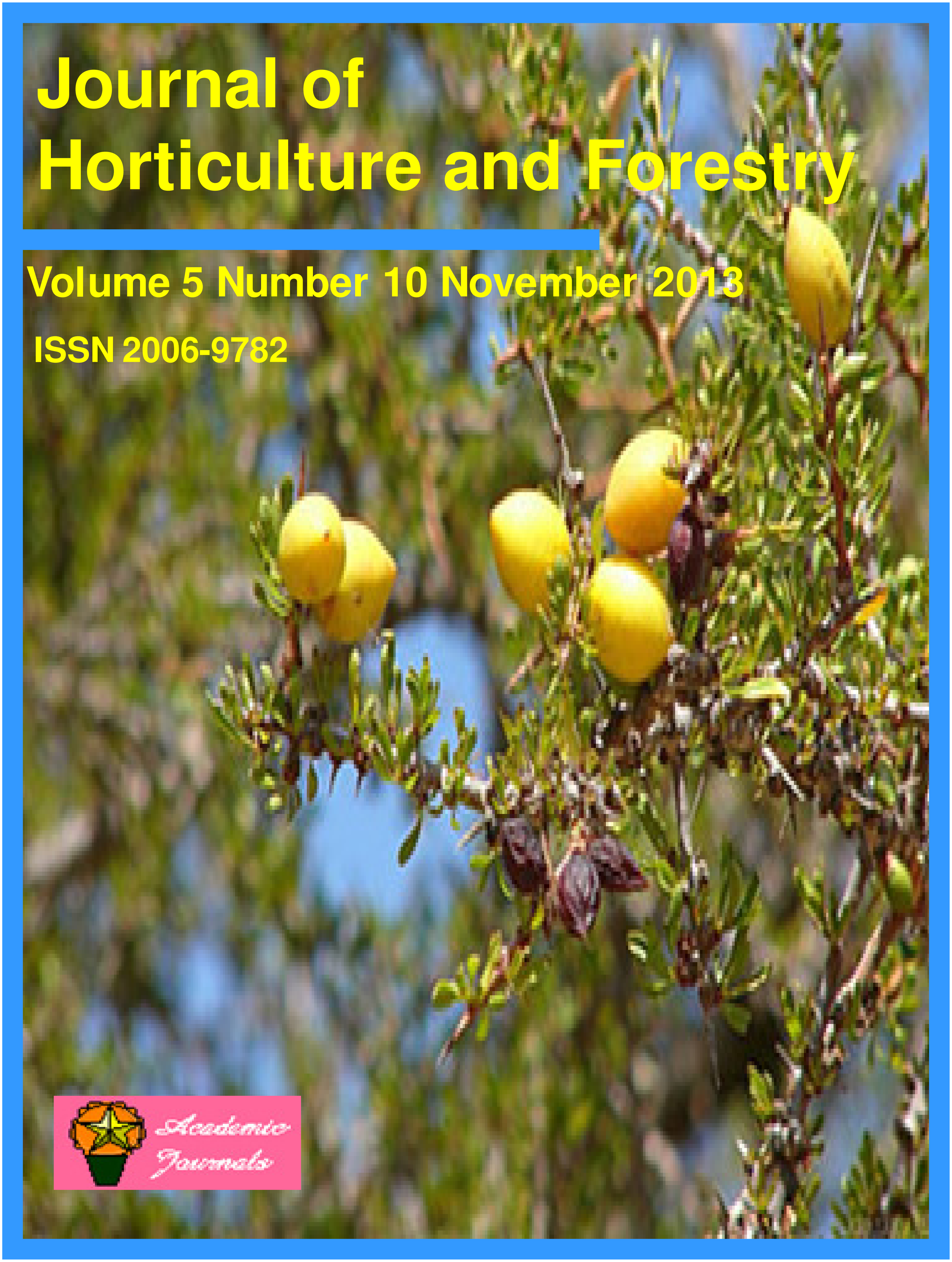
Journal of Horticulture and Forestry

Volume 5 Number 10 November 2013

ISSN 2006-9782



Academic Journals

ABOUT JHF

The **Journal of Horticulture and Forestry (JHF)** is published monthly (one volume per year) by Academic Journals.

Journal of Horticulture and Forestry (JHF) is an open access journal that provides rapid publication (monthly) of articles in all areas of the subject such as Arboriculture, Plant growth by hydroponic methods on straw bales, Postharvest physiology of crops, Permaculture 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 JHF are peer-reviewed.

Submission of Manuscript

Submit manuscripts as e-mail attachment to the Editorial Office at: jhf@academicjournals.org. A manuscript number will be mailed to the corresponding author shortly after submission.

The Journal of Horticulture and Forestry will only accept manuscripts submitted as e-mail attachments.

Please read the **Instructions for Authors** before submitting your manuscript. The manuscript files should be given the last name of the first author.

Editors

Dr. Hamdino M.I. Ahmed
Horticulture Research Institute,
9 Gamaa Street, Giza 12619,Giza
Egypt

Dr. Amanullah Khan
Khyber Pakhtunkhwa Agricultural University
Peshawar
Department of Agronomy, Faculty of Crop
Production Sciences,
Khyber Pakhtunkhwa Agricultural University
Peshawar-25130
Pakistan.

Dr. Fahrettin Tilki
Artvin Coruh University
Faculty of Forestry
08000-Artvin,
Turkey

Dr. Peter Fredenburg
Freewheel Media
2D Samtoh Building
386 Queens Road West
Sai Ying Pun,
Hong Kong

Dr. Deepu Mathew
Kerala Agricultural University
Tavanur - 679 573,
India

Dr. Magdi Tawfik Abdelhamid
National Research Centre
Botany Department
Al-Behooth street, Dokki, Cairo,
Egypt

Dr. Ricardo Aroca
Dpto. Microbiología del Suelo
Estación Experimental del Zaidín (CSIC)
Profesor Albareda 1
18008 Granada
Spain

Prof. Paul K. Baiyeri
Department of Crop Science,
Faculty of Agriculture,
University of Nigeria, Nsukka,
Nigeria

Dr. Süleyman Korkut
Düzce University, Faculty of Forestry
Department of Forest Industrial Engineering
81620 Beciyorukler Campus, Duzce
Turkey

Prof. Shahrokh Khanizadeh
430 Gouin, St Jean sur Richelieu, Quebec,
Canada

Dr. Geoff Sellers
Research Fellow Agronomy Institute
UHI Orkney College Kirkwall
Orkney KW15 1LX

Prof. Festus K. Akinnifesi
Regional Coordinator & Principal Scientist
World Agroforestry Centre
(International Centre for Research in Agroforestry,
ICRAF)
Southern Africa Regional Programme
Chitedze Agricultural Research Station
Lilongwe,
Malawi

Dr. Xianmin Chang
Agronomy Institute, Orkney College
University of Highlands and Islands
East Road, Kirkwall, Orkney
UK

Dr. Alireza Iranbakhsh
Islamic Azad Univeristy,
Aliabad Katoul Branch, Aliabad Katoul,
Golestan
Iran

Dr. Anil Vyas
Microbial Biotechnology and Biofertilizer Laboratory,
Department of Botany
J. N. V. University,
Jodhpur -342005,
Rajasthan,
India.

Editorial Board

Dr. Gecele Matos Paggi
Federal University of Mato Grosso do Sul
Brazil

Dr. Mekou Youssoufa Bele
Center for International Forestry Research (CIFOR)
Central Africa Regional Office (CARO)
P.O.Box 2008, Messa.
Yaounde - CAMEROON

Dr Ugur Cakilcioglu
Firat University,
Faculty of Science and Arts,
Department of Biology
TURKEY

Dr Hare Krishna
Central Institute of Temperate Horticulture-Regional Station,
Mukteshwar-263 138, District- Nainital, Uttarakhand,
India

Dr. Zhonglian('Julie') Huang
Donald Danforth Plant Science Center
975 North Warson Road
St.Louis, MO 63132
USA

Dr. Gholamreza Sharifisirchi
Reza Sharifi-Sirchi
Biotechnology Department, Agriculture college,
Shahid Bahonar University-Kerman
Iran

Dr Ashwani Tapwal
Scientist
Rain Forest Research Institute (RFRI),
Ministry of Environment & Forests (GOI)
P.O. Box -136, Deovan, Jorhat-785 001,
Assam, Tanzania

Dr. Karim Hosni
School of Agriculture, Mograne,
Department of Agricultural Production, 1121, Zaghouan,
Tunisia

Dr. Jasper Abowei
Department of Biological Sciences,
Faculty of Science,
Niger Delta University, Wilberforce Island,
Bayelsa State
Nigeria

Dr. Hasan Turkez
Faculty of Science, Molecular Biology and Genetics Department,
Erzurum Technical University,
Erzurum, Turkey

Dr. Ricardo Aroca
Department of Soil Microbiology
Zaidín Experimental Station (CSIC)
Professor Albareda 1
18008 Granada
Spain

Dr. Maarit Kallio
Finnish Forest Research Institute
Vantaa Unit,
POB 18,
FI-01301 VANTAA
Finland

Dr. Iulian Costache
University of Craiova
Faculty of Agriculture and Horticulture
Department of Biology and Environmental Engineering
13 A. I. Cuza Street, 200583 Craiova,
Romania

Dr. Rajesh Kumar
Scientist C
Forest Protection Division
Rain Forest Research Institute (RFRI),
P.O. Box -136, Deovan, Jorhat-785 001,
Assam, India

Bharat Sharma Acharya
Ratnanagar 01, Chitwan, Nepal
Nepali

Dr. Subhasis Panda
Taxonomy & Biosystematics Laboratory
Post-Graduate Department of Botany
Darjeeling Govt. College
Darjeeling-734101
India

Dr. Kadiriye URUÇ PARLAK
Agri Ibrahim Cecen University
Science and Arts Faculty
Department of Biology
04100 Agri/TURKEY

Instructions for Author

Electronic submission of manuscripts is strongly encouraged, provided that the text, tables, and figures are included in a single Microsoft Word file (preferably in Arial font).

The **cover letter** should include the corresponding author's full address and telephone/fax numbers and should be in an e-mail message sent to the Editor, with the file, whose name should begin with the first author's surname, as an attachment.

Article Types

Three types of manuscripts may be submitted:

Regular articles: These should describe new and carefully confirmed findings, and experimental procedures should be given in sufficient detail for others to verify the work. The length of a full paper should be the minimum required to describe and interpret the work clearly.

Short Communications: A Short Communication is suitable for recording the results of complete small investigations or giving details of new models or hypotheses, innovative methods, techniques or apparatus. The style of main sections need not conform to that of full-length papers. Short communications are 2 to 4 printed pages (about 6 to 12 manuscript pages) in length.

Reviews: Submissions of reviews and perspectives covering topics of current interest are welcome and encouraged. Reviews should be concise and no longer than 4-6 printed pages (about 12 to 18 manuscript pages). Reviews are also peer-reviewed.

Review Process

All manuscripts are reviewed by an editor and members of the Editorial Board or qualified outside reviewers. Authors cannot nominate reviewers. Only reviewers randomly selected from our database with specialization in the subject area will be contacted to evaluate the manuscripts. The process will be blind review.

Decisions will be made as rapidly as possible, and the journal strives to return reviewers' comments to authors as fast as possible. The editorial board will re-review manuscripts that are accepted pending revision. It is the goal of the JHF to publish manuscripts within weeks after submission.

Regular articles

All portions of the manuscript must be typed double-spaced and all pages numbered starting from the title page.

The Title should be a brief phrase describing the contents of the paper. The Title Page should include the authors' full names and affiliations, the name of the corresponding author along with phone, fax and E-mail information. Present addresses of authors should appear as a footnote.

The Abstract should be informative and completely self-explanatory, briefly present the topic, state the scope of the experiments, indicate significant data, and point out major findings and conclusions. The Abstract should be 100 to 200 words in length.. Complete sentences, active verbs, and the third person should be used, and the abstract should be written in the past tense. Standard nomenclature should be used and abbreviations should be avoided. No literature should be cited.

Following the abstract, about 3 to 10 key words that will provide indexing references should be listed.

A list of non-standard **Abbreviations** should be added. In general, non-standard abbreviations should be used only when the full term is very long and used often. Each abbreviation should be spelled out and introduced in parentheses the first time it is used in the text. Only recommended SI units should be used. Authors should use the solidus presentation (mg/ml). Standard abbreviations (such as ATP and DNA) need not be defined.

The Introduction should provide a clear statement of the problem, the relevant literature on the subject, and the proposed approach or solution. It should be understandable to colleagues from a broad range of scientific disciplines.

Materials and methods should be complete enough to allow experiments to be reproduced. However, only truly new procedures should be described in detail; previously published procedures should be cited, and important modifications of published procedures should be mentioned briefly. Capitalize trade names and include the manufacturer's name and address. Subheadings should be used. Methods in general use need not be described in detail.

Results should be presented with clarity and precision. The results should be written in the past tense when describing findings in the authors' experiments. Previously published findings should be written in the present tense. Results should be explained, but largely without referring to the literature. Discussion, speculation and detailed interpretation of data should not be included in the Results but should be put into the Discussion section.

The Discussion should interpret the findings in view of the results obtained in this and in past studies on this topic. State the conclusions in a few sentences at the end of the paper. The Results and Discussion sections can include subheadings, and when appropriate, both sections can be combined.

The Acknowledgments of people, grants, funds, etc should be brief.

Tables should be kept to a minimum and be designed to be as simple as possible. Tables are to be typed double-spaced throughout, including headings and footnotes. Each table should be on a separate page, numbered consecutively in Arabic numerals and supplied with a heading and a legend. Tables should be self-explanatory without reference to the text. The details of the methods used in the experiments should preferably be described in the legend instead of in the text. The same data should not be presented in both table and graph form or repeated in the text.

Figure legends should be typed in numerical order on a separate sheet. Graphics should be prepared using applications capable of generating high resolution GIF, TIFF, JPEG or Powerpoint before pasting in the Microsoft Word manuscript file. Tables should be prepared in Microsoft Word. Use Arabic numerals to designate figures and upper case letters for their parts (Figure 1). Begin each legend with a title and include sufficient description so that the figure is understandable without reading the text of the manuscript. Information given in legends should not be repeated in the text.

References: In the text, a reference identified by means of an author‘s name should be followed by the date of the reference in parentheses. When there are more than two authors, only the first author‘s name should be mentioned, followed by ’et al‘. In the event that an author cited has had two or more works published during the same year, the reference, both in the text and in the reference list, should be identified by a lower case letter like ’a‘ and ’b‘ after the date to distinguish the works.

Examples:

Abayomi (2000), Agindotan et al. (2003), (Kelebeni, 1983), (Usman and Smith, 1992), (Chege, 1998; 1987a,b; Tijani, 1993,1995), (Kumasi et al., 2001)

References should be listed at the end of the paper in alphabetical order. Articles in preparation or articles submitted for publication, unpublished observations, personal communications, etc. should not be included in the reference list but should only be mentioned in the article text (e.g., A. Kingori, University of Nairobi, Kenya, personal communication). Journal names are abbreviated according to Chemical Abstracts. Authors are fully responsible for the accuracy of the references.

Examples:

Chikere CB, Omoni VT and Chikere BO (2008). Distribution of potential nosocomial pathogens in a hospital environment. Afr. J. Biotechnol. 7: 3535-3539.

Moran GJ, Amii RN, Abrahamian FM, Talan DA (2005). Methicillinresistant Staphylococcus aureus in community-acquired skin infections. Emerg. Infect. Dis. 11: 928-930.

Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). Microbiology: Concepts and Applications. McGraw-Hill Inc., New York, pp. 591-603.

Short Communications

Short Communications are limited to a maximum of two figures and one table. They should present a complete study that is more limited in scope than is found in full-length papers. The items of manuscript preparation listed above apply to Short Communications with the following differences: (1) Abstracts are limited to 100 words; (2) instead of a separate Materials and Methods section, experimental procedures may be incorporated into Figure Legends and Table footnotes; (3) Results and Discussion should be combined into a single section.

Proofs and Reprints: Electronic proofs will be sent (e-mail attachment) to the corresponding author as a PDF file. Page proofs are considered to be the final version of the manuscript. With the exception of typographical or minor clerical errors, no changes will be made in the manuscript at the proof stage.

Fees and Charges: Authors are required to pay a $550 handling fee. Publication of an article in the Journal of Horticulture and Forestry is not contingent upon the author's ability to pay the charges. Neither is acceptance to pay the handling fee a guarantee that the paper will be accepted for publication. Authors may still request (in advance) that the editorial office waive some of the handling fee under special circumstances.

Submission of a manuscript implies: that the work described has not been published before (except in the form of an abstract or as part of a published lecture, or thesis) that it is not under consideration for publication elsewhere; that if and when the manuscript is accepted for publication, the authors agree to automatic transfer of the copyright to the publisher.

Disclaimer of Warranties

In no event shall Academic Journals be liable for any special, incidental, indirect, or consequential damages of any kind arising out of or in connection with the use of the articles or other material derived from the JHF, whether or not advised of the possibility of damage, and on any theory of liability.
This publication is provided "as is" without warranty of any kind, either expressed or implied, including, but not limited to, the implied warranties of merchantability, fitness for a particular purpose, or non-infringement. Descriptions of, or references to, products or publications does not imply endorsement of that product or publication. While every effort is made by Academic Journals to see that no inaccurate or misleading data, opinion or statements appear in this publication, they wish to make it clear that the data and opinions appearing in the articles and advertisements herein are the responsibility of the contributor or advertiser concerned. Academic Journals makes no warranty of any kind, either express or implied, regarding the quality, accuracy, availability, or validity of the data or information in this publication or of any other publication to which it may be linked.

Journal of Horticulture and Forestry

Table of Contents: Volume 5 Number 10 November 2013

ARTICLES

Review

Research Articles

academicJournals

Vol. 5(10), pp. 156-159, November, 2013
DOI 10.5897/JHF11.055
ISSN 2006-9782 © 2013 Academic Journals
http://www.academicjournals.org/JHF

Journal of Horticulture and Forestry

Review

Agroforestry practices and concepts in sustainable land use systems in Nigeria

Alao, J. S.[1]* and Shuaibu, R. B.[2]

[1]Department of Social and Environmental Forestry, College of Forestry and Fisheries, University of Agriculture, Makurdi, P. M. B. 2373, Makurdi, Nigeria.
[2]Department of Forestry and Wildlife Management, Faculty of Agriculture and Agricultural Technology, Federal University , P. M. B. 5001, Dutsin-Ma, Katsina State, Nigeria.

Accepted 23 August, 2013

Agroforestry has been defined as a dynamic ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. This paper highlighted Agroforestry practices and concepts in sustainable land use systems. The benefit derivable from the interface between forest trees and agricultural crops are enormous. They include the optimal use of land for both agricultural and forestry production on a sustainable basis including the improvement of the quality of soil. This is in addition to the socio-economic benefits that are accruable from agroforestry. Indeed the advantage of agroforestry is all encompassing and germane to a sustainable production system and livelihood.

Key words: Agroforestry, practices, concepts, sustainable, land use systems.

INTRODUCTION

Agroforestry practices offer practical ways of applying various specialized knowledge and skills to the development of sustainable rural production systems. Agro-forestry is recognized as a land use option in which trees provide both products and environmental services. In agroforestry systems, the trees grown on different farmlands in the same locality when aggregated can bring about improved wooded situation thereby enhancing environmental protection (Otegbeye, 2002).

In most agroforestry systems, the trees grown do not have the usual silivicultural recommendations in terms of spacing (Owonubi, 2002). Given the reality of awareness among the farmers of multiple land use management, the need to improve on the existing agroforestry practices becomes necessary in the face of increasing population and limited nature of land.

Rural people have been discovered to have a wealth of indigenous knowledge and have incorporated trees in production systems in areas where they lived for a very long period of time (Evans and Alexander, 2004). Agroforestry has both protective and social-economic benefit. Kang (1993) reported that besides direct agricultural benefit, trees exhibit social - economic values. The benefit of the tree components derived by farmers from agroforestry was evaluated from a social-economic and ecological perspective (Anderson and Sinclair, 1993). The social - economic benefits of agroforestry can be evaluated in terms of productivity, stability and sustainability.

The objective of this paper is to highlight the importance and concepts of Agroforestry as a veritable tool in sustainable land use systems.

*Corresponding author. E-mail: alaojs@yahoo.com. Tel: +234 (0) 8062078098.

Table 1. Agroforestry practices among farmers in Lafia Local Government Area, Nasarawa State, Nigeria.

Types of agroforestry practices	Lafia North	Lafia South	Lafia West	Lafia East	Respondents	Percentage
Row/hedges	11	8	6	5	30	25
Trees on farm land	2	4	6	7	19	15.8
Scattered trees on farmland	13	10	16	14	53	44.2
Wind break	4	8	2	4	18	15
Total	30	30	30	30	120	100

Source. Alao and Shuaibu (2011).

TYPES OF AGROFORESTRY SYSTEMS

There are various types of agroforestry systems, some of which are listed as follows:

1. Trees on farmland: The farmers plant or retain trees on their farmland, both for food, income, soil improvement and environmental amelioration and for shade during the harsh weather period.
2. Parkland also known as scattered trees: Parklands are characterized by well grown scattered trees on cultivated and recently fallowed land (CTA, 2003). These parklands develop when crop cultivation on a piece of land becomes more permanent. The trees are scattered far apart so that they do not compete with their neighbours. Parklands consist of indigenous trees like *Parkia biglobosa, Vitellaria paradoxa, Tamarindus indica, Azadirachta indica,* etc.

Parkland trees have the following characteristics:They are deep rooting, preferably reaching ground water table. They have capacity to fix nitrogen Produce litter that decomposes well and add as much as possible to soil organic matter.

3. Alley cropping as described by (CTA, 2003) is a system in which strips of annual crops are grown between rows of trees or shrubs. Lining up the woody plants in hedges should ensure that there is little interference with cultivation of the field. The extension of alley cropping to include animal husbandry by the International Livestock Research Institute (ILRI) has led to the concept of alley farming (Okali and Submerge, 1985).
4. Wind breakers and shelter belts. Their major purpose is primarily to control wind erosion. The species used include, *Azadirachta indica, Anacardium occidentale, Mangifera indica, Musa species, Khaya senegalenses,* etc.

Alao and Shuaibu (2011) have shown that these practices are commonly practiced by farmers as shown in Table 1.

CONCEPTS OF AGROFORESTRY

Agroforestry has been defined as a dynamic, ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (Leakey, 1996).

Agroforestry, generally refers to land used system or farming system in which trees or shrubs are grown in association with agricultural crops, pastures or livestock and in which there is ecological and economic interaction between the trees and other components. Agroforestry practice is a distinctive arrangement of components in space and time. It is a specific local example of a practice, e.g Taungya. It is characterized by environment, plant species, and arrangement, management, social and economic functions.

RANGE AND CLASSIFICATION OF AGROFORESTRY

The range and classification of agroforestry practices are the following.

Agro silvicultural

Agrosilviculture was aptly regarded as a variant of taungya to be practiced outside of forest reserve (Nwoboshi, 1982). It envisages multiple land use involving arable and tree crops, but the emphasis here is shifted to the agricultural crops which are of dominant interest. Indeed, agrosilviculture could be likened to shifting cultivation (Nwoboshi, 1982) except that the fallow vegetation is planted with economic trees whose gestation period is equivalent to the fallow period.

Silvo – pastoral

These are mostly trees with pastures and livestock. It is essentially the practice of animal production along with trees and pastures.

Shifting cultivation

Shifting cultivation was the farming system widely

Table 2. Uses and Importance of Agroforestry to farmers in Lafia Local Government Area, Nasarawa State, Nigeria.

Uses of trees	Respondents	Percentage
Additional income	23	19.2
Human nutrition	8	6.7
Reduce weeding	6	5
Fuel, stakes and timber	34	28.3
Shade for livestock	9	7.5
Medicinal herbs	4	3.3
Wind break	9	7.5
Soil improvement	27	22.5
Total	120	100

Source. Alao and Shuaibu, 2011.

embraced by peasants in the tropics in the past (Greenland, 1974). This form of farming is no longer common, because rapid population growth has increased food demand tremendously to the level that fallow periods had to be reduced and the forestry sector had to give way gradually to agricultural needs. This has led to un-precedented deforestation, lowering of soil productivity, loss of biodiversity, increased soil erosion and weed infestation, and consequently lowered crop yield (Okigbo, 1984a).

Unfortunately, the continued relying on expanding cultivated areas has not been able to contribute substantially to resolving the food crisis, because not all the available land is equally productive (Okigbo, 1984b). It is not even economical on the long run. Utilization levels of land and water resources are close to maximum potentials and future growth will be possible only through better management of a fixed resource base (Banuri and Holmberg, 1992).

Intensive rather than extensive use would be the way out of the log jam (Fagbemi, 1997). In order to achieve the twin goal of satisfying increasing demands for food as well as retain the biologically beneficial effects of shifting cultivation, many workers have in the last two decades advocated the development of land use systems based on age-old practices of intentionally mixing trees in crop animal production fields (Nwoboshi, 1980).

Mixed farming

Mixed farming system practiced by majority of the farming communities indicated the existence of traditional agroforestry system common in the semi-arid zones of Nigeria (Oboho, 1989). Integration of trees into farming system and subsequent modification of the system could be easy with earlier understanding of the importance of trees in the farming system. Similarly, the practice of animal production could make the intensification of fodder bank system an easily acceptable agroforestry model. With soil fertility, maintenance as the major problem of the farming system, adoption of appropriate agroforestry system will be easy. Hayashi et al. (1995) opined that since trees have traditional value and importance among the farmers in the agro-ecological zone the modification of their integration within the farming system could be readily adapted and accepted by the farmers. Fruits, fodder and fire wood species are common on the farmlands. Improvement on these species will make it readily acceptable.

ADVANTAGES OF AGROFORESTRY

It should be noted that the attempts being made under agroforestry are to optimize the use of land for agricultural production on a sustainable basis at the same time meeting other needs from forestry (Fagbemi, 2002). Nitrogen-fixing and non-nitrogen-fixing trees thrive adequately in agroforestry with annual crops, presents a farming system in which arable crop yields can be enhanced. The tree rooting system brings about stability that can lead to soil conservation. What is needed would be mutual interaction and proper management techniques that would reduce the adverse effects that may result when trees are integrated into agro-ecosystem (Connor, 1983).

Various authors (Kang et al., 1990; Young, 1986; Rocheleau and Dianne, 1987) were of the view that successful agroforestry practices benefits the farmers in the following ways:

a. Consistent restoration of the fertility status of the soil through the recycled litter deposition and nitrogen fixing mechanism of trees.
b. A variety of products, firewood, poles, woodcraft, fodder, medicinal herbs and food for livestock and man respectively.
c. Prevention of wind and water erosion by trees acting as wind break and intercepting the raindrop impact on the soil respectively.
d. Improving the micro-climate effect of the immediate and adjourning environment.
e. Restoration of water table to an absorbable level for crops use.
f. Increased income opportunities.
g. Increased economic stability
h. Reduce cost for establishing plantation
i. Increased ability to manage for sustained yield.

Also, Alao and Shuaibu (2011) from their studies have shown in Table 2, the inherent advantages in agroforestry accruable to farmers

CONCLUSION

The role of Agroforestry in sustainable land use system cannot be over emphasized. Agroforestry practices offer practical ways of applying various specialized knowledge and skills to the development of rural production systems. It evolves a synergy between agricultural production and forestry that is beneficial for increased food production, sustainable wood production and improvement of the quality of the soil. This is a win-win situation.

The advantages of Agroforestry are quite quantum. Agroforestry, among other benefits strive to optimize the use of land for agricultural production on a sustainable basis and at the same time meeting other needs from forestry.

REFERENCES

Alao JS, Shuaibu RB (2011). Agroforestry Practices and Preferential Agroforestry Trees among farmers in Lafia Local Government Area, Nasarawa State, Nigeria. Waste Management and Bioresource Technology 1(2)12-20. www.waoj.com

Anderson IS, Sinclair FL (1993). Ecological Interactions in Agroforestry Systems. Agroforestry Systems 6(2);58-61.

Banuri I, Holmberg J (1992). Governance for Sustainable Development: A Southern Perspective. Islamabad and London. P. 50.

Connor BJ (1983). Plant Stress Factors and Their Influence on Production of Agroforestry plant Association. In: Plant Research and Agroforestry (P.A. Huxley: ed) ICRAF, Nairobi, pp. 401-426.

CTA (2003). Agroforestry. Arbrus et Agricultures Multietagees D' Afrique. CTA, Wageningan, the Netherlands, P. 280.

Evans A, Alexander I (2004). Organic Farming Supports Biodiversity in Farming with Nature, Low external Input and Sustainable agriculture Amersfoort, the Netherlands. P. 36.

Fagbemi T (1997): Agroforestry for Sustaining Agricultural production in the Tropics. In: Strategies and Tactics of Sustainable Agriculture in the Tropics (M.A. Badejo and A.O. Togon, eds) STASAT 1:45-68.

Fagbemi T (2002). Investment Opportunities in Renewable Resources Industry-Forestry. 1st Edn., Belodan Press, Nigeria.

Greenland DS (1974). Evaluation and Development of Different types of Shifting Cultivation: In Shifting Cultivation and Soil Conservation in Africa. SIDA/FAO Soils Bull. 24:5-13.

Hayashi X, Carsky RJ, Ladipo DO (1995): Uses of Indigenous Tree Species in a Selected Area in the Northern Guinea Savanna of Nigeria. Nig. J. Forest. 26(1):14-21.

Kang BT, Reynolds L, Atta-krah AN (1990). Alley Farming advances in Agro-forestry. Agroforestry Sys. 43:315-359.

Leakey R (1996). Definition of Agroforestry Revisited. Agroforestry Today 8:1.

Nwoboshi LC (1980). Agroforestry and the Nigeria Food production Target. In: Food and Nutrition policy for Nigeria Eds: Atinmo and Akinyele. Ibadan University Press. pp. 117-124.

Nwoboshi LC (1982). Tropical Silviculture-Principles and Techniques. Ibadan University Press. P. 333.

Oboho EG (1989). Important Forest Products in the Semi-Arid Area of Sokoto State. In Forest Resources Development and the Sourcing of Local Raw Materials in Nigeria. Proceedings of the 19th Annual Conference of the Forestry Association of Nigerian. Eds: J.A Okojie and P.C Obiaga. pp. 33-38.

Okali C, Submerge JE (1985). Sheep and Goats, Men and Women: Household relations and small Ruminant Development in Southwest Nig. Agric. Sys. 18:39-45.

Okigbo BN (1984a) Improved Permanent Production Systems as an Alternative to Shifting Cultivation. In: Improved Permanent Production Systems as an Alternative to Shifting cultivation. FAO, Rome, Italy 53:1-100.

Okigbo BN (1984b). Cropping Systems and Rotations Development from Improving Shifting Cultivation and Related Intermittant Production Systems in Tropical Africa. In: Improved Permanent Production Systems as an Alternative to Shifting Cultivation. FAO, Rome, Italy 50:121-140.

Otegbeye GO (2002). Report on Agroforestry and Land Management Practices, Diagnostics Survey of Katsina State of Nigeria. May 2000, Katsina State Agricultural and Rural Development Authority.Katsina. P. 89.

Owonubi JJ (2002). Disappearing Forests: A Review of the Challenges for Conservation of Genetic Resources and Environmental Management. J. Forest. Res. Manage. 1:11-20.

Young A (1986). Effects of Trees on Soils. In Amelioration of soil by Trees. Commonwealth Science Council, Longon. Technical Publication 190:28-41.

academicJournals

Vol. 5(10), pp. 160-167, November, 2013
DOI 10.5897/JHF2013.0317
ISSN 2006-9782 © 2013 Academic Journals
http://www.academicjournals.org/JHF

Journal of Horticulture and Forestry

Full Length Research Paper

Influence of weather and growing environment on vegetable growth and yield

M. Rajasekar[1], **T. Arumugam**[1] **and S. Ramesh Kumar**[2]*

[1]Department of Horticulture, Agricultural College and Research Institute, TNAU, Madurai-625 104, Tamil Nadu, India.
[2]Department of Horticulture, Vanavarayar Institute of Agriculture, Manakkadavu, Pollachi-642 103, TNAU, Tamil Nadu, India.

Accepted 23 August 2013

An experiment was conducted at the Department of Horticulture, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India to screen ten vegetables for cultivation under shadenet house (33% shade) and open field for year round production of vegetables. Tomato, eggplant, chilli, cucumber, cluster bean, radish, amaranthus, coriander, bhendi and capsicum were grown in the summer and winter. The influence of environmental variables temperature, relative humidity and light intensity were studied. Tomato, eggplant, chilli, cucumber, radish, amaranthus and coriander registered better performance for growth and yield during both seasons. Cluster bean performed well in the open field during both seasons. Relative humidity was always higher under shadenet house than in open field during both seasons. Light intensity in the shadenet house was lower than in the open field. Mean weekly temperature during summer and winter were higher under open field conditions than in the shadenet house. Lower temperature caused plant height, number of branches, internodal length, average fruit weight and yield per plant to be higher in the shadenet house than in the open field. Hence, the growing of tomato, eggplant, chilli, cucumber, radish, amaranthus and coriander under shade house conditions will be more profitable irrespective of the seasons.

Key words: Shadenet cultivation, season, quality.

INTRODUCTION

Growing vegetable demand could be achieved through bringing additional area under cultivation crops, using hybrid crops, and adoption of improved agro-techniques. Protected cultivation of vegetables could be used to improve yield quantity and quality (Singh et al., 1999; Ganesan, 2004). Vegetables grown under field conditions are exposed to abiotic and biotic stress which affects productivity and quality. Protected cultivation has the potential to reduce biotic and abiotic stresses. A shadenet house can modify environmental conditions with reduced labor.

In southern India, the dry season is from April to June with a rainy season from June to October. In northern India the dry season is from April to July and the rainy season is from July to October (Ramesh and Arumugam, 2010). Winter is from November to February. Protected cultivation could possibly extend the growing season. Protected cultivation of vegetable crops suitable for domestic and export purposes could be a more efficient alternative for land use and other resources (Sanwal et al., 2004). However, profitability in protected cultivation depends upon the choice of structure, selection of crop,

*Corresponding author. E-mail: rameshamar06@gmail.com

Table 1. Mean values of weather parameters (crop period) recorded during summer and winter seasons.

Seasons	Parameters	Shade	Open	t-value	P-value
Summer	Temperature (°C)	32.06	34.20	5.19	1.64^{-5}
	Relative humidity (%)	59.50	52.60	7.93	1.21^{-8}
	Light intensity (lux)	25867.01	34044.45	3.78	0.0007
Winter	Temperature (°C)	30.10	32.85	7.63	2.59^{-8}
	Relative humidity (%)	67.10	59.42	9.12	7^{-10}
	Light intensity (lux)	18333.74	25867.01	3.34	0.002

selection of varieties, production technology and market price. The protected cultivation could solve the problem of low productivity during extreme weather conditions. Therefore, in the present scenario of perpetual demand for vegetables and drastically shrinking land holdings, protected cultivation of vegetable crops suitable for domestic as well as export purposes is the best alternative for using land and other resources more efficiently (Sanwal et al., 2004). To date, there is not much work available on shade net cultivation of vegetables. There is an urgent need to assess the cultivation and suitability of different vegetables under shade net house to meet the growing demand of the vegetables. Thus, the investigation was aimed to determine the efficacy of shadenet cultivation compared to open field on growth, yield of vegetables during summer and winter season.

MATERIALS AND METHODS

The present investigation was conducted at the Department of Horticulture, Agricultural Collage and Research Institute, Madurai, India, during 2010 and 2011. Areas of the shadenet house and open field plots were each 500 m^2. Tomato, cv. Lakshmi (NP 5005); chilli pepper, cv. Sierra (MHCP 317); eggplant, cv. MEBH - 11; bell pepper, cv. Radhika; Bhendi, cv. No-64; radish, cv. Pusa Chetki – Long; coriander, cv. Greengold; cluster-bean, cv. Haritima; cucumber, local type, and amaranthus, cv. Thandukeeri were used.

Experiments were arranged in randomized block design replicated three times. Ten plants were used in each replication. Standard horticultural practices (TNAU Crop Production Guide, 2013) and plant protection measures were followed. Soil inside the shade net house was turned to a depth of 20 to 25 cm. One month prior to planting, weeds and stubble were removed and the soil brought to a fine tilth by ploughing 3 to 4 times with cultivator. Fumigation was with 2% formaldehyde to control soil borne pathogens. After application of formaldehyde, the soil was covered with black polythene for one week and then removed. Application of the fungicides Topaz at 0.5 mL·L^{-1}, Tilt at 1 mL·L^{-1}, Ridomil MZ at 2 g·L^{-1} and of Vitavax at 2 g·L^{-1} was carried out for control of powdery mildew, dieback, fruit rot and sclerotium rot.

Air temperature, relative humidity and light were recorded from time of transplanting to last harvest in both shadenet house and open field. Temperature and relative humidity above the plant canopy was measured using a sensor in a temperature and humidity meter. The amount of light above the plant canopy was measured using a sensor in a TES Digital Light Meter (model 1332A). Growth and yield of vegetables were determined. The independent t-test was used to separate means.

RESULTS AND DISCUSSION

Growth, development, productivity and post-harvest quality of any crop largely depend on the interaction between the plant genetics and the environmental conditions under which they are grown. Every plant species has its own specific inherent characters (such as color, size, and growth rate, storability, cooking and processing qualities). Mean weekly temperature during summer and winter season were higher under open field than in the shadenet house (Table 1). The lower temperature increased plant height, number of branches, internodal length, average fruit weight and yield per plant were higher inside the shadenet house than in the open field condition. This agrees with findings of Ganesan (2004) and Ramesh and Arumugam (2010) under a polyhouse.

Influence of weather under shadenet and open field

The lowest yield of capsicum under open field might be due to high temperature. This agrees with Hawthron and Pollard (1957). Relative humidity was always higher under shadenet house than in open field during both seasons (Table 1). However, Nimje and Shyam (1993) observed that the relative humidity was higher inside the greenhouse than in the open field which influenced tomato growth and yield. The yield of sweet pepper was higher under shadenet house due to high relative humidity, which enhanced vegetative growth and improved fruit production. These results agree with findings of Priya et al. (2002a). Tomato, eggplant, capsicum, radish, amaranthus and coriander had higher yield under shadenet house due to light compensation for higher photosynthesis. Similar results were reported by Quaglitto (1976) and Priya et al. (2002b) in sweet pepper. Since, cluster bean, bhendi and cucumber are tropical crops, the requirement for light is more than chilli. This agrees with findings of Krishna-Mohan et al. (1993), who suggested that under 25% shade formation of photosynthates and their partitioning and distribution for the final sink were reduced resulting in poor yield in chilli. The light intensity in the shadenet house was lower than in the open field (Table 1). Kaname and Itagi (1973), Ganesan (2004), Ramesh and Arumugam (2010) found

Table 2. Influence of growing environments on growth and yield of tomato.

Tomato	Shadenet condition						Open condition					
	Mean		SD		t - value	P- value	Mean		SD		t - value	P- value
	Summer	Winter	Summer	Winter			Summer	Winter	Summer	Winter		
Plant height (cm)	150.25	200.69	18.17	8.37	13.80	5.19^{-17}	52.41	90.96	6.22	8.34	20.27	6.41^{-27}
Number of branches	19.79	14.36	4.52	3.21	5.35	1.95^{-6}	9.73	11.46	2.11	3.32	2.40	0.01
Number of leaves	599.63	1178.0	16.75	75.75	17.23	4.12^{-20}	254.83	370.0	10.00	41.00	5.82	9.81^{-7}
Internodal length(cm)	11.75	14.52	2.49	1.51	5.20	3.94^{-6}	6.96	9.54	1.04	0.81	10.64	2.87^{-15}
Earliness (days)	37.33	41.23	1.34	2.64	7.18	1.41^{-9}	28.46	30.53	1.47	2.08	4.43	4.17^{-5}
Fruit circumference(cm)	16.98	18.40	0.32	0.47	13.45	1.76^{-19}	15.96	15.04	0.26	0.52	8.52	8.14^{-12}
Number of fruits	58.36	73.10	4.38	5.44	11.54	2.56^{-16}	45.03	50.16	5.72	2.58	4.47	6.21^{-5}
Fruit weight (g)	100.92	106.50	4.07	4.10	5.27	2.02^{-6}	88.93	92.80	3.48	3.64	4.21	8.99^{-5}
Yield (kg / plant)	5.75	7.78	4.82	6.40	13.83	2.19^{-19}	3.19	4.65	5.11	2.75	6.96	1.31^{-8}
Chlorophyll content (%)	53.58	43.86	2.29	2.72	14.94	3.4^{-21}	49.55	50.71	2.25	3.43	1.54	0.12
Leaf area (mm^2)	6867.26	6679.97	1264.14	1436.66	0.53	0.59	1978.63	1929.01	350.92	433.08	0.48	0.62
Leaf area index	1.90	1.90	0.35	0.41	0.001	0.99	0.56	0.55	0.10	0.10	1.05	0.95

similar results for tomato cultivation under protected cultivation.

Influence of growing season/environment on growth and development of vegetables

Environment is the aggregate of all external conditions which influence growth and development of plants. Generally, crops are not profitable unless they are adapted to the region in which they are produced (Reddy et al., 1999). Among environmental factors, light intensity, temperature and relative humidity influence crop growth and development. Solar radiation consists of different wave-lengths of light, in which the visible portion is useful for crop growth; ultra-violet and infrared radiations are not beneficial for crop growth, as they change molecular levels which lead to cellular disorganization. Temperature is the major regulator of development processes. Higher temperatures have more adverse influence on net photosynthesis than lower temperatures leading to decreased production of photosynthates above a certain temperature (Reddy et al., 1999). Temperature can be controlled and regulated under protected conditions, and better growth of plants might be expected under protected culture. Relative humidity increases availability of net energy for crop growth and improves survival of crops under moisture stress conditions. Relative humidity reduces evaporation loss from plants which lead to optimum utilization of nutrients. It also maintains turgidity of cells which is useful in enzyme activity leading to a higher yield (Reddy et al., 1999).

The plant height, number of branches, number of leaves per plant, internodal length, leaf area and leaf area index were influenced by growing environment (Tables 2 to 11). In all, vegetables plant height was highest under shadenet house in both seasons compared to open field. This may be due to enhanced photosynthesis and respiration due to the favorable micro-climatic conditions in the shadenet house. This agrees with results of Ramesh and Arumugam (2010) on vegetables grown under poly house and Ryelski (1986) and El-Aidy et al. (1988) in sweet pepper under shadenet house. Numbers of branches per plant were higher under shadenet house in tomato, eggplant and chillies than in open field during both seasons. This might be due to the favorable micro-climatic conditions. Similar results were reported by Rylski (1986). Ramesh and Arumugam (2010) observed increases in numbers of branches per plant under poly house, in tomato, eggplant and chillies.

For cluster bean, bhendi and cucumber had more branches per plant in open field than in shadenet during both seasons (Tables 5, 6 and7). This indicates that this crop might require more light intensity and high temperature for better

Table 3. Influence of growing environments on growth and yield of eggplant.

Eggplant	Shadenet condition				t -value	P-value	Open condition				t-value	P- value
	Mean		SD				Mean		SD			
	Summer	Winter	Summer	Winter			Summer	Winter	Summer	Winter		
Plant height (cm)	127.43	131.73	5.59	4.46	3.28	0.001	91.2	99.87	5.63	6.38	5.57	7.04^{-7}
Number of branches	20.23	9.8	3.07	1.60	16.49	1.87^{-20}	15.13	10.4	2.09	1.77	9.44	2.50^{-13}
Number of leaves	165.43	150.03	16.04	11.04	4.33	6.9^{-56}	104.6	57.3	26.81	3.53	9.56	0.19^{-10}
Internodal length (cm)	9.98	12.34	0.72	0.93	10.93	2.0^{-155}	8.07	10.82	0.46	0.95	14.20	1.55^{-20}
Earliness (days)	36.63	42.90	7.51	1.91	14.02	8.23^{-20}	41.60	49.40	2.48	2.09	13.14	4.87^{-19}
Fruit circumference (cm)	13.91	15.64	0.52	0.67	11.06	1.30^{-15}	11.84	12.46	0.35	0.73	4.17	9.96^{-5}
Fruit length (cm)	11.88	12.68	0.35	0.53	6.88	4.57^{-9}	8.58	9.07	0.38	0.31	5.54	7.70^{-7}
Number of fruits	59.7	73.9	2.56	4.45	15.12	8.69^{-22}	48.36	53.93	2.78	4.26	5.98	1.45^{-7}
Fruit weight (g)	90.21	99.33	2.28	2.63	14.32	1.05^{-20}	88.45	88.79	2.52	1.94	0.58	0.56
Yield (kg/ plant)	4.86	7.34	1.86	4.92	25.76	1.90^{-33}	2.78	4.79	2.97	4.03	21.89	3.22^{-28}
Chlorophyll content (%)	39.33	35.96	1.69	1.35	8.49	9.13^{-12}	37.72	38.67	2.10	2.92	14.44	0.15
Leaf area (mm$^{2)}$	23538.03	22715.19	3168.16	2630.08	1.09	0.27	13327.17	12938.35	1005.72	1488.83	1.18	0.24
Leaf area index	6.55	6.53	0.88	1.15	0.001	0.99	3.77	3.75	0.31	0.51	0.20	0.83

Table 4. Influence of growing environments on growth and yield of chilli.

Chilli	Shadenet condition				t-value	P-value	Open condition				t -value	P-value
	Mean		SD				Mean		SD			
	Summer	Winter	Summer	Winter			Summer	Winter	Summer	Winter		
Plant height (cm)	83.43	158.99	18.27	8.86	20.37	2.15^{-23}	60.45	78.68	7.66	6.09	10.19	1.54^{-14}
Number of branches	14.63	10.5	2.91	1.65	6.74	2.18^{-8}	9.36	8.73	2.38	1.83	1.14	0.25
Number of leaves	202.86	515.56	8.34	18.75	83.45	2.34^{-46}	157.23	379.06	18.54	44.26	25.31	4.87^{-33}
Internodal length (cm)	7.78	13.83	1.32	1.55	16.21	5.12^{-23}	6.85	7.48	0.47	0.94	3.27	0.001
Earliness (days)	28.66	29.55	1.84	2.01	1.73	0.08	36.76	37.60	1.52	1.77	1.95	0.05
Fruit circumference (cm)	3.01	3.35	0.27	0.19	5.48	9.42^{-7}	2.81	2.18	0.18	0.15	14.22	1.45^{-20}
Fruit length (cm)	10.88	12.10	0.35	0.33	13.73	6.94^{-20}	8.85	12.10	0.31	0.33	38.81	3.39^{-43}
Number of fruits	78.76	115.53	3.03	9.49	20.19	6.36^{-28}	64.06	85.8	3.43	4.90	19.89	1.39^{-27}
Fruit weight (g)	10.07	10.58	0.39	0.56	4.04	0.0001	8.85	12.10	0.31	0.33	38.81	3.39^{-05}
Yield (kg / plant)	0.79	1.22	3.97	1.13	19.48	3.92^{-27}	466.25	721.84	26.82	48.00	25.45	3.62^{-33}
Chlorophyll content (%)	54.11	52.23	2.48	4.19	2.10	0.03	56.45	56.14	3.02	3.92	0.35	0.72
Leaf area (mm^2)	2132.1	2083.74	576.18	572.83	0.34	0.73	1003.1	975.97	79.52	134.65	0.95	0.34
Leaf area index	0.78	0.79	0.19	0.21	0.02	0.78	0.37	0.36	0.03	0.05	0.10	0.87

Table 5. Influence of growing environments on growth and yield of bhendi.

Bhendi	Shadenet condition				t - value	P-value	Open condition				t -value	P-value
	Mean		SD				Mean		SD			
	Summer	Winter	Summer	Winter			Summer	Winter	Summer	Winter		
Plant height (cm)	225.12	205.87	14.23	7.63	6.52	5.70^{-8}	173.52	136.39	7.61	9.75	16.43	6.99^{-23}
Number of branches	2.90	4043	0.71	1.07	6.52	1.84^{-8}	4.00	8.66	0.69	1.62	14.45	6.94^{-21}
Number of leaves	58.36	60.16	9.85	6.01	0.85	0.39	54.03	78.50	5.15	18.49	6.98	3.15^{-9}
Internodal length (cm)	15.87	13.19	1.02	0.90	10.74	2.06	14.67	8.74	0.52	0.95	29.66	9.57^{-37}
Earliness (days)	36.33	38.2	1.76	1.76	4.08	0.0001	42.43	45.36	2.31	1.37	5.96	3.03^{-7}
Fruit circumference (cm)	5.06	5.5	0.24	0.22	7.17	1.49^{-9}	4.72	4.98	0.16	0.28	4.21	8.93^{-5}
Fruit length (cm)	15.19	14.08	0.37	0.51	9.67	1.05^{-13}	13.82	11.85	0.28	0.37	22.81	2.14^{-29}
Number of fruits	49.76	45.26	2.26	6.88	3.40	0.001	46.76	64.7	1.61	16.49	5.92	1.79^{-7}
Fruit weight (g)	24.17	24.48	0.48	1.22	1.30	0.19	22.15	22.04	3.34	0.97	0.17	0.85^{-5}
Yield (kg / plant)	1.20	1.10	5.43	1.67	2.99	0.004	1.03	1.42	1.61	3.52	5.46	1.02^{-6}
Chlorophyll content (%)	52.00	50.23	1.83	5.03	1.81	0.07	46.28	54.78	1.18	5.28	8.59	6.19^{-12}
Leaf area (mm^2)	16770.13	6329.67	2558.42	2979.21	0.61	0.54	9459.1	8366.25	861.60	766.36	5.19	2.8^{-6}
Leaf area index	8.28	8.29	1.26	1.58	0.02	0.97	5.86	5.81	1.03	1.26	0.15	0.87

Table 6. Influence of growing environments on growth and yield of cucumber.

Cucumber	Shadenet condition				t - value	P- value	Open condition				t - value	P- value
	Mean		SD				Mean		SD			
	Summer	Winter	Summer	Winter			Summer	Winter	Summer	Winter		
Plant height (cm)	375.92	405.87	30.20	15.50	4.83	1.75^{-5}	345.76	366.81	27.68	27.89	2.93	0.004
Number of branches	8.75	10.6	2.35	1.40	3.8	0.0004	9.6	11.46	2.29	1.30	3.86	0.0003
Number of leaves	64.43	78.9	9.82	7.22	6.49	2.04^{-8}	54.66	58.76	8.15	4.78	1.21	0.22
Internodal length (cm)	13.68	10.6	2.07	1.40	6.74	1.38^{-8}	14.22	11.46	1.00	1.30	9.16	1.35^{-12}
Earliness (days)	33.46	37.26	2.19	1.74	7.43	5.47^{-10}	28.40	31.50	1.92	1.92	6.24	5.46^{-8}
Fruit circumference (cm)	14.54	14.60	1.31	1.32	0.17	0.86	12.93	12.26	0.65	0.44	4.62	2.59^{-5}
Fruit length (cm)	20.16	19.47	1.51	1.29	1.91	0.06	16.31	17.7	0.89	0.88	6.00	1.33^{-7}
Number of fruits	29.30	25.83	2.01	2.39	6.06	1.20^{-7}	26.96	21.40	2.17	2.02	10.25	1.19^{-14}
Fruit weight (g)	230.57	218.11	6.35	5.69	7.99	6.24^{-11}	215.46	208.56	4.08	5.50	5.50	1.08^{-6}
Yield (kg / plant)	6.75	5.63	4.85	5.39	8.45	1.23^{-11}	5.80	4.46	4.62	4.47	11.44	1.67^{-16}
Chlorophyll content (%)	38.14	37.48	3.48	3.55	0.72	0.47	29.34	35.78	2.63	3.94	7.43	5.54^{-10}
Leaf area (mm^2)	21119.43	20578.39	2220.05	3412.29	0.72	0.46	12696.77	11860.73	1318.77	945.97	2.82	0.006
Leaf area index	2.11	2.01	0.22	0.32	0.007	0.99	1.35	1.35	0.17	0.23	1.004	0.99

Table 7. Influence of growing environments on growth and yield of cluster bean.

	Shadenet condition						**Open condition**					
Cluster bean	**Mean**		**SD**		**t -value**	**P- value**	**Mean**		**SD**		**t - value**	**P-value**
	Summer	**Winter**	**Summer**	**Winter**			**Summer**	**Winter**	**Summer**	**Winter**		
Plant height (cm)	201.52	205.86	19.49	8.79	1.11	0.27	219.40	216.77	16.74	5.76	0.81	0.42
Number of branches	3.47	2.46	1.10	0.73	3.86	0.0003	3.96	3.06	1.03	0.98	3.46	0.001
Number of leaves	62.50	74.00	23.42	5.14	2.62	0.01	63.06	75.86	11.55	5.53	5.47	2.27^{-6}
Internodal length (cm)	6.28	6.16	0.71	0.30	0.82	0.41	8.53	6.91	1.26	0.29	6.81	1.06^{-7}
Earliness (days)	51.46	58.50	2.20	1.88	13.25	3.37^{-19}	43.6	49.46	3.37	1.92	7.64	1.53^{-9}
Fruit circumference (cm)	2.83	2.55	0.30	0.30	3.52	0.0008	3.00	2.79	0.23	0.19	3.89	0.0002
Fruit length (cm)	9.96	11.08	0.36	0.40	11.12	6.57^{-16}	10.14	12.02	0.69	0.51	11.91	3.15^{-17}
Number of fruits	103.66	96.23	6.05	5.27	5.07	4.36^{-6}	121.53	117.0	4.52	3.32	4.42	4.32^{-5}
Fruit weight (g)	5.89	5.74	0.36	0.20	1.95	0.05	6.04	5.99	0.32	0.22	0.64	0.51
Yield (kg / plant)	0.61	0.55	0.47	0.39	5.13	3.41^{-6}	0.73	0.70	0.45	0.35	0.31	0.002
Chlorophyll content (%)	58.39	55.89	4.54	3.60	2.35	0.02	55.42	52.96	3.22	3.56	2.80	0.006
Leaf area (mm^2)	15144.6	14700.79	1661.70	2023.44	0.92	0.35	9267.63	9007.84	1575.60	9760.89	0.60	0.54
Leaf area index	16.82	16.84	1.84	2.66	0.003	0.99	10.28	10.36	1.68	2.03	0.003	0.99

Table 8. Influence of growing environments on growth and yield of radish.

	Shadenet condition						**Open condition**					
Radish	**Mean**		**SD**		**t -value**	**P-value**	**Mean**		**SD**		**t -value**	**P-value**
	Summer	**Winter**	**Summer**	**Winter**			**Summer**	**Winter**	**Summer**	Winter		
Plant height (cm)	37.71	66.82	4.08	3.45	29.80	7.29^{-37}	22.95	39.11	3.48	3.38	18.34	8.00^{-26}
Number of leaves	15.2	14.73	2.29	1.36	0.95	0.34	13.46	10.32	2.48	1.55	5.91	3.22^{-7}
Fruit circumference (cm)	14.03	14.31	1.01	1.30	0.88	0.37	9.53	8.65	0.69	0.54	5.50	8.68^{-7}
Fruit length (cm)	25.26	26.91	3.20	3.95	1.77	0.08	15.13	16.65	13.5	1.54	4.04	0.0001
Fruit weight (g)	263.47	225.06	4.08	1.93	4.65	3.36^{-5}	179.33	146.99	18.99	5.26	8.98	2.19^{-10}
Yield (kg / plot)	22.31	25.70	26.02	29.01	4.76	1.33^{-5}	10.50	11.68	12.40	12.73	3.65	0.0005
Chlorophyll content (%)	33.84	34.89	8.00	3.76	0.64	0.51	30.09	31.94	3.14	4.42	1.86	0.06
Leaf area (mm^2)	19841.87	19290.25	1505.44	2453.43	1.04	0.29	11923.9	11550.03	1336.17	1433.98	1.044	0.300
Leaf area index	141.40	132.30	51.85	17.99	0.90	0.36	81.15	81.10	8.57	12.52	0.02	0.98

growth and development (Marcelis and Baan Hofman-Eijer, 1993). Numbers of leaves per plant was highest under shadenet house in all vegetables during summer and winter seasons. This might be due to taller plants, increased number of secondary branches and the beneficial micro-climate in the shadenet house. Similar results were reported by Nimje and Shyam (1993) in sweet pepper and eggplant. The maximum

Table 9. Influence of growing environments on growth and yield of amaranthus.

	Shadenet condition						Open condition					
Amaranthus	**Mean**		**SD**		**t -value**	**P- value**	**Mean**		**SD**		**t - value**	**P-value**
	Summer	**Winter**	**Summer**	**Winter**			**Summer**	**Winter**	**Summer**	**Winter**		
Plant height (cm)	67.366	88.09	3.56	4.60	19.19	4.78^{-26}	33.2	39.11	4.16	4.0	5.28	2.00^{-6}
Number of leaves	74.00	30.36	5.14	3.22	39.36	9.55^{-39}	18.5	20.33	2.78	1.95	2.94	0.004
Yield (kg/ plot)	16.76	25.58	19.18	28.80	13.95	3.42^{-20}	7.80	11.67	8.96	1.32	13.24	3.52^{-19}
Chlorophyll content (%)	27.85	25.87	1.79	2.21	3.79	0.0003	31.90	31.81	2.78	3.95	0.09	0.92
Leaf area (mm^2)	7061.7	6933.19	1528.19	1545.65	0.32	0.74	3191.26	3113.73	1069.43	1011.85	0.28	0.77
Leaf area index	23.54	23.55	5.09	5.79	0.001	0.99	10.63	10.64	3.56	3.78	0.003	2.00

Table 10. Influence of growing environments on growth and yield of coriander.

	Shadenet condition						Open condition					
Coriander	**Mean**		**SD**		**t -value**	**P- value**	**Mean**		**SD**		**t - value**	**P-value**
	Summer	**Winter**	**Summer**	**Winter**			**Summer**	**Winter**	**Summer**	**Winter**		
Plant height (cm)	26.95	33.97	3.58	2.46	8.83	7.37^{-12}	NA	24.11	NA	NA	NA	NA
Number of leaves	53.9	172.96	6.21	6.74	71.07	4.14^{-58}	NA	74.00	NA	NA	NA	NA
Yield (kg / plot)	15.63	19.61	18.08	22.26	7.58	3.77^{-10}	NA	8.70	NA	NA	NA	NA
Chlorophyll content (%)	29.11	28.12	1.90	2.71	1.63	0.10	NA	28.65	NA	NA	NA	NA
Leaf area (mm^2)	999.13	979.36	226.58	269.76	0.30	0.75	NA	532.30	NA	NA	NA	NA
Leaf area index	3.33	3.34	0.75	0.85	0.05	0.95	NA	1.80	NA	NA	NA	NA

NA, Not available.

internodal length was under shadenet house in bhendi during summer, while cucumber had the highest internodal length during winter under shadenet house. This finding agrees with Ramesh and Arumugam (2010) under poly house condition. Earliness in was under shadenet house during summer and winter in all vegetables except radish. This might be due to accumulation of photosynthates which triggered early initiation of flowers. Similar findings were reported by Rui et al. (1989) in capsicum. In tomato and cluster bean earliness occurred in open field during both seasons.

This might be due to the micro-climate which was not sufficient for photosynthesis and accumulation of photosynthates (Suchindra, 2002). Leaf area per plant was highest under shadenet house compared to open field in all vegetables during summer season and winter. The exception was for coriander which had the most leaf area under open field during the winter. While the most leaf area was observed under shadenet house during summer season. The highest leaf area per plant was for tomato under shadenet house during summer and winter seasons. This might be due to leaf physiology and increased number of stomatoes and photosynthesis. These results agree with Papadopoulos and Ormrod (1991) in tomato. Amaranthus had the highest leaf area index during summer and winter seasons under shadenet house compared to open field. This might be due to accumulation of more photosynthates during the cropping period. Ultimately, the study revealed that the prospects of cultivation of tomato, brinjal, chilli, cucumber,

Table 11. Influence of growing seasons on the growth and yield of capsicum.

Capsicum	Summer				t -value	P-value	Winter				t - value	P-value
	Mean		SD				Mean		SD			
	Shade	Open	Shade	Open			Shade	Open	Shade	Open		
Plant height (cm)	NA	NA	NA	NA	NA	NA	89.50	NA	NA	NA	NA	NA
Number of branches	NA	NA	NA	NA	NA	NA	6.93	NA	NA	NA	NA	NA
Number of leaves	NA	NA	NA	NA	NA	NA	60.40	NA	NA	NA	NA	NA
Internodal length (cm)	NA	NA	NA	NA	NA	NA	8.18	NA	NA	NA	NA	NA
Earliness (days)	NA	NA	NA	NA	NA	NA	39.7	NA	NA	NA	NA	NA
Fruit circumference (cm)	NA	NA	NA	NA	NA	NA	22.93	NA	NA	NA	NA	NA
Fruit length (cm)	NA	NA	NA	NA	NA	NA	11.04	NA	NA	NA	NA	NA
Number of fruits	NA	NA	NA	NA	NA	NA	11.76	NA	NA	NA	NA	NA
Fruit weight (g)	NA	NA	NA	NA	NA	NA	155.48	NA	NA	NA	NA	NA
Yield (kg / plant)	NA	NA	NA	NA	NA	NA	1.92	NA	NA	NA	NA	NA
Chlorophyll content (%)	NA	NA	NA	NA	NA	NA	61.96	NA	NA	NA	NA	NA
Leaf area (mm^2)	NA	NA	NA	NA	NA	NA	4893.80	NA	NA	NA	NA	NA
Leaf area index	NA	NA	NA	NA	NA	NA	1.81	NA	NA	NA	NA	NA

NA, Not available.

radish, coriander and amaranthus under shadenet house are bright.

REFERENCES

El-Aidy F, El-Afry M, Ibrahim F (1988). The influence of shade nets on the growth and yield of sweet pepper. International. Symposium on Integrated Management Practice AVRDC, Taiwan.

Ganesan M (2004). Effect of poly-greenhouse on plant microclimate and fruit yield of tomato. IE (I).J.-AG 80:12-16.

Hawthron LR, Pollard H (1957). Vegetable and flower seed production, Biakisten Company, New York.

Kaname T, Itagi T (1973). Effect of various air and soil temperature on the growth and yield of tomatoes under protected cultivation. Bull. Kanagawa Horticult. Exp. Stat. 27:67-76.

Krishna-Mohan K, Hanumantha Rao GV, Srinivasulu R (1993). Effect of light stress and hormonal sprays on plant growth, retention of reproductive structures and yield in chilli (*C. annuum* L.). South Indian Hortcult. 41(1):22-27.

Marcelis LFM, Baan Hofman-Eijer LR (1993). Effect of temperature on growth of individual cucumber fruits. Physiol. Plantarum 87:321-328.

Nimje PM, Shyam M (1993). Effect of plastic Greenhouse on plant microclimate and vegetable production. Farm. Syst. 9:13-19.

Papadopoulos AP, Ormrod DP (1991). Plant spacing effects on growth and development of the greenhouse tomato. Canadian J. Plant Sci. 71:297-304.

Priya N, Jeyakumar P, Vijayakumar M (2002). Eco physiological changes in paprika due to varying seasons and growth conditions. South Indian Hortcult. 50(4-6):708-713.

Priya W, Vijayakumar M, Veeragavathatham D, Jeyakumar P, Chezian N (2002). Effect of seasons and growth environments on paprika (*Capsicum annum* var. *longum*) growth and yield. South Indian Hortcult. 50(4-6):463-471.

Quaglitto L (1976). The effects of shading on sweet peppers. Informatore Agrario 32(16):22517-22518.

Ramesh KS, Arumugam T (2010). Performance of vegetables under naturally ventilated polyhouse condition. Mysore J. Agric. Sci. 44(4):770-776.

Reddy MT, Ismail S, Reddy YN (1999). Shade and allelopathic effects of ber on growth, productivity and quality of radish (*Raphanus sativus* L.) under pot culture. South Indian Horticult. 47:77-80.

Rui RL, Nie YQ, Tong HY (1989). Protective effect of plastic film coverage on photosynthesis of capsicum in summer. Jiangsu Agric. Sci. 8:30-31.

Rylski I (1986). Improvement of pepper fruit quality and timing of harvest by shading under high solar radiation conditions. Acta Hort. 191:221-227.

Sanwal SK, Patel KK, Yadav DS (2004). Vegetable production under protected conditions in NEH region: Problems and prospects. Indian Soc. Veg. Sci. 3:120-129.

Singh, Narender, Diwari SK, Paljor (1999). Ladakh Mein Sabjion Kei Sanrakshi Kheti. Regional Research Laboratory of DRDO, Leh. Pub. D.R.D.O., Leh. Pub. D.R.D.O. A.P.O. P. 56.

Suchindra R (2002). Studies on evaluation of tomato (*Lycopersicon esculentum* Mill.) hybrids under four different growing environments for yield and quality characters. MS (Ag.) Thesis, Tamil. Nadu Agricultural University, Coimbatore, India.

TNAU Crop Production Guide (2013). http://www.agritech.tnau.ac.in/pdf/2013/cpg_horti_2013.pdf.

academicJournals

Vol. 5(10), pp. 168-182, November, 2013
DOI 10.5897/JHF2013.0311
ISSN 2006-9782 © 2013 Academic Journals
http://www.academicjournals.org/JHF

Journal of Horticulture and Forestry

Full Length Research Paper

Morphological variability of the fruiting branches in *Argania spinosa*: Effects of seasonal variations, locality and genotype

ZAHIDI A.*, BANI-AAMEUR F. and EL MOUSADIK A.

Laboratory of Biotechnologies and Valorization of Naturals Ressources, Faculty of Sciences, Ibn Zohr University,
BP 8106 Agadir 80000 Morocco.

Accepted 9 May, 2013

The argan tree, is a member of the tropical family Sapotaceae, is an endemic of south western Morocco appreciated for its edible, high nutritional oil, extracted from the kernels of the fruit. The total number of fruiting branches (F), with one (F1), two (F2), three (F3) and four or more fruits (F4) in ten units of four different types of branches were observed for three consecutive seasons in three localities in south west Morocco. The twigs of the season and those less than two seasons have not fruited even if they have flourished. In contrast, the twigs more than two seasons and the main branches bear fruits. Fruit production in argan tree is largely dependent on temperatures and rainfalls during the cycle of flowering and fruiting which covers about 16 months. Prolonged drought during the flowering season is manifested by a significant reduction of the fruiting branches and number of fruits on twigs during the fruit ripening season. Contribution in the phenotypic variance of the climatic season and tree x environment interaction were very significant (18.5 and 52.9%). Broad sense heritabilities were low and ranged between 0 and 14.4%. Differentiation between the three populations for the fruiting branches is not established. However, most trees from Argana and Ait Melloul were most fruit bearing. Argan is especially valued by its fruit and oil, this work shows the existence of significant potential to improve fruiting in this species, which is in the wild state, by the choice of plus genotypes and the optimization of fruit production techniques for the argan domestication as a fruit tree for oil production.

Key words: *Argania spinosa*, diversity, fruit, fruiting branches, repeatability, multivariate analysis.

INTRODUCTION

Fruit trees have the potential to contribute towards food security, nutritional health and income generation and mitigate environmental degradation in developing countries (Jamnadass et al., 2009; Cuni-Shanchez et al., 2011; Simbo et al., 2012). Plant growth and productivity is hampered by environmental conditions, such as water scarcity, recurrent aridity and others. Under these conditions, few species were capable to stand to adverse situation maintaining some productivity. Such is the case of *Argania spinosa* in arid and semi-arid areas of North Africa, able to provide a diversity of resources that are the basis of economy for the local population (Zunzunegui et al., 2010). This multi-purpose tree is often described as an endangered species since several physical and anthropogenic factors reduce the density and surface of the arganeraie ecosystem (Msanda et al.,

---

*Corresponding author. E-mail: Dr.abdelaziz.zahidi@gmail.com. Tel.: +212667265028.

2005). The argan tree is best known for its adaptation to drought and oil extracted from kernels of harvested fruit from trees in the wild state. However, the dried pulp, meal and leaves are sources of food for livestock (Sandret, 1957; Ehrig, 1974; M'Hirit, 1989, Prendergast and Walker, 1992; Maurin, 1992). Its exploitation is always in the economy picking mode. However, argan oil constitute up to 25% of fat consumed in the region. It is the subject of a commercial flow through Morocco and starts even if required at the international level for uses in dietetics and cosmetics. The multiple uses of the argan tree, especially the interest of oil combined with resistance to drought, make it a good candidate for domestication as a fruit tree for oil production and genetic improvement for arid areas (Bani-Aameur and Benlahbil, 2004; Ait Aabd et al., 2011).

Most of the reports available on the fruit were devoted to the chemical composition of argan oil, but very little research has focused on the fruit productivity in particular. The yield of fresh fruit varies according to tree, environment and climate season. It is 500 kg / ha / year per hectare on average (M'Hirit, 1989) and about 15 kg / tree (Rahali, 1989). The total production of ripe fruit in hot and dry season varies within wide limits according to trees at the Ait Melloul (Bani-Aameur, 2002a). Dried fruit yields are between 1.52 and 22.4 kg / tree / year. In addition, the frequency of fruit-bearing trees, fruit, pulp and kernel weights was highly variab Bani-Aameur le depending on season, trees and trees x environment interaction (Ferradous et al., 1996). These authors also reported that a minimum of 100 mm of rainfall recorded in autumn of fruit ripening promotes good fruiting. However large variability of flowering intensity was observed among climatic years, sites, tree genotypes and types of twigs. In any case, the peak of flowering occurs in spring (Bani-Aameur, 2002a). Small fruits on tree start to grow from October (Metro, 1952). But in February, fruits grow very quickly. In July, the fruit maturation was almost complete. The young fruits from flowering this season remain incompletely developed until the first rains next autumn. Thus, the flowering-fruiting cycle cover a period of nine to 16 months depending on trees (Bani Aameur et al., 1998; Benlahbil and Bani-aameur, 1999).

Some trees are able to have fruit once per season in March (early tree) or June (late tree), while other trees were able to flourish twice and then produce early and later fruits on the same individual (Ferradous et al., 1996; Bani Aameur et al., 1998). In early trees, the ripening of fruit from flowers fertilized in autumn of the last season occurs in May (Ferradous et al., 1996). In late trees, fruit maturation from flowers fertilized in spring of the last campaign occurs in August. While in intermediate trees, fruits are highly variable in size; their maturation is spread between spring and summer. All fruits from fertilized flowers do not persist until maturity, but a drop more or less important interested young fruit, ripe fruit and fruit whose maturation process is interrupted. The percentages of losses expressed in number of fruit varied from 3 to 39% depending on the trees (Bani Aameur et al., 1998). On the same tree, there are different branches and twigs with variable age and size. Twig of the season, twig less than two seasons, twig more than two seasons and the main branches growing on the carpenter branches (Zahidi et al., 1995). All these twigs and main branches bear flowers in very variable proportions (Ferradous et al., 1996; Bani-Aameur, 2000); we aimed to know what types can bear the fruits at maturity, and to establish the relationship between seasonal variations in temperatures and rainfall, the locality and the tree genotype and fruiting in three populations of argan in southwestern Morocco.

MATERIALS AND METHODS

Plant material and measurements

The experiment concerned trees was located at Ait Melloul at 35 m altitude in the Souss plain, Argana at 620 m altitude on southern slopes of High Atlas Mountains and Ait Baha (AB) at 50 km from the Atlantic ocean at 550 m altitude on the northern slopes of Anti Atlas mountains south west of Morocco. Thirty trees randomly selected and characterized for several morphological characters of fruit, kernel, flower, pollen, branching and foliation were observed in each site (Ferradous et al., 1996; Zahidi and Bani-Aameur, 1999a, b; Bani-Aameur and Benlahbil, 2004). Observations occur during three consecutive seasons, the first season was dry and warm; the second season was very wet with a relatively warm autumn, but winter and spring were cold. The third season is characterized as wet and hot, with gaps relatively high between the minimum and maximum temperatures (Figure 1).

Among the twigs and main branches facing South because of its large flowering (Bani-Aameur, 2002a), we observed at the end of April for three consecutive seasons the following characters (Figure 2): Among the 10 twigs of the season labeled (green twigs) we counted: Total number of the fruiting twigs (F); number of twigs with one fruit (F1); number of twigs with two fruits (F2); number of twigs with three fruits (F3); number of twigs with four or more fruits (F4). The same operation is performed for the ten twigs less than two seasons labeled (red color), ten twigs more than two seasons (lignified) and 10 principal branches (lignified with different ages and dimensions).

Variability characterization

The variance components and the relative percentage of the variance related to different factors in the total variance were estimated using the model in Table 1:

$$\sigma^2 T = \sigma^2 A + \sigma^2 l + \sigma^2 A \times l + \sigma^2 a/l + \sigma^2 A \times a/l + \sigma^2 e$$

Where, σ^2 T, Total variance (phenotypic variance); σ^2 A, variance related to seasonal variations (season factor); σ^2 l, variance due to locality; σ^2 A x l, variance due to season x locality interaction; σ^2 a/l, variance due to tree / locality (genotype); σ^2 A x a/l, variance related to genotype x environment interaction (season x tree / locality); and σ^2e: variance due to error. The percentage of the variance of each factor in phenotypic variance per each site was calculated using the model in Table 1.

$$\sigma^2 Ts = \sigma^2 A + \sigma^2 a + \sigma^2 A \times a + \sigma^2 e$$

Where, σ^2Ts, Total variance by site; σ^2A, variance related to season; σ^2a, variance due to tree; σ^2A x a, variance due to season x tree interaction; σ^2e: variance by site due to error.

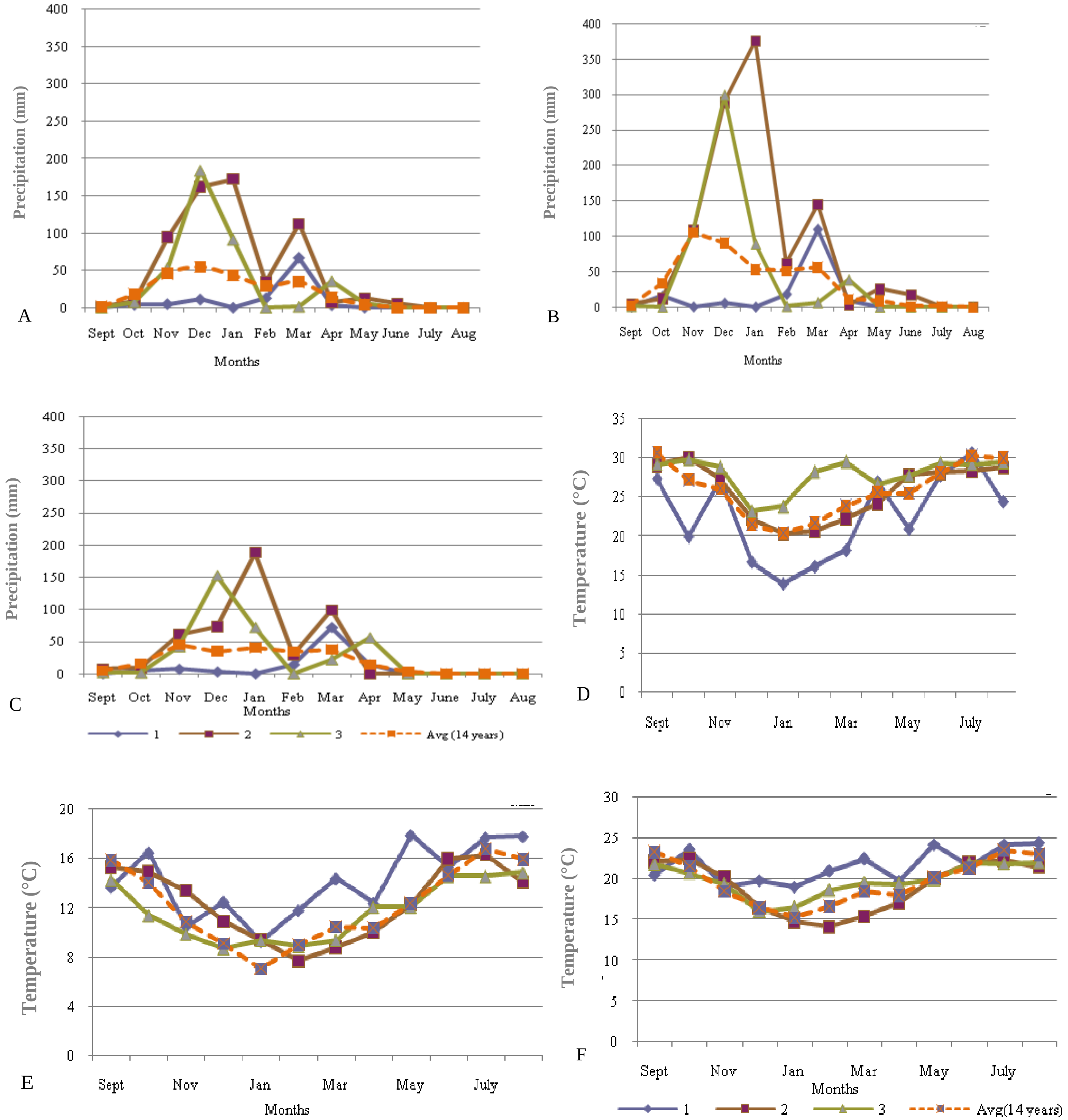


Figure 1. Climatic data from meteorological stations: mean monthly precipitation (mm), maximum, minimum and mean temperatures recorded at Ait Melloul (AM), Argana (AR) and Ait Baha. A, AM; B, AR; C, AB; D, max; E, min; F, avg.

Repeatability (broad sense heritability estimated by the ratio of variance tree / locality to the total phenotypic variance) was calculated according to the formula below given that trees are not repeated between sites and in each site (Pfahler et al., 1996; Bani-Aameur et al., 2001):

$$r^2 = 100 \text{ x } (\sigma^2 a/l \ / \ \sigma^2 a/l + \sigma^2 A \text{ x } a/l + \sigma^2 e)$$

Where the sum $\sigma^2 a/l + \sigma^2 A$ x $a/l + \sigma^2 e)$ represents the total phenotypic variance in the three site and ($\sigma^2 a/l$) constitute the

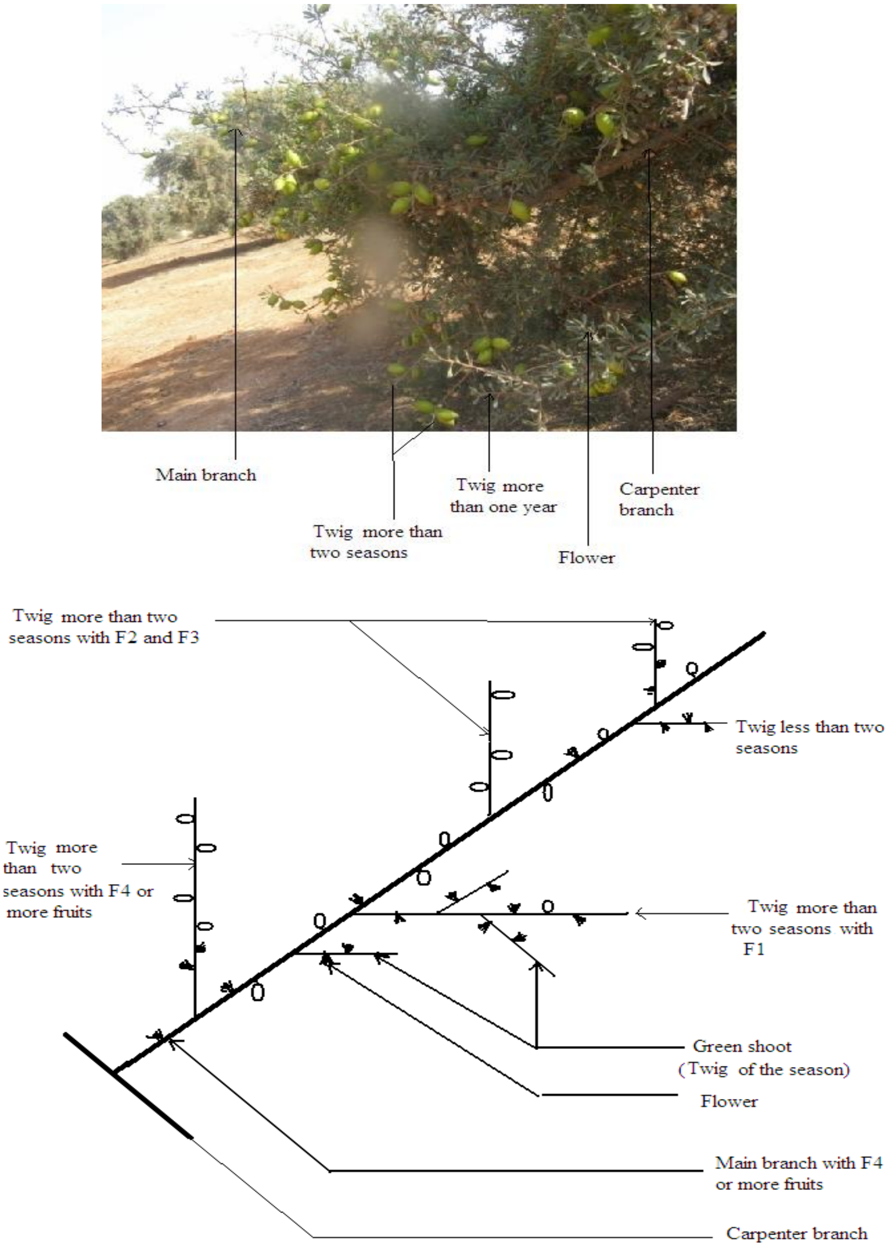


Figure 2. Morphological characters of the fruiting branches observed in Ait Melloul, Ait Baha and Argana during three consecutive seasons.

genetic variance. The repeatability per site was estimated using the following model:

$$r^2 = 100 \text{ x } (\sigma^2 a \ / \ \sigma^2 a + \sigma^2 A \text{ x } a + \sigma^2 e)$$

Where the sum ($\sigma^2 a + \sigma^2 A$ x a $+ \sigma^2 e$) represents the total phenotypic variance per locality and ($\sigma^2 a$) variance related to tree.

Data analysis

An analysis of variance with four factors in hierarchical model was adopted (Table 1). Genotype (tree / locality) is hierarchical to locality factor because trees are not repeated between sites. Climatic season, locality and type of branch were crossed. The least significant difference test (LSD $\alpha = 5$ %) of equality of means was used to compare differences between means (Steel and Torrie, 1960; Dagneli, 1984; Sokal and Rohlf, 1995). Factorial discriminate analysis (AFD) was performed on annual averages of each tree in order to examine the simultaneous contribution of all parameters studied in discriminating trees and sites (Frontier, 1981; Bernstein et al., 1988).

Dendogram was built using clustering method UPGMA "pair-group method unweighetd arithmetic average". Statistical treatments were performed using Statitcf, Statistix software and Ntsys version 1.40 (Rohlf, 1988).

Table 1. Expectations of mean squares and estimated variance components for morphological characters in the three localities.

Source of variation	DF	Mean square	Expectations of mean squares
Global			
Season	2	CM A	$\sigma^2e + 2\sigma^2Aal + 60\sigma^2Al + 180\sigma^2A$
Locality	2	CM l	$\sigma^2e + 2\sigma^2Aal + 60\sigma^2Al + 6\sigma^2al + 180\sigma^2l$
Tree / locality	87	CM al	$\sigma^2e + 2\sigma^2Aal + 6\sigma^2al$
Season x locality	4	CM Al	$\sigma^2e + 2\sigma^2Aal + 60\sigma^2Al$
Season x tree / locality	174	CM Aal	$\sigma^2e + 2\sigma^2Aal$
Error	270	CM e	σ^2e
By locality			
Season	2	CM A	$\sigma^2e + 2\sigma^2Aa + 60\sigma^2A$
Tree	29	CM a	$\sigma^2e + 2\sigma^2Aa + 6\sigma^2a$
Season x tree	58	CM Aa	$\sigma^2e + 2\sigma^2Aa$
Error	90	CM e	σ^2e

Table 2. Analysis of variance of number of main branches and twigs more than two seasons fruit bearing (F), with one (F1), two (F2), three (F3) and four or more fruits (F4) observed in the three localities.

Source of variation	DF	Mean square				
		F	F1	F2	F3	F4
Season	2	2806.8*	579.3^{ns}	282.9**	81.46*	26.2^{ns}
Locality	2	749.01^{ns}	248^{ns}	27.8^{ns}	32.5**	28.6**
Type of branch	1	90.7^{ns}	1.13^{ns}	12.03^{ns}	12.3^{ns}	12.9^{ns}
Tree / locality	87	14.25^{ns}	5.5^{ns}	2.03^{ns}	1.81**	1.5**
Season x locality	4	234.6**	125.03**	8.88**	8.5**	8.45**
Season x type of branch	2	52.64*	6.6^{ns}	2.88**	6.89**	7.85**
Locality x type of branch	2	11.27^{ns}	2.07^{ns}	0.76^{ns}	1.6*	2.26*
Season x locality x type of branch	4	6.34**	1.82^{ns}	0.86^{ns}	0.9^{ns}	0.82^{ns}
Season x tree / locality	174	12.14**	5.96**	1.76**	1.31**	1.12**
Season / locality x type of branch	87	1.83^{ns}	1.05^{ns}	0.61^{ns}	0.36^{ns}	0.5*
Season x tree / locality x type of branch	174	1.34^{ns}	1.13^{ns}	0.57**	0.38**	0.39**
Error	540	1.45	1.26	0.4	0.25	0.21

^{ns}Not significant; *: significant at 5%; **, significant at 1%.

RESULTS

Variability characterization

Type of branch

The principal branches and twigs more than two seasons have borne fruits for three seasons, but twigs of the season and those less than two seasons have not borne fruits at maturity even if they have flowered. The type of branch was not significant for all traits (F, F1, F2, F3 and F4) (Table 2). Type of branch x climatic season interaction is significant for total number of fruiting the twigs (F), number of twigs to two (F2), three (F3) and four or more fruits (F4), but not significant for number of twigs with one fruit (F1). Locality x type of branch interaction was significant for F3 and F4. Locality x climatic season x type of branch interaction was significant only for F. Type of branch x tree / locality interaction (genotype x type of branch) was significant for F4, while climatic season x type of branch x tree / locality interaction was highly significant for F2, F3 and F4.

During the second season (2nd) characterized as low fruiting and even during the season at intermediate fruiting (1st), no difference was found between the main branch and twig over than two seasons for F1, F2, F3 or F4. But, in season of high fruiting, twigs more than two seasons have borne more fruits (72%) than the main branch (57.3%). They bear more than one fruit in 58.9% of cases against 48.2% for main branch (Table 3).

In all three localities, no difference was observed for F, F1 and F2 between the main branches and twigs more

Table 3. Average number of branches (main branch and twigs more than two seasons) with fruits (F), one (F1), two (F2), three (F3) and four or more fruits (F4) per season observed in three localities.

Type of branch	Season	Main branch	Twig more than two seasons
Twig or main branch with fruits (F)	1	4.13	4.17
	2	0.78	1.02
	3	5.73 b	7.19 a
	Average	3.55	4.13
Twig or main branch with one fruit (F 1)	1	2.82	2.47
	2	0.54	0.73
	3	3.01	2.97
	Average	2.12	2.06
Twig or main branch with two fruits (F 2)	1	0.66	0.8
	2	0.16	0.24
	3	1.72 b	2.14 a
	Average	0.85	1.06
Twig or main branch with three fruits (F 3)	1	0.42	0.55
	2	0.06	0.05
	3	0.74 b	1.28 a
	Average	0.41	0.63
Twig or main branch with four or more fruits (F 4)	1	0.2	0.32
	2	0.01	0.0
	3	0.3 b	0.82 a
	Average	0.17	0.38

Means followed by letters are significantly different at 5%.

Table 4. Average number of branches (main branch and twigs more than two seasons) with fruits (F), one (F1), two (F2), three (F3) and four or more fruits (F4) observed in Ait Melloul (AM), Argana (AR) and Ait Baha (AB).

Type of branch	Main branch				Twig more than two seasons			
	AM	AR	AB	Average	AM	AR	AB	Average
With fruit (F)	4.18	4.37	2.09	3.55	4.99	5.13	2.26	4.13
With one fruit (F 1)	2.87	2.25	1.25	2.12	2.93	2.02	1.23	2.06
With two fruits (F 2)	0.92	1.04	0.59	0.85	1.17	1.31	0.7	1.06
With three fruits (F 3)	0.33^{b}	0.7^{b}	0.22^{b}	0.41	0.58^{a}	1.01^{a}	0.28^{a}	0.62
With four or more fruits (F 4)	0.67^{a}	0.4^{b}	0.02^{b}	0.16	0.3^{b}	0.77^{a}	0.07^{a}	0.38

Means followed by different letters are significantly at 5%.

than two seasons (Table 4). In Argana and Ait Baha, the twigs more than two seasons have more fruits, four or more fruits in greater proportions than the main branch. In Ait Melloul, twigs more than two seasons had formed three fruits in greater proportions, but the main branches had formed more than four fruits. In the three sites, main branches and twigs more than two seasons are capable of producing at least one or two fruits, but the young twigs (twig more than two seasons) have a higher production potential than older branches (main branches). All trees have not borne the same number of twigs with three, four or more fruits. In trees (1, 4, 5, 14, 23 and 29) from Ait Melloul, (2, 5, 6, 13, 17, 20, 19 and 27) from Argana and (2, 11 and 20) from Ait Baha, the twigs more than two seasons have more fruits than the main branches. While among the trees (20, 21 and 25) of Ait Melloul (11, 18 and 28) of Argana, and (21, 22, 30) of Ait Baha, the main branches were more fruiting than the

Table 5. Average number of branches (main branches and twigs more than two seasons) with fruit (F), one (F1), two (F2), three (F3) and four or more fruits (F4) per season and locality.

Type of branches	Season \ locality	Ait Melloul	Argana	Ait Baha	Average
Number of branches with fruits (F)	1	5.94^{b}	5.81^{b}	0.7^{b}	4.15^{b}
	2	1.38c	1.01c	0.32c	0.9c
	3	6.44^{a}	7.43^{a}	5.51^{a}	6.46^{a}
	Average	4.59	4.75	2.18	3.84
Number of branches with one fruit (F1)	1	4.5^{a}	2.87^{a}	0.56^{b}	2.64
	2	1.07c	0.7^{b}	0.16c	0.64
	3	3.13^{b}	2.84^{a}	3.0^{a}	2.99
	Average	2.89	2.13	1.24	1.99
Number of branches with two fruits (F2)	1	0.93^{b}	1.18^{b}	0.08^{b}	0.73^{b}
	2	0.27c	0.23c	0.1^{b}	0.2c
	3	1.93^{a}	2.12^{a}	1.74^{a}	1.93^{a}
	Average	1.04	1.18	0.64	0.95
Number of branches with three fruits (F3)	1	0.37^{b}	1.04^{b}	0.05^{b}	0.5^{b}
	2	0.05c	0.06c	0.06^{b}	0.06c
	3	0.95^{a}	1.43^{a}	0.64^{a}	1.01^{a}
	Average	0.46^{b}	0.84^{a}	0.25c	0.52
Number of branches with four or more fruits (F4)	1	0.07^{b}	0.7^{b}	0^{b}	0.26
	2	0^{b}	0c	0.03^{b}	0.01
	3	0.48^{a}	1.06^{a}	0.11^{a}	0.55
	Average	0.18^{b}	0.59^{a}	0.04c	0.27

Means followed by different letters are significantly at 5%.

twigs more than two seasons.

Climatic season

The climatic season is significant for F, F2 or F3 (Table 2). It is not significant for F1 and F4. The fructification is higher during the third season compared to the first and second seasons (Table 5). Indeed, during the humid season (3rd) following a very humid campaign, 65% of main branches and the twigs more than two seasons have fructified. Whereas during very dry season (1st) following a dry campaign, 41.5% of total of the twigs or main branches observed have borne fruits, while during the campaign very humid (2nd) following a very dry season, about 9% of main branches and the twigs more than two seasons have fructified. Among these fruiting the twigs, 45.5% in the 3rd season, 29.6% in the 1st and 28.8% in 2nd season had borne two or three fruits.

Locality

Locality is highly significant for F3 and F4, but not significant for F, F1 and F2 (Table 2). Locality x climatic season interaction is highly significant for all traits. In Argana site, number of twigs or main branches to three and four or more fruits is higher than in Ait Melloul, and Ait Baha (Table 5). Reducing the number of fruits on the branches is probably a reaction to variations of temperatures and rainfalls. This reduction was more pronounced in Ait Baha, more arid site than in Ait Melloul to mild temperatures and Argana the most humid site especially during the 1st and 2nd season (Table 5). These effects are manifested by a remarkable reduction in the number of fruiting branches, since 7% of the total branches during the dry season and only 3.2% in very humid season following a dry campaign have fruited in Ait Baha. In the three stations, in season at low and intermediate fruiting, most (over 50%) of branches bear fruits. In contrast, in season at high fruiting, 62.1% in Argana, 52.2% at Ait Melloul and 45.1% Ait Baha having more than one fruit.

Genotype

Tree / locality (genotype) is highly significant for F3 and F4 (Table 2). Indeed some trees as (6 and 10) of Ait Melloul, (6, 7, 11, 17, 26, 27 and 28) of Argana (4 and 21) from Ait Baha were able to produce more fruiting branches (main branches or twigs more than two seasons) with three and with four or more fruits and therefore more fruits. So, these trees are of high potential

Table 6. Frequencies of trees that produced fruits at Ait Melloul, Argana and Ait Baha.

Type of branch	Season \ locality	Ait Melloul		Argana		Ait Baha		Average	
		Number of trees	Frequency (%)	Number of trees	Frequency	Number of trees	Frequency (%)	Number of trees	Frequency (%)
Branches with one fruit (F1)	1	28	93.3	27	90	9	30	21.3	71
	2	13	43.3	7	23.3	2	6.7	7.3	24.4
	3	30	100	30	100	30	100	30	100
Branches with two fruits (F2)	1	15	50	25	83.3	4	13.3	14.7	48.9
	2	13	43.3	6	20	2	6.7	7	23.3
	3	30	100	30	100	30	100	30	100
Branches with three fruits (F3)	1	6	20	21	70	2	6.7	9.7	32.2
	2	3	10	5	16.7	2	6.7	3.3	11.1
	3	28	93.3	30	100	27	90	28.3	94
Branches with four or more fruits (F4)	1	1	3.3	13	43.3	0	0	4.7	16
	2	0	0	0	0	2	6.7	0.7	2.2
	3	21	70	25	83.3	8	26.7	18	60

for fruit production and then can serve as germplasm in a breeding program and for domestication as a fruit tree for the production of argan oil. Season x tree / locality interaction is highly significant for all traits (Table 2). Trees in the three sites have reacted differently with respect to seasonal variations of temperatures and rainfalls (Table 6). This differential response was reflected by the frequency of trees whose fruiting branches have presented one fruit, two, three and four or more fruits. Thus, during the very humid season (2), following a very dry season, 6.7% of total trees at Ait Baha, 23.3% in Argana and 43.3% in Ait Melloul were fruitful. While during the humid season (3), which followed a very humid campaign all trees have borne fruits. During the first season, which followed a dry campaign, about 93.3% in Ait Melloul and Argana and 30% in Ait Baha have fruited.

Variance components

The relative percentage of variance due to climatic season in the total variance is high more than 50% for F and F2, but relatively low to moderate (8% to 28%) for the others characters (Figure 3). Climatic season effect is more pronounced at Ait Baha than in Argana and Ait Melloul for all characters except number of branches (twigs more than two seasons and main branches) to four or more fruits. The percentages of total variance per site varied between 44.1 and 83.4% in Ait Baha, 26.1 and 70.9% in Argana, and between 35.4 and 61.5% in Ait Melloul. The relative contribution of variance related to locality and locality x season interaction in the phenotypic variance is relatively low and ranged from 3.6 and 13.2% except the number of branches with one fruit (22.7%) The contribution of variance due to genotype x environment interaction (season x tree / locality) in phenotypic variance is greater for all characters. It varied from 18.5% for F and 42.8% for F4 (Figure 3). Percentages remarkable of genotype x environment interaction are mainly related to the importance of season x tree interaction in Ait Melloul and Argana compared to Ait Baha. Thus, at Ait Melloul and Argana where seasonal variations are less important, season x tree interaction explains 30.1 to 59.9% in Ait Melloul and about 0 to 44.4% in Argana. By cons, at Ait Baha, the driest site, this contribution varied from 8.6 to 57.1%. The relative contribution of variance associated to genotype (tree/locality) in the phenotypic variance is low and ranged from 0% for F1 and 6.2% for F4 (Figure 3). The same observation is noted in each locality, the percentage of total variance attributed to tree factor is also low (0% for F, F2, F3 and 7.7% for F4). Highest repeatabilities (8.9 and 9.8%) were observed for F3 and F4, while for the other characters, the repeatabilities were low (0 and 4.8%) (Table 7). Low repeatability (overall and by station) recorded for the fruiting branches reflect the crucial role of seasonal variation in the fruits productivity in argan tree.

Variability distribution

The total number of the fruiting branhes (F) is correlated in different degrees with F1, F2 and F3 during the dry season (1st), and during the very humid season (2nd) (Table 8). While during the humid season (3rd), F is highly correlated with F2, F3 and F4. The correlation coefficients of F1 were low in very dry season but higher with F2, F3 in very humid season and F3, F4 in humid

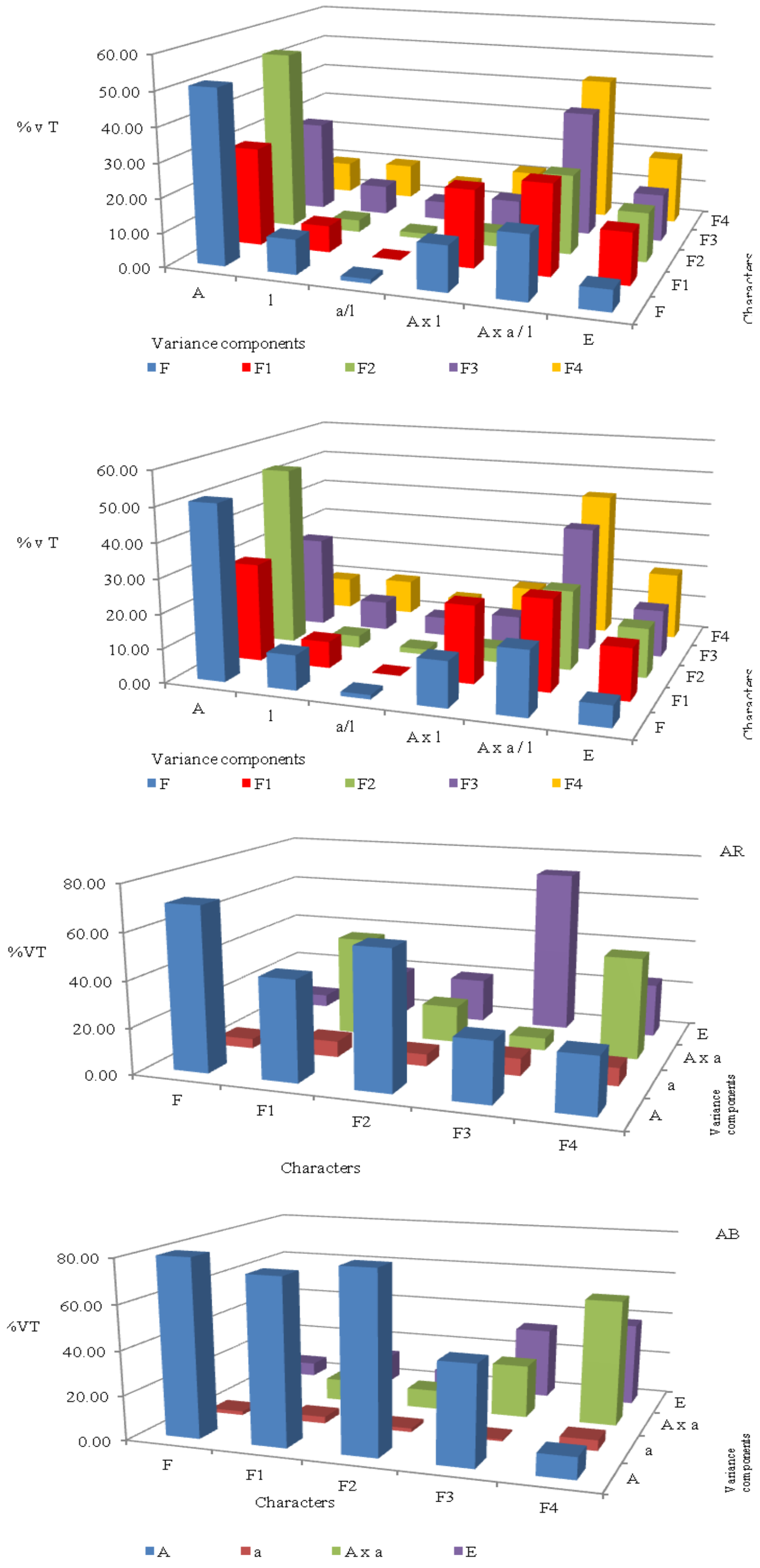


Figure 3. Percentage in phenotypic variance of variance components for main branches and twigs more than two seasons with fruit (F), with one (F1), two (F2), three (F3) and four or more fruits (F 4) observed in Ait Melloul (AM), Argana (AR) and Ait Baha (AB). (A, Season, l, locality, a / l, tree / locality, a, tree, A x l, season x locality; A x a / l, season x tree / locality; e, error).

Table 7. Repeatabilities in percentage for the fruiting branches observed in the three localities.

Character	F	F1	F2	F3	F4
Global	4.8	0.0	4.04	9.8	8.9
Ait Melloul	0.0	1.03	0.0	0.00	5.4
Argana	14.4	0.0	12.7	10.1	10.2
Ait Baha	10.2	11.8	8.9	0.0	0.0

Table 8. Matrix of correlations for the fruiting branches observed in the three localities during the three consecutive seasons.

Characters	Fs1	Fs2	Fs3	F1s1	F1s2	F1s3	F2s1	F2s2	F2s3	F3s1	F3s2	F3s3	F4s1	F4s2	F4s3
Fs1	1.00														
Fs2	0.15	1.00													
Fs3	0.43	0.21	1.00												
F1s1	0.75	0.12	0.23	1.00											
F1s2	0.16	0.97	0.18	0.14	1.00										
F1s3	-0.01	-0.02	-0.1	0.14	0.01	1.00									
F2s1	0.67	0.13	0.25	0.23	0.16	0.02	1.00								
F2s2	0.11	0.93	0.21	0.1	0.84	-0.03	0.08	1.00							
F2s3	0.32	0.17	0.73	0.22	0.166	-0.11	0.19	0.18	1.00						
F3s1	0.58	0.1	0.4	-0.03	0.09	-0.19	0.56	0.09	0.2	1.00					
F3s2	-0.03	0.69	0.14	0.01	0.53	-0.06	-0.06	0.77	0.07	0.01	1.00				
F3s3	0.32	0.15	0.82	0.15	0.11	-0.49	0.13	0.15	0.49	0.37	0.13	1.00			
F4s1	0.43	-0.01	0.35	-0.06	-0.03	-0.23	0.18	0.01	0.25	0.67	-0.03	0.24	1.00		
F4s2	-0.13	0.34	-0.1	-0.1	0.21	0.06	-0.07	0.45	-0.03	-0.08	0.7	-0.11	-0.05	1.00	
F4s3	0.33	0.21	0.78	0.08	0.19	-0.53	0.2	0.2	0.4	0.44	0.15	0.78	0.37	-0.1	1.00

season. The values of F, F1, F2, F3 and F4 obtained in the dry season were not correlated with the values of humid seasons.

Discriminate factorial analysis shows that 100% of the total variance could be explained using only the two canonical components. First CP1, explaining about 69.5% of variation, was linked to F, F2 and F3 in the three seasons, to F1 in the 1st and 2nd season, and F4 in the 2nd and 3rd season. Thus individuals to high fruiting such as (1, 2 and 3) of Ait Melloul, (1, 3 and 23) of Argana and (27) of Ait Baha were projected on the negative side of the first axis. But, individuals with low fruiting such as (8 and 15) of Ait Melloul (4 and 24) of Argana and great number of trees from Ait Baha were projected on the negative side of this axis (Figure 4). Second CP2 that was responsible for 30.5% of variation is linked to F1 in 3rd season and F4 in 1st season, to F, F4 and F2 in 3rd season and in varying degrees to F3 in the three seasons (Table 9).

The ordering of trees revealed that genotypes are not grouped according to their origins since respectively 58.9% (53/90 trees) from Ait Melloul, 48.8% (44/90 trees) from Argana are among trees most fruiting and which produce three and four fruits. But more than 60% of trees from Ait Baha are among genotypes low fruiting. We can therefore conclude that there is no differentiation of the three populations for the fruiting branches. Ait Melloul and Argana sites are relatively far from Ait Baha, while Ait Melloul and Argana are nearer (Table 10).

The dendrogram generated based on all morphological traits, showed a similar pattern. Two groups are distinguished in a Euclidean distance 3.2 (Figure 5). The first group is divided in a Euclidean distance of 2.74 in a first class containing M15, R24 and B22 characterized by low fruiting, and a second class containing 13.9% from Ait Melloul, 16.7% from Argana and 69.4% from Ait Baha. The second group is divided in a Euclidean distance of about 2.63 into two subgroups. The first subgroup includes 39.4% from Ait Melloul, 51.5% from Argana, and 9.1% from Ait Baha. The second subgroup contains 61.1% from Ait Melloul, 33.3% from Argana and 9.1% from Ait Baha. Sites classification shows two groups at a Euclidean distance about 2.56 (Figure 6). A first group consists Ait Baha and a second group containing Ait Meloul and Argana. This classification is not the result of geographical isolation. Argana characterized by cold winter, and Ait Melloul with mild temperatures are generally not differentiated from Ait Baha known for its drought summer.

DISCUSSION

The main branch and the twigs more than two seasons

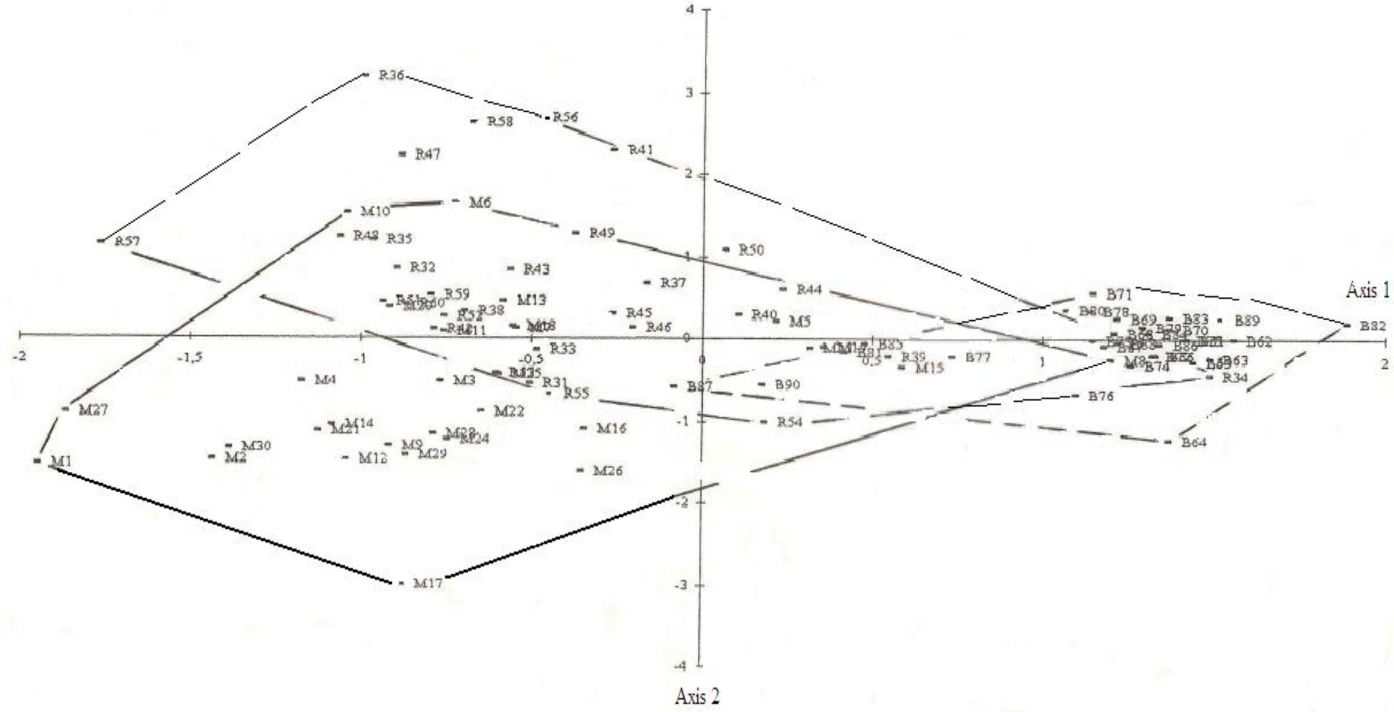


Figure 4. Projection of individuals from the three populations on the plane defined by the first two canonical components.

Table 9. Correlations between canonical components and characters of the fruiting branches observed in the three localities.

Variable	CP1	CP2
Fs1	-0.99	0.1
Fs2	-0.97	-0.24
Fs3	-0.8	0.61
F1s1	-0.95	-0.31
F1s2	-0.95	-0.31
F1s3	-0.04	-0.99
F2s1	-0.95	0.32
F2s2	-0.99	-0.15
F2s3	-0.81	0.58
F3s1	-0.67	0.74
F3s2	0.6	0.81
F3s3	-0.73	0.69
F4s1	-0.48	0.88
F4s2	0.99	-0.11
F4s3	-0.72	0.69
Eigenvalues	0.68	0.3
Explained Percentages (%)	69.5	30.5
Cumulative percentages (%)	69.5	100

CP1, First canonical component; CP2, second canonical component.

have borne the fruits during the three campaigns, but the twigs of the season and those less two seasons have not borne the fruits at maturity even if they have flowered. The type of branch (main branches or twigs more than two seasons) does not affect the fruiting of argan tree. However, the fruiting is strongly influenced by the season, locality and tree. The twigs more than two seasons are more fruiting than the main branches in

Table 10. Mahalanobis distance between Ait Melloul, Argana and Ait Baha for characters of the fruiting branches.

Locality	Ait Melloul	Argana	Ait Baha
Ait Melloul	0		
Argana	1.35	0	
Ait Baha	1.92	1.81	0

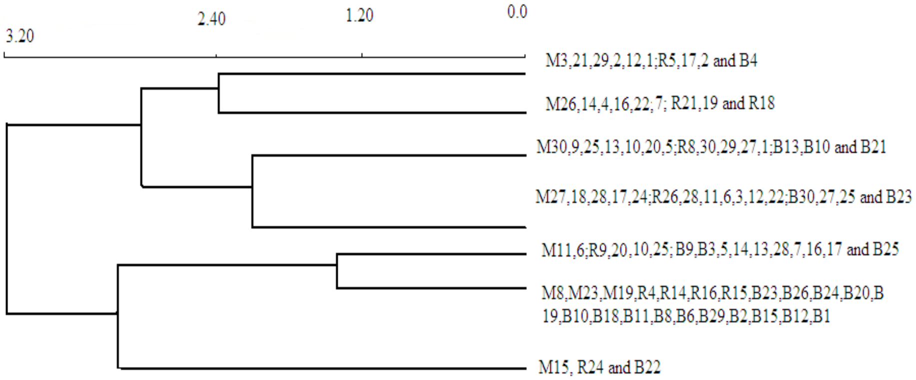


Figure 5. Dendrogram obtained when clustering individuals of Ait Melloul (M), Argana (R) and Ait Baha (B) on the basis of characters of the fruiting branches characters.

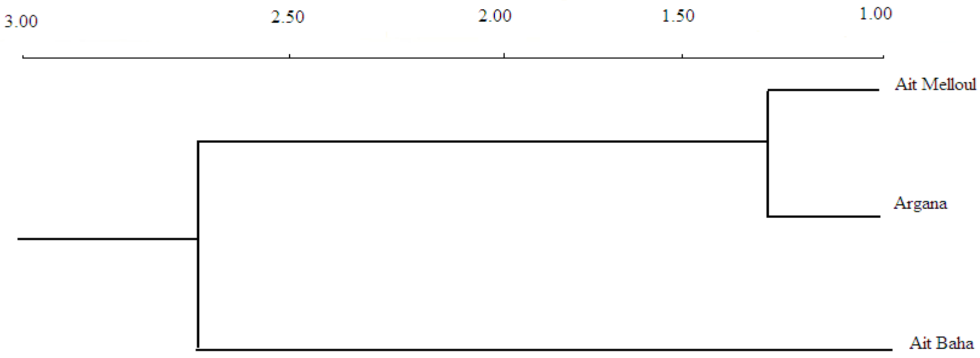


Figure 6. Classification of localities Ait Melloul (AM), Argana (AR), and Ait Baha (AB) for characters of the fruiting branches in argan tree.

favorable seasons. It seems that this difference has a trophic origin in relation to the age of the branches. Thus, for the regulation of the fruiting in argan tree, pruning-lightening operations by removing some old branches that grow on the carpenter branches reduces nutrient competition and ensure regularity of fruit production in argan as is practiced in other fruit species (Andales et al., 2006; Tworkoski and Glenn, 2010). For the establishment of orchards, this operation must be coupled with an appropriate irrigation in case of drought, at least during the flowering period since 100 mm of rainfall recorded in autumn of fruit ripening promotes good fruiting as reported by Bani-Aameur (2002a) and Bani-Aameur (2002a). Those operations must take into account yield components (number of fruiting branches, number of flowers, number of fruits per flower).

In a given season, in the three localities, all trees do not bear fruits. The effect of drought occurs partly by a reduction in number of branches with fruits and secondly by reducing the number of fruit on the twigs. The flowering-fruiting cycle cover a period of 9 to 16 months depending on trees (Bani Aameur et al., 1998; Benlahbil and Bani-aameur, 1999). Thus, in case of drought during the flowering period, most fruiting branches in the next season produce mainly one or two fruits and secondarly three fruits. But, if the flowering season is humid, fruiting in the following season will be more important and number of branches bearing fruits will be also higher. Significant decrease in the number of the fruiting branches and the number of fruits on twigs during the very humid season (2nd) is related to minimum flowering observed during the previous season characterized as dry and warm. Indeed, during the dry seasons, the flowering was late (March), it concerned only 50 to 70% of trees in the three sites and the number of glomerules ranged from 0.18 to 24 units. By cons, during the humid seasons, all trees have flowered, and the number of glomerules ranged from between 10 and 74 units (Benlahbil and Bani-aameur, 1999).

In addition, the percentage of losses expressed in number of fruits due to physiological drop (young fruits), which interrupted the process of maturation and ripe fruits ranged from 3 to 39% depending on the tree in hot and dry season (Bani Aameur et al., 1998). It appears that the adjustment of fruiting was a response to unfavorable conditions by a reduction in number of fruits on the branches. If the effects of the climatic season were manifested in the three localities by a reduction of fruiting during the second campaign, it appears that Ait Baha site was the most affected than Ait Melloul and Argana during the dry season (1st) and during the very humid season (2nd). Thus, at Ait Baha, this reaction is manifested by a very limited number of trees producing fruits (9 trees in first season, and 2 trees in second season) and a reduction in number of fruit-bearing branches. These observations confirm the findings reported by Ferradous et al. (1996) for the frequency of trees bearing fruits, weight of fruit, kernel and pulp where the effects of climatic year was perceived at Ait Baha. This station will be considered as a medium for selection of resistant genotypes to drought.

Trees in the three populations have reacted differently to seasonal variations of temperatures and rainfalls. Some individuals from Ait Baha (4 and 21), (6 and 10) of Ait Melloul and (6, 7, 11, 17) of Argana have borne the fruits in dry seasons or in humid seasons. But other trees have not borne fruits in the same conditions. Those behaviors have been observed previously since frequencies of trees that borne fruits differ mainly at Ait Melloul and Argana (Ferradous et al., 1996) confirm the impotance of genotype, in addition to seasonal variation in determining the fruiting in Argan tree. In argan, there are two categories of genotypes. Some genotypes are able to produce fruits even under unfavorable conditions. Other genotypes may only bear the fruits if temperatures and rainfalls are in favor of the flowering and ripening fruits. Trees from Ait Baha are the most affected by these changes of environmental conditions.

The relative percentage of variance related to seasonal variations in the phenotypic variance is higher than that observed for fruits characters (0.71% and 11.2%). But, this contribution related to locality and season x locality interaction was relatively low as reported by Bani-Aameur et al. (2001) (0.7 to 4.2%) except the fruit color (64.8%) and for characters of simple leaves (0.5 and 17.9%) (Zahidi, 2004). These results confirm the idea that argan tree shows a high adaptive plasticity with respect to his living environment, as has been noticed in other plant species (Sultan, 2000; Mückschel and Otte, 2003; Ait Aabd et al., 2011).

Genotype x environment interaction (season x tree / locality) contribution in the phenotypic variance is remarkable for the studied characters of the fruiting branches. This result is also observed for characters of fruit (10.4 and 14.7%) (Bani-Aameur et al., 2001). But, genotype (tree / site) contribution in the total variability is very low. These values are low compared to those obtained in sour cherry germplasm collected from the most important growing regions in Serbia. The highest degree of variability was observed number and composition of the fruiting branches, fruit set and yield (Rakonjac et al., 2010); and for characters of fruit (7.5 and 43.9%) (Bani-Aameur et al., 2001). Repeatabilities observed for the fruiting branches are much lower than those recorded for simple leaves characters except leaf dry weight (21.4 and 56.9%) (Zahidi, 2004), for fruit characters (8.02% for number of almonds and 93.28% for oil content (Bani-Aameur et al., 2001; Ait Aabd et al., 2011).

In the fruiting branches, intra-population variability (difference between trees in the same locality) is more important than inter-population variability (difference between localities). In addition, Euclidienne distance calculated based on characters of the fruiting branches is similar to that obtained for fruit and kernel (3.2) (Ferradous, 1995), but low in walnut (*Julans regia* L.) on the basis of leaf (4.6) and fruit (6.4) characters (Malvolti et al., 1994). So, differentiation of the three populations is not established since classification of individuals does not coincide with the groups that belong to the sites. This classification is not the result of geographic isolation; Ait Melloul and Argana with different climatic characteristics are not differentiated from Ait Baha. This result is confirmed by low contribution of variance related to locality (σ^2 inter-populations + σ^2geographical) in the phenotypic variance for the fruiting branches. But a large heterogeneity between trees is observed because approximately 93.3% of trees from Ait Baha, 13.3% of Ait Melloul and 6.7% of Argana are ranged in group of small producers. While about 93.3% of trees from Argana, 86.7% of Ait Melloul and 6.7% of Ait Baha (4 and 21) were among the fruit producers.

Dinis et al. (2011) suggested that annual climate conditions influence significantly the fruits and leaf characters. In addition, the morphological and phonological differences among ecotypes were not related to the small genetic differences, but were simply phenotypic adaptations to different climatic conditions. Both trees from Ait Baha, and some genotypes from Ait Melloul and Argana can produce fruits even in an arid environment will be used as germoplasm for domestication of argan as a fruit tree for oil production.

Conclusion

The main branch and the twigs more than two seasons have borne the fruits during the three campaigns, but the twigs of the season and those less two seasons have not borne the fruits at maturity even if they have flowered. The fruiting in argan tree is dependent on temperatures and rainfalls especially during the flowering season. For the establishment of orchards, the choice of efficient genotypes, pruning-lightening operations coupled with an appropriate irrigation in case of drought, at least during the flowering period should be taken into account. Differences observed for characters of the fruiting branches between trees and between localities indicate that an important genetic variation exists between individuals within each site. Ait Baha site is less far to Ait Melloul and Argana, but having some good genotypes with a high production potential even in unfavorable conditions. This variability can be exploited for the selection of desirable genotypes for breeding programme. Moreover, this result has practical implications for genetic management of resource for futur domestication programs of argan as oil-producing tree which is still in the wild state.

ACKNOWLEDGEMENTS

We gratefully acknowledge anonymous reviewers and office journal which provided helpful comments that greatly improved the manuscript. We thank the Morocco-Germany Co-operative Project ‘Conservation Project and Development the argan forest’ (PCDA-GTZ) and the project Pars-Agro 128 of the Morocan Ministery of Scientific Research for financial support.

REFERENCES

Ait Aabd N, El Ayadi F, Msanda F, El Mousadik A (2011). Evaluation of agromorphological variability of argan tree under different environmental conditions in Morocco: implication for selection. Int. J. Biodiver. Conserv. 3(3):73-82.

Andales A, Wang J, Sammis TW, Mexal JG, Simmons LJ, Miller DR, Gutschick VP (2006). A model of pecan tree growth for the management of pruning and irrigation. Agric. Water Manage. 84(1-2):77-88.

Bani-Aameur F (2000). Phenological phases of *Argania spinosa* (L. Skeels) flower. Forest Genetics 7:333-338.

Bani-Aameur F, Ferradous A, Dupuis P (2001). Fruit and stone variability in three argan (*Argania spinosa* (L.) Skeels) sites. Forest Genetics 8:39-45.

Bani-Aameur F (2002a). *Argania spinosa* (L.) Skeels flowering phenology. Genetic Resources Crop Evolution 49:11-19.

Bani-Aameur F, Benlahbil S (2004). Variation in RAPD markers of *Argania spinosa* trees and their progenies. Forest Genetics 11(3-4):337-342.

Benlahbil S, Bani-Aameur F (1999). Pollination of the argan tree is mostly entomophilous. In: Symposium of international plant resources: Argan and plants in arid and semi-arid areas. Faculty of Sciences, Agadir 23-25 April: pp. 119-120.

Bernstein IH, Teng GK, Garbin CP (1988). Applied Multivariate Analysis. Springer-Verlag New York Berlin Heidelberg London Paris Tokyo, P. 508.

Cuni-Shanchez A, De Smedt S, Haq N, Samson R (2011). Variation in baobab seedling morphology and its implications for selecting superior planting material. Scientia Horticulturae 130:109-117.

Dagneli P (1984). Théorie et Méthodes Statistiques. Applications Agronomiques. Tome II, 2Ed. Les Presses Agronomiques A.S.B.L. de Gembloux (Belgique), 464 pages.

Dinis LT, Peixoto F, Pinto T, Costa R, Bennett RN, Gomes-Laranjo J (2011). Study of morphological and phenological diversity in chestnut trees (‘Judia’ variety) as a function of temperature sum. Environ. Exper. Bot. 70(2-3):110-120.

Ehrig FR (1974). The argan character, ecology and economic maintenance of a significant tertiary in Morocco. Ptermanns geographical releases, 118(2):117-125.

Ferradous A (1995). Genetic diversity of some morphological characters of fruit and kernel of the argan tree (*Argania spinosa* (L.) Skeels). Third cycle thesis of higher education, Faculty of Sciences, University Ibn Zohr. Agadir. 180p + appendices.

Ferradous A, Bani-Aameur F, Dupuis P (1996). Stationnel climate, phenology and fruiting of the argan tree. Act. Inst. Agron. Vet. Hassan II. 17(1):51-60.

Frontier S (1981). Statistical Methods. Applied to Biology, Medicine and Ecology. Eds Masson, Paris, New York, Barcelona, Milan. P. 246.

Jamnadass R, Lowe, AJ, Dawson I (2009). Molecular markers and the management of tropical trees: the case of indigenous fruits. Trop. Plant Biol. 2:1-12.

Maurin R (1992). Argan oil, *Argania spinosa* (L.) Skeels Sapotaceae. French Rev. Fatty Substances 56:139-146.

Malvolti ME, Fineschi S, Pigliucci M (1994). Morphological integration and genetic variability in *Juglans regia* L. J. Heredity 85:389-394.

Metro A (1952). Preliminary observations on argan tree in Oued Cherrate and Dar Askraoui for genealogical selections. Ann. Forest. Rech. (Rabat), Annual Report: pp. 201-215.

M'hirit O (1989). Argan: a forest and fruit tree to multiple uses. Continuous Forest Formation, theme "argan". Forest Research Station. Rabat. 13-17 March. pp. 31-58.

Msanda F, El Aboudi A, Peltier JP (2005). Biodiversity and biogeography of the Moroccan argan tree. Cahiers Agricultures. 14(4):357-364.

Mückschel C, Otte A (2003). Morphometric parameters: an approach for the indication of environmental conditions on calcareous grassland. Agriculture, Ecosyst. Environ. 98(1-3):213-225.

Pfahler PL, Pereira MJ, Barnett RD (1996). Genetic and environmental variation in anther, pollen and pistil dimensions in sesame. Sex Plant Reprod. 9:228-232.

Prendergast HDV, Walker CC (1992). The argan: multipurpose tree of Morocco. The Kew Magazine. pp. 9:76-85.

Rahali M (1989). The production of argan forest. Continuous Forest Formation, theme "argan". Forest Research Station, Rabat, 13-17 March. pp. 31-58.

Rakonjac V, Akšić MF, Nikolić D, Milatović D, Čolić S (2010). Morphological characterization of ‘Oblačinska’ sour cherry by multivariate analysis. Scientia Horticulturae 125(4):679-684.

Rohlf FJ (1988). NTSYS-pc Numerical Taxonomy and Multivariate Analysis System. Version 1.80 Exeter Publ., Ltd, Setauket, New York.

Sandret F (1957). The argan pulp: Chemical composition and fodder value, change during maturation. Ann. For. Rech. (Rabat) 4:153-177.

Simbo DJ, De Smedt S, Den Bilcke NV, De Meullenaer B, Camp JV, Uytterhoeven V, Tack F, Samson R (2012). Opportinities for domesticating the African baobab (*Adonsonia digitata* L.): multi-trait fruit selection. Agroforest Syst, DOI: 10.1007/s10457-012-9568-7.

Sokal RR, Rohlf FJ (1995). Biometry, the Principales and Practice of Statistics in Biological Research. 3Ed. W. H. Freeman and Company New York. P. 887.

Steel RGD, Torrie JH (1960). Principles and Procedures of Statistics. 1Ed. McGraw-Hill Book Company, Inc. New York Toronto London. P. 481.

Sultan SE (2000). Phenotypic plasticity for plant development, function and life history. Plant Sci. 5(12):537-542.

Tworkoski TJ, Glenn DM (2010). Long-term effects of managed grass competition and two pruning methods on growth and yield of peach trees. Scientia Horticulturae 126(2):130-137.

Zahidi A, Bani Aameur F, Dupuis P (1995). Characterization of branching of the argan tree. Acts of International Symposium: Forest Facing Desertification: the case of argan. Faculty of Sciences Agadir:pp. pp. 36-52.

Zahidi A (1997). Phenology, typology and genetic variability of branching and foliation traits *Argania spinosa* (L.) Skeels. Third cycle thesis, Faculty of Sciences, University Ibn Zohr. Agadir. 177p + appendices.

Zahidi A, Bani-Aameur F (1999a). Leaf phenology of *Argania spinosa*. In: Symposium of international plant resources: Argan and plants in arid and semi-arid areas. Faculty of Sciences, Agadir 23-25 April: pp. 173-176.

Zahidi A, Bani-Aameur F (1999b). Phenology of branching in argan tree. In: Symposium of international plant resources: Argan and plants in arid and semi-arid areas. Faculty of Sciences, Agadir 23-25 April: pp. 177-179.

Zahidi A (2004). Genetic diversity of leaf, growth and branching of stem and root in *Argana spinosa* (L.) Skeels seedlings. Doctorate Thesis. Faculty of Sciences, University Ibn Zohr. 180p + appendices.

Zunzunegui M, Ain-Lhout F, Jáuregui J, Díaz Barradas MC, Boutaleb S, Álvarez-Cansino L, Esquivias MP (2010). Fruit production under different environmental and management conditions of argan, *Argania spinosa* (L.) Skeels. J. Arid Environ. 74:1138-1145.

academicJournals

Vol. 5(10), pp. 183-185, November, 2013
DOI 10.5897/JHF11.011
ISSN 2006-9782 © 2013 Academic Journals
http://www.academicjournals.org/JHF

Journal of Horticulture and Forestry

Short Communication

Impact of bio-inoculants on seed germination and plant growth of guava (*Psidium guajava*)

D. V. Pathak*, Surender Singh and R. S. Saini

Chaudhary Charan Singh Harayana Agricultura University (CCSHAU) Regional Research Station, Bawal (Haryana), India.

Accepted 21 October, 2011

An experiment was conducted to study the impact of bio-inoculants on seed germination and plant growth of guava at CCSHAU Regional Research Station, Bawal, during the period 2007 to 2008. The bio-inoculants tested were *Azotobacter chroococcum*, phosphate solubulising bacteria (PSB), plant growth promoting bacteria (PGPR) and mycorrhiza. Their impact on seed germination, plant height and other plant growth parameters was studied in presence of farmyard manure (FYM) as well as vermicompost. During the 2007 period, maximum percent seed germination (34.2) was observed in the treatment having FYM + PGPR or FYM + *A. chroococcum* at 40 days (DAS); followed by PGPR (29.2) and vesicular arbuscular mycorrhizae (VAM) (25.8) treatments. While during the 2008 period, highest seed germination (51.1%) was observed in the treatment having FYM + PGPR or FYM + *A. chroococcum* at 40 DAS; followed by the treatments having FYM + PGPR + PSB + *A. chroococcum* or vermicompost + PSB + *A. chroococcum* (48.9%). Number of leaves per plant observed at 150 DAS were maximum in the treatment having FYM + VAM (18.8). Plant height at 150 DAS was maximum in FYM treatment having all the three bio-inoculants (31.5 cm). However, these values were quite comparable to each other in FYM as well as in vermicompost filled plastic bags.

Key words: Bio-inoculants, seed germination, guava (*Psidium guajava*), phosphate solubulising bacteria (PSB), plant growth promoting bacteria (PGPR), vesicular arbuscular mycorrhizae (VAM), *Azotobacter chroococcum.*

INTRODUCTION

Due to rising cost of chemical fertilizers and their adverse effects on soil health, an economically attractive and alternate potential source of plant nutrients should be exploited. The excessive use of these chemical fertilizers adversely affects human health resulting in dreadful diseases like cancer, hypertension and other abnormalities. Further, to sustain the productivity, the bio-inoculants can supplement them to certain extent in various food crops. But it is not the common practice in various horticultural crops. The seed coat of most of the fruit crops is very hard. To break the seed dormancy, either some chemical treatment or long incubation period is required. These bio-inoculants can be helpful in breaking the seed dormancy by producing various plant growth substances. Hence, the present investigations were undertaken to study the response of different bio-inoculants in combination with either farmyard manure (FYM) or vermicompost on seed germination and plant growth in guava (*Psidium guajava*).

MATERIALS AND METHODS

The experiment was conducted at the Experimental Farm, CCSHAU Regional Research Station, Bawal, during the years 2007/2008 and 2008/2009. The experiment was laid out in randomized block design with six replications of each treatment

---

*Corresponding author. E-mail: pathak_dv@rediffmail.com.

Table 1. Effect of bio-inoculants on seed germination and plant height in guava.

Treatment	Seed germination (%)		Plant height (cm)	
	2007	2008	2007	2008
FYM alone	20.8	37.7	18.8	27.5
FYM + PGPR	25.8	51.1	29.7	28.7
FYM + VAM	29.2	45.5	28.0	29.2
FYM + PSB	20.0	44.4	18.3	27.9
FYM + *Azoto*.	24.0	51.1	22.3	28.2
FYM + PSB+ *Azoto*. + PGPR	34.2	48.9	19.2	31.5
VC alone	21.0	23.3	15.5	20.3
VC + PGPR	22.5	46.6	27.7	25.0
VC + VAM	21.7	37.5	26.3	26.7
VC + PSB	26.3	37.7	16.3	23.3
VC + *Azoto*.	25.2	48.9	18.0	27.4
VC + PSB+ *Azoto*. + PGPR	26.7	28.9	25.2	28.4
Mean	24.8	41.8	22.1	27.0
CD at 5%	2.04	3.41	1.87	2.17

both with vermicompost as well as farm yard manure. For filling up of polythene bags, the loamy sand soil and vermicompost/ FYM were mixed together in 1:1 ratio. The different treatment combinations were T_0: uninoculated treatment; T_1: *Azotobacter chroococcum*; T_2: phosphate solubilizing bacteria (PSB); T_3: vesicular arbuscular mycorrhizae (VAM); T_4: plant growth promoting bacteria (PGPR) (*Pseudomonas maltophilia* PM4); T_5: PGPR+PSB+ *A. chroococcum*. In total, there were twelve treatments; six each of vermicompost + soil and FYM + soil. The seeds of guava were surface sterilized with 0.2% mercuric chloride solution for five minutes and then washed 2 to 3 times with sterilized distilled water, coated with charcoal based inoculants and then, twenty seeds per replication for each treatment were impregnated into the polythene bags. The bio-inoculants used in the study were collected from Department of Microbiology, CCSHAU, Hisar, and grown in their respective media under aseptic conditions.

Glomus fasciculatum, species of VAM fungi was used as VAM inoculant. The inoculum consisted of soil, spores, hyphae from chopped root fragments of pearl millet. Ten gram of the inoculum was mixed with the top soil in each polythene bag before sowing of guava seeds. The observations were recorded in terms of percent seed germination at different time intervals up to 40 days of sowing. Then, plant saplings were thinned down to one healthy sapling per bag and observed for plant height, number of leaves per plant and dry shoot weight at 150 days of sowing.

RESULTS AND DISCUSSION

During the period 2007/2008, maximum percent germination (34.2) was observed in the treatment having FYM + PSB + *Azotobacter* + PGPR; followed by FYM + VAM (29.2). Percent seed germination was slightly better in the treatments having FYM over their respective vermicompost treatments; however, the difference between them was non-significant. During 2008/2009, the maximum germination (51.1) was recorded in FYM + PGPR and FYM + *Azotobacter*; closely followed by FYM + PSB + *Azotobacter* + PGPR and vermicompost+ *Azotobacter* (48.9%) (Table 1). Plant height was also stimulated by different bio-inoculants in combination with farm yard manure as well as vermicompost during the period of investigation. However, PSB alone did not contribute much on different plant growth parameters.

VAM inoculation with FYM as well as with vermicompost positively affected number of leaves per plant during both years (Table 2). The similar trends were followed when dry weight of shoot was recorded after 150 days (DAS). In general, VAM culture and coinoculation of PSB, PGPR and *Azotobacter* stimulated plant growth parameters more positively as compared to single inoculation or untreated control. The response with FYM was slightly better over their respective vermicompost treatments.

Various reports in horticultural crops indicated that bio-inoculants either individually or in combination had synergistic effect on plant growth. The dual inoculation of *Azotobacter* and *G. fasciculatum* had more positive response in peach seedlings as compared to single inoculation or control (Godara et al., 1998). Sharma et al. (2002) reported that VAM fungi enhanced nutrient uptake and level of plant growth substances in apple seedlings. Subbiah (1990) also reported that when adequate amount of farmyard manure added to the soil with biofertilizers, it improved biofertilizer efficiency and ultimately nutrient status of the soil. Similar increase in growth of fruit plants with biofertilizers has also been reported by Sharma and Bhutani (1998). Increase in the growth of pecan seedlings could be attributed to the combined effect of biofertilizers on nutrient uptake and plant growth (Joolka et al., 2004). The possible reason for better plant growth and germination can be attributed to maximum and early bacterization near root zone which induce germination by inducing root inducing substances (Wani et al., 1988). Similar reports have been made by

Table 2. Effect of bio-inoculants on other plant growth parameters in guava.

Treatment	Number of leaves/plant		Dry shoot weight (g)	
	2007	2008	2007	2008
FYM alone	11.5	15.42	0.38	0.56
FYM + PGPR	21.8	17.17	1.17	0.77
FYM + VAM	22.5	18.80	0.95	0.83
FYM + PSB	15.5	15.75	0.53	0.79
FYM + *Azoto*.	17.2	18.20	0.48	0.67
FYM + PSB + *Azoto*. + PGPR	14.8	17.75	0.95	0.92
VC alone	13.3	14.24	0.42	0.48
VC + PGPR	19.0	17.33	1.25	0.62
VC + VAM	20.5	15.67	1.08	0.68
VC + PSB	15.0	18.20	0.59	0.72
VC + *Azoto*.	14.0	16.50	0.57	0.84
VC + PSB + *Azoto*. + PGPR	14.5	17.83	0.82	0.82
Mean	16.6	16.9	0.76	0.72
CD at 5%	1.49	1.35	0.12	0.17

Nath and Korla (2000) in ginger.

REFERENCES

Godara RK, Awasthi RP, Kaith NS (1998). Interaction effect of VA-mycorrhizae and Azotobacter inoculation on growth and macronutrients of peach seedlings. Hary. J. Hort. Sci. 27:235-240.

Joolka NK, Singh RR, Sharma MM (2004). Influence of biofertilizers, GA3 and their combinations on groth of pecan seedlings. Ind. J. Hort. 61:226-228.

Nath B, Korla BN (2000). Studies on effect of biofertilizers in ginger.Ind. J. Hort. 57:168-171.

Sharma SD, Bhutani VP (1998). Response of apple seedlings to VAM, Azotobacter and inorganic fertilizers. Hort. J. 11:1-8.

Sharma SD, Bhutani VP, Awasthi RP (2002). Effect of vesicular-arbiscular mycorrhizae and phosphorus on leaf and soil mineral nutrient status of apple seedlings. Ind. J. Hort. 59:140-144.

Subbiah K (1990). Nitrogen and Azospirillum interaction on fruit yield and nitrogen use efficiency in tomato. South Ind. Hort. 38:342-344.

Wani SP, Chandrapalaiah S, Zambre MA, Lee KK (1988). Association between N2 fixing bacteria and pearl millet plants-Response, mechanisms and resistance. Plant Soil 110:284-302.

UPCOMING CONFERENCES

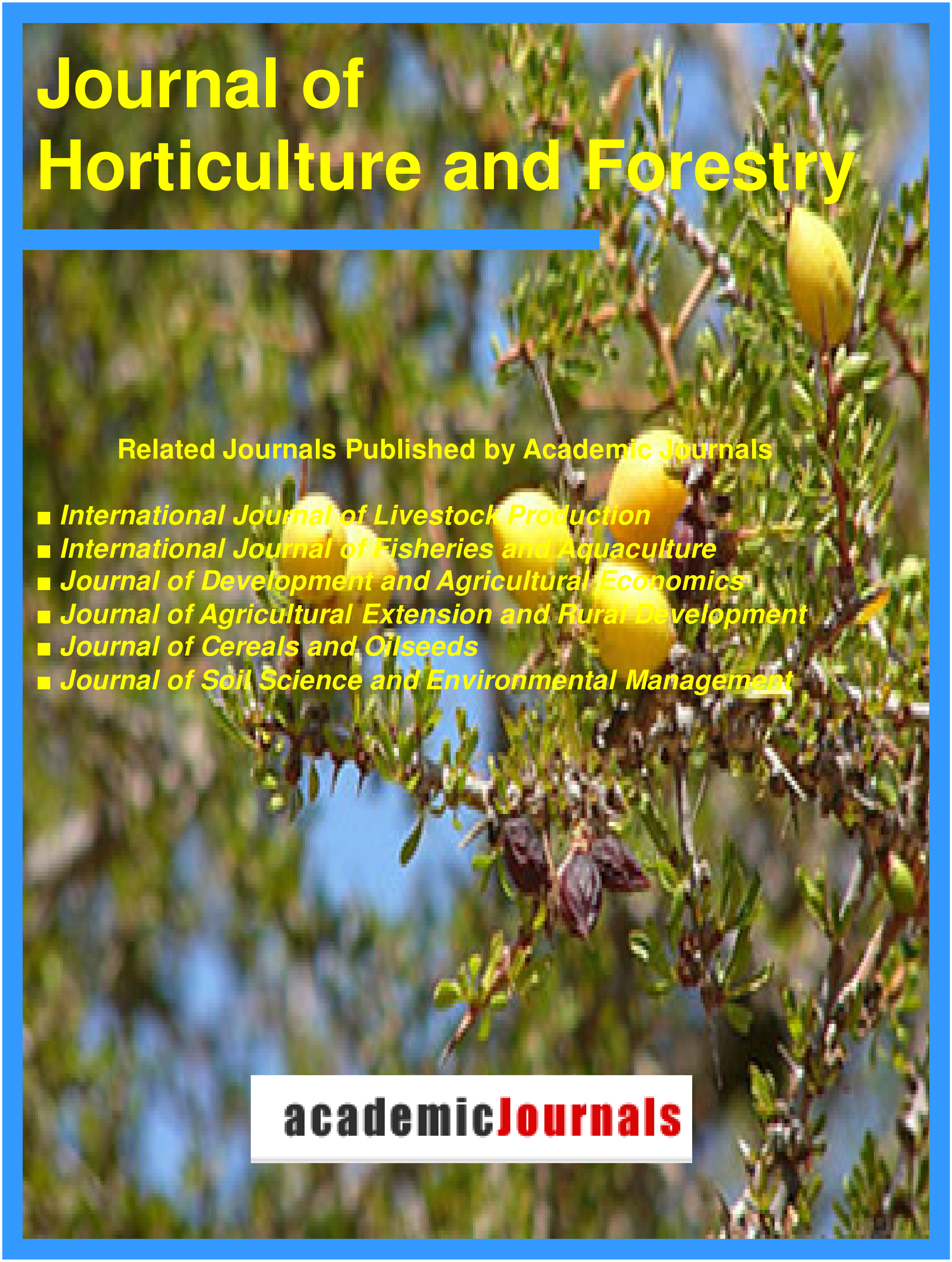
International Plant Breeding Congress, Antalya, Turkey, 10 Nov 2013

Beltwide Cotton Conferences, New Orleans, Louisiana, 6 Jan 2014

Conferences and Advert

November 2013
International Plant Breeding Congress, Antalya, Turkey, 10 Nov 2013

January 2014
Beltwide Cotton Conferences, New Orleans, Louisiana, 6 Jan 2014



Journal of Horticulture and Forestry

Related Journals Published by Academic Journals

- *International Journal of Livestock Production*
- *International Journal of Fisheries and Aquaculture*
- *Journal of Development and Agricultural Economics*
- *Journal of Agricultural Extension and Rural Development*
- *Journal of Cereals and Oilseeds*
- *Journal of Soil Science and Environmental Management*

academicJournals