

International Journal for Biotechnology and Molecular Biology Research

Volume 8 Number 3, October 2017

ISSN 2141-2154



ABOUT IJBMBR

The **International Journal for Biotechnology and Molecular Biology Research (IJBMBR)** (ISSN 2141-2154) is published Monthly (one volume per year) by Academic Journals.

International Journal for Biotechnology and Molecular Biology Research (IJBMBR) provides rapid publication (monthly) of articles in all areas of the subject such as Green energy from chemicals and bio-wastes, Studies in the graft copolymerization of acrylonitrile onto cassava starch by ceric ion induced initiation, Antimutagenic activity of aqueous extract of Momordica charantia, Ethnomedicinal plants and other natural products with anti-HIV active compounds and their putative modes of action etc.

The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in IJBMBR are peer-reviewed.

Contact Us

Editorial Office: ijbmb@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: <http://academicjournals.org/IJBMBR>

Submit manuscript online <http://ms.academicjournals.me/>

Editors

Prof Atagana, Harrison

*Institute for Science and Technology Education
University of South Africa*

Prof. UC Banerjee

*Department of Pharmaceutical Technology
(Biotechnology)
National Institute of Pharmaceutical Education and
Research
Punjab, INDIA*

Dr. Y. Omid

*Faculty of Pharmacy,
Research Center for Pharmaceutical Nanotechnology,
School of Advanced Biomedical Sciences,
Tabriz University of Medical Sciences,
Tabriz, Iran.*

Prof. Mohamed E. Wagih

*University of New Brunswick (UNB-SJ),
Saint John College, NB,
E2L 4L5, Canada*

Dr. Sripada M. Udupa

*ICARDA-INRA Cooperative Research Project,
International Center for Agricultural Research in the
Dry Areas(ICARDA), B.P. 6299,
Rabat Instituts, Rabat, Morocco*

Dr. Amjad Masood Husaini

*Sher-e-Kashmir University of Agricultural Sciences &
Technology
Bohlochipora, Dr. Ali Jan Road,
Nowshera, Srinagar, J&K-190011, India*

Dr. Om Prakash Gupta

*Directorate of Wheat Research (ICAR)
Post Box-158, A
grasain Marg, Karnal-132001,
Haryana, India*

Editorial Board

Dr. Amro Hanora

*Suez Canal University, Department of Microbiology
and Immunology,
Faculty of Pharmacy, Suez Canal University,
Box 41522 Ismailia, Egypt*

Dr. C. Rajasekaran

*VIT University
School of Bio-Sciences & Technology (SBST)*

Dr. Yasar Karadag

*Gaziosmanpasa University
Faculty of Agriculture,
Department of Field Crops, Tokat-Turkey*

Dr. Ahmet Tutus

*KSU (Kahramanmaras Sutcu Imam University)
Faculty of Forestry,
Department of Forest Industrial Engineering,
Kahramanmaras 46100 Turkey*

Dr. Vinod Joshi

*Desert Medicine Research Centre,
Indian Council of Medical Research
New Pali Road, Jodhpur, India*

Dr. Eshrat Gharaei Fathabad

*K.M.18 Khazarabad road,
Sari, Mazandaran, Iran*

Dr. Shashideep Singhal

*121 Dekalb Ave, Brooklyn,
NY 11201, New York, USA*

Dr Masayoshi Yamaguchi

*101 Woodruff Circle, 1305 WMRB,
Atlanta, Georgia 30322-0001, USA*

Dr. Okonko Iheanyi Omezuruike

*Department of Virology,
Faculty of Basic Medical Sciences,
College of Medicine,
University College Hospital,
Ibadan, Nigeria*

Dr. S. M. Shahid

*University of Karachi,
Karachi-75270, Pakistan*

Prof. Reda Helmy Sammour

*Botany Department,
Faculty of Science,
Tanta University,
Tanta, Egypt*

Dr. Premendra D. Dwivedi

*Food Toxicology Division,
Room No 303,
P.O. Box 80,
M. G. Road, Lucknow-226001, UP, India*

Dr. Amro Hanora

*Microbiology and Immunology department,
Faculty of Pharmacy,
Suez Canal University,
Box 41522 Ismailia, Egypt*

Dr. Tamilnadu

*1501 N. Campbell Ave
Tucson, AZ 85724 India*

Dr. Yadollah Omid

*Faculty of Pharmacy,
Tabriz University of Medical Sciences,
Daneshgah St., Tabriz, Iran*

Dr. Mohsen Selim Asker

*National Research Centre, Dokki, Cairo,
Egypt*

Dr. Fanuel Lampiao

P.O.Box 360, Blantyre, Malawi

Prof. Mohamed E. Wagih

Saint John, NB, E2L 4L5, Canada

Dr. Santosh Kumar Singh

*Centre of Experimental Medicine and Surgery,
Institute of Medical Sciences,
Banaras Hindu University, Varanasi-221005, India*

Dr. Zhanhuan Shang

*No.768, Jiayuguan West Road,
Lanzhou City, Gansu Province, China*

Dr. Worlanyo Eric Gato

*Southern Illinois University – Carbondale,
1245 Lincoln Dr, 144 Neckers, Carbondale IL 62901*

Dr. Chun Chen

*College of Life Sciences,
China Jiliang University
Xueyuan Street, Xiasha, Hangzhou,
Zhejiang Province, PR China*

Dr. Efthimios J.Karadimas

*LGI, Leeds NHS Trust 10th Timoleonos Vassou str,
11521, Athens Greece*

Dr. Samuel Toba Anjorin

University of Abuja, Abuja, Nigeria

Dr. Rupali Agnihotri

*Department of Periodontics,
Manipal college of Dental Sciences,
Manipal,576104. Karnataka. India*

Dr. Mahbuba Begum

*Tuber Crops Research Centre,
Joydebpur, Gajipur-1701, Bangladesh*

Prof. S. Mohan Karuppaiyl

*School of Life Sciences
Srtm University
Nanded. MS. India*

Dr. Neveen Helmy Aboelsoud

*Complementary Medicine Researches and Application
Department
National Research Center, Cairo
Egypt.*

Dr. D.E. Chandrashekar Rao

*National Research Council,
Plant Biotechnology Institute
Canada*

Dr. Nikolaos Papanas

*Democritus University of Thrace
G. Kondyli 22, Alexandroupolis, Greece*

Dr. Sivakumar Swaminathan

*Iowa State University
USA*

Dr. El Sayed Hussein El Sayed Ziedan

*National Research Centre,
Plant Pathology Department
Tahrir St.,Dokki Cairo,
Egypt*

Dr. Chethan Kumar M

*Post Graduate Departments of Bio-technology and Biochemistry,
Ooty Road, Mysore - 570 025,
Karnataka,
India*

Dr. M. Sattari

*Rice Research Ins. of Iran
Iran*

Dr. Zaved Ahmed Khan

*VIT University
India*

Dr. Subbiah Poopathi

*Vector Control Research Centre
Indian Council of Medical Research
(Ministry of Health & Family Welfare,
Govt. of India)
Medical Complex, Indira Nagar
India*

Dr. Reyazul Rouf Mir

*International Crops Research Institute for the Semi-Arid Tropics (ICRISAT),
Patancheru - 502 324, Greater Hyderabad,
India*

Dr. Prasanna Kumar S

*Virginia Commonwealth University,
USA*

Dr. Naseem Ahmad

*Plant Biotechnology Laboratory
Department of Botany
Aligarh Muslim University
Aligarh- 202 002, (UP)
India*

Dr. Zhen-Xing Tang

Food Bioengineering institute, Hangzhou Wahaha Co. Ltd, Hangzhou, Zhejiang, China

Dr. Jayanthi Abraham

*VIT (Vellore Institute of Technology) University,
Tamilnadu,
India*

Dr. Gobianand Kuppannan

*National Institute of Animal Science
South Korea*

Dr. R. Harikrishnan

*Jeju National University
South Korea*

Dr. Asit Ranjan Ghosh

*Vellore Institute of Technology (VIT) University,
School of Bio Sciences & Technology,
Medical Biotechnology Division, Vellore-632014,
India*

Dr. Kamal Dev

*Shoolini University of Biotechnology and Management Sciences (SUBMS)
India*

Dr. Wichian Sittiprapaporn

*Maharakham University
Thailand*

Dr. Vijai Kumar Gupta

*Molecular Glycobiotechnology Group, Department of Biochemistry,
School of Natural Sciences,
National University of Ireland, Galway,
Ireland*

Dr. Jeffy George

*Department of Microbiology and Immunology
F. Edward Hébert School of Medicine
Uniformed Services University of the Health Sciences
4301 Jones Bridge Road,
Bethesda, MD 20814
USA.*

Dr. Gyanendra Singh

*Stanley S. Scott Cancer Center,
School of Medicine,
Louisiana State University Health Sciences Center
New Orleans, LA 70112,
USA.*

Dr. Anupreet Kour

*1620 Chevy Chase Dr.
Champaign, IL 61821
USA.*

Dr. Arun Sharma

*Institute for Plant Genomics and Biotechnology (IPGB)
Borlaug Center,
TAMU 2123
Texas A&M University
College Station, TX 77843
USA.*

Dr. Mohsen Asker

*Microbial Biotechnology Dept.
National Research Centre
Cairo,
Egypt.*

Dr. Elijah Miinda Ateka

*Department of Horticulture,
Jomo Kenyatta University of Agriculture and
Technology (JKUAT)
Kenya.*

Dr. Jozélio Freire De Carvalho

*Faculdade de Medicina Da USP, Reumatologia
Av. Dr. Arnaldo, 455 - 3ª andar – Sala 3133.
São Paulo - SP
Brazil*

Dr. Premendra Dhar Dwivedi

*Food Toxicology Division
Industrial Institute of Toxicology Research,
Post Box No: 80, Mahatma Gandhi Marg,
Lucknow 226001,
India*

Dr. Muhammad Abd El-Moez El-Saadani

*Universities and Research Center District,
New Borg El-Arab,
P.O.Box: 21934 Alexandria,
Egypt.*

Dr. Donald J. Ferguson

*Advanced Orthodontic Training Program,
Nicolas & Asp University College
Dubai,
UAE*

Dr. Kalyan Goswami

*Department of Biochemistry & JB Tropical Disease
Research Centre,
Mahatma Gandhi Institute of Medical Sciences,
Sevagram, Wardha-442102*

Dr. A.K. Handa

*National Research Centre for Agroforestry,
Gwalior Road, JHANSI-284003 UP
India.*

Dr. Amjad M.Husaini

*Metabolic Engineering & Biotechnology Laboratory
Division of Plant Breeding & Genetics
Sher-e-Kashmir University of Agricultural Sciences &
Technology of Kashmir
J&K-191121,
India*

Dr. Vinod Joshi

*Laboratory of Virology & Molecular Biology,
Desert Medicine Research Centre,
Pali Road, Jodhpur-342 005,
India*

Dr. T. Kalaivani

*D/O S. Thiagarajan
B-43, Rajaram Nagar,
Salem - 636 007,
Tamil Nadu, India*

Dr. Priya Kalia

*Orthopaedic Research Unit,
Department of Surgery,
Cambridge University, Cambridge,
UK*

Dr. Patricia Khashayar

*Tehran University of Medical Sciences
Endocrinology and Metabolism Research Center
Shariati Hospital*

Dr. Zaringhalam Moghadam

*Shahid Beheshti Medical University (M.C)
Tehran,
Iran*

Dr. Okeke Ikechukwu Linus

*Department of Surgery, University of Ibadan
Nigeria.*

Dr. Rajesh Kumar Patel

*Centre for Analysis and Learning in Livestock and Food
(CALF)
National Dairy Development Board (NDDB)
Anand- 388 001 (Gujarat)
INDIA*

Dr. Pooja Ralli-Jain

*Department of Pathology and Laboratory Medicine
University of California Irvine,
Irvine, California,
U.S.A.*

Dr. Meltem Sesli

*College of Tobacco Expertise,
Turkish Republic, Celal Bayar University 45210,
Akhisar, Manisa,
Turkey*

Dr. Reda H. Sammour

*Tanta University, Faculty of Science, Tanta,
Egypt*

Dr. Seyed Soheil Saeedi Saravi

*Mazandaran University of Medical sciences, Sari,
Iran*

Dr. R. Senthil Kumar

*St. Matthew's University, School of Medicine
Grand Cayman
Cayman Islands*

Dr. Mohammad Reza Shakibaie

*Kerman University of Medical Sciences, Kerman,
Iran*

Dr. Srividya Shivakumar

*Dept of Microbiology,
CPGS, Jain university,
Bangalore*

Dr. Shashideep Singhal

*The Brooklyn Hospital Center
NewYork-Presbyterian Healthcare System
Brooklyn,
NY.*

Dr. Sripada M. Udupa

*International Center for Agricultural Research in the
Dry Areas (ICARDA),
B.P. 6299, Rabat Instituts, Rabat,
Morocco.*

Dr. Wei Wu

*Institute for Biocomplexity and Informatics
Department of Bio Science
The University of Calgary
Canada*

Dr. Xiao-Bing Zhang

*Molecular Regeneration Laboratory, MC1528B
11234 Anderson Street
Loma Linda, CA 92350*

Prof. Dr. Ozfer Yesilada

*Inonu University
Faculty of Arts and Sciences
Department of Biology
44280 Malatya
Turkey*

Dr. Edson Boasquevisque

*Universidade do Estado do Rio de Janeiro- UERJ
Av 28 de setembro, 87, fundos (LMMC-IBRAG).
Vila Isabel, city: Rio de Janeiro/ RJ
Brasil*

Dr. Abhilash M.

*The Oxford College of Engineering
Hosur Road, Bangalore - 560068*

Dr. Nasar Uddin Ahmed

*Department of Genetics and Plant Breeding
Patuakhali Science and Technology University
Dumki, Patuakhali-8602
Bangladesh*

Dr. Mervat Morsy EL- Gendy

*Chemistry of Natural and Microbial Products
Department,
National Research Center, Dokki, Cairo,
Egypt*

Dr. Gjumarakch Aliev

*Health Science and Healthcare Administration
Program,
University of Atlanta, Atlanta, Georgia,
USA*

Dr. Muhammad Asgher

*Department of Chemistry and Biochemistry,
University of Agriculture,
Faisalabad,
Pakistan*

Dr. Anand Bharatkumar

*Parul Institute of Pharmacy, Limda, Waghodia,
Vadodara*

Dr. Chinmoy Kumar Bose,

*Netaji Subhash Chandra Bose Cancer Research Institute
16A, Park Lane, Park Street, Kolkata 700 016,
India.*

Dr. Mousumi Debnath

*Jaipur Engineering College and Research Centre
(JECRC) Department of Biotechnology,
Shri Ram ki Nangal, Via Vatika ,Tonk Road , Jaipur-
303905 ,
India*

Dr. Dolan C. Saha

*Dept. of Biochemistry and Molecular Biology,
Faculty of Medicine,
University of Calgary,
Canada*

Dr. Ramasamy Harikrishnan

*Department of Aquatic Biomedical Sciences
School of Marine Biomedical Science
College of Ocean Sciences
Jeju National University
Jeju city, Jeju 690 756,
South Korea*

Dr. Abdul Haque

*Health
Biotechnology division, nibge,
Faisalabad,
Pakistan*

Dr. Kuvalekar Aniket Arun

*Interactive Research School for Health Affairs
(IRHSA),
Bharati Vidyapeeth University, Pune, Maharashtra,
India*

Dr. Asit Ranjan Ghosh

*School of Bio Science & Technology,
Division of Medical Biotechnology,
Vellore Institute of Technology (VIT) University,
Vellore-632014,
India*

Dr. Prasanna Kumar Santhekadur

*Department of Human and Molecular Genetics
Virginia Commonwealth University
Richmond,
VA*

Dr. Majid Sattari

*Rice Research Institute of Iran
Iran*

Dr. Mihael Cristin Ichim

*National Institute Research and Development for
Biological Sciences /
"Stejarul" Research Centre for Biological Sciences
Alexandru cel Bun St., 6, Piatra Neamt, 610004,
Romania*

Dr. Sailas Benjamin

*Enzyme Technology Laboratory
Biotechnology Division
Department of Botany
University of Calicut
Kerala - 673 635
India*

Dr. Sreeramanan Subramaniam

*School of Biological Sciences,
Universiti Sains Malaysia (USM),
Minden Heights, 11800, Penang,
Malaysia*

Dr. Vijai Kumar Gupta,

*Department of Biochemistry, NUI, Galway,
Ireland*

Dr. Vitor Engrácia Valenti

*Universidade Federal de São Paulo
Rua Napoleão de Barros, 715, Térreo
São Paulo, SP
Brazil.*

Dr. Ravindra Pogaku

*School of Engineering and IT
Universiti Malaysia Sabah
88999 Kota Kinabalu
Sabah,
Malaysia*

Dr. Ahmed Eid Abdel-Hamid Eweis Fazary

*School of Pharmacy,
College of Medicine,
National Taiwan University, Taipei 100,
Taiwan.*

Dr. Mohammad Hashemi

*Dept. of Clinical Biochemistry,
School of Medicine,
Zahedan University of Medical Sciences,
Zahedan,
Iran*

Dr. Hesham, Abd El-Latif

*Genetics Department,
Assiut University, Assiut 71516,
Egypt.*

Prof. Jia-ying Xin

*College of Food Engineering
Harbin University of Commerce
138 Tongda Road
Daoli District
Harbin 150076, Heilongjiang
P.R.China*

Dr. Kabir Mohammad Humayun

*Plant Molecular Biotech Lab
Department of Medical Biotechnology
College of Biomedical Science
Kangwon National University
Kangwon-do, Chuncheon, 200-701
South Korea*

Dr. Kalpesh Gaur

*Geetanjali College of Pharmaceutical Studies Manwa
Khera,
Udaipur- 313002. Rajasthan,
India*

Dr. Meganathan, Kannan

*Center for Biologics Evaluation and Research (CBER),
U.S. Food and Drug Administration (FDA),
Bldg. NIH 29A, Room 2C-10,
8800 Rockville Pike,
Bethesda, MD 20892.
USA.*

Assist. Prof. Ali Karadeniz

*Department of Physiology,
Faculty of Veterinary Medicine,
University of Atatürk 25240 ERZURUM
Turkey*

Dr. Matthew Kostek

*Department of Kinesiology
University of Connecticut
Storrs CT*

Dr. Tansu Kucuk

*Gulhane School of Medicine
Department of Obstetrics and Gynecology
Etlik 06018 Ankara,
Turkey*

Dr. Kuo-Sheng Hung

*Department of Neurosurgery
Taipei Medical University - Wan Fang Medical Center
111 Section 3, Hsing-Long Rd,
Taipei 116,
Taiwan*

Dr. V. Manju

*Department of Biochemistry,
Periyar University,
Salem -11.*

Dr. Mbagwu Ferdinand Nkem

*Department of Plant science and Biotechnology,
Faculty of Science,
Imo State University
Nigeria.*

Dr. Anand Pithadia

*Parul Institute of Pharmacy
Vadodara, Gujarat,
India*

Dr. Radhakrishnan Ramaraj

*Department of Internal Medicine
University of Arizona
Tucson 85724
AZ*

Dr. M. Rasool

*School of Bio Sciences and Technology,
VIT University,
Vellore-632104, Tamil Nadu,
India*

Dr. Reda A.I. Abou-Shanab

*Genetic Engineering & Biotechnology Research
Institute (GEBRI)
Mubarak City for Scientific Research and Technology
Applications
New Burg El-Arab City, Universities and Research
Institutes
Zone, P.O. 21934, Alexandria,
Egypt.*

Dr. MR. Pravin Babarao Suruse

*Department of Pharmaceutics
Sharad Pawar College of Pharmacy
Wanadongri, Hingna Road
Nagpur- 441 110. (M. S.)*

Dr. Jan Woraratanadharm

*GenPhar, Inc.,
Mount Pleasant,
SC*

Dr. Serap Yalin

*Mersin University Pharmacy Faculty
Department of Biochemistry, Mersin
Turkey*

Dr. YongYong Shi

*Bio-X Center,
Shanghai Jiao Tong University,
Hao Ran Building, 1954 Hua Shan Road,
Shanghai 200030,
PR China*

Dr. Jyotdeep Kaur

*Department of Biochemistry,
Post Graduate Institute of Medical Education and
Research (PGIMER),
Chandigarh*

Dr. Rajkumar

*Dept. Of Radiation Biosciences,
Institute of Nuclear Medicine and Allied Sciences
Brig. S.K. Mazumdar Road, Timarpur,
Delhi-110054
India*

Dr. Meera Sumanth

*Visveswarapura Institute of Pharmaceutical Sciences,
22nd Main, 24th Cross, B.S.K II stage,
Bangalore-560070
Karnataka,
India.*

Dr, Jai S. Ghosh

*Department of Microbiology,
Shivaji University,
Kolhapur 416004,
India*

Prof. Dr. Alaa H. Al-Charrakh

*Babylon University, College of Medicine.
Dept. of Microbiology
Hilla, Iraq*

ARTICLE

Genotype by environment interactions and grain yield stability of released and advanced Desi type chickpea (<i>Cicer arietinum</i> L.) genotypes in western Ethiopia	30
Biru Alemu, Kassahun Tesfaye, Teklehaimanot Haileselassie and Dagnachew Lule	

Full Length Research Paper

Genotype by environment interactions and grain yield stability of released and advanced Desi type chickpea (*Cicer arietinum* L.) genotypes in western Ethiopia

Biru Alemu^{1,3*}, Kassahun Tesfaye^{2,3,4}, Teklehaimanot Haileselassie⁴ and Dagnachew Lule⁵

¹Haro Sabu Agricultural Research Center, P. O. Box 010, Haro Sabu, Ethiopia.

²Ethiopian Institute of Biotechnology, Addis Ababa, Ethiopia.

³Department of Microbial, Cellular and Molecular Biology, Addis Ababa University, Ethiopia.

⁴Institute of Biotechnology, Addis Ababa University, Ethiopia.

⁵Oromia Agricultural Research Institute, Addis Ababa, Ethiopia.

Received 1 August, 2017; Accepted 14 October, 2017

Genotype by environment interaction (G×E) obstructs breeding by persuading variations in genotype performance in different environments and thereby complicating selection. The aim of the present study was to determine the stability and yield performance of desi type chickpea varieties and advanced lines at multiple growing environments of western Ethiopia, using genotype-by-environment interaction (GGE) biplot analysis and AMMI model to find stable high yielding cultivar(s) and ratify for wider production. The experiment was laid out in a randomized complete block design with three replicates. The analysis of variance (ANOVA) indicated highly significant differences ($P \leq 0.01$) for environments, genotypes and importantly genotype by environment interaction (G×E). Additive main effects and multiplicative interactions (AMMI) and GGE biplot, AMMI Stability Value (ASV) and Genotype Selection Index (GSI) indices indicate that Natoli (G8) variety and DZ-2012-CK-20113-2-0042 (G16) advanced lines showed better grain yield with better stability across environments and thus are recommended for wider production in test locations and similarly agro-ecologies in Ethiopia.

Key words: Chickpea (*Cicer arietinum* L.), genotype-by-environment interaction (GGE) biplot, Additive main effects and multiplicative interactions (AMMI), AMMI stability value (ASV), genotype selection index (GSI), stability.

INTRODUCTION

Population growth, dwindling agricultural land, and climate change present increasing risks to crop production. The impact of these factors can simply be sensed in a country like Ethiopia where the overall economic growth is heavily dependent on the success

of the agriculture sector. Particularly, the importance of pulses such as chickpea (*Cicer arietinum* L.) cannot be overstated because of their significant role in sustaining food security, balancing ecosystem, and generating revenue (Getachew et al., 2015). Socioeconomically,

*Corresponding author. E-mail: birrollee@gmail.com. Tel: +251917096447.

chickpea is an essential staple crop in Ethiopia. It is the main food legume in the northern and central highlands of Ethiopia (Keneni et al., 2012). The country is a major producer and consumer of this legume next to Haricot bean. Annual production of 10.8464 tons has been recorded for 2015/2016 growing season of which 77.27% is used for home consumption (CSA, 2015).

The development of superior varieties in terms of grain yield, quality, stress resistance, and yield stability is an important consideration in plant breeding programs. Chickpea breeding programs in Ethiopia have been focused mainly on major abiotic and biotic stresses that adversely affect the yield of chickpea. However, genotype and environment interaction (G×E) hampers breeding by inducing variations in genotype performance in diverse environments and affecting selection (Zobel, 1990).

Different crops including chickpea are sensitive to environmental variations and hence the development of stable genotypes fixed with improved yield has become one of the alternatives to mitigate the effects of genotype by environment interaction (G×E), and making the recommendation of cultivars with such attributes more reliable (Zobel, 1990). Adaptability of any genotype is the product of the inherent capacity of genotype, the environmental factor in which a given genotype is raised and the interplay between the environment and genotype. Thus, the assessment of adaptability and stability parameters supports to define the response of genotypes to environmental variations, sketch realistic conclusion and solidifying the recommendation of new cultivars (Zobel, 1990). Consequently, multi- environmental yield trials are critical to detect adaptable high yielding cultivars and discover sites that best represent the target environment.

Through a series of time, various statistical models have been engaged in examining the adaptability and stability of genotypes over environments. However, traditional statistical models such as analysis of variance (ANOVA) flop to detect a significant interaction component, and principal component flops to detect and separate the significant effects of genotype by environment interactions (Flores et al., 1996). The linear regression model accounts only for a small portion of the interaction sum square (Yau, 1995).

Therefore, by indicating these deficits of traditional models, some authors suggested a model that integrates the analysis of variance and principal component analysis into an incorporated method (Gauch and Zobel, 1988; Crossa et al., 1990). In this regards, two multivariate models viz., additive main effects and multiplicative interaction models (AMMI) and the genotype plus genotype by environment interaction effect (G×E) model, is the most widely used analytical and statistical tools to determine the pattern of genotypic responses across diverse environments using different crops (Smith and Smith, 1992; Yan and Kang, 2002).

The aim of the present study was, therefore, to

determine the stability and yield performance of advanced Desi type chickpea varieties and advanced lines at multiple locations using GGE biplot analysis and AMMI model in order to identify stable high yielding cultivar(s) recommended for wider production in the test environments and similar agro-ecologies in Ethiopia.

MATERIALS AND METHODS

The experiment was conducted under field condition at five locations viz., Shambu, Hawa Galan, Mata, Alaku Belle and Badesso, western Ethiopia, during the 2016/17 main cropping season. A total of 16 desi type chickpea varieties viz., 8 cultivars released over three decades, 1 local variety and 7 advanced lines collected from Debre Zeit Agricultural Research Center (DZARC) were used (Table 1).

The experiment was laid out in a randomized complete block design with three replicates and plot size of 3 m length and 1.8 m width. All other crop management practices and recommendations were applied uniformly to all varieties as recommended for the crop.

Statistical analysis

Analyses of variance (ANOVA) was done for each environment and combined across environments using SAS (SAS Inc., 2002). The presence or absence of genotype by environment interactions (G×E) was determined from the combined analysis of variance (ANOVA) table. Bartlett's test of homogeneity was used to check the homogeneity of variances between environments before performing combined analyses of variance. Total variation attributed due to an environment, genotype, and genotype by environment interaction (G×E) was calculated from the sums squares of the analysis of variance (ANOVA) table.

Additive Main Effects and Multiplicative Interaction Model (AMMI) which help to envisage relationships among genotypes and environments by demonstrating both main and interaction effects was investigated using GenStat software (GenStat, 2012). Integrating biplot display and genotypic stability statistics allow genotypes to be grouped grounded on the similarity of a performance of each genotype across diverse environments.

AMMI method as described in Zobel et al. (1988) was used to analyze adaptability and phenotypic stability using the following statistical model:

$$y_{ij} = \mu + g_i + e_j + \sum_{k=1}^n \lambda_k \alpha_{ik} \gamma_{kj} + r_{ij} + \varepsilon_{ij}$$

Where, Y_{ij} is the yield of the i^{th} genotype in the j^{th} environment; μ is the grand mean; g_i and e_j are the genotype and environment deviations from the grand mean, respectively; λ_k is the eigenvalue of the PCA analysis axis k; α_{ik} and γ_{kj} are the genotypes and environment principal component scores for axis k; n is the number of principal components retained in the model and ε_{ij} is the error term.

AMMI stability value was used to determine stability value and rank of each genotype as given below (Purchase et al., 2000).

AMMI Stability Value (ASV)

$$= \sqrt{\left[\left(\frac{IPCA1SS}{IPCA2SS} \right) (IPCA1\ Score)^2 + (IPCA2\ Score)^2 \right]}$$

Stability was not merely selection parameter and therefore,

Table 1. Passport description of the Desi type chickpea varieties and advanced lines evaluated at multi-locations.

Genotype code	Genotype names	Status	Year of release
G1	Akaki	Released	1995
G2	Dalota	Released	2013
G3	Dimtu	Released	2012
G4	Dubie	Released	1978
G5	Local	Local variety	-
G6	Mariye	Released	1985
G7	Minjar	Released	2010
G8	Natoli	Released	2007
G9	Teketay	Released	2013
G10	DZ-2012-CK-0032	Advanced line	-
G11	DZ-2012-CK-0034	Advanced line	-
G12	DZ-2012-CK-0233	Advanced line	-
G13	DZ-2012-CK-0237	Advanced line	-
G14	DZ-2012-CK-0312	Advanced line	-
G15	DZ-2012-CK-0313	Advanced line	-
G16	DZ-2012-CK-20113-2-0042	Advanced line	-

Table 2. Partitioning of the Explained Sum of square (SS) and Mean of square (MS) from AMMI analysis of variance for grain yield of 16 chickpea varieties evaluated at five environments.

Source of variation	DF	SS	Explained % SS	MS
Total	239	143.45	100	0.6
Treatments	79	113.08	78.83	1.43***
Genotypes	15	15.89	11.08	1.06***
Environments	4	79.62	55.50	19.9***
Block	10	10.62	7.40	1.06***
Interactions	60	17.56	12.25	0.29***
IPCA1	18	11.15	63.49	0.62***
IPCA2	16	3.41	19.40	0.21ns
Residuals	26	3.01	17.11	0.12
Pooled error	150	19.76		0.13

Genotype Selection Index (GSI) which combines both mean yield and stability in a single index has been introduced (Magari and Kang, 1993; Mohammadi et al., 2007; Mohammadi and Amri, 2008; Farshadfar, 2008). Genotype Selection Index (GSI) was calculated as:

$$\text{GSI} = \text{RASV} + \text{RY}$$

Whereas RASV is the rank of AMMI stability value and RY is the rank of mean grain yield of genotypes across environments.

GGE biplot was first coined by Gabriel (1971) and subsequently improved by (Zobel et al., 1988). The reason that makes GGE biplot preferred by plant breeders is that it can accommodate genotype and genotype by environment interaction concurrently to make meaningful decisions. Therefore, GGE biplot which is mostly useful for cultivar evaluation of the multi- environmental trial was computed as suggested by Yan and Kang (2002) as follows:

$$\hat{y}_{ij} = \mu + \alpha_i + \beta_j + \phi_{ij}$$

Whereas, \hat{y}_{ij} is the expected yield of genotype i in environment j , μ is the grand mean of all observations, α_i is the main effect of genotype i , β_j is the main effect of environment j , and ϕ_{ij} is the interaction between genotype i and environment j .

RESULTS AND DISCUSSION

AMMI analysis of variance (ANOVA) with the appropriate AMMI model was indicated in Table 2. The analysis of variance (ANOVA) indicated highly significant differences ($P \leq 0.01$) for environments, genotypes and importantly

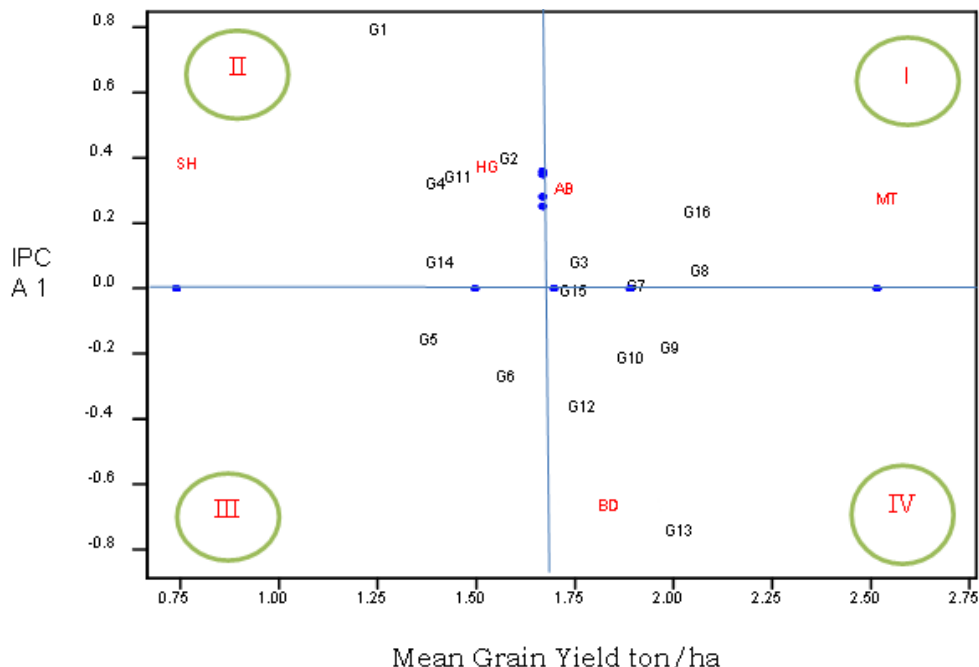


Figure 1. Biplot of interaction principal component axis (IPCA-1) against mean yield of chickpea varieties evaluated across five environments.

genotype by environment interaction (G×E).

The IPCA-1 axis of genotype by environment interaction (G×E) was also highly significant ($P \leq 0.01$). The first principal component managed over 63% of the genotype by environment interaction (G×E) sum squares while the second principal component revealed 19% of the interaction, and the remaining 17% is due to residual (noise) and it is difficult to interpret and thus need to be discarded. Different authors suggest the importance of apprehending most of the genotype by environment interaction (G×E) sum squares in the first axis, to attain accurate information (Gauch and Zobel, 1988; Zobel et al., 1988; Crossa et al., 1990; Purchase et al., 2000).

The most striking piece of AMMI analysis is the construction of biplot graphs, by combining the analysis of variance with multivariate analysis through principal component analysis. There is two basic AMMI biplot, that is, AMMI 1 biplot, which is the main effect (Genotype and Environment means) and IPCA-1 scores which are plotted against each other, and AMMI 2 biplot where scores of IPCA-1 and IPCA-2 are plotted against each other (Shafii et al., 1992). Only the first IPCA-1 explaining 63% of the total genotype by environment interaction (G×E) was significant in the AMMI analysis of variance, demonstrating that the AMMI model-1 was the best fit for this data set. Stability of genotypes over environments is foretold by IPCA scores of a genotype in the AMMI analysis.

The greater and lesser the IPCA scores of the genotypes to the origin of the axis, the more designated

are the instability of genotype and stability of genotype, respectively. That is the more the IPCA scores approximate to zero, the more stable the genotype is all over the environments sampled (Purchase et al., 2000). In another word, the ideal genotype is one with high productivity and IPCA-1 values close to zero and undesirable genotype has low stability associated with low productivity (Kempton, 1984; Gauch and Zobel, 1988). In the AMMI-1 biplot display, genotypes or environments that fall on a perpendicular and horizontal line of the graph had similar mean yield and similar interaction, respectively. On the other hand, genotypes or environments on the left and right-hand side of the midpoint line have less and higher yield than the grand mean, respectively. The score and sign of IPCA-1 reflect the magnitude of the contribution of both genotypes and environments to genotype by environment interaction (G×E), where scores near zero are the characteristic of stability and a higher score (absolute value) designate instability and specific adaptation to a certain environment (Gollob, 1968).

The characterization of each promising lines (genotypes) to mean grain yield and contribution to genotype by environment interaction (G×E) by mean of IPCA-1 indicated that genotypes Natoli (G8), and DZ-2012-CK-20113-2-0042 (G16) were specifically adapted to high yielding environments Mata (MT) and Alaku Belle (AB) having a grain yield more than grand mean yield (Figure 1). But with respect to their contribution to genotype by environment interaction (G×E) (the IPCA-1

Score, that is, stability), DZ-2012-CK-20113-2-0042 (G16) and Natoli (G8) were intermediately stable genotypes. However, Minjar (G7) and DZ-2012-CK-0237 (G15) were shown to have a higher stability for yield than any other genotypes because these genotypes were positioned near the origin of the biplot (Figure 1).

However, any genotype to be considered as best genotype should be able to combine good grain yield and stable performance across a range of production environments. In this regard, Natoli (G8) and DZ-2012-CK-20113-2-0042 (G16) were relatively high yielding and stable variety and pipeline genotype, respectively. On the other hand, Dalota (G2), Dubie (G4), DZ-2012-CK-0034 (G11) and DZ-2012-CK-0312 (G14) were adapted to the low-yielding environment and unstable. Local material (G5) and Mariye (G6) were poor yielder genotypes and also phenotypically unstable. Akaki (G1) and DZ-2012-CK-0237 (G13) were the most unstable genotypes but, the latter showed specific adaptation to Badeso (Figure 1).

Genotypes and environments positioned close to each other in the biplot have positive associations which enable us to create agronomic zones with relative ease. For instance, DZ-2012-CK-0237 (G13) had a peculiar adaptation to Badeso (BD) environment whereas G1 (Akaki) was comparatively better adapted to Shambu (SH) and Hawa Galan (HG) areas. The current results indicated that, even under very heterogeneous environments (be it due to soil character and other agro-ecological condition) cultivars with wide geographic adaptation and high productivity ($> 2\text{-ton ha}^{-1}$) were identified. Besides, suitable growing environments with better productivity were also identified for each variety and genotype tested in the present study.

The environments showed considerable variability in both additive main effects and interactions (Table 2). In AMMI biplot, environments are more dispersed than the genotypes demonstrating that variability due to environments is higher than the variation among the tested chickpea materials. This is fully in agreement with the analysis of variance indicated in Table 2. The contribution of the environments to the interaction is high for Badeso (BD) and intermediate for others. The average yield in environments Mata (MT), Alaku Belle (AB) and Badeso (BD) exceeded the grand mean (1.67-ton ha^{-1}).

The most potential environment Mata (MT) having positive IPCA-1 score showed a differential performance of genotypes for grain yield. The lowest yielding environment was Shambu (SH) with positive IPCA-1 score suggesting that, though all the genotypes poorly performed under this environment has a significant role in differentiating genotypes.

AMMI stability value (ASV) and genotype selection index (GSI)

AMMI stability value was also computed to determine a stability of the genotypes. Stability was not merely selection parameter and therefore, Genotype Selection Index (GSI) which combine both mean yield and stability in a single index (Mohammadi et al., 2007; Mohammadi and Amri, 2008) have been introduced to further detect high yielding genotypes with unswerving yield performance, through diverse growing environments.

In AMMI model, a genotype with least ASV score was seen as the most stable. Accordingly, genotypes Minjar (G7), DZ-2012-CK-0312 (G14), Dimtu (G3), Local variety (G5), Natoli (G8), Teketay (G9) and DZ-2012-CK-20113-2-0042 (G16) had general adaptation, while genotypes Akaki (G1), Dalota (G2), DZ-2012-CK-0233 (G12) and DZ-2012-CK-0237 (G13) were the most unstable and/or they are specifically adapted to certain environments (Table 3). This result was consistent with that of AMMI biplot.

Nevertheless, stable genotypes would not inevitably provide the best yield performance and hence identifying genotypes with high grain yield coupled with consistent stability across growing environments has paramount importance. In this regard, Genotype Selection Index (GSI) was utilized to further identify stable genotypes with better yield performance. Accordingly, Minjar (G7), Natoli (G8), DZ-2012-CK-20113-2-0042 (G16), Teketay (G9), and Dimtu (G3) were considered as most stable genotypes, whereas, Akaki (G1), Dalota (G2), Dubie (G4), Local variety (G5), Mariye (G6), DZ-2012-CK-0034 (G11), DZ-2012-CK-0233 (G12), and DZ-2012-CK-0237 (G13) were the least stable genotypes.

Genotype and Genotype by Environment interaction (GGE) biplot analysis

Environments and genotypes that fall in the central (concentric) circle are considered as an ideal environments and stable genotypes, respectively (Yan and Kang, 2002). In the present study, Mata (MT) was the most stable environment where variability between genotypes was minimum followed by Alaku Belle (AB) (Figure 3). Genotype-focused scaling biplot comparison revealed that Natoli (G8) fell in the central circle indicating its high yield potential and stability compared to the rest of the varieties and advanced lines evaluated in this study (Figure 2).

Besides, DZ-2012-CK-20113-2-0042 (G16), Teketay (G9) and Minjar (G7) are on the brink of the ideal cultivar and are, therefore, most desirable of all the other tested

Table 3. AMMI stability Value, Genotype selection index, yield rank and principal component axis.

Genotypes name	Mean	R. Yield	ASV	R. ASV	GSI	IPCA-1	IPCA-2
Akaki(G1)	1.23	15	2.52	16	31	0.77	0.04
Dalota(G2)	1.56	10	1.23	13	23	0.38	-0.08
Dimtu(G3)	1.74	7	0.28	3	10	0.06	-0.20
Dubie(G4)	1.38	12	1.02	11	23	0.30	0.33
Local variety(G5)	1.36	14	0.60	6	20	-0.18	0.10
Mariye(G6)	1.55	11	0.97	10	21	-0.30	-0.06
Minjar(G7)	1.88	5	0.21	1	6	-0.01	-0.20
Natoli(G8)	2.04	1	0.48	5	6	0.03	-0.47
Teketay(G9)	1.97	3	0.69	7	10	-0.20	0.16
DZ-2012-CK-0032(G10)	1.85	6	0.93	9	15	-0.24	0.51
DZ-2012-CK-0034(G11)	1.42	13	1.04	12	25	0.32	0.08
DZ-2012-CK-0233(G12)	1.73	8	1.26	14	22	-0.39	-0.02
DZ-2012-CK-0237(G13)	1.91	4	2.51	15	19	-0.76	-0.19
DZ-2012-CK-0312(G14)	1.37	13	0.25	2	15	0.06	0.17
DZ-2012-CK-0313(G15)	1.71	9	0.30	4	13	-0.03	0.28
DZ-2012-CK-20113-2-0042(G16)	2.02	2	0.82	8	10	0.21	-0.45

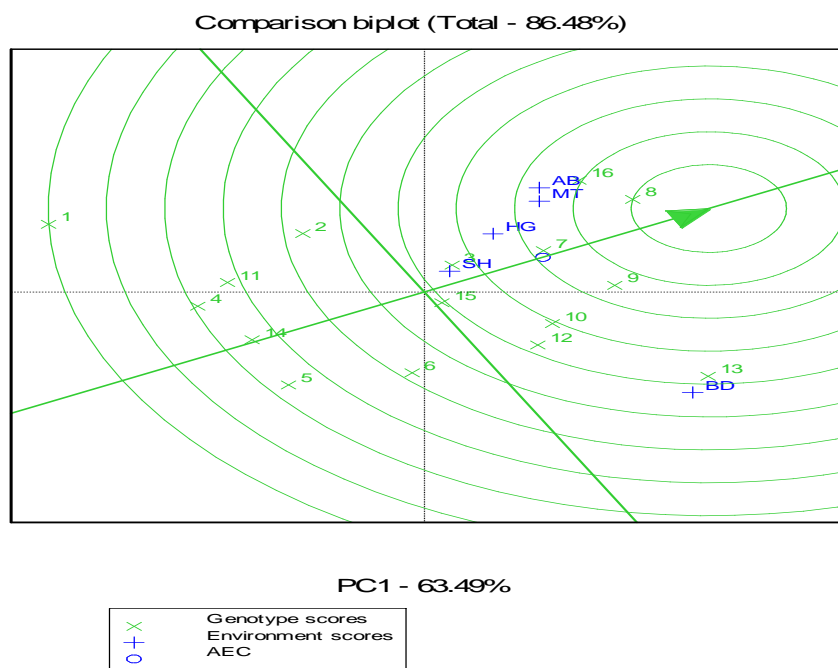


Figure 2. GGE biplot based on genotype-focused scaling for comparison of chickpea materials for their yield potential and stability.

cultivars. Most importantly, the genotype-focused scaling pattern of GGE biplot indicates that advanced pipeline genotype DZ-2012-CK-20113-2-0042 (G16) was desirable genotype in that, it has broad adaptability. This result agrees with that of AMMI biplot. The scenario is parallel to the environments too. An environment is desirable and discriminating when positioned nearer to

the center circle or nearer to an ideal environment in environment-focused GGE biplot (Dabessa et al., 2016). This study clearly discloses that Mata (MT), as the ideal environment and Alaku Belle (AB) and Hawa Galan (HG) as desirable environments discriminating and representative environment. On the other hand, Badesso (BD) was positioned distant from centric circle and

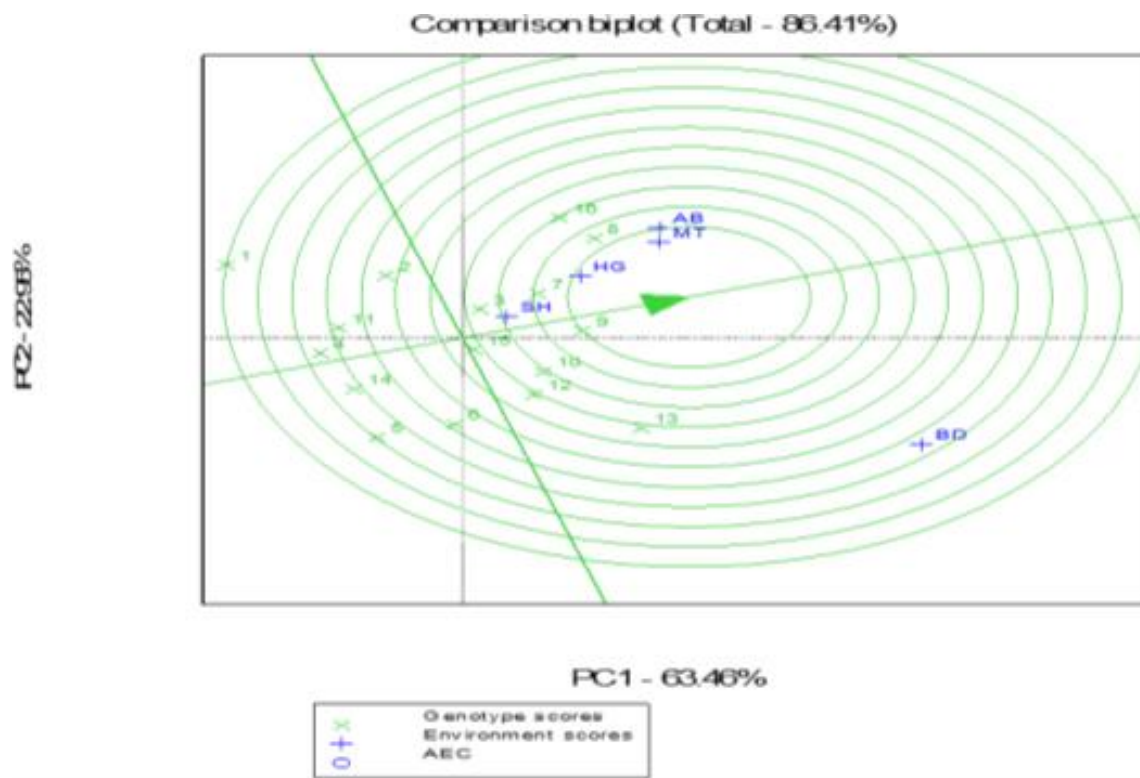


Figure 3. GGE biplot based on environment-focused scaling for comparison of test environment.

therefore, it is not an ideal environment.

Conclusion

The AMMI model analysis of variance (ANOVA) for grain yield displayed that genotypes, environments, genotype by environment interaction ($G \times E$), and interaction principal component axis (IPCA-1) were significant. Thus, grain yield and the first principal component axis were used to construct a biplot graphs because of its significant contribution to the genotype by environment interaction ($G \times E$). A graphical interpretation of the AMMI analysis, GGE biplot and GSI index incorporating with the ASV and the yield capacity of the different genotypes in a single non-parametric index, were useful for discriminating genotypes with superior and stable grain yield.

Generally, the current results indicated that, based on yield performance, AMMI and GGE biplot, ASV and GSI indices DZ-2012-CK-20113-2-0042 (G16) and Natoli (G8) variety showed better grain yield with better stability across environments and thus are recommended for wider production in test locations and similar agro-ecologies. To sum up both yields, stability should be considered concurrently to recommend any varieties for wider production and thus reducing the impact of genotype by environment interaction ($G \times E$) and

drawing a realistic conclusion for growers.

CONFLICTS OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The authors would like to thank PEER grant scheme (USAID) project for financial support and collaborators at Bako and Haro Sabu Agricultural Research Center, who contributed greatly during the carrying out of the research and exceptionally, our thanks are due to Merara Gidisa, field assistant of Bako Agricultural Research Center (BARC), at Shambu. We are grateful to Debre Zeit Agricultural Research Center (DZARC) for the provision of testing germplasms.

REFERENCES

- Crossa J, Gauch HG, Zobel RW (1990). Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. *Crop Sci.* 30(3):493-500.
- Central Statistical Agency (CSA) (2015). Crop and livestock product utilization. *Statistical Bulletin.* Central Statistical Agency (CSA), Addis Ababa, Ethiopia.
- Dabessa A, Alemu B, Abebe Z, Lule D (2016). Genotype by Environment

- Interaction and Kernel Yield Stability of Groundnut (*Arachis hypogaea* L.) Varieties in Western Oromia, Ethiopia. *J. Agric. Crops* 2(11):113-120.
- Farshadfar E (2008). Incorporation of AMMI stability value and grain yield in a single non-parametric index (GSI) in bread wheat. *Pak. J. Biol. Sci.* 11(14):1791.
- Flores F, Moreno MT, Martinez A, Cubero JI (1996). Genotype-environment interaction in Faba Bean: Comparison of AMMI and principal coordinate models. *Field Crops Res.* 47(23):117-127.
- Gabriel KR (1971). The biplot graphic display of matrices with application to principal component analysis. *Biometrika* 58(3):453-467.
- Gauch HG, Zobel RW (1988). Predictive and postdictive success of statistical analyses of yield trials. *Theor. Appl. Genet.* 76(1):1-10.
- GENSTAT (2012). GenStat Statistical Software, version 15.01. GenStat CO, UK.
- Getachew T, Firew M, Asnake F, Million E (2015). Genotype x environment interaction and stability analysis for yield and yield related traits of Kabuli-type Chickpea (*Cicer arietinum* L.) in Ethiopia. *Afr. J. Biotechnol.* 14(18):1564-1575.
- Gollob HF (1968). A statistical model which combines features of factor analytic and analysis of variance techniques. *Psychometrika* 33(1):73-115.
- Kempton RA (1984). The use of biplots in interpreting variety by environment interactions. *J. Agric. Sci.* 103(1):123-135.
- Keneni G, Bekele E, Imtiaz M, Dagne K, Getu E, Assefa F (2012). Genetic diversity and population structure of Ethiopian chickpea (*Cicer arietinum* L.) germplasm accessions from different geographical origins as revealed by microsatellite markers. *Plant Mol. Biol. Report.* 30(3):654-665.
- Magari R, Kang MS (1993). Genotype selection via a new yield-stability statistic in maize yield trials. *Euphytica* 70(1):105-111.
- Mohammadi R, Abdulahi A, Haghparast R, Aghaee M, Rostae M (2007). Nonparametric methods for evaluating of winter wheat genotypes in multi-environment trials. *World J. Agric. Sci.* 3(2):137-242.
- Mohammadi R, Amri A (2008). Comparison of parametric and non-parametric methods for selecting stable and adapted durum wheat genotypes in variable environments. *Euphytica* 159(3):419-432.
- Purchase JL, Hatting H, Van Deventer CS (2000). Genotypex environment interaction of winter wheat (*Triticum aestivum* L.) in South Africa: II. Stability analysis of yield performance. *South Afr. J. Plant Soil* 17(3):101-107.
- SAS Institute (2002). SAS/STAT guide for personal computers, version 9.0 edition. SAS Institute Inc., Cary, NC, USA.
- Shafii B, Mahler KA, Price WJ, Auld DL (1992). Genotype X Environment Interaction Effects on Winter Rapeseed Yield and Oil Content. *Crop Sci.* 32(4):922-927.
- Smith MF, Smith A (1992). The success of the AMMI model in predicting Lucerne yields for cultivars with differing dormancy characteristics. *South Afr. J. Plant Soil* 9(4):180-185.
- Yan W, Kang MS (2002). GGE Biplot Analysis: A graphical tool for breeders, geneticists, and agronomists. CRC press.
- Yau SK (1995). Regression and AMMI analyses of genotypex environment interactions: An empirical comparison. *Agron. J.* 87(1):121-126.
- Zobel RW, Wright MJ, Gauch HG (1988). Statistical analysis of a yield trial. *Agron. J.* 80(3):388-393.
- Zobel RW (1990). A powerful statistical model for understanding genotype by environment interaction. *Genotype-by-Environment Interaction and Plant Breeding* (MS Kang, ed.). pp. 126-140.

International Journal for Biotechnology and Molecular Biology Research

Related Journals Published by Academic Journals

- *African Journal of Environmental Science & Technology*
- *Biotechnology & Molecular Biology Reviews*
- *African Journal of Biochemistry Research*
- *African Journal of Microbiology Research*
- *African Journal of Pure & Applied Chemistry*
- *Journal of Cell and Animal Biology*
- *African Journal of Biotechnology*
- *Scientific Research and Essays*

academicJournals