_n with $(h+1)2^{n-h}$ vertices that is not removable. By writing Q_n as $Q_{n-h}\Box Q_h$, we see that $Q_{n-h}\Box K_{1,h}$ is a subgraph of Q_n consisting of $h+1$ copies of the graph Q_{n-h}, say G^0, G^1, ..., G^h. We may assume that G^0 corresponds to degree h vertex and the remaining copies correspond to the pendant vertices of $K_{1,h}$. Let F be the set of all edges having one end vertex in G^0 and the other in G^i for some $1 \leq i \leq h$. Let H_0 be the subgraph of Q_n induced by the edges of F. If $h \leq (n+1)/2$, then $h-1 \leq n-h$. Choose an $(h-1)$-regular spanning subgraph H_i of G^i for $i = 1, 2, \ldots, h$. Then $H = H_0 \cup H_1 \cup H_2 \cup \cdots \cup H_h$ is a required subgraph. Note that for $h > (n+1)/2$, the condition $(h+1)2^{n-h} \geq 2^h$ may not be satisfied for all n and so, there may not exist an h-regular subgraph on $(h+1)2^{n-h}$ vertices by Lemma 2.1.

(3) We can easily construct an h-regular, spanning subgraph that is *not removable* in Q_n for $1 \leq h \leq n$. Borse and Kandekar [2] obtained an opposite result. They established that there exists a *removable* h-regular spanning subgraph of Q_n for $2 \leq h \leq n-2$.

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Discussiones Mathematicae
Graph Theory xx (xxxx) 1–18
doi:10.7151/dmgt.2348

ON CONDITIONAL CONNECTIVITY OF THE CARTESIAN PRODUCT OF CYCLES

J.B. Saraf

Department of Mathematics
Amruteshwar Arts, Commerce and Science College
Vinzar- 412213, India

e-mail: sarafjb@gmail.com

Y.M. Borse

Department of Mathematics
Savitribai Phule Pune University
Pune-411007, India

e-mail: ymborse11@gmail.com

AND

Ganesh Mundhe

Army Institute of Technology
Pune-411015, India

e-mail: ganumundhe@gmail.com

Abstract

The conditional h-vertex (h-edge) connectivity of a connected graph H of minimum degree $k > h$ is the size of a smallest vertex (edge) set F of H such that $H - F$ is a disconnected graph of minimum degree at least h. Let G be the Cartesian product of $r \geq 1$ cycles, each of length at least four and let h be an integer such that $0 \leq h \leq 2r-2$. In this paper, we determine the conditional h-vertex-connectivity and the conditional h-edge-connectivity of the graph G. We prove that both these connectivities are equal to $(2r-h)a_h^r$, where a_h^r is the number of vertices of a smallest h-regular subgraph of G.

Keywords: fault tolerance, hypercube, conditional connectivity, cut, Cartesian product.

2010 Mathematics Subject Classification: 05C40, 68R10.

1. Introduction

One of the feature of a good interconnection network is its high fault tolerance capacity. Interconnection network can be modelled into a graph with the help of which we can study many properties of the network. Connectivity of a modelled graph measures the fault tolerance capacity of the interconnection network. High fault tolerance capacity of the network plays an important role in practice. Traditional connectivities have some limitations to measure the fault tolerance capacity of a network accurately. In order to compute traditional edge connectivity, one allows failure of all the links incident with the same processor, practically which is rare. One can overcome this limitation effectively by considering the conditional connectivity of graphs introduced by Harary [6].

Let G be a connected graph with minimum degree at least $k \geq 1$ and let h be an integer such that $0 \leq h < k$. A set F of vertices (edges) of G such that $G - F$ is disconnected and each component of it has minimum degree at least h is an *h-vertex (edge) cut* of G. The *conditional h-vertex (edge)* connectivity of G, denoted by $\kappa^h(G)$ ($\lambda^h(G)$), is the minimum cardinality $|F|$ of an h-vertex(edge) cut F of G. Clearly, $h = 0$ gives the traditional vertex (edge) connectivity.

Many researcher have worked on the problem of determining the conditional connectivities for various classes of graphs and determined these parameters for smaller values of h [4, 5, 7, 9]. Exact values of one or both conditional connectivities are known for some classes of graphs. For the n-dimensional hypercube Q_n, the conditional connectivities λ^h and κ^h are same and their common value is $2^h(n-h)$; see [3, 7]. Li and Xu [10] proved that λ^h of any n-dimensional hypercube-like network G_n is also $2^h(n-h)$. Ye and Liang [16] established that κ^h is also $2^h(n-h)$ for some members of hypercube-like networks such as Crossed cubes, Locally twisted cubes, Möbius cubes. Independently, Wei and Hsieh [14] determined κ^h for the Locally twisted cubes. Ning [13] obtained κ^h for the exchanged crossed cubes. Both λ^h and κ^h are determined for the class of (n,k)-star graphs by Li *et al.* [11].

An r-dimensional torus is the Cartesian product of r cycles. The *k-ary r-cube*, denoted by Q_r^k, is the Cartesian product of r cycles each of length k. In particular, the hypercube Q_{2r} is Q_r^4. Hypercubes, k-ary r-cubes and multidimensional tori are widely used interconnection networks; see [2, 8, 12, 15].

It is easy to see that an r-dimensional torus is a $2r$-regular graph with traditional vertex connectivity and edge connectivity $2r$; see [15]. In this paper, we determine the conditional h-edge-connectivity as well as the conditional h-vertex-connectivity of the given multidimensional torus.

By C_k we mean a cycle of length k. For integers $h, r, k_1, k_2, \ldots, k_r$ with $0 \leq h \leq 2r$ and $4 \leq k_1 \leq k_2 \leq \cdots \leq k_r$, we define a quantity a_h^r as follows.

Definition 1.1.

$$a_h^r = \begin{cases} 2^h & \text{if } 0 \le h \le r, \\ 2^{r-i}\ k_1k_2\cdots k_i & \text{if } h = r+i,\ 1 \le i \le r. \end{cases}$$

We prove that both the conditional connectivities λ^h and k^h are equal to $a_h^r(2r-h)$ for the Cartesian product of cycles $C_{k_1}, C_{k_2}, \ldots, C_{k_r}$.

The following is the main theorem of the paper.

Theorem 1.2. *Let $h, r, k_1, k_2, \ldots, k_r$ be integers such that $0 \le h \le 2r-2$ and $4 \le k_1 \le k_2 \le \cdots \le k_r$ and let G be the Cartesian product of the cycles $C_{k_1}, C_{k_2}, \ldots, C_{k_r}$. Then $\lambda^h(G) = \kappa^h(G) = a_h^r(2r-h)$.*

Corollary 1.3. *Let h, r, k be integers such that $0 \le h \le 2r-2$, $4 \le k$ and let Q_r^k be the k-ary r-cube. Then $\lambda^h(Q_r^k) = k^h(Q_r^k) = a_h^r(2r-h)$, where $a_h^r = 2^h$ if $0 \le h \le r$ and $a_h^r = 2^{r-i}k^i$ if $h = r+i$ and $1 \le i \le r$.*

Corollary 1.4 [3, 7]**.** *For integers h and r with $0 \le h \le 2r-2$, $\lambda^h(Q_{2r}) = k^h(Q_{2r}) = 2^h(2r-h)$.*

The proof of our main result, Theorem 1.2 is divided into three sections. In Section 2, we characterize the h-regular subgraph of the graph G with minimum number of vertices and explore some of its properties. Using these properties we determine the conditional h-vertex connectivity and the conditional h-edge connectivity of G in Sections 3 and 4, respectively.

2. Smallest h-Regular Subgraph

In this section, we define a smallest h-regular subgraph of the Cartesian product of r cycles and obtain some properties of it. We first introduce some notations.

For a graph K, let $V(K)$ denote the set of all vertices of K. If H is a subgraph K, then $\delta(K)$ is the minimum degree of K while $\delta_K(H)$ is the minimum degree of H in K. The *Cartesian product* of two graphs H and K is a graph $H\Box K$ with vertex set $V(H) \times V(K)$. Two vertices (x, y) and (u, v) are adjacent in $H\Box K$ if and only if either $x = u$ and y is adjacent to v in K, or $y = v$ and x is adjacent to u in H. The hypercube Q_n is the Cartesian product of n copies of the complete graph K_2.

We use the following notations about the structure of the multidimensional torus.

Notation.

Consider the graph G of Theorem 1.2. We have $G = C_{k_1}\Box C_{k_2}\Box\cdots\Box C_{k_r}$, where C_{k_i} is a cycle of length k_i for $i = 1, 2, \ldots, k_r$ and $4 \le k_1 \le k_2 \le \cdots \le k_r$. We can

write G as $G = H\Box C_{k_r}$, where $H = C_{k_1}\Box C_{k_2}\Box\cdots\Box C_{k_{r-1}}$. Label by $1, 2, \ldots, k_r$ the vertices of the cycle C_{k_r} so that i is adjacent to $(i+1) \pmod{k_r}$. Hence G can be obtained by replacing i^{th} vertex of C_{k_r} by a copy H^i of H and replacing edge joining i and $i+1$ of C_{k_r} by the perfect matching M_i between the corresponding vertices of H^i and H^{i+1}. Thus $G = H^1 \cup H^2 \cup \cdots \cup H^{k_r} \cup (M_1 \cup M_2 \cup \cdots \cup M_{k_r})$; see Figure 1.

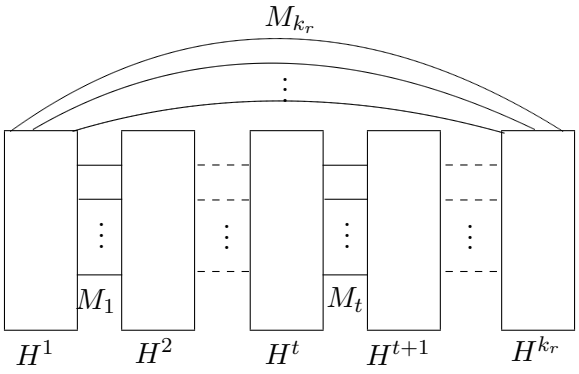


Figure 1. $G = H\Box C_{k_r}$.

Henceforth, by G we mean the graph $C_{k_1}\Box C_{k_2}\Box\cdots\Box C_{k_r}$ with $4 \le k_1 \le k_2 \le \cdots \le k_r$, that is, the graph of Theorem 1.2.

From the following lemma, it is clear that G is a $2r$-regular and $2r$-connected graph on $k_1k_2\cdots k_r$ vertices.

Lemma 2.1. *If G_i is an m_i-regular and m_i-connected graph on n_i vertices for $i = 1, 2$, then $G_1\Box G_2$ is an (m_1+m_2)-regular and (m_1+m_2)-connected graph on n_1n_2 vertices.*

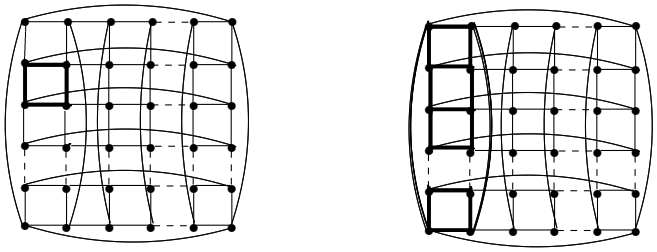
We now define an h-regular subgraph, denoted by W_h^r, of the graph G.

Definition 2.2. For $4 \le k_1 \le k_2 \le \cdots \le k_r$ and $0 \le h \le 2r$, let

$$W_h^r = \begin{cases} Q_h & \text{if } 0 \le h \le r, \\ Q_{r-i}\Box C_{k_1}\Box C_{k_2}\Box\cdots\Box C_{k_i} & \text{if } h = r+i \text{ and } \quad 1 \le i \le r. \end{cases}$$

In the following figure, a 2-regular subgraph W_2^2 and a 3-regular subgraph W_3^2 of the graph $C_5\Box C_5$ are shown by bold lines.

It is known that a smallest h-regular subgraph of the hypercube Q_n is isomorphic to Q_h (see [1]). We prove the analogous result for the Cartesian product of cycles. In fact, we establish that W_h^r is a smallest h-regular subgraph of the above graph G.



(a) W_2^2 (b) W_3^2

Figure 2. The subgraph W_2^2 and W_3^2 of $C_5 \square C_5$.

The following lemma follows from Lemma 2.1, Definition 1.1 of the number a_h^r and the fact that the hypercube Q_n is an n-regular, n-connected graph on 2^n vertices for any integer $n \geq 0$.

Lemma 2.3. *The graph W_h^r is h-regular and h-connected with a_h^r vertices.*

We need the following lemma that gives relations between different values of a_h^r.

Lemma 2.4. *Let $r \geq 2$ and let a_h^r be the quantity given in Definition* 1.1. *Then the following statements hold.*

1. $a_h^r = 2a_{h-1}^{r-1}$ *if* $1 \leq h \leq 2r-1$;
2. $k_r a_{h-2}^{r-1} \geq a_h^r$ *if* $2 \leq h \leq 2r$;
3. $a_h^{r-1} \geq a_h^r$ *if* $0 \leq h \leq 2r-2$.

Proof. Recall that $a_h^r = 2^h$ if $0 \leq h \leq r$ and $a_h^r = 2^{r-i}k_1k_2\cdots k_i$ if $h = r+i$ with $1 \leq i \leq r$, where $4 \leq k_1 \leq k_2 \leq \cdots \leq k_r$.

(1) If $1 \leq h \leq r$, then $a_h^r = 2^h = 2(2^{h-1}) = 2a_{h-1}^{r-1}$. For $r+1 \leq h \leq 2r-1$, we have $h = r+i$ for some $1 \leq i \leq r-1$. Hence $h-1 = (r-1)+i$ gives $a_{h-1}^{r-1} = 2^{(r-1)-i}k_1k_2\cdots k_i$. Therefore $2a_{h-1}^{r-1} = a_h^r$.

(2) Suppose $2 \leq h \leq r+1$. Then $a_{h-2}^{r-1} = 2^{h-2}$, and $a_h^r = 2^h$ if $h < r+1$ and $a_h^r = 2^{r-1}k_1$ if $h = r+1$. For $r+2 \leq h \leq 2r$, we have $h-2 = (r-1)+(i-1)$ for some $2 \leq i \leq r$ and so, $a_{h-2}^{r-1} = 2^{r-i}k_1k_2\cdots k_{i-1}$. Therefore, $k_r a_{h-2}^{r-1} \geq a_h^r$ in each case as $k_r \geq k_i \geq k_1 \geq 4$.

(3) Note that $a_h^{r-1} = 2^h$ for $1 \leq h \leq r-1$, and $a_h^{r-1} = 2^{(r-2)}k_1$ for $h = r = (r-1)+1$, and finally, $a_h^{r-1} = 2^{r-i-2}k_1k_2\cdots k_ik_{i+1}$ for $h = (r-1)+(i+1)$ for $1 \leq i \leq r$. Since $k_{i+1} \geq k_1 \geq 4$, we have $a_h^{r-1} \geq a_h^r$ in all the three cases. ∎

Lemma 2.5. *Every subgraph of the graph G of minimum degree at least h has at least a_h^r vertices.*

Proof. The graph G is the product of r cycles. We prove the result by induction on r. The result holds obviously for $h = 0$ and $h = 1$ and so it holds for $r = 1$. Suppose $r \geq 2$ and $h \geq 2$. Assume that the result holds for the product of $r-1$ cycles. We have $G = C_{k_1} \Box C_{k_2} \Box \cdots \Box C_{k_r}$, where $4 \leq k_1 \leq k_2 \leq \cdots \leq k_r$. Write G as $G = H \Box C_{k_r}$, where $H = C_{k_1} \Box C_{k_2} \Box \cdots \Box C_{k_{r-1}}$. Then $G = H^1 \cup H^2 \cup \cdots \cup H^{k_r} \cup (M_1 \cup M_2 \cup \cdots \cup M_{k_r})$, where H^i is the copy of H corresponding to vertex i of C_{k_r} and M_i is the perfect matching between the corresponding vertices of H^i and H^{i+1}.

Let K be a subgraph of G with $\delta(K) \geq h$. We prove that $|V(K)| \geq a_h^r$. Clearly, K intersects at least one H^i. Let $K^i = K \cap H^i$ for $i = 1, 2, \ldots, k_r$. We have the following three cases.

(1) Suppose only one K^i is non-empty. Due to symmetry in G, we may assume K^1 is non-empty and K^j is empty for every $j \neq 1$. Therefore K is a subgraph of H^1 and it has minimum degree at least h in H^1. Since H^1 is $2(r-1)$-regular, $h \leq 2r-2$. Suppose $h = 2r-2$. Then $K = H^1$ and so, $|V(K)| = k_1 k_2 \cdots k_{r-1}$. If $r = 2$, then $|V(K)| = k_1 \geq 4 = a_2^2 = a_h^r$. If $r \geq 3$, then $|V(K)| \geq 4k_1 k_2 \cdots k_{r-2} = a_h^r$ as $k_{r-1} \geq 4$. If $h < 2r-2$, then, by induction and Lemma 2.4(3), we have $|V(K)| \geq a_h^{r-1} \geq a_h^r$.

(2) Suppose K^i is non-empty for all i. Note that in the graph G, every vertex of H^i has exactly one neighbour in H^{i-1} and one in H^{i+1}. Hence the minimum degree of K^i is at least $h-2$. By induction, $|V(K^i)| \geq a_{h-2}^{r-1}$. Therefore, by Lemma 2.4(2),

$$|V(K)| = \left|V\left(K^1\right)\right| + \left|V\left(K^2\right)\right| + \cdots + \left|V\left(K^{k_r}\right)\right| \geq k_r a_{h-2}^{r-1} \geq a_h^r.$$

(3) Suppose at least two K^i are non-empty and at least one K^i is empty. Hence, we may assume that $K^1 \neq \emptyset$ but $K^{k_r} = \emptyset$. Further, we get an integer $1 < t < k_r$ such that $K^t \neq \emptyset$ but $K^{t+1} = \emptyset$. Then $\delta(K^j) \geq h-1$ and so, by induction, $|V(K^j)| \geq a_{h-1}^{r-1}$ for $j = 1, t$. Now, by Lemma 2.4(1),

$$|V(K)| \geq \left|V\left(K^1\right)\right| + \left|V\left(K^t\right)\right| \geq 2a_{h-1}^{r-1} = a_h^r.$$

This completes the proof. ∎

The following result is an immediate consequence of Lemmas 2.3 and 2.5.

Corollary 2.6. *W_h^r is a smallest subgraph of the graph G of minimum degree at least h.*

We obtain some more properties of the subgraph W_h^r of G to obtain an upper bound on the conditional connectivity of the graph G.

First, we introduce some notations. Let K be a graph and let Y be a subgraph of K. A *neighbour* of Y in K is a vertex in $V(K) \setminus V(Y)$ that is adjacent to

a vertex of Y. Let $N(Y)$ denote the set of all neighbours of Y in K and let $N[Y] = N(Y) \cup V(Y)$. Also, for a subgraph H of K, let $N_H(Y)$ be the set of all neighbours of Y that are present in H and let $N_H[Y] = N_H(Y) \cup V(Y)$.

The following result is analogous to the result of hypercubes which states that if K is a subgraph of the hypercube Q_n isomorphic to Q_h, then every vertex of Q_n which is not in K has at most one neighbour in K; see [1].

Lemma 2.7. *If $0 \leq h < 2r-1$ and K is a subgraph of G isomorphic to the graph W_h^r, then every vertex of G belonging to $V(G) \setminus V(K)$ has at most one neighbour in the subgraph K.*

Proof. We argue by induction on r. If $r = 1$, then G is just a cycle and so the result holds obviously. Suppose $r \geq 2$. Assume that the result holds for the product of any $r-1$ cycles. We have $G = H \Box C_{k_r}$. Then $G = H^1 \cup H^2 \cup \cdots \cup H^{k_r} \cup (M_1 \cup M_2 \cup \cdots \cup M_{k_r})$, where H^i is the copy of H corresponding to vertex i of C_{k_r} and M_i is the perfect matching between the corresponding vertices of H^i and H^{i+1}. Since the graph W_h^r is isomorphic to $W_{h-1}^{r-1} \Box K_2$, we may assume that W_h^r is a subgraph of $H \Box K_2$ by considering W_{h-1}^{r-1} as a subgraph of H. Hence, we may assume that K is a subgraph of $H^2 \cup H^3 \cup M_2$, where M_2 is the perfect matching between H^2 and H^3.

Let $K^i = K \cap H^i$ for $i = 2, 3$. Then K^i is isomprphic to W_{h-1}^{r-1}. Let x be any vertex of $V(G) \setminus V(K)$. If x is in $V(H^2)$, then, by induction, x has at most one neighbour in K^2. Then x has no neighbour in K^3 and so, it has at most one neighbour in K. Similarly, x has at most one neighbour in K if it belongs to $V(H^3)$. Suppose x is in H^j for some $j \notin \{2, 3\}$. Then x has exactly one neighbour in H^{j+1} and one in H^{j-1} each and no neighbour in H^i for any $i \notin \{j-1, j+1\}$. This shows that x has at most one neighbour in $H^2 \cup H^3$ and hence in K as $k_r \geq 4$. This completes the proof. ∎

Lemma 2.8. *If $0 \leq h \leq 2r-1$ and $Y = W_h^r$, then any vertex of G which is not in $N[Y]$ has at most two neighbours in $N[Y]$.*

Proof. We proceed by induction on r. The result holds trivially for $r = 1$ as G is just a cycle in this case. Suppose $r \geq 2$. Assume that the result holds for the product of any $r-1$ cycles. Write G as $H \Box C_{k_r}$, where $H = C_{k_1} \Box C_{k_2} \Box \cdots \Box C_{k_{r-1}}$. Since the graph W_h^r is isomorphic to $W_{h-1}^{r-1} \Box K_2$, we may assume that $Y = W_h^r$ is a subgraph of $H^2 \cup H^3 \cup M_2$. Then Y has neighbours in H^1 and H^4. Let $Y_i = W_h^r \cap H^i$ for $i = 2, 3$. Let $S_1 = N_{H^1}(Y_2)$, $S_2 = N_{H^2}[Y_2]$, $S_3 = N_{H^3}[Y_3]$ and $S_4 = N_{H^4}(Y_3)$. Then $N[Y] = S_1 \cup S_2 \cup S_3 \cup S_4$.

Let $x \in V(G) \setminus N[Y]$. Then x is a vertex of H^j for some j. If $j > 4$, then x has at most two neighbours in the set $V(H^1) \cup V(H^2) \cup V(H^3) \cup V(H^4)$ and so in its subset $N[Y]$. Suppose $j \in \{1, 2, 3, 4\}$. Then $h \leq 2r-2$ as for $h = 2r-1$, we have $Y = H^2 \cup H^3 \cup M_2$ and so, $N[Y] = V(H^1) \cup V(H^2) \cup V(H^3) \cup V(H^4)$.

The subgraph of G induced by the set S_i is isomorphic to the graph W_{h-1}^{r-1} for $i = 1, 4$. If $j \in \{1, 4\}$, then x has at most one neighbour in $S_1 \cup S_4$ and at most one in $V(H^2) \cup V(H^3)$ by Lemma 2.7. If $j = 2$, then, by induction, x has at most two neighbours in S_2 and no neighbour in $S_1 \cup S_3 \cup S_4$. Similarly, if $j = 3$, then x has at most two neighbours in S_3 and no neighbour in $S_1 \cup S_2 \cup S_4$. Thus, in any case, x has at most two neighbours in $N[Y]$. ∎

Lemma 2.9. *For $0 \leq h \leq 2r-1$, the inequality $(2r-h+1)a_h^r \leq k_1k_2\cdots k_r$ holds. Moreover, the inequality is strict if $h < 2r-1$.*

Proof. Recall that $4 \leq k_1 \leq k_2 \cdots \leq k_r$, and $a_h^r = 2^h$ if $h \leq r$ and $a_h^r = 2^{(r-i)}k_1k_2\cdots k_i$ if $h = r+i$. For convenience, let $L = (2r-h+1)a_h^r$ and $R = k_1k_2\cdots k_r$. Then $L = 2a_h^r = 4k_1k_2\cdots k_{r-1} \leq R$ for $h = 2r-1$. Suppose $h \leq 2r-2$. If $h = 0$ or $h = 1$, then $L < 4^r \leq R$. Similarly, if $2 \leq h \leq r$, then $L < 2ra_h^r = 2r2^h \leq 2r2^r \leq 4^r \leq R$ as $2r \leq 2^r$. Suppose $h = r+i$ with $1 \leq i \leq r-2$. Then $L = (r-i+1)2^{r-i}k_1k_2\cdots k_i < 2^{2(r-i)}k_1k_2\cdots k_i$, as $2l \leq 2^l$ if $l \geq 1$. This shows that $L \leq 4^{r-i}k_1k_2\cdots k_i \leq k_1k_2\cdots k_r = R$. ∎

3. Conditional Vertex Connectivity

Recall from Section 2 the graph $G = C_{k_1}\Box C_{k_2}\Box\cdots\Box C_{k_r}$ and its h-regular subgraph W_h^r with a_h^r vertices, where $4 \leq k_1 \leq k_2 \leq \cdots \leq k_r$. In this section, we prove that the conditional h-vertex connectivity $\kappa^h(G)$ the graph G is $(2r-h)a_h^r$. Using Lemmas 2.7, 2.8 and 2.9, it easily follows that $\kappa^h(G) \leq (2r-h)a_h^r$.

Lemma 3.1. *If $0 \leq h \leq 2r-2$, then $\kappa^h(G) \leq (2r-h)a_h^r$.*

Proof. We have $G = C_{k_1}\Box C_{k_2}\Box\cdots\Box C_{k_r}$. We simply denote the subgraph W_h^r of G by Y. Then $|V(Y)| = a_h^r$. Since G is $2r$-regular and Y is h-regular, every vertex of Y has $2r-h$ neighbours in the $G - V(Y)$. By Lemma 2.7, $|N(Y)| = (2r-h)|V(Y)| = (2r-h)a_h^r$. This gives $|N[Y]| = |V(Y) \cup N(Y)| = |V(Y)| + |N(Y)| = (2r-h+1)a_h^r$. Therefore, by Lemma 2.9, $|N[Y]| < k_1k_2\cdots k_r = |V(G)|$. Hence $V(G) \setminus N[Y]$ is a non-empty set and by Lemma 2.8, every member of this set has at most two neighbours in $N[Y]$. Consequently, the minimum degree of the subgraph of G induced by this set is at least $2r-2 \geq h$. Already, the minimum degree of the graph Y is h. Hence the graph $G - N(Y)$ is disconnected and every component of it has minimum degree at least h. Thus $N(Y)$ is an h-vertex cut of G. Therefore $\kappa^h(G) \leq |N(Y)| = (2r-h)a_h^r$. ∎

To prove the reverse inequality for $\kappa^h(G)$, we obtain the following lemma.

Lemma 3.2. *If $0 \leq h \leq 2r-1$ and Y is a subgraph of the graph G with minimum degree at least h, then $|N[Y]| \geq a_h^r(2r-h+1)$.*

Proof. If $N[Y] = V(G)$, then the result follows obviously from Lemma 2.9. Suppose $N[Y] \neq V(G)$. We prove the result by induction on r. Since G is $2r$-regular, all $2r$ neighbours of any vertex of Y belong to the set $N[Y]$. Hence $|N[Y]| \geq 2r+1$. Therefore the result holds for $h = 0$. Also, the result trivially follows for $r = 1$ and $h = 1$ as in this case G is a cycle of length $k_1 \geq 4$, Y is a path on at least two vertices and $a_1^1 = 2$.

Suppose $r \geq 2$ and $h \geq 1$. Assume that the result holds for a graph that is the product of $r-1$ cycles. Let $G = C_{k_1}\Box C_{k_2}\Box\cdots\Box C_{k_r}$. Then $G = H\Box C_{k_r}$, where $H = C_{k_1}\Box C_{k_2}\Box\cdots\Box C_{k_{r-1}}$. Then G contains k_r vertex-disjoint copies $H^1, H^2, \ldots, H^{k_r}$ of H. Then every vertex of H^i has one neighbour in H^{i-1} and H^{i+1}, where the addition and subtraction in the superscript is carried out modulo k_r. Let Y be a subgraph of G with $\delta(Y) \geq h$ and $N[Y] \neq V(G)$. Then Y intersects at least one copy of H^i. Let $Y_i = Y \cap H^i$ for $i = 1, 2, \ldots, k_r$.

Case 1. $Y_i \neq \emptyset$ for only one value of i. Without loss of generality we may assume that only Y_1 is non-empty. Then $Y = Y_1$ is contained in the graph H^1. Since H^1 is $(2r-2)$-regular, $h \leq 2r-2$. Also, the minimum degree of Y in H^1 is at least h. Hence, by Lemma 2.5, Y has at least a_h^{r-1} vertices. We have $N[Y] = N_{H^1}[Y] \cup N_{H^{k_r}}(Y) \cup N_{H^2}(Y)$. If $h = 2r-2$, then $Y = H^1$ and so, $N[Y] = V(H^1) \cup V(H^2) \cup V(H^{k_r})$. Therefore

$$|N[Y]| \geq 3\big|V\big(H^1\big)\big| = 3k_1k_2\cdots k_{r-1} \geq 12k_1k_2\cdots k_{r-2} = (2r-h+1)a_h^r.$$

Suppose $0 \leq h \leq 2r-3 = 2(r-1)-1$. Then, by induction, $|N_{H^1}[Y]| \geq a_h^{r-1}(2r-h-1)$. As $|N_{H^{k_r}}(Y)| = |N_{H^2}(Y)| = |V(Y)| \geq a_h^{r-1}$, by Lemma 2.4(3) we have

$$|N[Y]| \geq a_h^{r-1}(2r-h-1) + 2a_h^{r-1} = (2r-h+1)a_h^{r-1} \geq (2r-h+1)a_h^r.$$

Case 2. $Y_i \neq \emptyset$ for all $i = 1, 2, \ldots, k_r$. In this case, $N[Y] \supseteq N_{H^1}[Y_1] \cup N_{H^2}[Y_2] \cup \cdots \cup N_{H^{k_r}}[Y_{k_r}]$. If $h = 1$, then $\delta_{H^i}(Y_i) \geq 0$ and so, by induction, $|N_{H^i}[Y_i]| \geq a_0^{r-1}(2(r-1)-0+1) = 2r-1$ implying

$$\begin{aligned} |N[Y]| &\geq \big|N_{H^1}[Y_1]\big| + \big|N_{H^2}[Y_2]\big| + \cdots + \big|N_{H^{k_r}}[Y_{k_r}]\big| \\ &\geq k_r(2r-1) \geq 8r-4 \geq 4r \geq a_1^r(2r) = a_h^r(2r-h+1). \end{aligned}$$

Suppose $h \geq 2$. Then $\delta_{H^i}(Y_i) \geq h-2 \geq 0$ and so, by induction, $|N_{H^i}[Y_i]| \geq a_{h-2}^{r-1}(2r-h+1)$ for all i. Therefore, by Lemma 2.4(2),

$$\begin{aligned} |N[Y]| &\geq \big|N_{H^1}[Y_1]\big| + \big|N_{H^2}[Y_2]\big| + \cdots + \big|N_{H^{k_r}}[Y_{k_r}]\big| \\ &\geq k_r a_{h-2}^{r-1}(2r-h+1) \geq a_h^r(2r-h+1). \end{aligned}$$

Case 3. $Y_i \neq \emptyset$ for more than one but not all values of i. Without loss of generality, we may assume that Y_1 is non-empty but Y_{k_r} is empty. Let t be

the largest integer such that Y_t is non-empty. Then $1 < t < k_r$; see Figure 3. Suppose that $h = 2r - 1$. Then $Y_1 = H^1$ and $Y_t = H^t$. Hence $N[Y] \supseteq V(H^1) \cup V(H^2) \cup V(H^t) \cup V(H^{t+1}) \cup V(H^{k_r})$. Since $k_r \geq 4$, $t \neq 2$ or $t + 1 \neq k_r$ and $|V(H^1)| = |V(H^i)|$ for all $i > 1$. By Lemma 2.9,

$$|N[Y]| \geq 4\big|V\big(H^1\big)\big| = 4|V(H)| \geq 4k_1k_2\cdots k_{r-1} = (2r - h + 1)a_h^r.$$

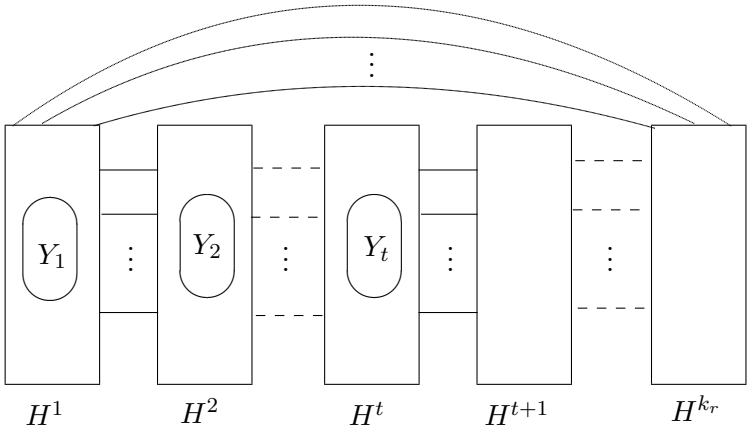


Figure 3. The graph G with $Y_j = \emptyset$ for $t < j \leq k_r$.

Suppose that $0 \leq h \leq 2r - 2$. The graph Y_i has $|V(Y_i)|$ neighbours in H^{i-1} and H^{i+1} for $i = 1, t$. Therefore $|N[Y]| \geq |N_{H^1}[Y_1]| + |N_{H^t}[Y_t]| + |V(Y_1)| + |V(Y_t)|$. If $i \in \{1, t\}$, then $\delta_{H^i}(Y_i) \geq h - 1$ and so, by induction, $|N_{H^i}[Y_i]| \geq a_{h-1}^{r-1}(2r - h)$. Also, by Lemma 2.5, $|V(Y_i)| \geq a_{h-1}^{r-1}$. Hence, by Lemma 2.4(1), we have

$$|N[Y]| \geq 2a_{h-1}^{r-1}(2r - h) + 2a_{h-1}^{r-1} = a_h^r(2r - h) + a_h^r = a_h^r(2r - h + 1).$$

Thus $|N[Y]| \geq a_h^r(2r - h + 1)$ in each case. This completes the proof. ∎

Proposition 3.3. *If $0 \leq h \leq 2r - 2$ and S is an h-vertex cut of the graph G, then $|S| \geq a_h^r(2r - h)$.*

Proof. We argue by induction on r. Suppose $h = 0$. Then S is a traditional vertex cut of G. Therefore $|S| \geq 2r = a_0^r(2r - 0)$ as G is $2r$-connected by Lemma 2.1. Hence the result holds for $h = 0$ and so for $r = 1$. Suppose $r \geq 2$ and $h \geq 1$. Assume that the result is true for the Cartesian product of $r - 1$ cycles, each of length at least 4. Let $G = C_{k_1} \Box C_{k_2} \Box \cdots \Box C_{k_r}$. Then $G = H \Box C_{k_r}$, where $H = C_{k_1} \Box C_{k_2} \Box \cdots \Box C_{k_{r-1}}$. Then G is obtained by replacing i^{th} vertex of C_{k_r} by the copy H^i of H and replacing each edge C_{k_r} by the matching between the two copies of H^i corresponding to the end vertices of that edge.

As S is an h-vertex cut of G, the graph $G-S$ is disconnected and each component of it has minimum degree h. Let Y be a subgraph of $G-S$ consisting of at least one but not all components of $G-S$ and let Z be the subgraph consisting of the remaining components. Thus $G-S = Y \cup Z$ and further, $\delta(Y) \geq h$ and $\delta(Z) \geq h$. As S is a cut, $N(Y) \subseteq S$ and $N(Z) \subseteq S$ and so, $|S| \geq |N(Y)|$ and $|S| \geq |N(Z)|$. Note that Y and Z each intersects H^i for at least one i. Let $S_i = S \cap V(H^i)$, $Y_i = Y \cap V(H^i)$ and $Z_i = Z \cap V(H^i)$. Depending upon the nature of Y and Z, the proof is divided into several cases.

Case 1. Suppose $Y_i \neq \emptyset$ for only one i. Without loss of generality, we may assume that only Y_1 is non-empty. Then $Y = Y_1$ is contained in H^1. Therefore $\delta_{H^1}(Y) \geq h-1$. As H^1 is $(2r-2)$-regular, $0 \leq h \leq 2r-2$. If $h = 2r-2$, then $Y = H^1$, $N(Y) = V(H^{k_r}) \cup V(H^2)$ and therefore,

$$\begin{aligned} |S| \geq |N(Y)| &= \big|V\big(H^{k_r}\big)\big| + \big|V\big(H^2\big)\big| = 2k_1k_2\cdots k_{r-2}k_{r-1} \\ &\geq 8k_1k_2\cdots k_{r-2} = a_h^r(2r-h). \end{aligned}$$

Suppose $0 \leq h \leq 2r-3 = 2(r-1)-1$. The graph Y has $|V(Y)|$ neighbours in each of H^{k_r} and H^2. Therefore $|N(Y)| = |N_{H^1}(Y)| + |V(Y)| + |V(Y)| = |N_{H^1}[Y]| + |V(Y)|$. By Lemmas 2.4(3), 2.5 and 3.2,

$$|S| \geq |N(Y)| \geq a_h^{r-1}(2r-h-1) + a_h^{r-1} = a_h^{r-1}(2r-h) \geq a_h^r(2r-h).$$

Case 2. Suppose $Y_i \neq \emptyset$ for more than one but not all values of i. Without loss of generality, we may assume that Y_1 is non-empty but Y_{k_r} is empty. Suppose there is an integer t with $1 < t < k_r$ such that Y_t is non-empty. Note that $\delta_{H^1}(Y_1) \geq h-1$. Further, the set S_{k_r} contains all $|V(Y_1)|$ neighbours of Y_1 present in H^{k_r} and S_1 contains the set $N_{H^1}(Y_1)$ of neighbours of Y_1 in H^1. Therefore, by Lemma 3.2,

$$|S_1 \cup S_{k_r}| \geq \big|N_{H^1}(Y_1)\big| + |V(Y_1)| = \big|N_{H^1}[Y_1]\big| \geq (2r-h)a_{h-1}^{r-1}.$$

Suppose Y_i is empty for more than one values of i. Suppose Y_{k_r-1} is empty. Then we can choose t so that Y_{t+1} is empty. Then $\delta_{H^t}(Y_t) \geq h-1$. The set S contains $|N_{H^1}(Y_1)|$ neighbours of Y_t present in H^t and the $|V(Y_t)|$ neighbours of Y_t that are present in H^{t+1}. Thus, by Lemmas 2.4(1) and 3.2,

$$\begin{aligned} |S| &\geq \big|S_1 \cup S_{k_r}\big| + \big|N_{H^t}(Y_t)\big| + \big|V(Y_t)\big| \geq (2r-h)a_{h-1}^{r-1} + \big|N_{H^t}[Y_t]\big| \\ &\geq 2(2r-h)a_{h-1}^{r-1} \geq a_h^r(2r-h). \end{aligned}$$

Similarly, if Y_{k_r-1} is non-empty, then we can choose t so that Y_{t-1} is empty and so, in this case S contains $N_{H^t}(Y_t)$ and $N_{H^{t-1}}(Y_t)$ implying $|S| \geq a_h^r(2r-h)$.

Suppose Y_i is non-empty for all $1 \leq i \leq k_r - 1$. Here we calculate $|S_i|$ by using Lemma 3.2 or induction. To use induction, we need to consider the nature

of the graph Z also. If $Z_i \neq \emptyset$ for only one value of i, then result follows from Case 1. Suppose $Z_i \neq \emptyset$ for more than one values of i. If $Z_i = \emptyset$ for at least two values of i, then the result follows from the above paragraph by replacing Y with Z. It remains to consider the two subcases depending on whether Z_i is empty for exactly one value of i or no value of i.

Subcase 1. $Z_i = \emptyset$ for exactly one value of i. We have two subcases depending on $i = k_r$ or $i < k_r$.

(i) Suppose Z_{k_r} is empty. Then Z_j is non-empty like Y_j for $1 \leq j < k_r$; Figure 4(a). Suppose $h = 1$. Then $\delta_{H^i}(Y_i) \geq 0$ and $\delta_{H^i}(Z_i) \geq 0$ for all i. Hence $|S_1 \cup S_{k_r}| \geq (2r-1)a_0^{r-1} = (2r-1)$ and by induction, $|S_i| \geq (2(r-1)-0)a_0^{r-1} = 2r-2$ for $i \in \{2, 3, \ldots, k_r - 1\}$. Therefore, as $S = S_1 \cup S_2 \cup \cdots \cup S_{k_r}$, we have

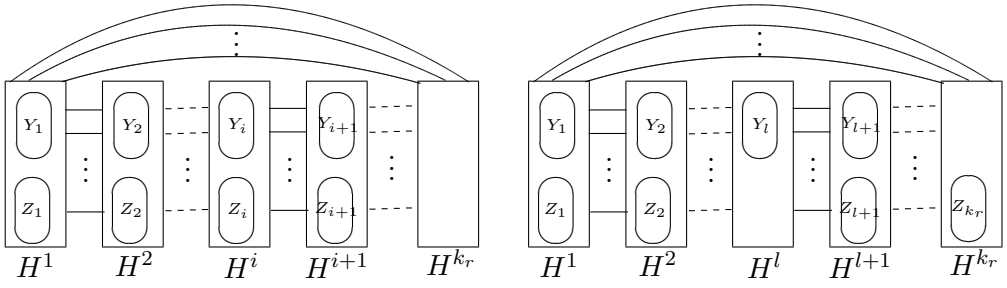
$$\begin{aligned} |S| &= (|S_1 \cup S_{k_r}|) + \sum_{i=2}^{k_r-1} |S_i| \geq (2r-1) + \sum_{i=2}^{k_r-1} (2r-2) \\ &= (2r-1) + (2r-2)(k_r - 2) \geq 2(2r-1) = (2r-h)a_h^r. \end{aligned}$$

Suppose $h \geq 2$. Since Y_{k_r} and Z_{k_r} are empty, $\delta_{H^{k_r-1}}(Y_{k_r-1}) \geq h-1 > h-2$ and $\delta_{H^{k_r-1}}(Z_{k_r-1}) \geq h-1 > h-2$. Thus S_{k_r-1} is an $(h-2)$-cut in H^{k_r-1}. For $i \in \{2, 3, \ldots, k_r - 2\}$, as both Y_i and Z_i are non-empty subgraphs of H^i of minimum degree at least $h-2$, S_i is an $(h-2)$-cut in H^i. Hence, by induction, $|S_i| \geq (2r-h)a_{h-2}^{r-1}$ for $i \in \{2, 3, \ldots, k_r - 1\}$. Therefore

$$\begin{aligned} |S| &= (|S_1 \cup S_{k_r}|) + \sum_{i=2}^{k_r-1} |S_i| \geq (2r-h)a_{h-1}^{r-1} + \sum_{i=2}^{k_r-1} (2r-h)a_{h-2}^{r-1} \\ &= (2r-h)a_{h-1}^{r-1} + (k_r - 2)(2r-h)a_{h-2}^{r-1} \\ &\geq (2r-h)a_{h-1}^{r-1} + \frac{k_r}{2}a_{h-2}^{r-1}(2r-h) \text{.....(since } k_r \geq 4) \\ &\geq (2r-h)a_{h-1}^{r-1} + \frac{1}{2}a_h^r(2r-h) \text{.....(by Lemma 2.4(2))} \\ &= (2r-h)a_{h-1}^{r-1} + a_{h-1}^{r-1}(2r-h) \text{.....(by Lemma 2.4(1))} \\ &= 2a_{h-1}^{r-1}(2r-h) \\ &= a_h^r(2r-h) \text{.....(by Lemma 2.4(1)).} \end{aligned}$$

(ii) Suppose Z_{k_r} is non-empty. Then Z_l is empty for some l with $1 \leq l < k_r$ and Z_j is non-empty for every $j \neq l$; see Figure 4(b). Then the minimum degree of Z_{l+1} is at least $h-1$ in H^{l+1}. Also, the neighbours of Z_{l+1} present in H^i are contained in S_i for $i = l, l+1$. Hence $|S_l \cup S_{l+1}| \geq |N_{H^{l+1}}[Z_{l+1}]| \geq a_{h-1}^{r-1}(2r-h)$ by Lemma 3.2. Thus, if $l \notin \{1, k_r - 1\}$, then

$$|S| \geq |S_1 \cup S_{k_r}| + |S_l \cup S_{l+1}| \geq 2a_{h-1}^{r-1}(2r-h) = a_h^r(2r-h).$$



(a) $Z_{k_r} = \emptyset$. (b) $Z_l = \emptyset$ for some $l < k_r$.

Figure 4. The graph G with $Y_{k_r} = \emptyset$.

Suppose $l = 1$. Then by using similar arguments, we see that $S_1 \cup S_2 \supseteq N_{H^2}(Z_2) \cup N_{H^1}(Z_2)$ and $S_{k_r} \cup S_{k_r-1} \supseteq N_{H^{k_r-1}}(Y_{k_r-1}) \cup N_{H^{k_r}}(Y_{k_r-1})$. Hence

$$|S| \geq |S_1 \cup S_2| + \left|S_{k_r-1} \cup S_{k_r}\right| \geq 2a_{h-1}^{r-1}(2r-h) = a_h^r(2r-h).$$

Similarly, for $l = k_r - 1$,

$$|S| \geq |S_1 \cup S_{k_r}| + \left|S_{k_r-2} \cup S_{k_r-1}\right| \geq 2a_{h-1}^{r-1}(2r-h) = a_h^r(2r-h).$$

Subcase 2. Suppose that $Z_i \neq \emptyset$ for $i = 1, 2, \ldots, k_r$. Then $|S_1 \cup S_{k_r}| \geq a_{h-1}^{r-1}(2r-h)$ and $|S_i| \geq (2r-h)a_{h-2}^{r-1}$ for $i \in \{2, 3, \ldots, k_{r-1}\}$. As in Subcase 1(i), we have $|S| \geq a_h^r(2r-h)$.

Case 3. Suppose $Y_i \neq \emptyset$ for $i = 1, 2, \ldots, k_r$. If Z does not intersect H^i for some i, then the result follows by replacing Y by Z in Case 1 and Case 2. Suppose that Z intersects H^i for all $i = 1, 2, \ldots, k_r$. If $h = 1$, then the minimum degree of Y_i and Z_i is at least 0 and so, by induction, $|S_i| \geq a_0^{r-1}(2(r-1)-0) = 2r-2$, also as $r \geq 2$ implies

$$\begin{aligned} |S| &= \sum_{i=1}^{k_r} |S_i| \geq \sum_{i=1}^{k_r} (2r-2) = k_r(2r-2) \geq 4(2r-2) \\ &= 8(r-1) > 2(2r-1) = a_1^r(2r-1). \end{aligned}$$

Suppose $h \geq 2$. The minimum degree of Y_i and Z_i is at least $h-2 \geq 0$. This shows that S_i is an $(h-2)$-vertex cut of the graph H^i for $i = 1, 2, \ldots, k_r$. Therefore, by induction and by Lemma 2.4(2), we have

$$|S| = \sum_{i=1}^{k_r} |S_i| \geq \sum_{i=1}^{k_r} a_{h-2}^{r-1}(2r-h) = k_r a_{h-2}^{r-1}(2r-h) \geq a_h^r(2r-h).$$

Thus $|S| \geq a_h^r(2r-h)$ in all the above cases. This completes the proof. ∎

Corollary 3.4. *For the graph G of Theorem* 1.2, $\kappa^h(G) = a_h^r(2r-h)$.

Proof. By Lemma 3.1, $\kappa^h(G) \leq a_h^r(2r-h)$. Since $\kappa^h(G)$ is the cardinality of a smallest h-vertex cut of G, by Proposition 3.3, $\kappa^h(G) \geq a_h^r(2r-h)$. Hence $\kappa^h(G) = a_h^r(2r-h)$. ∎

4. Conditional Edge Connectivity

In this section, we prove that the conditional edge connectivity $\lambda^h(G)$ of the graph G of Theorem 1.2 is same as its conditional vertex connectivity $\kappa^h(G)$.

Recall that $G = C_{k_1} \Box C_{k_2} \Box \cdots \Box C_{k_r}$ with $4 \leq k_1 \leq k_2 \leq \cdots \leq k_r$ and W_h^r is an h-regular subgraph of G with a_h^r vertices. We get an upper bound for $\lambda^h(G)$ from the set of edges of G each of which has exactly one end vertex in W_h^r. For such edge sets we introduce the following notation. For a subgraph K of a graph H, let

$$E_H(K) = \{xy \colon x \in V(K) \text{ and } y \in V(H) \setminus V(K)\}.$$

Lemma 4.1. *For $0 \leq h \leq 2r-1$, $\lambda^h(G) \leq (2r-h)a_h^r$.*

Proof. Let $K = W_h^r$. Then K is h-regular and G is $2r$-regular. Hence $|E_G(K)| = (2r-h)|V(K)|$ and $G - E_G(K)$ is disconnected with K as one of its components. By Lemma 2.7, the minimum degree of every component of $G - E_G(K)$ other than K is at least $2r-1 \geq h$. Therefore $E_G(K)$ contains an h-edge cut of G. This shows that $\lambda^h(G) \leq |E_G(K)| = (2r-h)a_h^r$. ∎

Lemma 4.2. *For a subgraph Y of G of minimum degree at least h, $|V(Y)| + |E_G(Y)| \geq a_h^r(2r-h+1)$.*

Proof. If Y spans G, then $|V(Y)| = k_1 k_2 \cdots k_r \geq a_h^r(2r-h+1)$ by Lemma 2.9. Suppose Y is not a spanning subgraph of G. Since for every x in $N(Y)$ there is a vertex y of Y adjacent to x so that the edge xy belongs to the edge set $E_G(Y)$. This implies that $|E_G(Y)| \geq |N(Y)|$. Hence, by Lemma 3.2, $|V(Y)| + |E_G(Y)| \geq |N[Y]| \geq a_h^r(2r-h+1)$. ∎

Using this lemma we now obtain the reverse inequality for $\lambda^h(G)$.

Proposition 4.3. *Let F be an h-edge cut of the graph G. Then $|F| \geq a_h^r(2r-h)$.*

Proof. Since the graph G is $2r$-regular, $0 \leq h \leq 2r$. The result holds obviously for $h = 2r$. Suppose $h = 0$. Then F is a set of edges G such that $G - F$ is a disconnected graph. It follows from Lemma 2.1 that G is $2r$-edge connected and so, $|F| \geq 2r = a_0^r(2r-0)$. Thus the result holds for $h = 0$ also. Suppose $1 \leq h \leq 2r-1$. We prove the result by induction on r. The result follows trivially

for $r = 1$. Suppose $r \geq 2$. Assume that the result holds for the product of $r-1$ cycles. Let F be an h-edge cut of G. Then $G - F$ is disconnected and every component of it has minimum degree at least h.

Let Y be a subgraph of $G-F$ consisting of at least one but not all components of $G-F$ and let Z be the subgraph consisting of the remaining components. Then Y and Z are vertex disjoint subgraphs of $G - F$ of minimum degree at least h and their union is $G-F$. Note that F contains both edge sets $E_G(Y)$ and $E_G(Z)$. Hence $|F| \geq |E_G(Y)|$ and $|F| \geq |E_G(Z)|$.

Write G as $H \square C_{k_r}$, where $H = C_{k_1} \square C_{k_2} \square \cdots \square C_{k_{r-1}}$. Then G is obtained by replacing vertex i of the cycle C_{k_r} by a copy H^i of H and replacing the edge joining i and $i+1 \pmod{k_r}$ by the perfect matching M_i between the corresponding vertices of H^i and $H^{i+1 \pmod{k_r}}$. Then Y intersects at least one H^i. Similarly, Z intersects at least one H^i. Let $Y_i = Y \cap H^i$ and $Z_i = Z \cap H^i$ for $i = 1, 2, \ldots, k_r$.

For a subgraph K of G, let $M_i(K)$ be the set of all edges in the matching M_i each having exactly one end vertex in K.

Case 1. Suppose $Y_i \neq \emptyset$ for only one value of i. Without loss of generality, we may assume that Y_i is non-empty for only $i = 1$. Then Y is contained in the graph H^1 and $\delta_{H^1}(Y) \geq h$. Since H^1 is $(2r-2)$-regular, $h \leq 2r-2$. If $h = 2r-2$, then $Y = H^1$ and so, $|E_G(Y)| = |M_1| + |M_{k_r}| = 2|V(H^1)| = 2k_1k_2 \cdots k_{r-1}$. As $4 \leq k_{r-1}$, we have

$$\begin{aligned} a_h^r(2r-h) &= 2a_h^r 2(2^{r-(r-2)}k_1k_2 \cdots k_{r-2}) = 2(4k_1k_2 \cdots k_{r-2}) \\ &\leq 2k_1k_2 \cdots k_{r-2}k_{r-1} = |E_G(Y)| \leq |F|. \end{aligned}$$

Suppose $h < 2r-2$. Then $E_G(Y) \supseteq E_{H^1}(Y) \cup M_1(Y) \cup M_{k_r}(Y)$. As $|M_1(Y)| = |M_{k_r}(Y)| = |V(Y)|$, by Lemmas 2.4(3), 2.5 and 4.2, we have

$$\begin{aligned} |E_G(Y)| &\geq \big(\big|E_{H^1}(Y)\big| + |V(Y)|\big) + |V(Y)| \geq a_h^{r-1}(2r-h-1) + a_h^{r-1} \\ &= a_h^{r-1}(2r-h) \geq a_h^r(2r-h). \end{aligned}$$

Case 2. Suppose $Y_i \neq \emptyset$ for more than one but not all values of i. Without loss of generality, we may assume that Y_1 is non-empty but Y_{k_r} is empty. Let t be the largest integer such that Y_t is non-empty. Then $1 < t < k_r$. The minimum degree of Y_i in H^i is at least $h-1$ for $i = 1, t$. The graph Y_1 has $|V(Y_1)|$ neighbours in H^{k_r} and Y_t has $|V(Y_t)|$ neighbours in H^{t+1}. Hence $E_G(Y) \supseteq E_{H^1}(Y_1) \cup E_{H^t}(Y_t) \cup M_{k_r}(Y_1) \cup M_t(Y_t)$.

Suppose $h = 2r-1$. Then $Y_j = H^j$ for $j = 1, t$ giving $M_{k_r}(Y_1) = M_{k_r}(H^1) = M_{k_r}$ and $M_t(Y_t) = M_t(H^t) = M_t$. Hence

$$\begin{aligned} a_h^r(2r-h) &= a_h^r = 2k_1k_2 \cdots k_{r-1} = |V(H^1)| + |V(H^t)| \\ &= |M_{k_r}| + |M_t| \leq |E_G(Y)| \leq |F|. \end{aligned}$$

Suppose $h \leq 2r-2$. Then $h-1 \leq 2r-3$ and so, by Lemmas 4.2 and 2.4(1),

$$\begin{aligned}|F| &\geq |E_G(Y)| \geq \big(\big|E_{H^1}(Y_1)\big| + |V(Y_1)|\big) + \big(\big|E_{H^t}(Y_t)\big| + |V(Y_t)|\big) \\ &\geq 2a_{h-1}^{r-1}(2r-h) = (2r-h)a_h^r.\end{aligned}$$

Case 3. Suppose $Y_i \neq \emptyset$ for all $i = 1, 2, \ldots, k_r$. If the graph Z does not intersect H^i for some i, then the result follows easily by replacing Y by Z in Case 1 and Case 2. Suppose Z intersects H^i for all $i = 1, 2, \ldots, k_r$. Suppose $h = 1$. As $r \geq 2$, $\delta(Y_i) \geq 0$ and $\delta(Z_i) \geq 0$, by induction, we have

$$\begin{aligned}|E_G(Y)| &= \sum_{i=1}^{k_r} |E_{H^i}(Y_i)| \geq \sum_{i=1}^{k_r} (2r-2) \geq k_r(2r-2) \\ &\geq 4(2r-2) = 8(r-1) > 2(2r-1) = a_1^r(2r-1).\end{aligned}$$

Suppose $h \geq 2$. The minimum degree of Y_i and Z_i is at least $h-2 \geq 0$. Therefore the edge set $E_{H^i}(Y_i)$ is an $(h-2)$-edge cut of H^i. By induction, $|E_{H^i}(Y_i)| \geq a_{h-2}^{r-1}(2r-h)$ for $i = 1, 2, \ldots, k_r$. By Lemma 2.4(2),

$$\begin{aligned}|F| \;&\geq\; |E_G(Y)| = \sum_{i=1}^{k_r} |E_{H^i}(Y_i)| \geq \sum_{i=1}^{k_r} a_{h-2}^{r-1}(2r-h) \\ &\geq\; k_r a_{h-2}^{r-1}(2r-h) \geq a_h^r(2r-h).\end{aligned}$$

This completes the proof. ∎

Corollary 4.4. *For the graph G of Theorem* 1.2, $\lambda^h(G) = a_h^r(2r-h) = \kappa^h(G)$.

Proof. By Proposition 4.3, $\lambda^h(G) \geq a_h^r(2r-h)$ and by Lemma 4.1, $\lambda^h(G) \leq a_h^r(2r-h)$. Hence $\lambda^h(G) = a_h^r(2r-h) = \kappa^h(G)$ by Corollary 3.4. ∎

This completes the proof of Theorem 1.2.

It is worth mentioning that the edge connectivity part of Theorem 1.2 proves that the following conjecture of Xu [7] holds for the classes of multidimensional tori and k-ary r-cubes.

Conjecture 4.5. *Let k, h be two non-negative integers and G be a connected graph with minimum degree at least k and $a_h(G)$ be the minimum cardinality of a vertex set of an h-regular subgraph of G. If $\lambda^h(G)$ exists, then $\lambda^h(G) \leq a_h(G)(k-h)$.*

Concluding Remarks.

We determine the conditional h-vertex connectivity and the conditional h-edge connectivity of a multidimensional torus G which is the Cartesian product of r

cycles each of length at least four, for all possible values of h. We first characterize the h-regular subgraph of G with minimum number of vertices and then establish that both these conditional connectivities of G are equal to $(2r - h)$ times the number of vertices of this subgraph.

Acknowledgement

The second author is financially supported by DST-SERB, Government of India through the project MTR/2018/000447.

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Received 5 February 2020
Revised 1 July 2020
Accepted 6 July 2020

VOLUME - X, ISSUE - I - JANUARY - MARCH - 2021
AJANTA - ISSN 2277 - 5730 - IMPACT FACTOR - 6.399 (www.sjifactor.com)

२१. आत्मनिर्भर भारत : योजना व नियोजन

प्राचार्य डॉ. संजीव लाटे
अमृतेश्वर कला, वाणिज्य व विज्ञान महाविद्यालय, विंझर, ता. वेल्हा, जि. पुणे.

प्रस्तावना

जीडीपी म्हणजे देशाच्या अर्थव्यवस्थेची तब्येत कशी आहे याचे मोजमाप करण्याचे साधन, देशाच्या अर्थव्यवस्थेत जीडीपी चे स्थान महत्त्वपूर्ण असते. कोणत्याही देशात रोज असंख्य आर्थिक व्यवहार होत असतात याची नोंद जीडीपीमध्ये होत असते. देशाने एका आर्थिक वर्षात किती मालाचे उत्पादन केले व किती सेवा पुरविल्या, याची आकडेवारी जीडीपीमध्ये असते. विविध संस्था या कामांत कार्यरत असतात.

आर्थिक वर्षात देशाने जो माल तयार केला व सेवा दिल्या, त्यांना प्राथमिक (शेती आदी), दय्यम क्षेत्र (उद्योग, व्यवसाय आदी) व सेवा क्षेत्र यांत विभागले जाते. अशा वार्षिक उत्पादनाला बाजारी किंमतीने गुणले, की जे उत्तर येईल ते म्हणजे 'ग्रॉस डोमेस्टिक प्रॉडक्ट (जीडीपी)' अर्थात एकूण देशांतर्गत उत्पादन। 'जीडीपी ची वाढ हा कोणत्याही देशाच्या आर्थिक प्रगतीचा मापदंड असतो, 'जीडीपी' वाढीचा दर चांगला असेल, तर देशाची अर्थव्यवस्था प्रगती करीत आहे, नागरिकांना चांगले उत्पन्न मिळत आहे, बेरोजगारीचे प्रमाण कमी आहे,

चागला उठाव आहे, सेवा क्षेत्रातही चागली मागणी दिसून येत आहे. असा त्याचा अर्थ होतो. थोडक्यात, देश आर्थिकदृष्ट्या प्रगती करीत आहे की नाही याचा अंदाज आपल्याला 'जीडीपी' वाढीच्या दरावरून बांधता येऊ शकतो.

कोरोना विषाणूची लागण नियंत्रित करण्यासाठी अवलंबलेली टाळेबंदी देशाच्या आर्थिक वृद्धीदर, उत्पादक क्षेत्रावर, रोजगार आणि बेकारीवर प्रतिकूल परिणाम करते. टाळेबंदीचा अर्थव्यवस्थेवर प्रतिकूल परिणाम झाला त्याचे विश्लेषण करणे आवश्यक आहे. देशाची आर्थिक वृद्धी स्थूल देशांतर्गत उत्पादन (GDP) मध्ये मोजली जाते. सैद्धांतिक दृष्ट्या GDP=C+G(X-MP) होय. म्हणजेच देशाची आर्थिक वृद्धी ठरविणारे खासगी उपभोग (C) गुंतवणूक (I), सरकारी खर्च (G) आणि निव्वळ आयात (X-M) हे घटक किंवा निर्धारक आहेत. रिझर्व्ह बँकेच्या मते, यात खासगी उपभोग खर्चाचा हिस्सा ६० टक्के असतो.

आशिया खंडातील तिसऱ्या क्रमांकाची मोठी अर्थव्यवस्था म्हणून भारतीय अर्थव्यवस्थेकडे पाहिले जाते. २०१९ मध्ये भारतीय अर्थव्यवस्था २.७ ट्रिलियन डॉलर्सची होती; ती २०२५ पर्यंत ५ ट्रिलियन डॉलर्स होईल असा अंदाज आहे त्यासाठी विकास दर ९ टक्क्यापेक्षा जास्त हवा, सध्या देशाचे दरडोई उत्पन्न १८०० डॉलर आहे. ५ ट्रिलियन डॉलर्स झाल्यास दरडोई उत्पन्न ३६०० डॉलर्सपर्यंत जाईल. (विकसित देश म्हणजे ज्या देशाचे दरडोई उत्पन्न १२००० डॉलरपेक्षा जास्त), २०१५-१६ मध्ये भारताचा विकासदर ८.२

टक्के, २०१८-१९ मध्ये ६.८ टक्के, २०१९-२० आर्थिक वर्षामधील पहिल्या तिमाहीतत ५ टक्के (सहा वर्षातील निचांकी पातळीवर आला) तर दुसऱ्या तिमाहीत ४.३ टक्के राहिल असा अंदाज होता. विकास दर घटण्यासाठी अनेक कारणे जबाबदार आहेत; त्यामध्ये प्रमुख कारणामध्ये नोटाबंदी, जीएसटी आकारणी यांचा समावेश होतो. भारतातील विकासदराचा संक्षिप्त आढावा पुढील प्रमाणे

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राखीव निधीचे प्रमाण निश्चित करण्यासाठी २६ डिसेंबर २०१८ रोजी रिझर्व्ह बँकेचे माजी गव्हर्नर बिमल जालन यांच्या अध्यक्षतेखाली समिती नियुक्त केली व जालान समितीने २६ ऑगस्ट २०१९ रोजी अहवाल सादर केला असून रिझर्व्ह बँकेकडे ९ लाख कोटी रु. ची राखीव गंगाजळी असून ती पुढील तीन ते पाच वर्षात सरकारकडे सुपूर्द करावी अशी शिफारस

मागील काही वर्षातील भारताचा विकास दर

वर्ष	विकास दर (टक्के)	वर्ष	विकास दर (टक्के)
१९९८-०४(सरासरी)	५.९	२०१५-१६	८.२
२००३-०६ (सरासरी)	८०	२०१६-१७	७.१
२०१२-१३	५.५	२०१७-१८	७.२
२०१३-१४	६.४	२०१८-१९	६.१
२०१४-१५	७.४	२०१९-२०	४.२

संदर्भ: केंद्रीय सांख्यिकी विभाग दिल्ली.

क्षेत्रवार विकास दर

तपशील	२०१६-१७	२०१७-१८	२०१८-१९	२०१९-२०
कृषी विकास दर	६ .३	५.०	२.९	२.१
औद्योगिक उत्पादन वाढीचा निर्देक्षांक	४.६	४.४	३.९	२.९
गाभा क्षेत्रातील विकास दर	४.८	४.३	४.४	०.२
पतपुरवठ्यातील वाढीचा दर	०.९	-०.४	२.३	२.७
उत्पादन	-१.२	१.७	-१.४	०.७
व्यक्तिगत अंतिम क्रय	५६.१	५६.३	५६.९	५५.७
बेरोजगारी (शेकडा)	९.६५	४.०३	५.१४	७.०३

संदर्भ: रिझर्व्ह बँक, जानेवारी २०२०.

समितीने केली आहे. सरकारला हा निधी मिळाल्यास वितीय तुटीचे प्रमाण कमी होईल व आर्थिक विकासाचा दर वाढण्यास मदत होईल असे म्हटले आहे. सन २०१८-१९ मध्ये आरबीआयकडून सरकारला ६८ हजार कोटी रु. निधी दिला. सन २०१९-२० मध्ये १,७६,०५१ लाख कोटी रु. राखीव निधी रिझर्व्ह बँकेने केंद्र सरकारला दिला. रिझर्व्ह बँकेने राखीव गंगाजळी सरकारला द्यावी अशी मागणी अर्थ मंत्रालयाने केली होती याला तत्कालीन गव्हर्नर ऊर्जित पटेल यांनी विरोध केला होता; यावरून त्यांचे अर्थमंत्रालयशी मतभेद झाले होते. कोवीड -१९ मुळे २५ मार्च २०२० पासून देशात सतत लॉकडाऊनमुळे विकासदरात मोठी घट झाली आहे. कोराना काळात उपभोक्त्यांच्या मागणीत मोठी घट झाली आहे. त्यामुळे ग्राहक किंमत निर्देशांकात घट झाली आहे. संपूर्ण अर्थव्यवस्थेसाठीचा खरेदी व्यवस्थापक निर्देशांक (PMI) टाळेबंदी काळात वेगाने घटला आहे, तो उपभोग खर्च घटीचा निर्देशक आहे. बँकाकडून होणारा कर्जपुरवठा जानेवारी २०२० मधील ७.२ % वरून ६.३ % पर्यंत घटला आहे. त्यामुळे भांडवल गुंतवणूक आणि निर्मितीही घटली आहे, यातून गुंतवणूक खर्च घटल्याचे सिद्ध होते. व्यवसाय अपेक्षा निर्देशांक टाळेबंदीपूर्व ११५ वरून १०५ पर्यंत वेगाने घटून सेवाक्षेत्रातील घट दर्शवितो. टाळेबंदी काळात थेट परकीय गुंतवणूक ही मोठ्या प्रमाणात घटली आहे. वस्तू निर्माण क्षेत्राचा खरेदी व्यवस्थापक निर्देशांक (PMI) टाळेबंदी काळात वेगाने घटला असल्याने या क्षेत्राची प्रगती घटल्याचे दर्शवितो. मागणी घटल्याने उद्योगांची क्षमता वापर ७६ % वरून ६९% पर्यंत उल्लेखनीय प्रमाणात घटली आहे. आर्थिक संकट काळात सरकारी खर्चातील वृद्धी महत्त्वाची भूमिका बजावत असते, टाळेबंदीच्या काळात सरकारी खर्च लक्षणीय घटल्याचे दिसून येते. मे २०२० पर्यंत भारताची निर्यात ६० टक्के ने घटली आहे. रोजगार घटल्याने बेकारी वाढून कामगारांची मागणी घटली. उपभोग खर्चात वेगाने घट झाली. अशा प्रकारे टाळेबंदी काळात उपभोग खर्च (C), गुंतवणूक खर्च (I) सरकारी खर्च (G) आणि निव्वळ निर्यात (X) घटल्याने एकूण आणि क्षेत्रनिहाय आर्थिक वृद्धी वेगाने घटली आहे.

लॉकडाउनमुळे विकासदरात घट

राष्ट्रीय सांख्यिकी कार्यालयाने २०२०-२१ या आर्थिक वर्षातील एप्रिल -जून या पहिल्या तिमाहीचे जीडीपीचे आकडे प्रसिद्ध केले. कोरोना च्या प्रसारामुळे लॉकडाउन जारी झाल्याने अनेक अर्थतज्ज्ञांनी हा तिमाहीचा विकास दर मागील वर्षाच्या तुलनेत १८ ते २० टक्के घटेल असे भाकीत केले होते. त्यापेक्षा जास्त म्हणजे ही घट (केवळ एका तिमाहीत २३.९ टक्के घट) २३.९ टक्के आहे. रुपयांत मांडायचे झाल्यास ही अधोगती जवळपास १३ लाख कोटी रुपयांची आहे. स्वतंत्र भारताच्या इतिहासातील ही विक्रमी तिमाही घट अर्थातच, यामुळे २०२०-२१ आर्थिक वर्षाअंती विकासदरात घटच असेल व ती घट १९७९ च्या आजतागायत विक्रमी ५.२ टक्के घटीपेक्षाही जास्त असण्याच्या अंदाजांना बळ मिळाले आहे. कोरोनाचा प्रादर्भाव संपूर्ण जगावर झाला आहे. मात्र, एप्रिल-जूनचे तिमाही आकडे पाहता, इतर प्रमुख देशांच्या तुलनेत भारतावरील आघात (२३.९टक्के घट) मोठा आहे. याच तिमाहीत अमेरिका व आशियामधील प्रमुख देशांनी २ ते १० टक्के घट नोंदविली, ही घट युरोपीय देशात १५ टक्के नोंदवली आहे. ज्या देशातून कोरोना जगभर

पसरला त्या चीनने मात्र घट नव्हे तर वाढ नोंदविली आहे, ती सुद्धा ३.२ टक्के आहे. जी-७ देशांच्या विकासदरातील घट पुढील प्रमाणे भारत - २३.९टक्के, ब्रिटन -२०.४ टक्के, फ्रान्स -१३.८ टक्के, इटली -१२.४ टक्के, कॅनडा -१२ टक्के, जर्मनी -१०.१ टक्के, अमेरिका -९.५ टक्के, जपान-७.९ टक्के याप्रमाणे नोंदवली आहे.

चीनमधील स्थिती

जगातील दुसऱ्या क्रमांकाची महासत्ता म्हणून ओळख असणाऱ्या चीनला कोरोना संसर्गाची जबर किंमत मोजावी लागली आहे. प्रथमच चिनी अर्थव्यस्थेने विकासदरात गटांगळी खाल्याने ड्रॅगनचे प्रथमच ग्रेटफॉल झाले आहे. चीनमध्ये मालाला उठाव नाही, लोकांनी हॉटेल व रेस्टॉरंट्सकडे पाठ फिरवली, जनतेकडून केवळ गरजेपूर्तीच खरेदी, लोक बाहेर पडण्यास तयार नाहीत, विमान आणि रेल्वे प्रवासही घटला, चिनी कंपन्यांचा माल बाजारपेठेत पडून, महागड्या वस्तूंच्या खरेदीकडे लोकांची पाठ, शॉपिंग मॉल लोकाविना ओस, मोठ्या बांधमाकाची कामे ठप्प झाली आहेत. यावर उपाय म्हणून चीनने प्रथमच ४५ लाख कोटी डॉलरचे वित्त क्षेत्र खुले केले आहे, चीनच्या अर्थव्यवस्थेला मोठे वळण देणारा हा ऐतिहासिक निर्णय चीनच्या सरकारने घेतला आहे. त्यामुळे चीनमध्ये नव्याने गुंतवणूक होईल.

बांधकाम, उत्पादन क्षेत्राला मोठा फटका

या भयावह २३.९ टक्के घटीची कारणे व परिणाम यावरील विश्लेषणासाठी या संख्यचे पृथक्करण आवश्यक आहे. बांधकाम क्षेत्रातील ५० टक्के घट, व्यापार व हॉटेल क्षेत्रातील ४७ टक्के घट, आणि उत्पादन क्षेत्रातील ३९ टक्के घट ही विकास दरातील घटीची कारणे आहेत. योगायोगाने हीच क्षेत्रे प्रत्येकी एक लाख रुपयांच्या गुंतवणुकीमागे सर्वाधिक रोजगारनिर्मिती करतात. साहजिकच या अर्थव्यवस्थेच्या आकुंचनाचा परिणाम हा या सर्व क्षेत्रांतील रोजगार व त्या अनुषंगाने कामगारांच्या खरेदी करण्याच्या क्षमतेवर व मागणीवर झाला आहे. या तिमाही आकड्यांवर बारकाईने नजर टाकता, देशपातळीवर एकूण मागणीत ३१.२ टक्के घट झाल्याचे समोर येते. मागणीतील ही घट अर्थव्यवस्था उभारणीपुढील सर्वात मोठे आव्हान आहे. लॉकडाऊनच्या काळात भांडवली गुंतवणूकीत ८९ टक्के घट झाली. खाजगी उपभोगात ३६.४ टक्के घट, सरकारचा उपभोग खर्चात १६.४ टक्क्यांनी वाढून महसूली घट वाढली, एप्रिल ते जूलै या चार महिन्यात वित्तीय तूट अंदाजपत्रकीय तुटीच्या तुलनेत १०३ टक्क्यांनी वाढल्याचे दिसते.

अर्थव्यवस्थेत जीडीपीच्या तुलनेत कॅशचे प्रमाण अधिक

२७ मार्च २०२० पर्यंत देशाच्या अर्थव्यवस्थेत २४.३९ लाख कोटी रुपयाचे चलन वापरात होते. २०१९-२० च्या अर्थसंकल्पात देशातील अंदाजित जीडीपी २०३.८५ लाख कोटी रु. आहे. देशातील एकूण जीडीपीच्या १२ टक्के कॅश चलनात असणे अपेक्षित आहे हा आकडा सध्यस्थितीत अधिक आहे याचे कारण कोरानोमुळे जीडीपीमध्ये घट झाली आहे. अर्थव्यवस्थेत जीडीपीच्या तुलनेत कॅशचे प्रमाण अधिक आहे. २०१९-२० मध्ये जीडीपी २०० लाख कोटी गृहीत धरल्यास जीडीपीच्या तुलनेत कॅशचे प्रमाण १२.२

टक्के इतके होईल मात्र ३ एप्रिल २०२० अखेर देशातील वापरातील चलन २४.५७ लाख कोटी रु. होते. याचा अर्थ देशात जीडीपीच्या तुलनेत कॅशचे प्रमाण १२.२४ टक्क्यावर पोचले आहे. मार्च २०१६ मध्ये जीडीपीच्या तुलनेत कॅशचे प्रमाण १२.१ टक्के होते, मार्च २०१७ ते घसरून ८.७ टक्के इतके झाले होते नोटाबंदीनंतर कॅशच्या प्रमाणात घट झाली होती त्यानंतर मात्र देशात जीडीपीच्या तुलनेत कॅशचे प्रमाण वाढत असल्याचे दिसून येते. देशात कॅशचे प्रमाण वाढण्याचे कारण कोरोनाच्या भितीमुळे बँकेतून कॅश काढण्याचे प्रमाण वाढले, जनधन खात्यात शासनाने पैसे टाकल्यामुळे लोकांकडील कॅश वाढली.

वितीय संकट गडद

कोरोनामुळे वितीय स्थितीवरही संकट येणे स्वाभाविकच होते. २०२०-२१ म्हणजेच वर्तमान आर्थिक वर्षात १६ लाख कोटी रुपयांच्या महसूलप्राप्तीचे उद्दिष्ट राखले होते. प्रत्यक्षात पहिल्या आठ महिन्यात म्हणजेच नोव्हेंबर २०२० अखेर सरकारच्या तिजोरीत जमा कररुपी महसूल ७ लाख कोटी आहे. पुढील चार महिन्यात म्हणजेच ३१ मार्च २०२१ अखेर उरलेले ९ लाख कोटी रुपये जमा करण्याचे उद्दिष्ट कठीण आहे. गेल्या अर्थसंकल्पात सरकारतर्फे पूर्ण आर्थिक वर्षात ३० लाख कोटीचा खर्च करण्याचे उद्दिष्ट होते आणि सरकार ते करीतही आहे. परंतु कोरोनामुळे प्राधान्यक्रम बदलल्याने हा खर्च प्रामुख्याने आरोग्यावर आणि विविध आर्थिक मदतयोजनांवर करावा लागला. पण महसूल व खर्चातील तफावत रुंदावत चाललेली असताना सरकारला मोठ्या प्रमाणात कर्जे घ्यावी लागत आहेत. सन २०२१-२०२२ चा एकूण अर्थसंकल्प ३४.८३ लाख कोटी रुपयांचा दर्शविला आहे त्यापैकी १५.०७ लाख कोटी रु. रक्कम कर्जाव्दारे जमा केली जाणार आहे तर एकूण खर्चापैकी ८.१ टक्के रक्कम कर्जाच्या व्याजापोटी खर्च होणार आहे. तसेच पाहणी अहवालाने सूचित केल्याप्रमाणे नोटा छपाईचे प्रमाणही वाढवावे लागणार आहे. परिणामी चलनफुगवटा अटळ असल्याचे वास्तव स्विकारावे लागणार आहे. वितीय तुट आटोक्याबाहेर चालली आहे. सरकारने विविध आर्थिक मदतयोजना किंवा पॅकेज जाहीर केली परंतु त्यावर खर्च केलेल्या पैशातून सामान्यजनांना कोणताच थेट फायदा झालेला नाही. २०२०-२१ या आर्थिक वर्षात वितीय तूट (जीडीपीच्या तुलनेत) अर्थसंकल्पीय अंदाजानुसार ३.५ टक्के ग्राह्य धरली होती परंतु सुधारित अंदाजानुसार ती २०२१२०२२ च्या अंदाजपत्रकात ९.५ टक्के दर्शवली असून ही धोक्याची घंटा आहे. बेकारीत विक्रमी वाढः ____ जगाच्या आर्थिक नाड्या आवळणाऱ्या कोरोनाने अनेकांच्या तोंडाचा घास हिरावून घेतला आहे. बेकारीमुळे संपूर्ण जगात आत्महत्याचे प्रमाण वाढले. CMIE ने सादर केलेल्या आकडेवारीनुसार ऑगस्ट २०१९ मध्ये पांढरपेशा नोकरदारांची संख्या १.८८ लाख कोटी होती ती मे २०२० ऑगस्ट २०२० मध्ये १.२२ लाख कोटी पर्यंत घटली. एप्रिल २०२० ते ऑगस्ट २०२० या काळामध्ये ६६ लाख लोकांच्या नोकऱ्या गेल्या (सॉप्टवेअर, अभियंते, डॉक्टर, शिक्षक, लेखापाल व विश्लेषकयांचा समावेश) आहेत. दुसऱ्या एका पाहणीनुसार ऑगस्टपर्यंत पगारी नोकऱ्यांची संख्या ८ कोटीवरून ६.५ कोटीपर्यंत घटली म्हणजे २.१ कोटी कर्मचाऱ्यांच्या नोकऱ्या गेल्या. आजपर्यंतच्या इतिहासातील रोजगारीतील ही सर्वात मोठी घसरण आहे.

२०२०-२१ या आर्थिक वर्षात पहिल्या ९ महिन्यात विक्रमी ३०० कोटी मनुष्य दिवसांच्या रोजगाराचा विक्रम झाला. कोरोना काळात ग्रामीण भागात रोजगार तारणहार ही योजना ठरली. मनरेगामुळे १० कोटी लोकांना रोजगार मिळाला. मजूरी दरात १८२ वरून २०० रुपये वाढ करण्यात आली. एकूण रोजगारामध्ये महिलांची भागीदारी महिलांचे प्रमाण ५२.६२ टक्के होती. नुकतेच अर्थमंत्र्यांनी सांगितल्याप्रमाणे देशात ग्रामीण रोजगार हमी योजनेवर ४१ ते ४३ टक्के वाढ कोरोनामुळे झाली आहे.

राष्ट्रीय टाळेबंदीमुळे सुमारे १.२५ कोटी कामकऱ्यांवर बेकारीची कु-हाड कोसळली. ही आकडेवारी असंघटीत किंवा अनौपचारिक क्षेत्रातील आहे. औपचारिक किंवा संघटित क्षेत्रातील नोकरकपातीची मोहीम व्यापक आहे. नोकरकपातीबरोबरच वेतनकपातीलाही कर्मचाऱ्यांना तोंड यावे लागले. असंघटित क्षेत्रातील बेकारीचे प्रतिबिंब राष्ट्रीय ग्रामीण रोजगार योजनेवर अचानक प्रचंड प्रमाणात फोफावलेल्या कामगार नोंदणीवरुन लक्षात येते. परंतु तेथे काम कोणते पुरवाय वे या मुद्यावरील अस्पष्टतेमुळे तेथेही केवळ नोंदणी झाली पण काम व वेतन मिळू शकले नाही. याची चिकित्सा होणे गरजेचे आहे.

उपाययोजना

लॉकडाऊननंतर अर्थव्यवस्थेची विस्कटलेली घडी पुन्हा रुळावर आणण्यासाठी केंद्र सरकार व रिझर्व्ह बँकेमार्फत विविध उपाययोजना केल्या त्यामुळे विकासदर वाढण्यास मदत होणार आहे. १) केंद्र सरकारने उत्तेजक पॅकेज जाहीर केले. उदा : १.७० लाख कोटी रु. रीलिफ पॅकेज जाहीर केले व १२ मे २०२० रोजी २० लाख रु आर्थिक उत्तेजन पॅकेज जाहीर केले. त्याअंतर्गत प्रधानमंत्री गरीब कल्याण अन्नयोजनेअंतर्गत तांदूळ, गहू, डाळीचे वाटप. आरोग्य क्षेत्रात काम करणाऱ्या कर्मचाऱ्यांसाठी ५० लाख रु. विमा कवच, किसान सन्मान निधी अंतर्गत शेतकऱ्यांच्या खात्यावर २००० रु. जमा, जेष्ठ नागरिक, दिव्यांग अणि विधवांना १००० रु. दोन हप्त्यात, जनधन खाती असलेल्या स्त्रियांना तीन महिने महिना ५०० रु. याप्रमाणे खात्यात जमा. कर्ज हप्ते भरण्यास तीन महिने सवलत, कर्जावरील व्याजदर कमी, २)रिझर्व्ह बँकेने बँकेने काही उपाययोजना केल्या. रेपो रेट ४ टक्के पर्यंत (१५ वर्षातील सर्वात कमी) कमी केला. मागील काही दिवसात केंद्र सरकार आणि रिझर्व्ह बँक यांनी केलेल्या काही उपायोजना कार्यान्वित केलेल्या योजनांचा पुरवठा साखळी पूर्ववत होण्यासाठी चांगला फायदा होत आहे. मात्र सदर पावले अपुरी आहेत त्यासाठी सरकारने आणखी पावले त्वरीत उचलणे गरजेचे आहे. ३) पायाभूत सुविधावरील सरकारी गुंतवणूक वाढायला हवी त्याचा परिणाम खाजगी गुंतवणूक वाढायला मदत होईल. तसेच शहरी भागातील लोकांना रोजगार उपलब्ध होण्यासाठी नरेगा तर ग्रामीण भागातील लोकांना रोजगार उपलब्ध करण्यासाठी मनरेगा योजना तातडीन; राबविण्याची गरज आहे. प्रत्येक जिल्हयामध्ये १०० कि.मी ग्रामीण रस्त्याची निर्मिती, ५० प्राथमिक आरोग्य केंद्रे, ५० सरकारी शाळांची पुनर्बाधणी व १० छोटे मोठे सिंचन प्रकल्प हाती घ्यावेत त्यासाठी प्रत्येक जिल्हयासाठी १४० कोटी खर्च होतील देशात एकूण ७३९ जिल्हे आहेत अशी एकूण गुंतवणूक १ लाख कोटी रुपयाची हवी त्यामुळे विकासदर वाढण्यास मदत होईल. ४) जागतिक बँकेमार्फत

कोरोनाचा मुकाबला करण्यासाठी १ एप्रिल २०२० रोजी मदत जाहीर करण्यात आली त्यामध्ये भारताला १ अब्ज डॉलर, पाकिस्तान २० कोटी डॉलर, अफगाणिस्तान १० कोटी डॉलर, मालदीव ७३ लाख डॉलर, श्रीलंकेला १२.८६ कोटी डॉलर जाहीर करण्यात आले. त्याचा परिणाम आर्थिक विकास टिकवून ठेवण्यास हातभार लागेल. ५) देशात पतपुरवठ्यासाठी रिझर्व्ह बँकेने १७ एप्रिल २०२० रोजी रिव्हर्स रेपो दरात ०.२५ टक्के कपात (३.७५ ४) केली. गेल्या महिन्यात रिव्हर्स रेपो दरात ०.९० टक्के कपात केली होती , रिफायनान्ससाठी नाबार्डला २५ हजार कोटी, सिडबीला १५ हजार कोटी, एनएचबीला १० हजार कोटी रुपयाचे अर्थसहाय्य जाहीर करण्यात आले.

संदर्भ

१) सी. रंगराजन, अर्थव्यवस्थेची स्थिती वाईट, दैनिक सकाळ, २२ नोव्हेंबर २०१९.
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३) International Monetary Fund Reports 2020.
४) CMIE Report on Employment and Unemployment Report 2020.
५) Government of India, Economic Survey Report, New Delhi, 2020.
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'Akshar Wangmay' UGC Care Listed, International Research Journal, ISSN: 2229-4929, January 2021
Special Issue, Volume- IX *"Interdisciplinary View on Socio-Economic, Educational, Management, Environmental, Research, Language and Sustainable Development in Covid-19 Pandemic Situation"*

राष्ट्रीय उच्चस्तर शिक्षा अभियान (रुसा) व उच्च शिक्षणातील गुणवत्ता

प्राचार्य डॉ. संजीव लाटे
अमृतेश्वर कला, वाणिज्य व विज्ञान, महाविद्यालय विंझर, ता. वेल्हा, जि. पुणे. पीन-४१२ २१३.

प्रस्तावना:

व्यक्तीच्या सुप्त क्षमतांचा विकास करण्यासाठी आणि त्यांचा समाजहितासाठी उपयोग करण्याकरिता उच्च शिक्षणासारखे दुसरे माध्यम नाही. आयुष्य बदलण्याची शक्ती उच्च शिक्षणात आहे. देश स्वतंत्र झाला, तेव्हा देशात २० विद्यापीठे व ५०० महाविद्यालये आणि त्यात १ लाख विद्यार्थी उच्च शिक्षण घेत होते. यावरून लक्षात येते, की १९५० च्या दशकात कोट्यावधी नागरिकापैकी लाखभर नि मूठभर उच्च नागरिकांचाच उच्च शिक्षणात मक्ता होता. गोरगरीब व मध्यमवर्गीय तरुणांना अशी संधी मिळत नव्हती. उच्च शिक्षण क्षेत्राचे आज चित्र बदलले आहे. गेल्या ७० वर्षात विद्यापीठांचा संख्या २० वरून ९९३ वर गेली तर महाविद्यालयाची संख्या ५०० वरून ४० हजारवर पोहचली आहे. १९५० मध्ये देशात एक लाख विद्यार्थी उच्च शिक्षण घेत होते. आज ३ कोटी ७३ लाख विद्यार्थी शिक्षण घेत आहेत. ज्या देशात महिला, दलित, शेतकरी, मागासवर्गीयांना सामाजिक, धार्मिक कारणाने शिक्षण नाकारले होते, ते आज कोट्यावधीच्या संख्येने उच्च शिक्षण घेऊन देशात व परदेशात कर्तबगारी दाखवताहेत. उच्च शिक्षण लाखो गोरगरीब कुटुंबातील तरुण-तरुणीच्या जीवनात व कुटुंबात आर्थिक क्रांती झाली आहे. उच्च शिक्षण हे सामाजिक परिवर्तनाचे हत्यार मानले जाते. भारतातही ही प्रक्रिया घडते आहे. पण तिला अधिक वेग यायला हवा.

कायम विनाअनुदान व स्वायत्ततावर भर :

आपल्या शिक्षण व्यवस्थेत १९८० च्या दशकाआधी अनुदान, १९८० च्या दशकात विनाअनुदान आण{ २०१० च्या दशकात कायम विनाअनुदान धोरणाचा स्वीकार केला परिणामी शिक्षणाला बाजारी स्वरुप आले २००४ साली खासगी विद्यापीठे विधेयक व अध्यादेश आणून खासगी विद्यापीठाच्या स्थापनेस प्रोत्साहन देण्यात आले तर २०११ च्या दशकात स्वायत्त महाविद्यालयावर भर देण्यात आला. थोडक्यात शिक्षण क्षेत्रातील शासन स्वत:ची जबाबदारी हळू-हळू कमी करून खासगीकरणावर भरदिला जात आहे.

यापूर्वी १९८६ मध्ये राष्ट्रीय शैक्षणिक धोरण लागू करण्यात आले होते. १९९२ मध्ये त्यामध्ये किरकोळ सुधारणा वगळता कोणतेही बदल केले नाहीत. म्हणजे तीन दशकांहून अधिक काळ जुनेच शैक्षणिक धोरण चालत होते. ३४ वर्षात विज्ञान तंत्रज्ञान क्षेत्रात अनेक वैज्ञानिक संकल्पना नव्याने समाविष्ट झाल्या होत्या; परंतु या संगळ्यापासून आपली शिक्षणपद्धती अनभिज्ञ राहिली. या आधुनिक जगाशी सुसंगत अशी शिक्षण व्यवस्था उदयास येण ही काळाजी गरज होती. त्यास अनुसरून तब्बल ३४ वर्षानंतर आणलेल्या नव्या शैक्षणिक धोरणाला केंद्र सरकारने २९ जूलै २०२० ला परवानगी दिली आहे. नव्या शिक्षण धोरणातर्गत देशभरात उच्च शिक्षणासाठी एकच नियामक प्राधिकरण अस्तित्वात येणार असून मनुष्यबळ विकास मंत्रालयाचे नाव बदलून शिक्षण मंत्रालय करण्यात आले. नव्या शिक्षण धोरणाची भविष्यातील अंमलबजावणी केव्हा व कशी होईल यावर त्याची यशस्वीता अंबलंबून राहील. २०११ च्या जनगणेनुसार देशाची सरासरी साक्षरता ७७.७ टक्के, ग्रामीण भागात साक्षरता ७३.५ टक्के तर शहरी भागात सरासरी ८७.७ टक्के साक्षरता आहे. भविष्यात शिक्षण क्षेत्रात भारताला मोठी प्रगती करावी लागणार आहे.

नाविन्य आणि संशोधनाकडे दुर्लेक्ष :

जगभरातील शिक्षणाचा विचार केल्यास चीन (२९ टक्के) आणि भारत (१२ टक्के) या दोन देशांमध्ये मिळून जगातील तब्बल ४० टक्के पदवीधर दरवर्षी तयार होतात. तर अमेरिका १२, रशिया ७, इंडोनेशिया ६ टक्के , जपान व ब्रिटन ४ टक्के, कोरिया, मेक्सिको व ब्राझील ३ टक्के, स्पेन, तुर्कस्तान १ टक्का, इतर देशात १२ टक्के पदवीधर तयार होतात. भारतात शिक्षण क्षेत्राची संख्यात्मक वाढ होताना दिसून येत आहे; परंतु गुणात्मक वाढीकडे दुर्लक्ष होत आहे.

शिक्षण पद्धती ही संशोधन आणि नवनिर्मितीला प्रोत्साहन देणारी असायला हवी भारतात जीडीपीच्या केवळ ०.६९ टक्के खर्च संशोधनावर केला जातो. इस्त्राईलमध्ये हे प्रमाण ४.३ टक्के आहे. संशोधनात आणि असलेले लाखो विद्यार्थी परदेशाची वाट धरतात तर आपल्या युवकांचे संशोधन इतर देशांचे पेटंट्स होऊन बसत आहे. अमिरिकेत २०१९ मध्ये जगातील एकूण १५.२० लाख परदेशी विद्यार्थी शिक्षण घेत होते त्यापैकी ४८ टक्के विद्यार्थी चीन (४,७४,४९७) व भारताचे (२,४१,२२१) होते; द. कोरीया १.२४ लाख, जर्मनी १.१८ लाख, सौदी अरेबिया ६४ हजार, फ्रांस ६२ हजार, मलेशिया ५६ हजार, व्हिएतनाम ५४ हजार, इराण ५२ हजार विद्यार्थी शिक्षण घेत होते. शिक्षणांच्या माध्यमातून अमिरिका, इंग्लंड, ऑस्टेलिया यासारखे देश अब्जावधी डॉलर दरवर्षी कमवतात. भारतातून चीन मध्ये २०२० मध्ये २३००० विद्यार्थी शिक्षणासाठी गेले; त्यापैकी २१००० विद्यार्थी एमबीबीएसचे शिक्षण घेत होते. अलीकडील काळात रशिया, जॉजिया, कझाकिस्तान, मलेशिया, चीन व इतर देशात वैद्यकीय शिक्षणासाठी भारतातून मोठ्या प्रमाणात विद्यार्थी बाहेरच्या देशात जात आहेत. भारतातील सुमारे १० लाख विद्यार्थी परदेशी विद्यापीठामध्ये शिक्षण घेत आहेत तर भारतातून दरवर्षी सुमारे ३ लाख विद्यार्थी शिक्षणासाठी बाहेर जात आहेत. त्यातुलनेत परदेशातून भारतात शिक्षणासाठी येणाऱ्या विद्यार्थ्यांचे प्रमाण नगण्य आहे; भारतात २०१४ मध्ये ३३ हजार विद्यार्थी तर २०१९ मध्ये १६४ देशातील ४७ हजार विद्यार्थी शिक्षणासाठी आले होते; त्यातील प्रगत देशाचे प्रमाण केवळ २ टक्क्यापेक्षा कमी आहे.

भारतातील उच्च शिक्षणातील प्रवेश घेतलेल्या विद्यार्थ्यांची संख्या (२०२०)

वर्षे	मुले (कोटी)	मुली (कोटी)	एकूण (कोटी)	मुलींची टक्केवारी
२०११-१२	१.६१	१.३	२.९१	४४.५८
२०१२-१३	१.७४	१.४८	३.२३	४५.०९
२०१५-१६	१.८५	१.५९	३.८५	४६.२३
२०१७-१८	१.९२	१.७४	३.६६	४७.५९
२०१९-२०	१.९२	१.८१	३.७३	४८.६

१८ ते २३ वयोगटातील विद्यार्थ्यांसाठी ग्रॉस एनरोलमेंट रेशो (जीईआर)

वर्ष	एकत्रित	विद्यार्थी	विद्यार्थिनी	एससी	एसटी	सर्वाधिक जीआर असणारी राज्ये
२०११-१२	२०.८	२२.१	१९.४	१४.९	११	यूपी, महाराष्ट्र, तामिळनाडू
२०१२-१३	२१.५	२२.७	२०.१	१६	११.१	यूपी, तामिळनाडू,महाराष्ट्र,
२०१३-१४	२२.६	२३.७	२१.४	१७.४	१२	यूपी, महाराष्ट्र, तामिळनाडू

केंद्रीय मनुष्यबळ विकास मंत्रालयाने देशातील उच्च शिक्षणाचा लेखाजोखा मांडण्यासाठी राष्ट्रीय पातळीवरील उच्च शिक्षणाच्या सर्वेक्षणाचे काम गेल्या चार वर्षापासून (२०११) हाती घेतले होते, (राष्ट्रीय उच्च शिक्षण सर्वेक्षणाचा अहवाल) त्यामध्ये अनुसूचित जाती व जमातीच्या शिक्षणाचे प्रमाण जवळपास निम्याने कमी आहे, तसेच पुरुषांच्या तुलनेत स्त्र{यांचे प्रमाण कमी असल्याचे दिसून येते. मानव विकास निर्देशांकानुसार सन २०१९ मध्ये जगातील १८९ देशाच्या यादीमध्ये पुन्हा भारताची घसरण होऊन भारताचे स्थान १३१ व्या स्थानी (०.६४५) घसरले आहे. २०१८ मध्ये भारताचे सरासरी आयुर्मान ६९.७ वर्षे, बांगलादेश ७२.५ वर्षे, पाकिस्तान ६७.३ वर्षे होते. दरडोई उत्पन्नाचा विचार करता भारताचे २०१८ मध्ये ६८२९ डॉलर तर २०१९ मध्ये त्यात घसरण होऊन ६६८१ डॉलर आले. मार्च २०२० मधील कोरोनाच्या प्रादुर्भावामुळे व लॉकडाऊनमुळे बेरोजगारीत वाढ, आर्थिक विकास दरात कमालीची घट, दरडोई उत्पन्नात घट, राहणीमानाची पातळी खालावली. सन २०२०-२१ या शैक्षणिक वर्षात स्थलांतरामुळेव इतर कारणामुळे सुमारे ३ कोटी मुले शाळाबाह्य झाली आहेत. राज्यात १० विभागात १८३७ विनाअनुदानित अकृषी महाविद्यालये आहेत त्यापैकी नोव्हेंबर २०१९ अखेर १८१ महाविद्यालयांनी नॅक केले आहे तर १६५६ विनाअनुदानित महाविद्यालयांनी नॅक मुल्यमापनाकडे दुर्लक्ष केले आहे.

राज्यातील व्यावसायिक अभ्यासक्रमाची स्थिती (२०१९)

अभ्यासक्रम	प्रवेश क्षमता	झालेले प्रवेश	रिक्त जागा
बीई/बीटेक	१,२७,५३७	६५,९२३	६१,६१४
बी /फार्म	२२,५००	१८,५५३	३,९४७
एमबीए/एमएमएस	३३,९१५	२९,६५६	४,२५९
बीआर्क	५,५३७	२,९८९	२,५४८
एकूण	१,८९,४८९	१,१७,१२१	७२,३६८

२०१४-१५ मध्ये अभियांत्रिकीच्या १९ लाख १ हजार ५०१ जागा होत्या. अखिल भारतीय तंत्रशिक्षण परिषदेने सन २०१९ मध्ये देशातील पदवी आणि पदविका अभ्यासक्रमाच्या १ लाख ६२ हजार जागा रद्द केल्या आहेत तर आतापर्यंत एकूण ४ लाख ३५ हजार ३८७ जागा कमी झाल्या आहेत. एका सर्वेक्षणानुसार दरवर्षी महाराष्ट्रात हजारो नवे अभियंते तयार होत आहेत. त्यातील सुमारे ८० टक्के बेरोजगार आहेत. एका जागेसाठी ३०० अर्ज येत आहेत. उत्पादन क्षेत्रातील मंदीमुळे मेकॅनिकल आणि इलेक्ट्रीकल शाखेतील विद्यार्थी आयटी व सेवा क्षेत्राकडे वळत आहेत. आयटी क्षेत्राचे अर्थकारण अमेरिका व युरोपशी जोडलेले आहे. त्या देशांना मंदीची झळ पोचली आहे व अमेरिकेतील स्थलांतराविषयीचे कायदे कडक केले आहेत. त्यामुळे अभियांत्रिकी शाखेला घरघर लागली आहे. राज्यात सन २०१९ मध्ये १.८९ लाख जागा होत्या त्यापैकी ७२,२६३ जागा रिक्त होत्या.

उच्च शिक्षणाची संख्यात्मक वाढ व विस्तार जेवढा महत्त्वाचा, तेवढीच गुणवत्ताही महत्त्वाची आहे. भारतातील बहुतांशी महाविद्यालये व विद्यापीठासमोर गुणवत्ता वाढविणे हे मोठे आव्हान आहे. देशात उच्च शिक्षणाचा मोठा विस्तार झाला असला तरी ते समाजाच्या सर्व स्तरांतील तरुणांना समानतेने मिळत नाही. तिथेही जातीव्यवस्थेसारखी उच्च-नीचतेची उतरंड आहेच. समाजातील उच्चभ्रू

व संमत वर्गाला उत्तम शिक्षण व इतरांना कमी दर्जाचे शिक्षण हा भेदभाव दिसून येत आहे. उच्च शिक्षणात १८ ते २३ वयोगटातील प्रवेशाचे प्रमाण (जीईआर) २४.५ टक्के आहे, म्हणजे याचा अर्थ आजही ७५ टक्के युवकांना महाविद्यालयात जाण्याची संधी मिळत नाही. त्यांना कॉलेजबाह्य युवक म्हटले जाते. देशात त्यांची संख्या १२ कोटीच्या आसपास आहे.जगातील प्रगत देशात उच्च शिक्षण प्रवेशाचे प्रमाण (जीईआर) ८० ते ८३ टक्के आहे. देशात दलीतामध्ये प्रवेशाचे प्रमाण (जीईआर) १९.९ टक्के, आदिवासींमध्ये ४.९ टक्के, मुस्लिम समाजात ४.७ टक्के आहे.विद्यापीठ अनुदान मंडळाच्या एका पाहणीनुसार दार{द्रयरेषेखालील ग्रामीण कुटुंबांचे उच्च शिक्षणातील प्रमाण अवघे २ टक्के आहे. शकडो आदिवासी जमातीतील मुलींचे उच्च शिक्षणातील प्रमाण नगण्य आहे. इतकेच नव्हे तर शहरी गरिबांचेही उच्च शिक्षणातील प्रमाण कमी आहे. देशात उच्च शिक्षणाची समान संधी आपण निर्माण करू शकलेलो नाही.

रुसाच्या माध्यमातून उच्च शिक्षणाला चालना :

बहुतेक राज्यांतील उच्च शिक्षणांची स्थिती १९९० च्या दशकात दयनीय होती हे वास्तव ११ व्या पंचवार्षिक योजनेच्या (२००६-२०११) आढाव्याच्या वेळी प्रकाशात आले. उच्च शिक्षणाची स्थिती सुधारण्यासाठी केंद्र सरकारने वेळोवेळी निधी वाढवून दिला .म्हणूनच ११ व्या योजनेला शिक्षण योजना म्हटले गेले. उच्च शिक्षणाला बिकट अवस्थेतून बाहेर काढण्यासाठी २०१३ मध्ये सरकारने एक विशेष योजना आखली. राष्ट्रीय उच्चस्तर शिक्षा अभियान (आर यू एस ए : आद्याक्षरांनुसार 'रुसा) विद्यापीठांबरोबरच, सरकारी आण{ खासगी अनुदान{त महाविद्यालयांना न{धी देणे, हे 'रुसाइक चे उद्द{ष्ट आहे. महाविद्यालयाचे समुह तयार करून आण{ स्वायत्त महाविद्यालयांचे रुपांतर विद्यापीठांमध्ये करून नवी विद्यापीठे सुरू करणे, अशी ही योजना आहे.

उच्च शिक्षणाच्या विस्तारात दर्जा आणि समान संधीवर भर देणे 'रुसाइक ला अभ{प्रेत आहे. महिला, अल्पसंख्याक आणि अपंगांना उच्च शिक्षणासाठी प्रोत्साह{त करून अनुसूच{त जाती-जमातींबरोबरच सामाजिक -शैक्षणिक दृष्ट्या मागास वर्गांना उच्च शिक्षणामध्ये पुरेशी संधी हे 'रुसा ला अपेक्षित असलेल्या समदृष्टीचा अर्थ, गुणवत्ता आणि समान संधी या दोन पायांवर उच्च शिक्षणाचा विकास करणे हा या महत्त्वकांक्षी योजनेचा उद्देश आहे, परंतु ती काहीशी सदोष असल्याने शिक्षणाच्या गुणवत्तेबाबत संस्था-संस्थामध्ये भेद न{र्माण करू शकते. शिवाय, गरीब आणिमध्यमवर्गीयांना गुणवत्तापूर्ण शिक्षणाची समान संधी म{ळण्यातही अडचण निर्माण करू शकते. म्हणूनच या योजनेबर साधकबाधक चर्चा करून काही सूचना करणे क्रमपाप्त ठरते.

'रुसा योजनेतून विद्यापीठांबरोबरच सरकारी आणि खाजगी अनुदानित महाविद्यालयांना निधी दिला जातो. महाराष्ट्रात अशा किती उच्च शिक्षण संस्था आहेत. मनुष्यबळ विकास मंत्रालयाच्या (एचआरडी) २०१६-१७ च्या आकडेवारीनुसार महाराष्ट्रात ४८ विद्यापीठे आणि तत्सम शैक्षण{क संस्था आहेत. त्यापैकी २१ (४४ टक्के) सरकारी व{द्यापीठे आहेत. त्यांतील विद्यार्थ्यांचे प्रमाण ८५ टक्के होते. एक मुक्त विद्यापीठ वगळले तर हे प्रमाण ७० टक्के होते. महाराष्ट्रात ४०६६ महाविद्यालये आहेत. त्यापैकी ४४ टक्के महाविद्यालये सरकारी आणि खासगी अनुदानित आहेत. अशा प्रकारे महाराष्ट्रातील सुमारे ४४ टक्के विद्यापीठे आण{ ४४ टक्के महाविद्यालये 'रुसाच्या अनुदानासाठी कक्षेत येतात.

रुसाचे नियम जटील :

'रुसा च्या अनुदानासाठी मात्र, राष्ट्रीय मूल्यांकन आणि नामांकन परिषदेची (नॅक) मान्यता बंधनकारक आहे. त्याचबरोबर, कोणतेही अनुदान मिळविण्यासाठी ४० टक्के वाटा त्या-त्या महाविद्यालयांनी उचलणे आवश्यक असते. याचा अर्थ असा की, एखादी संस्था या निकषांत बसत नसेल तर ती आपोआप अनुदानासाठी अपात्र ठरते. मनुष्यबळ विकास मंत्रालयाने अनुदान पात्रतेसाठी तयार केलेले हे निकष सर्वांना समदृष्टीने शिक्षण देण्याच्या उद्दिष्टात बाधा आणू शकतात. उदाहरणार्थ महाराष्ट्रातील १७९८ सरकारी आणि खासगी अनुदानित महाविद्यालयापैकी फक्त १००२ महाविद्यालये विद्यापीठ अनुदान आयोगाच्या (युजीसी) अनुदानासाठी पात्र ठरतात. नॅकची मान्यता आण{ महाविद्यालयांचे ४० टक्के योगदान या निकषांमुळे आणखी काही महाविद्यालये 'रुसा कडून योजनेबाहेर फेकली जातात. हे वास्तव लक्षात घेतल्याशिवाय आपण पुढे जाऊ शकत नाही. निकष आवश्यक आहेतच; परंतु त्याच वेळी, मागे पडलेल्या विद्यापीठ/महाविद्यालयाला आर्थिक पाठबळ देणेही तितकेच महत्त्वाचे आहे. संपूर्ण शिक्षणव्यवस्थेच्या गुणवत्तेत सुधारणा करण्यासाठी हे आवश्यक आहे. किंबहुना तसे करणे म्हणजे गुणवत्तेच्या बाबतीत विषमता निर्माण करण्यासारखे आहे.. गुणवत्तेतील विषमतेचा मुद्दा अकराव्या विकास योजनेत धोरणात्म निर्णयांच्या अनुषंगाने उपस्थित झाला. अनेक सरकारी विद्यापीठे आणि महाविद्यालये यूजीसीच्या अनुदानासाठी अपात्र ठरली होती. ती पात्र ठरावीत म्हणून 'यूजीसी नेच त्यांच्यासाठी 'कॅचिंग अप ग्रॅण्ड योजना आणली. 'रुसाच्या अनुदानास अपात्र ठरू शकणारी महाविद्यालाये ग्रामीण आणि दुर्गम भागांत आहेत. तीसुद्धा आणि जाती-जमाती-ओबीसीं सारख्या दुर्बल समाजघटकांतील विद्यार्थ्यांना शिक्षण देतात, हेही लक्षात घेतले पाहिजे. त्यांना 'रुसा च्या अनुदानातून वगळणे म्हणजे समाजातील मागास घटकांना गुणवत्तापूर्ण शिक्षणापासून वंचितठेवण्यासाखे आहे. म्हणून ग्रामीण भागांतील विद्यापीठे आणि महाविद्यालयांना 'रुसा च्या अनुदानासाठी पात्र ठरण्यासाठी राज्य सरकारने 'कॅचिंग अप ग्रँड योजना राबविणे आवश्यक ठरते.

रुसाचे अनुदान मिळवण्यासाठी राज्यसरकारचे प्रोसहान द्यावे:

स्वायत्त महाविद्यालयांच्या किंवा महाविद्यालयांच्या समुहातून सुरू होणाऱ्या विद्यापीठांना ६०:४० या निकषांनुसार अनुदान देण्याचा प्रस्ताव आहे. समूहातील महाविद्यालयांनी अनुदानातील ४० टक्के निधी उभा करणे ग्रामीण भागांतील महाविद्यालयांसाठी कठीण आहे. दुर्बल घटकांतील विद्यार्थ्यांना शिक्षण देणाऱ्या संस्थाही 'रुसा च्या निकषांत बसणे अशक्य आहे. अनेक वर्षांपासून ग्रामीण भागांतील

विद्यार्थ्यांना नेटाने शिक्षण देणाऱ्या संस्था हाताच्या बोटावर मोजता येतील एवढ्या आहेत. त्यांत इतरांबरोबर साताऱ्याची रयत शिक्षण संस्था, अमरावतीची शिवाजी शिक्षण प्रसारक मंडळ किंवा औरंगाबादचे मराठवाडा शिक्षण प्रसारक मंडळ यांचा प्रामुख्याने उल्लेख करता येईल. अनुसूचित जाती-जमाती-ओबीसी किंवा भटक्या-विमुक्त यांसारख्या दुर्बल समाजांतील विद्यार्थ्यांना शिक्षण देणाऱ्या संस्थाही त्यात येतात. त्यांपैकी मुंबईची पीपल्स एजुकेशन सोसायटी, दीक्षाभूमीची (नागपूर) स्मारक समिती आणि आदिवासी -विमुक्तांच्या शिक्षणसाठी झटणाऱ्या संस्थांचे महत्त्व असाधारण आहे. त्यांना राज्य सरकारच्या पाठबळाची गरज आहे. 'रूसा च्या निकषनुसार अनुदानाचा ४० टक्के निधी उभा करणे या संस्थांना अशक्य असल्याने राज्य सरकारने अनुसूचित जाती-जमाती-ओबीसीसाठी असलेल्या खास तरतुदीतून (अनुसूचित जाती व जमाती विशेष घटक योजना) त्याची तजवीज करायला हवी. मनुष्यबळ विकास मंत्रालयाने काही विशेष राज्यांसाठी तशी सवलत दिली आहे. अशा विशेष राज्यांतील महाविद्यालयांनी अनुदानापैकी केवळ १० टक्के वाटा उचलणे अपेक्षित आहे. म्हणजे 'रुसा कडून त्यांना ९० टक्के निधी मिळू शकतो. ईशान्येकडील राज्यांना मात्र १०० टक्के अनुदानाची तरतूद आहे. हेच निकष ग्रामीण भागांतील शिक्षण संस्था आणि अनुसूच{त जाती-जमाती-ओबीसी किंवा भटक्या-विमुक्त विद्यार्थ्यांना शिक्षण देणाऱ्या संस्थांना लागू केले पाहिजेत. महाविद्यालयाच्या समूहातून स्थापन होणाऱ्या विद्यापीठांसाठीच्या नियमावलीत सरकारने बदल करण्याची अपेक्षा आहे. विद्यापीठ बनू पाहणाऱ्या महाविद्यालयांच्या कारभारात सुधारणेबाबतच्या नियमाचा समावेश करता येऊ शकतो. उदाहरणार्थ, पीपल्स एज्यूकेशन सोसायटीसारख्या संस्थांना जर विद्यापीठ बनायचे असेल तर या संस्थांच्या प्रशासन व कारभारात सुधारणेची गरज आहे. 'रुसा च्या नियमानुसार विद्यापीठ बनू पाहणाऱ्या संस्थांना कार्यकारी मंडळावर शिक्षणतज्ज्ञ, उत्तम शिक्षण प्रशासक, कायदेतज्ज्ञ, सामाजिक कार्यकर्ते आणि ती संस्था स्थापन करणाऱ्या कुटुंबातील प्रतिनिधी असणे आवश्यक आहे. अशा संस्थांच्या कार्यकारी मंडळाच्या सदस्यपदाचा कालावधी 'आजीव वरून पाच वर्षांवर आणणेही गरजेचे ठरेल. खरे तर, असे विद्यापीठ स्थापन करण्याचे प्रयत्न दीक्षाभूमीवरील स्मारक समिती ट्रस्ट, रयत, शिवाजी आणि ग्रामीण भागांतील इतर संस्थांनीही करायला हवेत. 'रुसा चे अनुदान मिळविण्यासाठी महाराष्ट्राने ग्रामीण भागात आणि समाजातील दुर्बल घटकांना शिक्षण देणाऱ्या संस्थांवर लक्ष केंद्रित करण्याची आवश्कता आहे.

इतरही अनेक प्रश्न आहेत. त्यातही मुक्त विद्यापीठांकडे अधिक लक्ष देण्याची गरज आहे. महाराष्ट्रातील विद्यापीठांकडे अधिक लक्ष देण्याची गरज आहे. महाराष्ट्रातील विद्यापीठांमध्ये शिकणाऱ्या विद्यार्थ्यांपैकी जवळपास ५८ टक्के विद्यार्थी मुक्त विद्यापीठांतील आहेत. आपण पुण्यातील स्मिबॉयसिस मुक्त विद्यापीठातील विद्यार्थ्यांचा समावेश केला तर हे प्रमाण वाढेल. समूह विद्यापीठांचे कार्यक्षेत्र संपूर्ण राज्य असले पाहिजे, ते जिल्ह्यापुरते मर्यादित ठेवू नये. शक्य असल्यास अशा विद्यापीठांचे कार्यक्षेत्र देशभर असावे आणि तेथे राज्यातील विद्यार्थ्यांसाठी कोटा (राखीव जागा) असावा. या सूचनांचा विचार झाला तर 'गुणवत्तापूर्ण शिक्षणाचा समदृष्टीने विस्तार किंवा समाजातील सर्व घटकांसाठी गुणवत्तापूर्ण शिक्षण हे 'रुसा चे ध्येय काही प्रमाणात साध्य करता येईल.

नवीन शिक्षण धोरणाविषयी केंद्रीय शिक्षण मंत्रालयाच्या वतीने आयोजित केलेल्या संमेलनात बोलताना भारताचे पंतप्रधान मा. नरेंन्द्र मोदी यांनी ''विद्यार्थ्यांना आवड जोपासण्याची संधी मिळायलाच हवी. विद्यार्थ्यांच्या आवडी निवडी बदलू शकतात, एक अभ्यासक्रम निवडला की त्यातच मन मारून कायम राहणे यापेक्षा बदल करावासा वाटला तर शाखा बदलास परवानगी हवी काळाच्या ओघात कोणताही व्यवसाय, नोकरीत कायम राहू शकत नाहीत त्यामुळे शिक्षण पद्धतीत देखील बदल होणे गरजेचे होते. असे मत मा. मोदींनी मांडले.

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Kanpur Philosophers
ISSN 2348-8301
International Journal of humanities, Law and Social Sciences
Published biannually by New Archaeological & Genological Society
Kanpur India
Vol. VIII, Issue I (Summer) 2021

नॅकच्या चक्रव्यूहात महाविद्यालयांचे मूल्यांकन

प्राचार्य डॉ. संजीव लाटे
अमृतेश्वर कला, वाणिज्य व विज्ञान
महाविद्यालय विंझर.
ता. वेल्हा, जि. पुणे-४१२ २१३

प्रास्ताविकः

व्यक्तीच्या सुप्त क्षमतांचा विकास करण्यासाठी आणि त्यांचा समाजहितासाठी उपयोग करण्याकरिता उच्च शिक्षणासारखे दुसरे माध्यम नाही. आयुष्य बदलण्याची शक्ती उच्च शिक्षणात आहे. देश स्वतंत्र झाला, तेव्हा शिक्षण क्षेत्रात अवघी २० विद्यापीठे व ५०० महाविद्यालये होती आणि त्यात १ लाख विद्यार्थी उच्च शिक्षण घेत होते. गेल्या ७० वर्षात विद्यापीठांची संख्या २० वरून ९५० हून अधिक झाली आहे. महाविद्यालयाची संख्या ५०० वरून ४१ हजारावर पोहचली आहे. १९५० मध्ये देशात एक लाख विद्यार्थी उच्च शिक्षण घेत होते, आज ३ कोटी ४६ लाख विद्यार्थी उच्च शिक्षण घेत आहेत. देशात उच्च शिक्षणात १८ ते २३ वयोगटातील प्रवेशाचे प्रमाण (जीईआर) २४.५ टक्के आहे म्हणजे याचा अर्थ आजही ७५ टक्के युवकांना महाविद्यालयात जाण्याची संधी मिळत नाही.

उच्च शिक्षणाची संख्यात्मक वाढ व विस्तार जेवढा महत्त्वाचा, तेवढीच गुणवत्ताही महत्त्वाची असते. भारतातील बहुतांशी महाविद्यालये व विद्यापीठासमोर गुणवत्ता वाढविणे व ती टिकविणे मोठे आव्हान आहे. देशात उच्च शिक्षणाचा मोठा विस्तार झाला असला तरी गुणात्मक वाढ झाली नाही.

जागतिकीकरणाच्या प्रक्रियेत परदेशी संस्था, कंपन्या अनेक क्षेत्रात मुक्तपणे संचार करु लागल्या आहेत. शिक्षण हे सेवा व्यापाराचा भाग बनत आहे. जागतिक शिक्षण प्रक्रियेत भारत मागे राहिला आहे. जागतिकीकरणात आपली विद्यापीठे व महाविद्यालये जागतिक ज्ञानदानाची दालने बनायला हवीत. आपल्या पारंपारिक विद्यापीठाच्या अभ्यासक्रमात आमुलाग्र बदल केला

पाहिजे. परदेशी विद्यापीठाकडे जाणारा भारतीय विद्यार्थ्यांचा लोंढा थाबवायला हवा यासाठी शिक्षणाची गुणवत्ता उंचावणे गरजेचे आहे.

अनेक महाविद्यालये त्यांना नॅक मूल्यांकनात किती गुण मिळाले हे अभिमानाने सांगतात. मात्र, राज्यात अनेक महाविद्यालये अशी आहेत, की त्यांनी गेल्या कित्येक वर्षात एकदाही नॅक मूल्यांकन करून घेतले नाही. राज्यातील नॅक मूल्यांकनाचा आढावा प्रस्तृत शोधनिबंधात घेतला आहे.

मुल्यांकनाचा आधार :

महाविद्यालयाची इमारत, विद्यार्थ्यांना पुरविण्यात येणाऱ्या सुविधा, प्राध्यापकांचा संशोधनात असलेला सहभाग, गुणवत्तावाढीसाठी राबविले जाणारे विविध उपक्रम, क्रीडा, कला यामधील सहभाग यांसह इतर गुणात्मक बाबींच्या आधारे मूल्यांकन केले जाते. यापूर्वी शैक्षणिक संस्थेमध्ये नॅक समिती (पीअर टीम) जाऊन प्रत्यक्ष पाहणी करून मूल्यांकन करत होती. मात्र आता २०१८ पासून नव्या पद्धतीनुसार ६५ टक्के मूल्यांकन हे संगणकीय व गणित पद्धतीने नॅक कार्यालयात होत असून, ३० टक्के मूल्यांकन हे महाविद्यालयाला भेट देणारी समिती करते, तर ५ टक्के मूल्यांकन विद्यार्थ्यांकडून माहिती भरून घेऊन केले जात आहे.

नॅकमार्फत मुल्यांकन :

नॅशनल असेसमेंट ॲण्ड ॲक्रिडिएशन कौन्सिल (नॅक) ही महाविद्यालये, विद्यापीठ यांच्या भौतिक तसेच गुणात्मक क्षमतेचे मूल्यांकन करणारी स्वायत्त संस्था आहे. उच्च शिक्षणाचा दर्जा वाढविण्यासाठी १९९४ मध्ये नॅकची स्थापना करण्यात आली. सुरुवातीच्या काळात विनाअनुदानित महाविद्यालयासाठी नॅक केले पाहिजे अशी सक्ती नव्हती परंतु युजीसीकडून मिळणारे अनुदान नॅक केले तरच मिळणार ही अट घातली; परंतु अलीकडीच्या काळात अनुदानित व विनाअनुदानित महाविद्यालयासाठी नॅक सक्तीचे केले आहे.

सन २००६ अखेर देशातील १६८८५ महाविद्यालयापैकी ३४९२ महाविद्यालयांचे, ३२० विद्यापीठापैकी १४० विद्यापीठांचे मुल्याकंन केले होते. सर्वाधिक मुल्याकंन झालेली महाविद्यालये महाराष्ट्रात ९४५, कर्नाटक ४६८, आंध्र प्रदेश २२२, आसाम १९२, गुजरात १२६, हरियाणा १५०, केरळ १५०, मध्यप्रदेश १२०, ओरिसा १४९, पजांब ९६, राजस्थान ९८ तमिळनाडू २४१, उत्तर प्रदेश ९७, पश्चिम बंगाल २१० महाविद्यालयांनी मुल्यांकन केले होते. सन २००७ मध्ये राज्यातील ९३९ महाविद्यालये व १५ विद्यापीठांचे नॅककडून मूल्यांकन करण्यात आले होते.

सन २०११ मधील नॅककडून प्राप्त झालेल्या माहितीनुसार देशात ए श्रेणीची १२ टक्के, बी श्रेणीची ७० टक्के, सी श्रेणीची २० टक्के महाविद्यालये आहेत तर राज्यात ए श्रेणीची १८ टक्के, बी श्रेणीची ६० टक्के, सी श्रेणीची २३ टक्के महाविद्यालये आहेत.

युजीसी रेग्यूलेशन २०१२ नुसार तंत्रशिक्षण संस्था सोडून केंद्र, राज्य; तसेच अभिमत विद्यापीठे आणि कॉलेजांना मूल्यांकन करून घेणे सक्तीचे केले आहे. नॅकसारख्या अधिकृत संस्थेकडून मूल्यांकन करून न घेतल्यास संस्थांची मान्यता रद्द करण्याची तरतूदही या नियमात करण्यात आली आहे. स्थापना होऊन पाच वर्षानंतर किंवा दोन बॅचेस बाहेर पडल्यानंतर मुल्यांकन केले पाहिजे.

मूल्यांकनाबाबत आक्षेपः

यातील महाविद्यालये व विद्यापीठांच्या शिक्षणाचा पायाभूत सुविधांचा दर्जा निश्चित करण्यास आरंभ झाला आहे. महाविद्यालये व विद्यापीठांच्या गुणवत्तेचे मुल्यांकन करण्याची सध्याची (नॅक) पद्धती बंद करून 'क्रसील' सारख्या खासगी पतमापन संस्थेकडून मूल्यांकन करून घ्यावे असे २३ मार्च २००८ रोजी तत्कालीन पतंप्रधान मा. मनमोहन सिंग यांनी सूचित केले होते; परंतु ही सूचना कागदावरच राहीली. नॅक, एआयसीटीई, एमसीआय, डीसीएस सारख्या संस्था मुल्याकंन करून दर्जा देताना गैरव्यवहारात गुंतल्याचे दिसून आले.

उच्च शिक्षण देणाऱ्या महाविद्यालयांना नॅककडून मुल्यांकन करून दर्जा दिला जातो. नॅकच्या धरतीवर राज्यात शाळा व महाविद्यालयाचे मुल्यांकन केले जाणार त्यासाठी राज्यस्तरीय समिती (सॅक) स्थापन करणार असल्याची घोषणा राज्य सरकारने केली. राज्य सरकाकडून (सॅक) देखील महाविद्यालयांना मुल्यांकन करून घ्यावे लागणार होते. शाळा प्रमाणे महाविद्यालयाची पतवारी केली जाणार होती; परंतु ही घोषणा देखील हवेतच विरली गेली.

राष्ट्रीय उच्चस्तर शिक्षा अभियान :

उच्च शिक्षणाला बिकट अवस्थेतून बाहेर काढण्यासाठी २०१३ मध्ये सरकारने एक विशेष योजना आखली. राष्ट्रीय उच्चस्तर शिक्षा अभियान (आर यू एस ए : आद्याक्षरांनुसार 'रुसा') विद्यापीठांबरोबरच, सरकारी आणि खासगी अनुदानित महाविद्यालयांना निधी देणे, हे 'रुसा' चे उद्दिष्ट आहे. महाविद्यालयाचे समुह तयार करून आणि स्वायत्त महाविद्यालयांचे रुपांतर विद्यापीठांमध्ये करून नवी विद्यापीठे सुरू करणे, अशी ही योजना आहे.

उच्च शिक्षणाच्या विस्तारात दर्जा आणि समान संधीवर भर देणे 'रुसा' ला अभिप्रेत आहे. 'रुसा' योजनेतन विद्यापीठांबरोबरच सरकारी आणि खाजगी अनुदानित महाविद्यालयांना निधी दिला जातो. मनुष्यबळ विकास मंत्रालयाच्या (एचआरडी) २०१६-१७ च्या आकडेवारीनुसार महाराष्ट्रात ४८ विद्यापीठे आणि तत्सम शैक्षणिक संस्था आहेत. त्यापैकी २१ (४४ टक्के) सरकारी विद्यापीठे आहेत. त्यांतील विद्यार्थ्यांचे प्रमाण ८५ टक्के होते. महाराष्ट्रात एकूण ४०६६ महाविद्यालये आहेत. त्यापैकी ४४ टक्के महाविद्यालये सरकारी आणि खासगी अनुदानित आहेत. अशा प्रकारे

महाराष्ट्रातील सुमारे फक्त ४४ टक्के विद्यापीठे आणि फक्त ४४ टक्के महाविद्यालये 'रुसा' च्या अनुदानासाठी पात्र ठरतात.

'रुसा' च्या अनुदानासाठी पात्र ठरण्यासाठी राष्ट्रीय मूल्यांकन आणि नामांकन परिषदेमार्फत (नॅक) मुल्यांकन करून घेणे बंधनकारक आहे; मुल्यांकनात किमान २.५ क्युम्युलेटिव्ह ग्रेड पॉईंट मिळाले तरच ते विद्यापीठ अथवा महाविद्यालय 'रुसा'च्या अनुदानासाठी पात्र ठरणार आहे. याशिवाय कोणतेही अनुदान मिळविण्यासाठी प्रकल्प खर्चाच्या ४० टक्के वाटा संबंधीत महाविद्यालयांने उचलणे आवश्यक असते. महाराष्ट्रातील १७९८ सरकारी आणि खासगी अनुदानित महाविद्यालयापैकी फक्त १००२ महाविद्यालये विद्यापीठ अनुदान आयोगाच्या (युजीसी) अनुदानासाठी पात्र ठरतात. नॅकच्या मुल्यांकनात २.५ ग्रेड पॉईंट व प्रकल्प खर्चामध्ये महाविद्यालयांचे ४० टक्के योगदान या निकषांमुळे अनेक अनुदानित महाविद्यालयेही 'रुसा'च्या योजनेबाहेर फेकली जातात.

कायद्यानुसार नॅक मूल्यांकन अनिवार्य असताना सध्या देशातील केवळ २० टक्के महाविद्यालयांनी नॅक मूल्यांकन करून घेतलेले आहे. केंद्र सरकारकडून नवीन शैक्षणिक धोरणाची अंमलबजावणी करताना महाविद्यालयाची संख्या कमी केली जाणार आहे. गुणवत्ता राखणारे महाविद्यालये टिकतील याद्दष्टीने पावले उचलली जात असून त्या दृष्टीनेच २०२२ पर्यंत सर्व महाविद्यालयांनी नॅक मूल्यांकन करावे तसेच त्यामध्ये २.५ पेक्षा जास्त गुण मिळविणे आवश्यक आहे असे 'यूजीसी' ने स्पष्ट केले आहे. अशा स्थितीत राज्यातील विनाअनुदानित संस्थांची स्थिती गंभीर आहे. पुढील वर्षभरात मूल्यांकन करून घेताना संस्थांची कसरत होणार आहे.

मुल्यांकनाची आवश्यकता:

देशातील ९० टक्के महाविद्यालये व ६८ टक्के विद्यापीठाचा दर्जा खालावलेला आहे. जगातील पहिल्या २०० विद्यापीठामध्ये भारतातील एकही विद्यापीठ समाविष्ठ नाही. भारतात शिक्षण क्षेत्राची संख्यात्मक वाढ झाली परंतु गुणात्मक वाढ होणे गरजेचे आहे. शैक्षणिक दर्जा राखण्यासाठी नॅक मूल्यांकन अनिवार्य आहे. त्यास अनुसरून नॅकमार्फत मुल्यांकन केले जात आहे. महाविद्यालयाची गुणवत्ता सिद्ध करण्यासाठी, दर्जा वाढविण्यासाठी नॅकमार्फत मूल्यांकन अनिवार्य असते.

मुल्यांकन करताना येणाऱ्या अडचणी:

नॅककडून मुल्यांकन करण्यामध्ये अनेक अडचणी आहेत त्यामध्ये प्राध्यापक व शिक्षकेतर कर्मचाऱ्यांची रिक्त पदे, अनेक महाविद्यालयामध्ये एकही कायमस्वरूपी प्राध्यापक नाही. तेथील शैक्षणिक कामकाज तात्पुरत्या प्राध्यापकांना तुटपुंजे वेतन देऊन सुरू आहे, महाविद्यालयांची स्वतःची इमारत नसल्याने भाड्याच्या जागेत संस्था सुरू आहेत, जागा स्वतःची असली तरी इमारत चांगली नाही, ग्रंथालय, लॅब, मैदान यासह इतर सुविधा नाहीत,

महाविद्यालयात असुविधांची वानवा, नॅकच्या तयारीसाठी येणारा मोठा खर्च यामुळे राज्यातील अशा विनाअनुदानित महाविद्यालयांनी नॅक मूल्यांकनाकडे पाठ फिरवली आहे. महाविद्यालयाचे अस्तित्व टिकविण्यासाठीचा संघर्ष सुरु असल्याने या चक्रव्यूहात नॅक मूल्यांकन अडकले आहे.

नॅक मूल्यांकन वेळेत करून घेणे गरजेचे आहे परंतु २०१२ पासून राज्यात प्राध्यापक भरती ही अनुदानित महाविद्यालयातील जवळपास ४०० प्राचार्यांची पदे रिक्त आहेत. तसेच ९० टक्के त्यापुढे आर्थिक संकट असताना नॅकच्या तयारीसाठी येणारा मोठा खर्च अनुदानित व विनाअनुदानित अशा दोन्ही संस्थांना परवडणारा नाही, त्यामुळे अनेक संस्थांनी अद्याप नॅकमार्फत मूल्यांकन करून घेतलेले नाही. नॅक मूल्यांकनाच्या तयारीसाठी येणारा लाखो रुपयांचा खर्चामुळे संस्थाचालक तयार होत नसल्याचे प्राचार्यांचे म्हणने आहे.

अभियांत्रिकी, औषधनिर्माण शास्त्र, विधी, व्यवस्थापन या शाखामध्ये सुरुवातीस पीएच. डी. धारक कमी असल्याने या शाखेत प्राचार्य मिळत नसत. कायमस्वरुपी विनाअनुदानित महाविद्यालयात कमी वेतनावर प्राचार्य म्हणून काम करण्यास कोणी तयार होत नाही; त्यामुळे प्राचार्या अभावी नॅक मुल्याकंनातात अडचणी येत आहेत.

राज्यातील शासकीय संस्था व अनुदानित संस्थांकडून मूल्यांकन करून घेतले जात असले तरी विनाअनुदानित संस्थांनी नॅक मूल्यांकन करून घेण्याकडे पाठ फिरवली आहे. यातच कोरोनामुळे महाविद्यालये बंद आहेत. त्यामुळे फेब्रुवारी २०२१ पर्यंत नॅक मूल्यांकनाची प्रक्रिया पूर्ण ठप्प होती.

नॅक मुल्यांकनाची महाराष्ट्रातील सध्यस्थिती:

देशभरातील केवळ सुमारे ४० हजार महाविद्यालये अथवा संस्थांपैकी आतापर्यंत केवळ ८ हजार १६६ महाविद्यालयांनी तर ९९३ विद्यापीठांपैकी ३६४ विद्यापीठांनी नॅक मूल्यांकन करून घेतले आहे. हे प्रमाण साधारणपणे २० टक्के आहे. यापेक्षा महाराष्ट्रातील हे प्रमाण ४० टक्के आहे. मात्र, गेल्या २७ वर्षात राज्यातील ६० टक्के संस्थांनी एकदाही नॅक मूल्यांकन करून घेतलेले नाही. त्यामुळे 'यूजीसी' ने नुकतेच एक परिपत्रक काढले असून, त्यामध्ये सर्व महाविद्यालये, विद्यापीठांनी २०२२ पर्यंत नॅक मूल्यांकनात किमान २.५ क्युम्युलेटिव्ह ग्रेड पॉइंट ॲव्हरेज मिळणे अनिवार्य आहेत. त्यामुळे नॅक मूल्यांकनाबाबात उदासीनता असलेल्या महाविद्यालयांना तयारीला लागावे लागणार आहे.

महाराष्ट्रातील एकूण महाविद्यालये ३१४१; त्यापैकी एकदा मूल्यांकन झालेली महाविद्यालये १२७७, दोन वेळा मूल्यांकन झालेली महाविद्यालये ८६७, तीन वेळा मूल्यांकन झालेली महाविद्यालये ३७९ व चार वेळा मूल्यांकन झालेली ४ महाविद्यालये आहेत.

नॅकची प्रक्रिया सुरु झाली त्यास साधारण २५ वर्षे पूर्ण झाली तरी देखील अनेक संस्थांनी अथवा महाविद्यालयांनी नॅक मूल्यांकन करून घेतले नाही ही गंभीर बाब आहे. त्यामुळे 'यूजीसी' ने २०२२ पर्यंत सर्व महाविद्यालयांनी व विद्यापीठांनी मूल्यांकन करावे हा धरलेला आग्रह महत्त्वाचा व

घराण्यात आहे. त्यामुळे संस्थांची आर्थिक स्थिती कशीही असली तरी संस्थांनी मूल्यांकन करून घेताना त्यांची वस्तूस्थिती दाखवली पाहिजे.

ऑगस्ट २०२० अखेर राज्यातील १० विभागात १९३६ विनाअनुदानित महाविद्यालये आहेत त्यापैकी १७४५ (१० टक्के) महाविद्यालयांनी नॅक मूल्यांकन करून घेतले आहे. संस्थांनी नॅक मुल्यमापनाकडे पूर्णता दुर्लक्ष केले आहे. तर फक्त १९१ विनाअनुदानित संस्था नॅक मूल्यांकन प्रक्रियेला सामोऱ्या गेल्या आहेत. अमरावती, औरंगाबाद, नांदेड, नागपूर या विभागाची स्थिती खूपच विदारक आहे.

राज्यातील नॅक मुल्याकंनाची सध्यस्थिती:

विभागाचे नाव	महाविद्यालयांची एकूण संख्या	पैकी नॅक झालेल्या महाविद्यालयांची संख्या	अनुदानित महाविद्यालय	पैकी नॅक न झालेल्या महाविद्यालयांची संख्या	पैकी नॅक केलेल्या महाविद्यालयांची संख्या	विनाअनुदानित महाविद्यालय	पैकी नॅक केलेले
अमरावती	२९१	१२६	१५२	३४	११८	१४४	४
औरंगाबाद	३८७	१११	११५	१३	१०२	२८९	६
जळगाव	१५१	९४	८३	१	८२	६४	१३
कोल्हापूर	२२४	१५४	१३३	१	१३२	९२	२०
मुंबई	२४२	१२८	१००	८	९२	१४०	३२
नागपुर	५७०	१६१	१९५	४१	१५४	३९२	१३
नांदेड	२६१	९१	९७	१४	९३	१५४	६
पनवेल	३६७	१३०	९४	२	९२	२८९	३९
पुणे	४७६	२१४	१६८	३	१६५	३३२	५१
सोलापूर	७७	४७	४०	००	४०	४०	७
एकूण	३०४२	१२६४	११७७	११७	१०७०	१९३६	१९१
शासकीय महाविद्यालये	२८	२३	२८	--	२३	--	--

संदर्भ: नॅशनल असेसमेंट अॅण्ड अॅक्रिडिएशन कौन्सिल बॅंगलोर, २०२०.

महाविद्यालयांनी नॅक मूल्यांकन करून घेणे आवश्यकच आहे; पण ज्या संस्थांनी अद्याप एकदाही मूल्यांकन करून घेतले नाही त्यांना तयारीला लागावे लागेल. तसेच विद्यापीठ व शासनाने महाविद्यालयांना विश्वासात घेऊन प्रोत्साहन देणे गरजेचे आहे. यूजीसीच्या परामर्श योजनेमुळेही हातभार लागू शकतो.

संदर्भ सूची:

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२) संयुक्त राष्ट्र विकास कार्यक्रम अहवाल-२०१९.

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९) युनेस्को ग्लोबल एज्यूकेशन डायजेस्ट: २०११.

१०) राजपूर कुलदीपसिंह, उच्च्य शिक्षणासमोर परकी गुंतवणुकीचे आव्हान, दैनिक सकाळ, २८ नोव्हेंबर २०१२, पान नं. ४ .

११) पाटील ब्रिजमोहन, राज्यातील अठराशे संस्थांचा 'नॅक'ला ठेंगा, दैनिक सकाळ, ९ मार्च २०२१, पान नं. १.

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Kanpur Philosophers
ISSN 2348-8301
International Journal of humanities, Law and Social Sciences
Published biannually by New Archaeological & Genological Society
Kanpur India
Vol. VIII, Issue I (Summer) 2021

नवीन शैक्षणिक धोरण

प्राचार्य डॉ. संजीव लाटे
अमृतेश्वर कला, वाणिज्य व विज्ञान
महाविद्यालय विंझर.
ता. वेल्हा, जि. पुणे-४१२ २१३

प्रास्ताविक:

यापूर्वी १९८६ मध्ये राष्ट्रीय शैक्षणिक धोरण लागू करण्यात आले होते. १९९२ मध्ये त्यामध्ये किरकोळ सुधारणा वगळता तीन दशकांहून अधिक काळ जुनेच शैक्षणिक धोरण चालत होते. त्या पार्श्वभूमीवर नवे धोरण तयार करण्यासाठी सरकारने टी. एस. आर सुब्रह्मण्यम यांच्या अध्यक्षतेखाली समिती नेमली होती. १९८६ नंतर विविध क्षेत्रात अनेक बदल घडून आले होते, ३४ वर्षात विज्ञान तंत्रज्ञान क्षेत्रात अनेक बदल, अनेक वैज्ञानिक संकल्पना नव्याने समाविष्ट, परंतु या संगळ्यापासून भारतीय शिक्षणपद्धती अनभिज्ञ राहिली होती. या आधुनिक जगाशी सुसंगत अशी शिक्षण व्यवस्था उदयास येणे ही काळाजी गरज होती. तब्बल ३४ वर्षांनंतर आणलेल्या नव्या शैक्षणिक धोरणाला केंद्र सरकारने २९ जूलैला परवानगी दिली. मल्टिपल एन्ट्री आणि एक्झिट सिस्टिम' वर धोरण आधारित असून ५-३-३-४ (पूर्वप्राथमिक , प्राथमिक, माध्यमिक, उच्चमाध्यमिक) अशी रचना असेल. बोर्डाच्या परिक्षेचा बोजा कमी होणार. एकाच वेळी दोन अभ्यासक्रम शिकण्याची मुभा राहणार आहे. सहावीपासून कौशल्य शिक्षण, मूल्यांकन पद्धतीत बदल, भारतीय भाषामध्ये ई अभ्यासक्रम सुरु. नविन शैक्षणिक धोरणाची तीन-चार वर्षात टप्या-टप्याने अंमलबजावणी केली जाणार आहे. नवीन शैक्षणिक धोरणासंबंधी भारताचे राष्ट्रपती रामनाथ कोविंद यांनी पुढील वकत्व केले आहे. "एका दीर्घ व व्यापक विचारविनिमयानंतर नवीन शैक्षणिक धोरण तयार केले" भारताचे पंतप्रधान मा. नरेन्द्र मोदी यांनी नवीन शिक्षण धोरणासंबंधी केलेले वकत्व "विद्यार्थ्यांना आवड जोपासण्याची संधी मिळायलाच हवी. विद्यार्थ्यांच्या आवडी निवडी बदलू शकतात, एक अभ्यासक्रम निवडला की त्यातच मन मारून कायम राहणे यापेक्षा बदल करावासा वाटला तर शाखा बदलास परवानगी हवीच काळाच्या ओघात कोणताही व्यवसाय, नोकरीत कायम राहू शकत नाहीत त्यामुळे शिक्षण पद्धतीत देखील बदल होणे गरजेचे होते."

नावातील बदल:
मनुष्यबळ विकास मंत्रालयाचे नामकरण पुन्हा शिक्षण मंत्रालय करण्यास आले. शिक्षणातून मनुष्यबळ विकसित करणे. शिक्षणातून माणसाचा सर्वांगीण विकास साधायला हवा त्यामुळे हे नामकरण करण्यात आले आहे. नविन शिक्षण धोरणाची उद्दिष्टे :
आपली मुले अपेक्षांच्या ओझ्याखाली पिचली जात आहेत, याची चर्चा दीर्घकाळापासून होती. नविन धोरणात याकडे विशेष लक्ष देण्यात आले आहे.
अंमलबजावणीचे प्रारुप जितके प्रभावी, तेवढी त्याची परिणाकमारकताही वाढते. यादृष्टीने धोरणात प्रशासनाची बाजूही प्रतिबिंबित केली आहे.
ज्याप्रमाणे परराष्ट्र व्यवहार धोरण असते, संरक्षण धोरण असते, तसेच शैक्षणिक धोरणही साऱ्या जगाचे असते आणि आहे.
पायाभूत शिक्षण मातृभाषेत असावे व शिक्षकांच्या प्रशिक्षणावरही यात भर देण्यात आला आहे.
ग्रेडेड ऑटोनॉमी या संकल्पनेमागे हेच प्रयत्न आहेत, की महाविद्यालये व विद्यापीठातील निकोप स्पर्धा वाढीस लागावी.
उच्चशिक्षणाचा प्रत्येक पैलू, मग तो शैक्षणिक असो, तांत्रिक असो, की व्होकेशनल, प्रत्येक प्रकारच्या शिक्षणाला भूमिगत स्थितीतून बाहेर काढणे.
हे शैक्षणिक धोरण घोकपट्टी किंवा अभ्यासापेक्षा शिकणे या प्रक्रियेवर लक्ष केंद्रित करते. ८) या धोरणात प्रत्येक विद्यार्थ्याला समर्थ होण्याचा रस्ता दाखविण्यात आला आहे.

कायम विनाअनुदान व स्वायत्तावर भर :
आपल्या शिक्षण व्यवस्थेत १९८० च्या दशकाआधी अनुदान, १९८० च्या दशकात विनाअनुदान आणि २०१० च्या दशकात कायम विनाअनुदान धोरणाचा स्वीकार केला. परिणामी शिक्षणाला बाजारी स्वरुप आले २००४ साली खासगी विद्यापीठे विधेयक व अध्यादेश आणून खासगी विद्यापीठाच्या स्थापनेस प्रोत्साहन देण्यात आले तर २०११ च्या दशकात स्वायत्त महाविद्यालयावर भर देण्यात आला. थोडक्यात शिक्षण क्षेत्रातील शासन स्वत:ची जबाबदारी हळू-हळू कमी करून खासगीकरणावर भर दिला जात आहे.

कालानुरूप शिक्षण पद्धतीत बदल नाही:
यापूर्वी १९८६ मध्ये राष्ट्रीय शैक्षणिक धोरण लागू करण्यात आले होते. १९९२ मध्ये त्यामध्ये किरकोळ सुधारणा वगळता कोणतेही बदल केले नाहीत. म्हणजे तीन दशकांहून अधिक काळ जुनेच शैक्षणिक धोरण चालत होते. ३४ वर्षात विज्ञान तंत्रज्ञान क्षेत्रात अनेक बदल, अनेक वैज्ञानिक संकल्पना नव्याने समाविष्ट झाल्या होत्या; परंतु या संगळयापासून शिक्षणपद्धती अनभिज्ञ राहिली. या आधुनिक जगाशी सुसंगत अशी शिक्षण व्यवस्था उदयास येणे ही काळाजी गरज होती. त्यास अनुसरून तब्बल ३४ वर्षांनंतर आणलेल्या नव्या शैक्षणिक धोरणाला केंद्र सरकारने २९ जूलै २०२० ला परवानगी दिली आहे.
नव्या शिक्षण धोरणाअंतर्गत देशभरात उच्च शिक्षणासाठी एकच नियामक प्राधिकरण अस्तित्वात येणार असून मनुष्यबळ विकास मंत्रालयाचे नाव बदलून शिक्षण मंत्रालय करण्यात आले आहे. नव्या शिक्षण धोरणाची भविष्यातील अंमलबजावणी केव्हा व कशी होईल यावर त्याची यशस्वीता

अंबलंबून राहील. २०११ च्या जनगनेनुसार देशाची सरासरी साक्षरता ७७.७ टक्के, ग्रामीण भागात साक्षरता ७३.५ टक्के तर शहरी भागात सरासरी ८७.७ टक्के साक्षरता आहे. भविष्यात शिक्षण क्षेत्रात भारताला मोठी प्रगती करावी लागणार आहे.

नाविन्य आणि संशोधनाकडे दुर्लक्षः

जगभरातील शिक्षणाचा विचार केल्यास चीन (२९ टक्के) आणि भारत (१२ टक्के) या दोन देशांमध्ये मिळून जगातील तब्बल ४० टक्के पदवीधर दरवर्षी तयार होतात. तर अमेरिका १२, रशिया ७, इंडोनेशिया ६ टक्के , जपान व ब्रिटन = ४ टक्के, कोरिया, मेक्सिको व ब्राझील = ३ टक्के, स्पेन, तुर्कस्तान १ टक्का, इतर देशात १२ टक्के पदवीधर तयार होतात. भारतात शिक्षण क्षेत्राची संख्यात्मक वाढ होताना दिसून येत आहे; परंतु गुणात्मक वाढीकडे दुर्लक्ष होत आहे.

शिक्षण पद्धती ही संशोधन आणि नवनिर्मितीला प्रोत्साहन देणारी असायला हवी; भारतात जीडीपीच्या केवळ 0.६९ टक्के संशोधनावर केला जातो. विकसित देशात हे प्रमाण ३ टक्क्यापेक्षा जास्त आहे; तर इस्त्राईलमध्ये हे प्रमाण ४.३ टक्के आहे. संशोधनात रस असलेले लाखो विद्यार्थी परदेशाची वाट धरतात. आपल्या युवकाचे संशोधन इतर देशांचे पेटंट्स होऊन बसत आहे.

अमेरिकेत २०१९ मध्ये जगातील एकूण १५.२० लाख परदेशी विद्यार्थी शिक्षण घेत होते त्यापैकी ४८ टक्के विद्यार्थी चीन(४,७४,४९७) व भारताचे (२,४१,२२१) होते, द. कोरिया १.२४ लाख, जर्मनी १.१८ लाख, सौदी अरेबिया ६४ हजार, फ्रान्स ६२ हजार, मलेशिया ५६ हजार, व्हिएतनाम ५४ हजार, इराण ५२ हजार विद्यार्थी शिक्षण घेत होते. शिक्षणांच्या माध्यमातून अमेरिका, इंग्लंड, ऑस्ट्रेलिया यासारखे देश अब्जावधी डॉलर दरवर्षी कमवतात. भारतातून चीन मध्ये २०२० मध्ये २३००० विद्यार्थी शिक्षणासाठी गेले; त्यापैकी २१००० विद्यार्थी एमबीबीएसचे शिक्षण घेत होते. अलीकडील काळात रशिया, मलेशिया, जॉर्जिया, कझाकिस्तान, चीन व इत्तर देशात वैद्यकिय शिक्षणासाठी भारतातून मोठ्या प्रमाणात विद्यार्थी बाहेरच्या देशात जात आहेत. भारतातील सुमारे १० लाख विद्यार्थी परदेशी विद्यापीठामध्ये शिक्षण घेत आहेत; तर भारतातून दरवर्षी सुमारे ३ लाख विद्यार्थी शिक्षणासाठी बाहेर जात आहेत. त्यातुलनेत विदेशातून भारतात शिक्षणासाठी येणाऱ्या विद्यार्थ्यांचे प्रमाण नगन्य आहे; भारतात २०१४ मध्ये ३३ हजार तर २०१९ मध्ये १६४ देशातील ४७ हजार विद्यार्थी शिक्षणासाठी आले होते. त्यातील प्रगत देशाचे प्रमाण २ टक्यापेक्षा कमी आहे.

भारतातील उच्च शिक्षणातील प्रवेश घेतलेल्या विद्यार्थ्यांची संख्या (२०२०)

वर्षे	मुले (कोटी)	मुली (कोटी)	एकूण (कोटी)	मुलींची टक्केवारी
२०११-१२	१.६१	१.३०	२.९१	४४.५८
२०१२-१३	१.७४	१.४८	३.२३	४५.०९
२०१५-१६	१.८५	१.५९	३.८५	४६.२३
२०१७-१८	१.९२	१.७४	३.६६	४७.५९
२०१९-२०	१.९२	१.८१	३.७३	४८.६०

संदर्भः युजीसी अहवाल-२०११-१२ ते २०१९-२०२०

वचिकता:

क्षणिक धोरण हे विद्यार्थ्यांना अधिक स्वायत्तता देते. सध्या मेजर आणि मायनर विषय डताना मोजकेच पर्याय उपलब्ध असतात. अभियांत्रिकी आणि संगीत अशा दोन्हीची आवड णाऱ्यांना हे दोन्ही विषय एकत्र घेता येतील. यासाठी लागणारी व्यवस्था उभी करण आव्हानात्मक असेल; पण ही व्यवस्था क्षण सुटले तर लिव्हींग सर्टिफिकेट काही मिळत नाही आणि त्यात काही काळानंतर व्यवस्थेत न यायचे पर्याय किचकट, नव्या धोरणानुसार पदवीच्या कुठल्याही वर्षानंतर बाहेर पडण्याचा आणि विक कालावधीच्या आत परत येऊन जिथून शिक्षण सोडल होत तिथून पुन्हा सुरुवात करण्याचा मानजनक पर्याय सुद्धा असेल पहिल्या पर्यानंतर फर्स्ट इयरनंतर शिक्षण सुटल तर तस प्रमाणपत्र ळेल. दुसऱ्या वर्षानंतर सुटल तर पदविका प्रमाणपत्र मिळेल.

ाध्यमाचा शास्त्रीय विचार:

जी हा खर तर एक भाषाविषय, पण अलिकडच्या काळात तेच शिक्षण होऊन बसले आहे इंग्रजी ा अत्यावश्यक आहे; पण इंग्रजी हेच माध्यम हा विचार चुकीचा आहे. इंग्रजी माध्यमातून मुलाला लन होत आहे किंवा नाही, हे पाहिल जात नाही. नव्या धोरणानुसार पाचवीपर्यंतचे शिक्षण तो मातृभाषेत अथवा स्थानिक भाषेतच दिले जाणार आहे. मातृभाषेतून सुरुवातीचे शिक्षण ळाले तर पाया भक्कम होऊन अभ्यासात मुलांची प्रगती लक्षणीय होते. अभ्यासाक्रमातील ावश्यक भाग वगळला जाणार आहे. जीवनावश्यक कौशल्याचे शिक्षण शालेय जीवनापासून दिले ईल. खेळ, कार्यानुभव असे विषय अभ्यासेत्तर नसतील, तर प्रमुख अभ्यासक्रमाचा भाग असतील हे बदल म्हणजे एका नव्या अध्यायाची आशादायी सुरुवात आहे.

ावित्य आणि संशोधनाला बळ:

शिक्षण पद्धती ही संशोधन आणि नवनिर्मितीला प्रोत्साहन देणारी असायला हवी; जीडीपीच्या केवळ ०.६९ टक्के संशोधनावर केला जातो. ईस्त्राईलमध्ये हे प्रमाण ४.३ टक्के आहे. संशोधनात रस असलेले लाखो विद्यार्थी परदेशाची वाट धरतात. आपल्या युवकाचे संशोधन इतर देशांचे पेटंट ऊन बसत आहे. नविन शिक्षण धोरणात संशोधनावर भर देण्यात आला आहे.

ुन्या पद्धतीत आमूलाग्र बदल :

ामाच्या, अध्यापनाच्या पारंपरिक पद्धतीतही आमूलाग्र बदल सुचविण्यात आले आहेत. नव्या अभ्यासक्रमाच्या सहाय्याने लहान बालकांची काळजी तर घेतली जाईलच, त्याचबरोबर त्यांना वेगवेगळे सार्वजनिक खेळ खेळण्यास दिले जातील. अक्षरओळख (साक्षरता मिशन) आणि आकडेमोड ासाठी सध्या सुरु असलेल्या मूलभूत कार्यक्रमांची जोड असेलच. शिक्षणांचे भक्कम अधिष्ठान निर्माण रणारे हे धोरण आहे. अभ्यासाक्रमांतर्गत विषय आणि
अभ्यासक्रमबाह्य विषय यासारख्या भिंती आता काढून टाकण्यात आल्या आहेत. मुख्य म्हणजे उच्च शिक्षणात आत येण्याचे आणि बाहेर पडण्याचे अनेक पर्याय उपलब्ध करून देण्यात आले आहेत.

यामुळे आलेली लवचिकता विद्यार्थ्यांना उपयोगी पडेल. त्यांना त्यांच्या आवडीनिवडी जोपासत शिकता येईल. हे शिक्षण आंनदायी असेल. नव्या अभ्यासक्रमामुळे निम्या विद्यार्थ्यांना तरी निश्चितच एखादे व्यावसायिक कौशल्य शिकण्याची संधी मिळणार आहे.

शिक्षकांसाठी :

शिक्षकांचे शिक्षण याचा व्यापक विचार यात करण्यात आला आहे. निकृष्ट संस्थाविरुद्ध कठोर कारवाई करण्यात येईल. धाडसी सुधारणांच्या माध्यमातून शिक्षणास बळकटी देण्यात येईल. स्पर्धात्मक शिक्षण, संवादावर भर देणारी अध्यापनशैली, गुणवत्ता आधारित शिक्षकनिवड, त्यासाठी योग्य निकष आणि पारदर्शक प्रणालींसाठी शालेय शिक्षण गुणवत्ता निर्देशांकाचा आधार घेणे हीदेखील नव्या शिक्षण धोरणाची वैशिष्ट्ये आहेत. या बदलांमुळे घोकपट्टी (पठण अध्ययन) पद्धतीला सोडचिठ्ठी देण्यात येणार आहे. सराव आधारित अभ्यासक्रम आणि स्थानिक व्यावसायिक तज्ञांसह ईटरशिपच्या माध्यमातून एनईपी-२० ची लोकल फॉर व्होकल या घोषणेची पुष्टी करणारे आहे.

भारताचे बँडिंग:

उच्च शिक्षणात शैक्षणिक पतपेढी (अॅकेडमिक क्रेडीट बँक) तयार करण्याची कल्पनाही शिक्षण क्षेत्रातील भारताचे बँडिंग सुधारण्यास उपयुक्त ठरेल. गुणवत्ता पूर्ण शिक्षणाकडे जाणारा प्रवास, डिजिटल शिक्षणाकडे जाणारा प्रवास, नव्या औद्योगिक क्रांतीच्या वाटचालीस मदत यासाठी नविन शिक्षण धोरण मदत करेल व नविन शिक्षण धोरण पुढच्या पिढयासाठी निश्चित उपयोगी पडेल.

विदेशी विद्यार्थी वाढविणे उद्दिष्टः

भारतात सन २०१९ मध्ये ४७ हजार १६४ देशातील परदेशी विद्यार्थी शिक्षण घेत होते. भारतात ९९३ विद्यापीठे आहेत. २०३० पर्यंत ही संख्या २ लाखापर्यंत वाढवण्याचे उद्दिष्ट आहे त्यासाठी नविन शैक्षणिक धोरणातील तरतुदीप्रमाणे प्रत्येक विद्यापीठात 'आंतरराष्ट्रीय कार्यालय (ऑफिस ऑफ इंटरनॅशनल अफेअर्स स्थापन करण्याचा युजीसीने आदेश दिला), भारतातील सुमारे १० लाख विद्यार्थी परदेशी विद्यापीठामध्ये शिक्षण घेत आहेत; भारतातील दरवर्षी २ ते ३ लाख विद्यार्थी परदेशात शिक्षण घेत आहेत. पुणे विद्यापीठात २०१६-१७ मध्ये ८५९, २०१७-१८ मध्ये ८०३, २०१८-१९ मध्ये ५६५, २०१९-२० मध्ये ६१० परदेशी विद्यार्थी शिक्षण घेत होते.

नवीन शिक्षण धोरणाचे फायदे:

१) नवीन शिक्षण धोरणात सरकारचा हस्तक्षेप कमी.

२) १० वी व १२ बोर्डाच्या परिक्षेचा ताण होता तो कमी झाला, आता १० वी चा ताण तरी कमी होईल.

३) मोठ्या शिक्षण संस्था लहान शिक्षणसंस्थांना मदत करतील, मैदाने, प्रयोगशाळा,ग्रंथालय यांचा एकत्रित वापर होऊ शकतो. शिक्षणातील नफेखोरीला पायबंद बसेल

४) परदेशी विद्यापीठांना पायघड्या व त्यामुळे गुणवत्ता उंचवण्यास मदत होईल त्यामुळे चांगल्या शिक्षकांची गरज भासणार आहे.
५) नविन शिक्षण धोरणाची अंमलबजावणी योग्य पद्धतीने न झाल्यास शिक्षणाचे सार्वत्रिकरण हे स्वप्नच ठरेल.

नवीन शिक्षण धोरणातील समस्या:

१) केंद्र सरकारने जाहीर केलेल्या नविन शैक्षणिक धोरणातमध्ये विद्यापीठाचे महत्त्व संपणार आहे.
२) २०३२ पर्यंत देशातील चांगल्या दर्जाची महाविद्यालये स्वायत्त करण्यात येतील व दर्जाहीन महाविद्यालये बंद होणार. देशाच्या अनेक भागात शिक्षणाची स्थिती विदारक आहे त्यामुळे महाविद्यालये बंद करणे योग्य नाही.
३) नव्या शिक्षण धोरणाअंतर्गत देशभरात उच्च शिक्षणासाठी एकच नियामक प्राधिकरण अस्तित्वात येईल.
४) शिखर संस्थाचे एकत्रिकरण केले जाणार त्यामुळे मोठे कायदेशिर बदल केले जाणार.
५) देशी विद्यापीठे व परदेशी विद्यापीठे यांना समान संधी असणार त्याचा परिणाम आपली पारंपारिक विद्यापीठे त्या स्पर्धेत टिकणे कठिण आहे.
६) खाजगी शिक्षण संस्था शासनाच्या पायाभूत सुविधा वापरु शकणार आहेत परंतु त्याच्या नफेखोरीला पायबंद कसा बसेल याचा कोठेही उल्लेख नाही.
७) केंद्र सरकारने शिक्षण हक्क कायदा आणला पण त्याची अंमलबजावणी पूर्ण झाली नाही तसे या नवीन शिक्षण धोरणाचे होऊ नये.
८) नव्या शैक्षणिक धोरणातून आरक्षण हद्दपार होणार आहे. त्यामुळे सर्वसामान्यांच्या शिक्षण आवाक्याबाहेर जाणार आहे.

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