Journal of Agriculture and Rural Development in the Tropics and Subtropics

DITSL

Vol. 110 No. 2 2009

kassel university press

Journal of Agriculture
and Rural Development in
the Tropics and Subtropics

Volume 110, No. 2, 2009

Journal of Agriculture and Rural Development in the Tropics and Subtropics

formerly:
Der Tropenlandwirt. Beiträge zur tropischen Landwirtschaft und Veterinärmedizin,
Journal of Agriculture in the Tropics and Subtropics

ISSN 1612-9830

Publisher

German Institute f. Tropical and Subtropical Agriculture (DITSL GmbH), Witzenhausen
Association for Sustainable Development (GNE mbH), Witzenhausen
Institute for tropical Agriculture e.V., Leipzig
University of Kassel, Faculty of Organic Agricultural Sciences, Witzenhausen
Association of Agronomists in the Tropics and Subtropics Witzenhausen, e. V., (VTW)

Executive Manager and Editor in Chief

Hans Hemann, Steinstraße 19, D 37213 Witzenhausen, Tel. 05542 - 981216,
Telefax 05542 - 981313, EMail: tropen@wiz.uni-kassel.de

Subscription

The *Journal of Agriculture and Rural Development in the Tropics and Subtropics* is published twice a year (April and October). It may be subscribed by a price of €30,– + shipping. The subscription is for at least one year and is automatically extended unless otherwise stated by the subscriber till the end of the year. Single copies may be purchased for €20,– + shipping. Orders may be placed at Kassel University Press, Diagonale 10, D-34127 Kassel (www.upress.uni-kassel.de), Fon ++49 (0)561 804 2159, Fax ++49 (0)561 804 3429 or at any bookstore.

Publishing House

kassel university press GmbH
www.upress.uni-kassel.de

Composition and Layout

Bierwirth & Gabele Softwaredesign GbR, Steinstr. 19, Postfach 1128,
D - 37201 Witzenhausen, http://www.bg-softwaredesign.de

Cover layout: Jochen Roth, Melchior v. Wallenberg, Kassel
Printed by: Uniprinter University of Kassel

Dear Reader,

With the issue 2 in 2009, and after my retirement I shall hand over the editorial work, which I took over from Prof. Dr. Peter Wolff in 1979. There has been thirty years of change, beginning with format, cover, title, publisher, distributor, editors and staff. Dr. Peter Wolff has written an article about the history of the publication, see pages 97 ff in this volume. The journal, drafted by the publisher and the editors, provides a wide span of information about tropical and subtropical agriculture and especially gives researchers from Africa, Asia, South- and Central America an opportunity to access and publish their work. In the beginning, most of the articles were published in German, but today they are mainly written in English, as English is becoming the universal language in science, only a few papers are still in German or Spanish.

"Sustainable development" is the aim, whereas the focus over the last few years is on organic agriculture. This is especially since we have the Faculty of Organic Agricultural Sciences at the University of Kassel. Organic agriculture can be sustainable, especially for the tropics and subtropics.

I would like to give special thanks to the editorial team for their work over the past thirty years, all of whom have contributed voluntarily. They are in name: Dr. Eckard Beer, Dr. Klaus Becker, Dipl.Agraring. Ulrich Türke, Prof. Dr. Carl Hoeppe, Prof. Dr. Ezzat Tawfik, RSD Johann G. Thierolf, Prof. Dr.-Ing. Rüdiger Krause, Prof. Dr. Samuel Jutzi, Prof. Dr. G. Franke, Prof. Dr. A. Pfeiffer, Dr. K. Richter, Dr. W. Werner, Prof. Dr. Beatrice Knerr, Dipl. Ing. agr. M. Mischkowsky, Prof. Dr. Christian Richter, Dr. Eberhard Klinge von Schultz and the persons now in the editorial board. I would also like to thank the publisher for the faith they had in me. I must also emphasise my thanks to the teamwork of the kassel university press and with my personal thanks to Mr. Jürgen Bierwirth for the layout and design. And for the former issues: Dieterichsche Universitäts-Buchdruckerei W.Fr. Kaestner, Druck + Papier Meyer, EkopanVerlag and IT Servies Michael Wright.

Last but not least, I thank the readers who have shown loyalty to the publication, whether reading the printed or Internet version.

I would like to conclude with Barbara Ward's book title and its content "We only have one World"

Hans Hemann

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 110, No. 2, 2009, pages 97–105

Anmerkungen zur Entwicklung des Journal of Agriculture and Rural Development in the Tropics and Subtropics

Remarks on the development of the Journal of Agriculture and Rural Development in the Tropics and Subtropics

P. Wolff [1]

Zusammenfassung

In der zweiten Jahreshälfte 2009 scheidet der langjährige geschäftsführende Schriftleiter des *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, Dipl.-Ing. Hans Hemann, aus der Redaktion dieser Zeitschrift aus. In Würdigung der geleisteten Arbeit erfolgt in dem vorgelegten Artikel eine Dokumentation der Entwicklung der Zeitschrift von ihren Anfängen als Alumni-Zeitschrift bis zur heutigen international anerkannten Fachzeitschrift.

Prof. Ernst Albert Fabarius, der Mitbegründer und erster Direktor der Deutschen Kolonialschule in Witzenhausen schuf die Zeitschrift zur Information und Kontaktpflege mit den Absolventen, den Freunden und Gönnern der Lehranstalt. Erst nach seinem Tod 1927 kam es zu vorsichtigen Versuchen der Zeitschrift einen mehr fachlichen Charakter zu verleihen, ohne dabei allerdings die Aufgabe des Kontaktes zu den Absolventen, Freunden und Gönnern aus dem Auge zu verlieren. Der Übergang von der Alumni-Zeitschrift zur Fachzeitschrift für die Landwirtschaft in den Tropen und Subtropen wurde 1966 vollzogen, nach dem die Lehranstalt ihren Betrieb wieder aufgenommen hatte. Aus dem *Deutschen Kulturpionier* wurde *Der Tropenlandwirt*. Im Jahre 1994 fusionierte die Zeitschrift mit *Beiträge zur tropischen Landwirtschaft und Veterinärmedizin*, der bis dahin von dem Institut für Tropische Landwirtschaft der Universität Leipzig herausgegebenen Fachzeitschrift. Als schließlich der Kreis der Leser und der Autoren zunehmend aus dem internationalen Umfeld kam, erfolgte die Umstellung auf eine überwiegend englischsprachige Fachzeitschrift. Der Name wurde entsprechend in *Journal of Agriculture and Rural Development in the Tropics and Subtropics* geändert. Hans Hemann hat neben der oft mühsamen Redaktionsarbeit diese Entwicklung von 1979 bis 2009 mitgetragen und vor allem die verschiedenen Änderungen umgesetzt.

Keywords: Entwicklung einer internationalen Fachzeitschrift, Journal of Agriculture and Rural Development in the Tropics and Subtropics, Der Tropenlandwirt, Der Deutsche Kulturpionier

[1] Prof. (i.R). Dr. Peter Wolff, Heiligenstädter Weg 5, D-37213 Witzenhausen (Germany). Email: p-wolff-witzenhausen@t-online.de

Vorbemerkung

Hans Hemann, tritt in der zweiten Jahreshälfte 2009 nach 33 Jahren im Dienst der Universität Kassel-Witzenhausen in den Ruhestand. Damit endet nicht nur seine erfolgreiche Tätigkeit am und für den Fachbereich Ökologische Agrarwissenschaften, sondern auch seine dreißigjährige Tätigkeit als geschäftsführender Schriftleiter des *Journal of Agriculture and Rural Development in the Tropics and Subtropics*. Als ISOS Mitglied und vor allem als Geschäftsführer des Tropenzentrums hat er sich besondere Verdienste um die internationale Profilierung des Universitätsstandortes Witzenhausen erworben.
Hans Hemann war von 1979 bis 2009 geschäftsführender Schriftleiter des *Journal of Agriculture and Rural Development in the Tropics and Subtropics* und deren Vorgängerpublikationen. Unter seiner Regie wurden 59 Ausgaben der Zeitschrift und 78 Hefte der Schriftenreihe Beihefte zu der Tropenlandwirt bzw. Supplements of the *Journal of Agriculture and Rural Development in the Tropics and Subtropics* herausgebracht.
In Würdigung der von Hans Hemann als geschäftsführender Schriftleiter geleisteten Arbeit erfolgt nachfolgend eine Darstellung der Entwicklung der Zeitschrift. Die Darstellung soll die Geschichte der Zeitschrift dokumentieren, zugleich aber die Rolle verdeutlichen die Hans Hemann in diesem Entwicklungsprozess gespielt hat.

Entwicklung zum Journal of Agriculture and Rural Development in the Tropics and Subtropics

1 Der Deutsche Kulturpionier

Ernst Albert Fabarius, Mitbegründer und erster Direktor der 1898 gegründeten Deutschen Kolonialschule in Witzenhausen a.d. Werra (DKS) kam sehr bald nach der Eröffnung dieser Lehranstalt zu der Erkenntnis, dass man zur Pflege der Außenkontakte eines eigenen Publikationsorgans bedurfte. Dies nicht nur zur Pflege der Kontakte mit den Absolventen. Genauso wichtig, wenn nicht noch wichtiger war es, die Freunde und Gönner, sowie potentielle Förderer über die Entwicklung der DKS zu informieren und zu weiterer finanzieller und materieller Unterstützung anzuregen. Die DKS war ein privates Wirtschaftsunternehmen, das mit einer viel zu geringen Kapitalausstattung den Betrieb in Witzenhausen aufgenommen hatte und zur Aufrechterhaltung eines geordneten Lehr- und Ausbildungsbetriebes ständig vor allem finanzieller Zuwendungen bedurfte.

In Abwägung der oben kurz skizzierten Umstände entschied man sich für die Herausgabe einer Zeitschrift. Fabarius war der Initiator dieser Idee und fungierte von 1900 bis zu seinem Tod im Jahr 1927 als deren Herausgeber. Bis 1921 nahm er auch die Funktion des Schriftleiters wahr. Fabarius gab der Zeitschrift den Namen „Der Deutsche Kulturpionier“ und prägte deren inhaltliche Entwicklung. Er beschrieb bereits in der ersten Ausgabe, dem so genannten „Stiftungsheft“ von 1900 den Zweck des DKP wie folgt:

„Diese zwanglosen Hefte wollen und sollen nicht irgend einem langgefühlten Bedürfnis abhelfen oder in Wettstreit treten mit anderen kolonialen, geographischen und ähnlichen Blättern und Zeitschriften. „Der deutsche Kulturpionier" will vielmehr nichts anderes sein als ein geistiges und doch sichtbar wirkendes Band, welches die Glieder der deutschen Kolonialschule daheim und über'm Meer zusammenhält, er soll in Sonderheit sein ein deutscher Heimatgruß an die Kameraden draußen, ein Liebesbote der in seiner Tasche nützliche und gute, freundliche und ernste Kunde hin und her trägt und nicht zum wenigsten auch ein treuer Freund, der unseren wackeren Pionieren auf einsamen Posten manch guten Wink geben soll für Arbeit und Streben wie für Herz und Gemüt! So trete er denn hin zu jedem mit einem herzlichen deutschen: „Grüß Gott"!"

Amthor (1983) die die Entwicklung der DKS im Rahmen ihrer Staatsexamensarbeit von deren Gründung bis zum Ende des Ersten Weltkrieges analysierte und dabei vor allem die Zeitschrift „Der Deutsche Kulturpionier" als Quelle benutzte, kommt zu der Feststellung, dass obige Zielsetzung der Zeitschrift deutlich macht: „Fabarius misst der Kameradschaft und der Verbundenheit der DKS-Mitglieder besonderen Wert bei, die somit auch über die Ausbildungszeit hinaus durch den Kulturpionier Bestand haben sollte. Dieses Band sollte durch den Kulturpionier erreicht und erhalten werden.

Die Nachrichten der „Kameraden draußen" schienen für Fabarius das Herzstück der Zeitschrift zu sein. Mehrmals beschwerte er sich in „Rückblick und Ausblick" über fehlende Adressen ausgewanderter „Kameraden" und das Ausbleiben von Briefen. Auch nach der Ausbildungszeit versuchte er, die Schüler zu maßregeln und die Disziplin mit Hilfe der Zeitschrift zu wahren. Für den DKS-Direktor gehörte es zum gefestigten, disziplinierten Charakter, der Schule durch den Briefverkehr Dankbarkeit und Verbundenheit auszudrücken (Amthor, 1983).

„Der Deutsche Kulturpionier" erschien seit 1900 meist zweimal pro Semester, teilweise auch als Doppelheft. Während des Ersten Weltkrieges erschienen lediglich vier Ausgaben. Danach änderte der „Kulturpionier" Form und Inhalt, worauf später noch eingegangen werden soll. Nach der ersten Ausgabe etablierte sich eine bis 1914 gleichbleibende Gliederung. Letztere trug den Nachrichten und Informationen der DKS, deren Umfeld und den Absolventen Rechnung. Damit hatte der Kulturpionier zunächst eindeutig den Charakter eines Alumni-Nachrichtenblattes/-Zeitschrift.

Nicht alle Leser der Zeitschrift waren offensichtlich mit deren Ausrichtung und inhaltlicher Gestaltung einverstanden. In der Ausgabe 1911, Nr. 3 diskutiert Fabarius Änderungsvorschläge für den „Kulturpionier", die er jedoch aufgrund mangelnder Zeit und Geld ablehnt. Es lässt sich hier nur erahnen, welche Vorschläge gemacht wurden. So ist die Rede von einer Umwandlung des „Kulturpionier" in ein „kolonialwirtschaftliches Blatt", was Fabarius von der „Opferwilligkeit der alten Kameraden" abhängig macht, die er in seinen weiteren Ausführungen schließlich sehr gering einschätzt (Amthor, 1983).

Wie oben dargelegt nahm Fabarius die Funktion des Herausgebers des „Kulturpioniers" bis zu seinen Tod wahr. Von 1922 bis 1927 wurde Fabarius als Schriftleiter durch Theodor Bindel unterstützt. Bindel kümmerte sich um den Ehemaligenverband und die Schriftleitung von „Der Deutsche Kulturpionier". Unter seiner Regie fanden vermehrt tro-

pen(land)wirtschaftliche Nachrichten Eingang in die Zeitschrift. Erste vorsichtige Versuche dem „Kulturpionier“ einen mehr fachlichen Charakter zu geben.

Nach dem Tod von Fabarius nahm sich Dr. Feldmann, Ehemaliger der DKS (1903-1904) und zum damaligen Zeitpunkt Dozent an der DKS (1919-1937), im Jahr 1928 der Zeitschrift „Der Deutsche Kulturpionier“ an. Als Schriftleiter förderte er die stärkere fachliche Ausrichtung der Zeitschrift, schied jedoch aus dieser Tätigkeit bereits 1933 wieder aus. Ob hierbei politische Gründe eine Rolle spielten ist nicht bekannt. Die später erfolgte Entlassung als Dozent und die Degradierung zum Sprachlehrer lässt dies allerdings vermuten. Im Jahr 1934 übernahm C. Oertel, der damalige Geschäftsführer des Verbandes Alter Herren der Deutschen Kolonialschule, die Schriftleitung und der Verband fungierte in den Folgejahren als Herausgeber der Zeitschrift. Von C. Oertel übernahm 1935 Theodor Frank, auch ein Absolvent der DKS, die Schriftleitung. Im Zuge der Auseinandersetzungen zwischen dem Altherrenverband und dem, von den Nationalsozialisten eingesetzten Direktor Koch, wurde der Sitz der Schriftleitung nach Berlin verlegt. Mit dem Beginn des zweiten Weltkrieges stellte die Zeitschrift vorübergehend ihr Erscheinen ein.

Trotz verschiedener Versuche den „Kulturpionier“ stärker tropenlandwirtschaftlich, wissenschaftlich auszurichten, blieb die Zeitschrift eine Alumni-Zeitschrift, die sich vor allem an die Absolventen der DKS richtete. Bei nüchterner Betrachtung waren die Entwicklungschancen zu einer reinen Fachzeitschrift eher gering einzustufen. Es gab ja bis in den zweiten Weltkrieg hinein den renommierten „Tropenpflanzer“, der sich als tropenlandwirtschaftliche Fachzeitschrift internationaler Anerkennung erfreute und in dem namhafte Autoren veröffentlichten.

Nach dem Ende des zweiten Weltkrieges war zunächst nicht an eine Fortsetzung der Herausgabe der Zeitschrift „Der Deutsche Kulturpionier“ zu denken. Die Absolventen der DKS hatten gewiss andere Sorgen und Nöte. Um so erstaunlicher ist es, dass es bereits 1949 Dr. Winter, einem ehemaligen Dozenten der DKS und Schwiegersohn von Fabarius, gelang, einen Kreis von Absolventen für eine Reaktivierung des Verbandes Alter Herren vom Wilhelmshof e.V. zu begeistern und die Herausgabe von „Der Deutsche Kulturpionier“ wieder aufleben zu lassen. Dr. Winter wurde 1949 der erste Nachkriegsschriftleiter und übte diese Funktion bis 1956 aus. Die Zeitschrift blieb eine Alumni-Zeitschrift und widmete sich dem Zusammenhalt der Absolventen der DKS und versuchte für die Wiedereröffnung der Deutschen Kolonialschule zu werben.

Nach dem Rückzug von Dr. Winter aus der Verbandsarbeit und der Schriftleitung der Zeitschrift kam es zu einer kurzzeitigen Unterbrechung des Erscheinens. Im Jahr 1960 übernahm Dr. Hartwig Golf, Absolvent der DKS, die Schriftleitung. Er nahm diese ehrenamtliche Aufgabe bis 1966 wahr. In dieser Zeit wurde die Zeitschrift umbenannt in „Der Deutsche Tropenlandwirt, Zeitschrift des Verbandes Alter Herren vom Wilhelmshof in Zusammenarbeit mit dem Deutschen Institut für tropische und subtropische Landwirtschaft Witzenhausen a.d. Werra“. D.h. die Trägerin der Ausbildungsstätte wurde Mitherausgeberin der Zeitschrift. Ferner entwickelte sich die Zeitschrift zu einem mehr fachlich orientierten Publikationsorgan, die Verbandsnachrichten nahmen einen immer

geringeren Raum ein. Auf Vorschlag von Dr. Peter Wolff wurden verbandsinterne Nachrichten in einem gesonderten Nachrichtenblatt, dem „Unter Uns“, den Mitgliedern des Verbandes Alter Herren vom Wilhelmshof e.V. übermittelt.

2 Der Tropenlandwirt

Im Jahr 1968 wurde Dr. Peter Wolff als Dozent für Kulturtechnik und Wasserwirtschaft an die damalige Ingenieurschule für Tropenlandwirtschaft Witzenhausen berufen. Durch seine vorausgegangene Mitarbeit in der Redaktion der Zeitschrift für Kulturtechnik und Flurbereinigung während seiner Tätigkeit am Institut für Kulturtechnik und Grünlandwirtschaft der TU Berlin und der Mitwirkung sowie der wissenschaftlichen Beratung bei der Erstellung verschiedener Publikationen der Verkaufsgemeinschaft Deutscher Kaliwerke in Hannover verfügte er über redaktionelle Erfahrungen und auch Interesse an solchen Arbeiten. Bald nach Aufnahme seiner Lehrtätigkeit in Witzenhausen übernahm er die Schriftleitung der Zeitschrift „Der Tropenlandwirt“. Während die Zeitschrift bis dahin nur einmal jährlich erschien setzte er eine zweimalige Erscheinungsweise und die Änderung des Untertitels in Zeitschrift für die Landwirtschaft in den Tropen und Subtropen“ durch.

Während seiner annähernd 12jährigen ehrenamtlichen Tätigkeit als Schriftleiter von „Der Tropenlandwirt“ versuchte Wolff die Zeitschrift zu einer Fachzeitschrift für das Gesamtgebiet der tropischen und subtropischen Landwirtschaft zu entwickeln. Zunächst war es schwierig, für dieses Unterfangen geeignete Autoren bzw. fachlich fundierte Arbeiten zu finden. Zur Gewinnung der fachlichen/wissenschaftlichen internationalen Anerkennung der Zeitschrift war dies entscheidend. Dies zu erreichen wurde schwieriger als zunächst erwartet und entwickelte sich zu einem langwierigen Prozess. Ursache hierfür war u.a. die Tatsache, dass in der Bundesrepublik zwei fachverwandte deutschsprachige Zeitschriften auf dem Markt erschienen: „Landwirt im Ausland“ und „Zeitschrift für Ausländische Landwirtschaft“, später kam noch die in der DDR erscheinende Zeitschrift „Beiträge zur tropischen Landwirtschaft und Veterinärmedizin“ hinzu. Durch verschiedene Werbeaktionen wurde versucht, die Zeitschrift in Fachkreisen bekannt zu machen.

Wolff konnte schließlich auch durchsetzen, dass in Ergänzung zur Zeitschrift die Schriftenreihe „Beihefte zu Der Tropenlandwirt“ aufgelegt und dieser zugeordnet wurde. Zunächst handelte sich dabei überwiegend um Berichte der vom Fachbereich Internationale Agrarwirtschaft durchgeführten Vortragstagungen (z.B. der jährlichen Witzenhäuser Hochschulwoche). Das erste Heft erschien 1971. In der Ära Hemann erschienen in der Schriftenreihe nicht nur eine steigende Anzahl von Heften pro Jahr sondern vor allem vermehrt Monographien, die sich mit speziellen Fragestellungen der Agrarwirtschaft in den Tropen und Subtropen befassen.

Da das digitale Zeitalter in den siebziger Jahren des 20.Jahrhunderts in den Redaktionsstuben noch nicht angekommen war, erwies sich die Redaktionsarbeit generell und speziell für kleinere Fachzeitschriften als äußerst schwierig, technisch kompliziert, zeitaufwendig und kostspielig. Die Redaktion des „Tropenlandwirts“ vermochte die Probleme nur Dank der Unterstützung der kompetenten Mitarbeiter der Druckerei Kaestner, Rosdorf

Kr. Göttingen zu lösen. Der Zwang zur Kosteneinsparung machte eine Fortführung der erfolgreichen Zusammenarbeit mit dieser Druckerei schließlich nicht mehr möglich.

In 1979 übernahm Hans Hemann, als ehrenamtliche Tätigkeit, die Schriftleitung und zwar als geschäftsführender Schriftleiter. Er erweiterte die Redaktion in dem er zunächst mit Unterstützung von Prof. Dr. E. Baum, des Geschäftsführers des DITSL, aus dem Kreis der Hochschullehrer des Fachbereiches Internationale Agrarwirtschaft der Gesamthochschule Kassel kompetente Fachleute für eine Mitarbeit in der Redaktion gewann. Dabei wurde Wert darauf gelegt, dass die für internationale Agrarwissenschaft wichtigsten wissenschaftlichen Fachgebiete in der Redaktion vertreten waren. Später wurde der Redaktionsausschuss durch externe Sachverständige erweitert. Durch die Schaffung des Redaktionsausschusses und die Nutzung externen Sachverstandes wurde es möglich, eine fundierte Beurteilung der eingereichten Manuskripte und eine kritische Auswahl der zur Veröffentlichung in der Zeitschrift geeigneten Arbeiten vorzunehmen.

Ab Ende 1985 konnte der damalige Fachbereich Internationale Agrarwirtschaft (FB21) der Gesamthochschule Kassel für die Mitherausgabe gewonnen werden, federführend für die Herausgabe blieb das DITSL. Die redaktionelle Verantwortung lag weiterhin bei Hans Hemann, die jetzt in sein Aufgabengebiet am FB 21 integriert wurde.

In der Ära Hemann haben es sich Herausgeber und Redaktion zur Aufgabe gemacht, in der Zeitschrift nicht nur Vorrangig aus dem produktionstechnischen Bereich sondern aus allen Fachgebieten der Landwirtschaft in den Tropen und Subtropen zu berichten. Die in den Ausgaben April 1982 und April 1988, sowie im Beiheft Nr. 77 (HEMANN, 2004) veröffentlichten Gesamtinhaltsverzeichnisse für den Zeitraum 1970 – 1987 machen das weite Spektrum deutlich, das die Zeitschrift abdeckt.

3 Fusion mit „Beiträge zur tropischen Landwirtschaft und Veterinärmedizin“

Im Jahre 1994 änderte die Zeitschrift ihren Namen in „Der Tropenlandwirt – Beiträge zur tropischen Landwirtschaft und Veterinärmedizin / Zeitschrift für die Landwirtschaft in den Tropen und Subtropen“. Die Namensänderung war das Ergebnis der Fusion der Zeitschriften „Der Tropenlandwirt“, Witzenhausen und „Beiträge zur tropischen Landwirtschaft und Veterinärmedizin“, Leipzig. Hintergrund der Fusion ist nicht nur die strukturelle Veränderung der beiden mitherausgebenden universitären Einrichtungen. In Witzenhausen hatte die Zusammenlegung der beiden agrarwirtschaftlichen Fachbereiche der Universität Kassel stattgefunden. In Leipzig war aufgrund der Schließung des Instituts für Tropische und Subtropische Landwirtschaft die Möglichkeit entfallen, die Zeitschrift „Beiträge zur tropischen Landwirtschaft und Veterinärmedizin“ weiterhin durch die Universität herauszugeben. Es wurde daher bereits 1991 in Leipzig ein Verein als Träger der Herausgeberschaft gegründet. Über letzteren und das Deutsche Institut für tropische und subtropische Landwirtschaft GmbH (Witzenhausen), als federführenden Herausgeber der Zeitschrift „Der Tropenlandwirt“, lief schließlich auch die Fusion der beiden Zeitschriften.

Nach der Fusion wurden Redaktionsstab und Herausgeberschaft erweitert. Eine grundlegende konzeptionelle Veränderung war mit der Zusammenlegung nicht verbunden, da

sich die Zeitschriften bereits an denselben Leserkreis wandten. Es bot sich daher an, die 95- bzw. 32-jährigen Erfahrungen in der Veröffentlichung wissenschaftlich fundierter und praxisrelevanter Arbeiten aus der tropischen und subtropischen Agrarwirtschaft fortan in ein gemeinsames Vorhaben einfließen zu lassen.

Die Herausgeber zeigten sich zum Zeitpunkt der Fusion davon überzeugt, „dass es den heutigen Gegebenheiten im wiedervereinigten Deutschland und im internationalen Bereich entspricht, wenn die Erfahrungen und der Sachverstand der bislang getrennt arbeitenden Redaktionen zusammengeführt werden. Ziel ist es nach wie vor, eine Fachzeitschrift auf hohem wissenschaftlichen Niveau herauszubringen. Wir erwarten, dass die Zusammenlegung mehr ergeben wird, als die bloße Addition des Bisherigen“ (Baum, 1994). Die Praxis der Redaktionsarbeit hat sehr schnell gezeigt, dass trotz eines qualifiziert und auch quantitativ gut besetzten Redaktionsausschusses der Großteil der zu leistenden Arbeit an Hans Hemann hängen blieb.

4 Journal of Agriculture and Rural Development in the Tropics and Subtropics

Um die Zeitschrift auch ausländischen Autoren, speziell auch Fachleuten aus den so genannten Entwicklungsländern zugänglich zu machen, wurde vor gut dreißig Jahren damit begonnen auch Arbeiten in Englisch in „Der Tropenlandwirt“ zu veröffentlichen. Seit dem Übergang der Zeitschrift von einer Alumni-Zeitschrift in eine Fachzeitschrift der angewandten Agrarwissenschaft der Tropen und Subtropen war und ist es ein besonderes Anliegen der Redaktion, jungen Wissenschaftlern aus Ländern der Dritten Welt Publikationsmöglichkeiten in einer international anerkannten Fachzeitschrift zu eröffnen. Eine Möglichkeit die ihnen ansonsten kaum gegeben wird.
Als sich im Laufe der Zeit herausstellte, dass auch deutschsprachige Autoren bevorzugt in Englisch publizieren, entschlossen sich die Herausgeber und die Redaktion die Zeitschrift auf eine englischsprachige Fachzeitschrift umzustellen. Dabei wurde zunächst die Zweisprachigkeit nicht aufgegeben.

In der Amtszeit von Herrn Prof. Dr.-Ing. R. Krause als Direktor der Wissenschaftlichen Betriebseinheit Tropenzentrum am Fachbereich Landwirtschaft, Internationale Agrarentwicklung und Ökologische Umweltsicherung der Universität Kassel wurde 2002 beschlossen, eine stärkere Einbindung der Zeitschrift in die Tropenbezogenen Arbeiten des Fachbereiches anzustreben. Aus den geführten Diskussionen und Gesprächen ergab sich als Ergebnis: (a) die Zeitschrift fortan im Verlag kassel university press GmbH erscheinen zu lassen; (b) die Zeitschrift neben der Papierversion auch als Internetpublikation durch den Verlag zu veröffentlichen; (c) die Finanzierung in der bisherigen Form weiterhin durch die Herausgeber vorzunehmen; (d) die Schriftleitung beim Tropenzentrum des Fachbereiches zu belassen; (e) den Namen der Zeitschrift in *Journal of Agriculture and Rural Development in the Tropics and Subtropics* zu ändern und (f) die Beihefte der Zeitschrift anzupassen und gleichfalls im Verlag kassel university press GmbH zu veröffentlichen. Die Vereinbarungen wurden zügig umgesetzt. Bereits 2002 erschien die Zeitschrift unter dem neuen Namen und im neuen Gewand. Der Druck der Zeitschrift und der Beihefte erfolgte fortan durch die Unidruckerei der Universität Kassel.

Als Herausgeber des Journals fungierten zum Zeitpunkt (2009) des Verfassens dieses Artikels:
Deutsches Institut für tropische und subtropische Landwirtschaft (DITSL GmbH), Witzenhausen; Gesellschaft Nachhaltige Entwicklung mbH, Witzenhausen; Institut für tropische Landwirtschaft e.V., Leipzig; Universität Kassel, Fachbereich Ökologische Agrarwissenschaften (FB11), Witzenhausen; Hochschulverband Witzenhausen e.V. (vormals Verband der Tropenlandwirte Witzenhausen e.V.)

Remarks on the development of the Journal of Agriculture and Rural Development in the Tropics and Subtropics

Summary
Hans Hemann the long time editor in chief of the *Journal of Agriculture und Rural Development* is retiring from this post during the last quarter of 2009. Honouring his work, especially in respect to achievements made during his period as editor in chief, development of the journal is documented in this paper.

The Journal of Agriculture und Rural Development has its roots in the Alumni-Journal (*Der Deutsche Kulturpionier*) of the German Colonial College of Witzenhausen, first published in 1900. In 1968 this journal was changed into *Der Tropenlandwirt*, dealing with agriculture in the tropics und subtropics. Since more and more non german speaking authors and readers became interested in the journal articles where published mostly in English. And as agricultural problems in the tropics and subtropics are recently being seen more under holistic aspects and as they are seen especially in context of rural development problems the name of the journal was changed into *Journal of Agriculture and Rural Development*.

Literatur

Amthor, C.; Zwischen Reform und Revisionismus. Die Deutsche Kolonialschule Wilhelmshof in Witzenhausen an der Werra und ihre Entwicklung bis zum Ende des Ersten Weltkriegs; Wissenschaftliche Hausarbeit zur Ersten Staatsprüfung für das Lehramt an Gymnasien im Fach Geschichte; 1983.

Baum, E.; Editorial: In eigener Sache; *Der Tropenlandwirt*; 1:3 – 4; 1994.

Hemann, H.; Agriculture and Rural Development. A synopsis of contributions in the „Journal of Agriculture in the Tropics and Subtropics", „Der Tropenlandwirt" over the past 25 years; in: *Ansatzpunkte Ländlicher Entwicklung. Approaches to Rural Development. Perspektiven aus Sozialökonomie, Technologie und Weiterbildung, Festschrift für Prof. Dr. Eckhard Baum, Beiheft Nr. 77 zu Journal of Agriculture and Rural Development in the Tropics and Subtropics*, edited by Amini, S. and Fremerey, M.; 263 – 276; DITSL, kassel university press GmbH; 2004.

Marcus, A.; Dem Tropenlandwirt zum Geleit; *Der Tropenlandwirt*; 70:5 – 6; 1969.

NN; Zur Einführung; *Der deutsche Kulturpionier*; 1:2; 1900.

NN; Inhaltsverzeichnis der Jahrgänge 1982 bis 1987 „Der Tropenlandwirt“; *Der Tropenlandwirt*; 89(1):63 – 79; 1988.

Redaktion „Der Tropenlandwirt“; Editorial: Der Tropenlandwirt – 90 Jahre Fachzeitschrift für die Landwirtschaft in den Tropen und Subtropen; *Der Tropenlandwirt*; 90(1):2; 1989.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 110, No. 2, 2009, pages 107–114

Effect of NaCl Salinity on Growth and Mineral Composition of *Ziziphus spina-christi* (L.) Willd.

M. Sohail [1], **A. S. Saied** [2], **J. Gebauer** [1*] and **A. Buerkert** [1]

Abstract

Ziziphus spina-christi (L.) Willd. is a fruit tree species growing wild in arid and semi-arid areas of Asia and Africa where rural populations intensively use its fruits, leaves, bark and wood. However, little is known about the effects of salinity, a widespread problem in these regions, on early growth and mineral composition of this species. This study was conducted under controlled conditions to contribute to filling this gap. Six weeks old seedlings of *Z. spina-christi* germinated in a full strength Hoagland solution were subjected to 0, 40, 80 and 160 mM NaCl. Compared to the unstressed control salinity levels of 80 and 160 mM reduced plant height, leaf number, leaf chlorophyll, total leaf area and dry matter by $>$ 50%. Salinity levels of 40, 80 and 160 mM enhanced leaf water contents by 14, 16 and 17%, respectively and 160 mM NaCl raised the concentration of Na and Cl ions in leaf tissues 81- and 21-fold. The $\mathrm{K/Na}$ ratio, in contrast, was hardly affected by increasing salinity indicating adaptation or tolerance of *Z. spina-christi* to low or moderate NaCl salinity. These results suggest that *Z. spina-christi* could be an interesting species for re-vegetation of moderately degraded saline lands.

Keywords: foliar injury, fruit tree, ion content, neglected species, salt stress-tolerance

1 Introduction

Soil salinity is becoming an increasingly serious constraint to plant growth in many parts of the world (FAO, 2005). This is particularly the case in semi-arid and arid zones, where already over a decade ago 50% of the cropland was salt affected (Flower and Yeo, 1995). This can lead to a reduction of biodiversity and land degradation (Ghassemi *et al.*, 1995). In many plant species soil salinity is known to reduce growth and development through osmotic stress, ion toxicity, mineral deficiencies and induced physiological and biochemical disorders in metabolic processes (Hasegawa *et al.*, 2000). However, species are varying widely in their ability to withstand salt stress (Craig *et al.*, 1990; Glenn *et al.*, 1996). Most previous studies focused on annual species' ability to tolerate salinity and only limited information is available on multipurpose fruit trees that

[1] Organic Plant Production and Agroecosystems Research in the Tropics and Subtropics, University of Kassel, Steinstr. 19, 37213 Witzenhausen, Germany

[2] Department of Horticulture, Faculty of Agriculture, University of Khartoum, 13314 Shambat, Sudan

[*] corresponding author: phone: +49-5542-98-1311, fax: +49-5542-98-1230, email: tropcrops@uni-kassel.de

often grow under harsh environmental conditions and are an important component of local livelihoods.

Ziziphus spina-christi (L.) Willd. is a multipurpose fruit tree that is ubiquous in arid and semi-arid Asia and Africa (ARBONNIER, 2004). The fruits, leaves, bark and the wood are intensively used by the rural population. Fruits of *Z. spina-christi* are mostly consumed raw, while leaves and twigs are highly palatable and nutritious fodder for sheep and goats (VERINUMBE, 1993; SUDHERSAN and HUSSAIN, 2003; SAIED *et al.*, 2008b). The plant is also well adapted to dry and hot climates which makes it suitable for re-vegetation of degraded lands (SAIED *et al.*, 2008b), but little is known about the physiological basis for these characteristics. This study therefore aimed at studying the effects of different levels of NaCl salinity on seedling growth of *Z. spina-christi*.

2 Materials and Methods

2.1 Plant material and growth conditions

In December 2006 seeds of *Z. spina-christi* were collected from the 'Jabra Saeed' forest (15°37' N, 32°33' E) about 110 km north of Khartoum, Sudan.
After extraction from the pulp, the seed surface was sterilized by immersion in 2% sodium hypochloride solution for 15 minutes (SAIED *et al.*, 2008a). Subsequently, seeds were placed on moist silica sand in inverted cells of plastic trays at 30/25°C (day/night) temperature and 50% (/10%) relative air humidity, the moisture level was periodically readjusted as necessary. After six weeks 40 seedlings were selected and transplanted into 2.5 l sand filled plastic pots. Before application of salt treatments the number of leaves per plant and plant height was determined. Plants were grouped into ten blocks (replications) of four similarly sized plants which were subjected to one of four salinity levels. The purpose of this development-based blocking was to separate potential effects of seedling size from treatment effects.

2.2 Salt treatments

The final salt treatments applied consisted of 0, 40, 80 and 160 mM NaCl, corresponding to electrical conductivities (EC) of 1.8, 5.6, 8.6 and 15.2 dS m^{-1}, respectively, dissolved in a full strength Hoagland solution. To avoid early plant death by a sudden salt stress shock of the young transplanted seedlings, the salt stress was imposed gradually by applying half of the salt concentration over four weeks and increasing it to the final concentration for another eight weeks. Total duration of the salt stress was therefore 12 weeks.

2.3 Growth parameters measured

Data on plant height and number of leaves per plant were recorded weekly. Chlorophyll readings (SPAD value) were taken fortnightly with a SPAD-502 chlorophyll meter (Konica-Minolta Corporation, Osaka, Japan). SPAD (Soil-Plant Analysis Development) readings are significantly related to extracted chlorophyll of leaves both on a fresh weight and leaf area basis (AZIA and STEWART, 2001).

At the end of experiment, plants were harvested and separated into leaves, stem and roots. Leaf area per plant was measured using a portable leaf area meter (LI-3000A Portable Area Meter, LI-COR Biosciences Inc., Lincoln, NE, USA). Area per leaf was calculated by dividing the total leaf area per plant by the number of leaves. Specific leaf area (SLA) was calculated as leaf area per unit of plant dry matter. After determining the fresh weight of all plant parts, plant samples were oven-dried at 65°C for 48 hours to measure their dry weight. The difference between fresh and dry weight divided by the fresh weight yielded the relative water contents of the leaves, stems and roots.

2.4 Ion analysis

To determine sodium (Na), phosphorus (P) and potassium (K) concentrations samples were ashed at 550 °C for 6 hours and the ash dissolved in concentrated HCl. Extracts were filtered and stored in plastic vials until analysis. Concentrations of Na and K were measured by flame photometry (AutoCal 743, Instrumentation Laboratory Co., Lexington, MA, USA) and P was determined by spectrophotometry (UVIKON 930, Kontron Instruments Ltd, Bletchley, UK). A continuous flow analyzer with potentiometric detection (AutoAnalyzer II, Technicon Instruments, NY, USA) was used to determine the Cl concentration in samples after hot water extraction. A protein/nitrogen analyzer (FP-328, LECO Instruments GmbH, Mönchengladbach, Germany) was used to measure nitrogen (N) in samples, dried at 60 °C.

2.5 Statistical analysis

All experimental data were analyzed with SPSS 12.0 (SPSS, Chicago, USA) using analysis of variance (ANOVA). Tukey-tests ($p < 0.05$) were used to separate means.

3 Results

3.1 Plant growth

NaCl-induced salinity significantly reduced the vegetative growth of *Z. spina-christi* seedlings. Compared to untreated control plants after 12 weeks of salt stress, seedling height was reduced by 28, 37 and 57% at 40, 80 and 160 mM salt treatments, respectively (Table 1). Three weeks after the application of final salt levels, at 80 and 160 mM salinity visible chlorosis and necrosis symptoms on the leaf surface appeared and regular shedding of mature basal leaves was observed. In the 80 and 160 mM treatments leaf number was reduced by 68 and 72%, respectively (Table 1). Compared to the control treatment SPAD values of seedling leaves were 27, 27 and 32% lower at 40, 80 and 160 mM NaCl, respectively (Table 1). Significant reductions in plant height and number of leaves per plant led to a significant decline in total leaf area and area per leaf with increasing salt stress. Reduction in total leaf area was largest (79%) at 160 mM salt concentration followed by decreases of 76 and 30% at 80 and 40 mM, respectively. Differences in leaf area between seedlings subjected to 40 mM salinity and untreated control plants were not statistically different. However, 80 and 160 mM NaCl led to respective reductions in leaf area by 35 and 38% (Table 1).

Table 1: Effect of different $NaCl$ salt levels on growth parameters of *Z. spina-christi* seedlings 12 weeks after the initiation of the treatments.

	$NaCl$ *concentration (mM)*				*F-probability*	
Growth parameter	*0*	*40*	*80*	*120*	*Treatment*	*Block*
Plant height (cm)	134 ± 8.2^a	96 ± 9.5^b	84 ± 5.9^b	58 ± 6.0^b	<0.001	<0.001
Leaves per plant	92 ± 2.8^a	73 ± 7.8^a	29 ± 5.2^b	26 ± 4.4^b	<0.001	0.133
Leaf chlorophyll (SPAD value)	44 ± 1.5^a	32 ± 1.4^b	32 ± 2.3^b	30 ± 2.8^b	0.005	0.643
Total leaf area (cm^2)	433 ± 20^a	304 ± 30^b	106 ± 17^c	93 ± 12^c	<0.001	0.532
Area per leaf (cm^2)	4.8 ± 0.3^a	3.7 ± 0.3^{ab}	3.1 ± 0.7^b	3.0 ± 0.8^b	0.006	0.586
Specific leaf area ($cm^2\,g^{-1}$)	82 ± 3.7^a	93 ± 7.1^a	88 ± 9.3^a	80 ± 5.2^a	0.544	0.338
Leaf dry matter (g)	5.37 ± 0.35^a	2.74 ± 0.46^b	1.45 ± 0.31^{bc}	1.07 ± 0.15^c	<0.001	0.047
Stem dry matter (g)	9.37 ± 1.00^a	4.42 ± 1.10^b	2.55 ± 0.23^b	2.37 ± 0.51^b	<0.001	0.001
Root dry matter (g)	4.90 ± 0.51^a	3.21 ± 0.35^b	1.71 ± 0.14^c	1.16 ± 0.27^c	<0.001	0.001
Total dry matter (g)	19.6 ± 1.44^a	10.4 ± 1.42^b	5.72 ± 0.56^c	4.60 ± 0.84^c	<0.001	0.002
Shoot / root ratio	3.21 ± 0.36^a	2.19 ± 0.39^a	2.37 ± 0.27^a	3.30 ± 0.43^a	0.445	0.254

Each value is a mean of 10 replicates $\pm$ standard error and different letters within a row specify significant difference ($p < 0.05$; Tukey test).

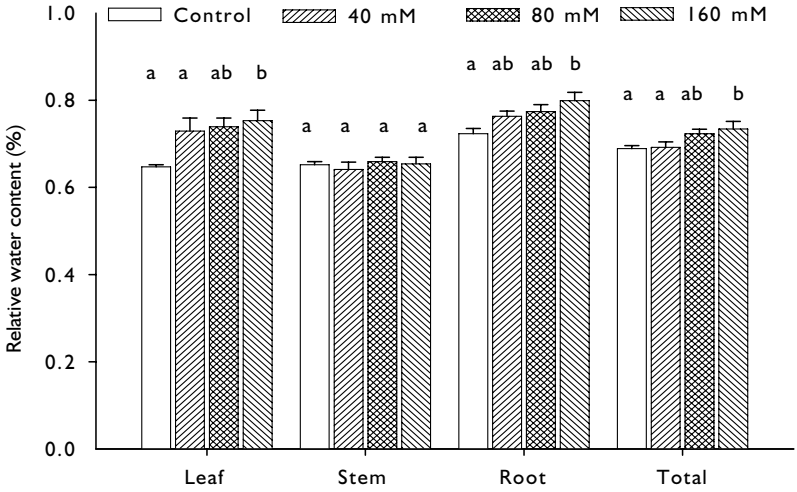
Salt stress of 80 and 160 mM $NaCl$ induced reductions in total dry matter of $>$ 50% which was equally reflected in leaf, stem and root dry matter (Table 1). Shoot / root ratio was not significantly effected by the salinity treatments (Table 1). Increasing salt concentrations also led to a significant increase in relative water contents of leaf and root tissues. These tissues contained 15 and 10% more water in the 80 and 160 mM $NaCl$ treatment than in the control (Fig. 1).

3.2 Concentration of minerals

When exposed to salinity stress, leaf tissue of *Z. spina-christi* had 49-, 68- and 90-fold higher Na and 13-, 20- and 21-fold higher Cl concentrations at 40, 80 and 160 mM $NaCl$, respectively compared to control plants (Table 2). Stem and root tissues followed the same trend in the accumulation of Na and Cl ions, however, the magnitude of ion accumulation was far lower than in leaf tissue (Table 2).

Compared to the unstressed control, $NaCl$ application did not lead to changes in the N and K balance of leaf and root tissue. At 40, 80 and 160 mM $NaCl$ stems showed a significant decrease in K concentration (Table 2). With an increase in salt concentrations to 80 mM $NaCl$ we observed a significant increase of the P concentration in all plant parts and of N in stem tissues. Leaf, stem and root tissues contained 1.5-, 3.2- and 2.4-fold higher P in their dry mass at 80 mM $NaCl$ salinity compared to the unstressed control (Table 2). The K/Na ratio in leaf, stem and root tissues was hradly reduced by $NaCl$ salinity (Table 2).

Figure 1: Effect of different $NaCl$ salt levels on relative water content (%) of leaf, stem and root tissues of *Z. spina-christi* seedlings after 12 weeks of treatment application.*



F-probability	Leaf	Stem	Root	Total
Treatment	0.015	0.869	0.047	<0.001
Block	0.206	0.107	0.662	0.200

* Each bar shows the mean of 10 replicates ± one standard error and different letters specify significant difference (p <0.05; Tukey test).

4 Discussion

4.1 Growth response

Under the conditions of our experiment, the $NaCl$ stress led to stunted seedling growth. Such decreases in plant height with increasing salinity are typical effects of the accumulation of toxic ions in cells which adversely affect cell division and expansion (Munns, 1993). At 80 and 160 mM $NaCl$ severe foliar injuries (chlorosis and necrosis) and shedding of affected leaves resulted in a typical reduction of leaf area per plant (Gupta *et al.*, 2002). Unlike salt stressed olive trees (*Olea europaea* L.) which were found to drop leaves of all size, age and from all positions (Therios and Misopolinos, 1988), seedlings of *Z. spina-christi* only shed their basal old leaves. Even if this was not measured, such differentiation may reflect removal of salts from the more active young tissues towards older ones, a typical trait of species that remove toxic salts from their transpiration stream (Munns, 2005). As indicated by the SPAD values, leaf chlorophyll concentration in seedlings declined with increasing salt level and time of exposure. Such salinity induced reduction of leaf chlorophyll through inhibition of chlorophyll synthesis or accelerated degradation has been well described by Reddy and Vora (1986). The large reduction in seedling dry matter and the increase in water contents (succulence)

Table 2: Effect of different NaCl salt levels on ion concentrations and K/Na ratio of leaf, stem and root dry matter of *Z. spina-christi* seedlings 12 weeks after the initiation of the treatments.

Tissue	*Treatments*	*Ion concentrations (mg g dm^{-1})*					
	NaCl *(mM)*	Na	Cl	N	P	K	K/Na *ratio*
Leaf	0	0.36±0.3^{d}	2.10±0.1^{c}	1.57±0.0^{a}	0.24±0.0^{c}	17.10±1.8^{a}	67.40±2.90^{a}
	40	17.60±2.1^{c}	26.96±1.3^{b}	2.14±0.2^{a}	0.26±0.0^{bc}	14.93±1.0^{a}	0.85±0.03^{b}
	80	24.63±3.4^{b}	42.85±2.2^{a}	1.84±0.2^{a}	0.35±0.0^{a}	15.80±2.1^{a}	0.64±0.02^{b}
	120	32.40±0.8^{a}	44.64±2.3^{a}	1.89±0.2^{a}	0.33±0.1^{ab}	14.06±1.2^{a}	0.43±0.02^{b}
Stem	0	0.60±0.1^{d}	2.75±0.1^{c}	1.59±0.1^{b}	0.17±0.0^{d}	12.56±0.1^{a}	21.32±1.96^{a}
	40	4.10±0.1^{c}	10.33±0.2^{b}	1.52±0.1^{b}	0.34±0.0^{c}	11.60±0.2^{b}	2.83±0.05^{b}
	80	5.90±0.1^{b}	12.87±0.1^{a}	2.05±0.1^{a}	0.55±0.0^{a}	9.96±0.1^{c}	1.69±0.02^{b}
	120	6.33±0.0^{a}	13.16±0.1^{a}	1.98±0.1^{a}	0.53±0.0^{b}	9.36±0.1^{c}	1.47±0.02^{b}
Root	0	1.03±0.0^{c}	3.34±0.2^{c}	2.93±0.1^{a}	0.16±0.0^{c}	8.83±0.1^{a}	8.57±1.02^{a}
	40	5.10±0.5^{b}	13.56±1.5^{b}	2.90±0.1^{a}	0.30±0.0^{b}	8.46±0.6^{a}	1.67±0.03^{b}
	80	6.86±0.6^{a}	15.80±0.7^{a}	2.96±0.2^{a}	0.39±0.0^{a}	8.10±0.4^{a}	1.19±0.04^{b}
	120	7.73±0.2^{a}	17.60±0.5^{a}	3.37±0.2^{a}	0.35±0.0^{b}	8.23±0.2^{a}	1.07±0.01^{b}
		F-probability					
Treatment	Leaf	<0.001	<0.001	0.397	0.006	0.249	0.014
	Stem	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Root	<0.001	<0.001	0.306	<0.001	0.738	<0.001
Block	Leaf	0.200	0.102	0.851	0.276	0.521	0.423
	Stem	0.422	0.210	<0.001	0.595	0.353	0.402
	Root	0.992	0.794	0.702	0.949	0.718	0.377

Each value is a mean of 10 replicates ± standard error and different letters with in column specify significant difference ($p < 0.05$; Tukey test).

under salt stress likely reflected increased metabolic energy costs and reduced CO_2 gain as a consequence of the seedlings' efforts to cope with salt stress by osmotic adjustment (MAAS and NIEMAN, 1978; YANG *et al.*, 1990; SANEOKA *et al.*, 2001; NETONDO *et al.*, 2004). Leaf succulence can also be attributed to increases in spongy mesophyll cells as a response to salt stress (ZEKRI and PARSONS, 1990).

4.2 Mineral composition

Large increases in Na and Cl concentrations of all tissue types with salinity stress indicated that unlike some eucalypt species seedlings of *Z. spina-christi* had little control over the uptake and translocation of salt ions (FLOWER and YEO, 1988; VAN DER MOEZEL *et al.*, 1988). However, despite large accumulation of Na and Cl in plant tissues, effects on tissue concentrations of N, P and K were not significant. Lacking decline in root

uptake efficiency of these nutrients with salt application may be attributed to internal osmotic adjustment of the seedlings in response to osmotic stress (YANG *et al.*, 1990; SANEOKA *et al.*, 2001). At 80 mM NaCl a significant increase in P concentration of plant tissues occurred which confirms results of ROBERT *et al.* (1984) that moderate salinity may enhance P uptake, when sufficient P is available in the substrate.

Over all, our results allow to conclude that *Z. spina-christi* can tolerate salinity up to 40 mM at the seedling stage. Being well adapted to arid climatic conditions, the species has the potential for re-vegetation of moderately degraded saline lands. However, further investigations are needed to screen ecotypes for genetic variation in salt tolerance which if existing would provide scope for selection towards enhanced salinity tolerance of this multipurpose fruit tree species.

Acknowledgements
We are thankful to the Higher Education Commission (HEC) of Pakistan and the German Academic Exchange Service (DAAD) for financial support to the first author.

References

ARBONNIER, M.; *Trees, shrubs and lianas of West African dry zones*; CIRAD, Margraf Publishers GmbH, Paris, France; 2004.

AZIA, F. and STEWART, K. A.; Relationships between extractable chlorophyll and SPAD values in muskmelon leaves; *Journal of Plant Nutrition*; 24:961–966; 2001.

CRAIG, G. F., BELL, D. T. and ALKYDS, C. T.; Response to salt and water logging stress of 10 taxa of acacias selected from naturally saline areas of Western Australia; *Australian Journal of Botany*; 38:619–630; 1990.

FAO; Global network on irrigated soil management for sustainable use of salt effected soils; FAO land and plant nutrition service, Rome, Italy; 2005.

FLOWER, T. J. and YEO, A. R.; Ion relations of salt tolerance; in: *Solute Transport in Plant Cells and Tissue*, edited by BAKER, D. and HALLS, J.; 392–414; Longman, Harlow; 1988.

FLOWER, T. J. and YEO, A. R.; Breeding for salinity resistance in crop plants: where next?; *Australian Journal of Plant Physiology*; 22:875–884; 1995.

GHASSEMI, F., JACKMAN, A. J. and NIX, A. H.; *Salinization of land and water resources*; CAB International, Wallingford, England; 1995.

GLENN, E. P., PFISTER, R., BROWN, J. J., THOMSON, T. L. and O'LEARY, J. W.; Na and K accumulation and salt tolerance of Atriplex canescens genotypes; *American Journal of Botany*; 83(8):997–1005; 1996.

GUPTA, N. K., MEENA, S. K., GUPTA, S. and KHANDELWAL, S. K.; Gas exchange, membrane permeability and ion uptake in two species of Indian jujube differing in salt tolerance; *Photosynthetica*; 40:535–539; 2002.

HASEGAWA, P. M., BRESSEN, R. A., ZHU, J. K. and BOHNERT, H. J.; Plant cellular and molecular responses to high salinity; *Annual Review of Plant Physiology*; 51:463–499; 2000.

Maas, E. V. and Nieman, R. H.; Physiology of plant tolerance to salinity; in: *Crop tolerance to suboptimal land conditions*, edited by Jung, G. A.; 277–299; ASA Spec. Publ., Amer. Soc. Agron. Spez., Madison, Wisconsin; 1978.

van der Moezel, P. G., Watson, L. E., Pearce-Pinto, G. V. N. and Bell, D. T.; The response of six eucalyptus species and *Casuarina obesa* to the combined effect of salinity and waterlogging; *Australian Journal of Plant Physiology*; 15:465–474; 1988.

Munns, R.; Physiological processes limiting plant growth in saline soils: some dogmas and hypotheses; *Plant Cell and Environment*; 16:5–24; 1993.

Munns, R.; Genes and salt tolerance bringing them together; *New Phytologist*; 167:645–663; 2005.

Netondo, G. W., Onyango, J. C. and Beck, E.; Sorghum and salinity: II. Gas exchange and chlorophyll fluorescence of sorghum under salt stress; *Crop Science*; 44:806–811; 2004.

Reddy, M. P. and Vora, A. B.; Changes in pigment composition, hill reaction activity and saccharides metabolism in bajra (*Pennisetum typhoides* S & H) leaves under NaCl salinity; *Photosynthetica*; 20:50–55; 1986.

Robert, J. K. M., Linker, C. S., Benoit, A. G., Jardetzky, O. and Nieman, R. H.; Salt stimulation of phosphate uptake in maize root tips studied by 31P nuclear magnetic resonance; *Plant Physiology*; 75:947–950; 1984.

Saied, A. S., Gebauer, J. and Buerkert, A.; Effect of different scarification methods on germination of *Ziziphus spina-christi* seeds; *Seed Science and Technology*; 36:201–205; 2008a.

Saied, A. S., Gebauer, J., Hammer, K. and Buerkert, A.; *Ziziphus spina-christi* (L.) Willd.: a multipurpose fruit tree; *Genetic Resources and Crop Evolution*; 55:929–937; 2008b.

Saneoka, H., Ishiguro, S. and Moghaieb, R. E.; Effect of salinity and abscisic acid on accumulation of glycinebetaine and betaine aldehyde dehydrogenase mRNA in sorghum leaves (*Sorghum bicolor*); *Journal of Plant Physiology*; 158:853–859; 2001.

Sudhersan, C. and Hussain, J.; In-vitro clonal propagation of a multipurpose tree, *Ziziphus spina-christi* (L.) Desf.; *Turkish Journal of Botany*; 27:167–171; 2003.

Therios, I. N. and Misopolinos, N. D.; Genotypic response to sodium chloride salinity of four major olive cultivars (*Olea europea* L.); *Plant and Soil*; 106:105–111; 1988.

Verinumbe, I.; Soil and *Leucaena leucocephala* L. growth variability under *Faidherbia albida* Del. and *Ziziphus spina-christi* L. Desf.; *Agroforestry Systems*; 21:287–292; 1993.

Yang, Y. W., Newton, R. J. and Miller, F. R.; Salinity tolerance in sorghum 1. Whole plant response to sodium chloride in *S. bicolor* and *S. helepense*; *Crop Science*; 30:775–781; 1990.

Zekri, M. and Parsons, L. R.; Calcium influences growth and leaf mineral concentration of citrus under saline conditions; *HortScience*; 25:784–786; 1990.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 110, No. 2, 2009, pages 115–126

Estimates of Carbon Reservoirs in High-Altitude Wetlands in the Colombian Andes

E. J. Peña [*1], **H. Sandoval** [2], **O. Zuñiga** [3] and **M. Torres** [4]

Abstract
The observed increase in emission of greenhouse gases, with attendant effects on global warming, have raised interests in identifying sources and sinks of carbon in the environment. Terrestrial carbon (C) sequestration involves capture of atmospheric C through photosynthesis and storage in biota, soil and wetlands. Particularly, wetland systems function primarily as long-term reservoirs for atmospheric carbon dioxide ($\mathrm{CO_2}$) and as sources of atmospheric methane ($\mathrm{CH_4}$). The objective of this study was to evaluate the patterns of carbon reservoirs in two high-altitude wetlands in the central Andean mountain of Colombia. Carbon cycle in both systems is related mainly with the plant biomass dynamics from the littoral zone. Thus, total organic carbon concentrate an average up to 329 kg of N ha^{-1} and 125 kg of P ha^{-1} every year vs only 17 kg N ha^{-1} and 6 kg P ha^{-1} in the water column of the limnetic zone in the wetland, evidencing spatial differences in carbon concentrations for these types of ecosystems. Results revealed that these systems participate in the balance and sequestration of carbon in the Colombian Andes.

Keywords: Terrestrial carbon, atmospheric carbon dioxide, atmospheric methane, storage in biota

1 Introduction

High-altitude wetlands cover only approximately 3% of the total land area (Maltby and Immirzi, 1993), but their importance in the carbon cycle has been recognized because they can store approximately 30% of the global terrestrial carbon, equivalent to 455 Pg C (Gorham, 1991; Blodau, 2002) (1 Pg C = 1 Gt C = 10^{15} g of carbon).

* corresponding author

[1] Prof. Dr. Enrique Javier Peña, Universidad del Valle, Departamento de Biología, Facultad de Ciencias Naturales y Exactas, Calle 13 # 100-00 A.A. 25360. Cali, Colombia. Email: enripena@univalle.edu.co

[2] Bs. Harrison Sandoval, Universidad del Valle, Departamento de Biología, Facultad de Ciencias Naturales y Exactas, Calle 13 # 100-00 A.A. 25360. Cali, Colombia. Email: enripena@univalle.edu.co

[3] Prof. Dr. Orlando Zuñiga, Universidad del Valle, Departamento de Física, Facultad de Ciencias Naturales y Exactas, Calle 13 # 100-00 A.A. 25360. Cali, Colombia.

[4] Prof. Dr. Alba Marina Torres, Universidad del Valle, Departamento de Biología, Facultad de Ciencias Naturales y Exactas, Calle 13 # 100-00 A.A. 25360. Cali, Colombia.

This percentage of carbon is sequestered primarily via the process of transforming the organic matter in plant biomass (BLODAU *et al.*, 2004), reaching total levels of 0.5-0.7 t of carbon ha^{-1} (HEATHWAITE, 1993).

The wetlands function primarily as long-term reservoirs for atmospheric carbon dioxide (CO_2) and as sources of atmospheric methane (CH_4). Atmospheric records have shown that the wetlands lower the atmospheric CO_2 considerably, but they have also raised the concentrations of CH_4 since the end of the last glaciation (BLODAU, 2002). Therefore, the wetlands can both sequester and produce gases with a greenhouse effect, which makes them an important carbon dioxide (CO_2) sink and a net source of methane (CH_4). Similarly, they contribute approximately 5% of the atmospheric load of CH_4 as well as the sources of dissolved organic matter (DOM) in groundwater's (BLODAU *et al.*, 2004).

The principal factors regulating the carbon cycle are associated with the conditions of oxygenation of the water column, alkalinity, soil temperature and reduction-oxidation equilibrium-type reactions in the groundwater table (BLODAU, 2002). Processes such as mineralization of the carbon and the release of dissolved organic carbon (DOC) in both aqueous systems and in their soils have not been sufficiently documented; but it is known that they are of great importance for their carbon reserves, similar in magnitude to the atmospheric CO_2 (BLODAU, 2002; SUHETT *et al.*, 2007). On the other hand, the interaction among the cycles of carbon (C), nitrogen (N) and phosphorus (P) in the wetlands is attracting more attention (BLODAU 2002) because it can contribute information on the variability of carbon sequestration and its relation to climate change (GORHAM, 1991; HEATHWAITE, 1993; BLODAU, 2002).

In Colombia the high-altitude wetlands are related to the formation of water sources characteristic of the region of the Andean paramos ($>$ 3000 m altitude), which are manifested in the form of ponds, swamps, lakes and springs that emerge from underground (VAN DER HAMMEN and HOOGHIEMSTRA, 2003). The objective of this study was to evaluate the patterns of carbon reservoirs and sequestration in two high-altitude wetlands located in the Chingaza NNP and Nevados (snow-capped mountains) NNP in the central Andean mountain range of Colombia and their relation as reservoirs in the carbon cycle in these systems.

2 Methods and Materials

2.1 Study area

The first type of wetland was located at an altitude of 4080 m. in the Nevados National Park-NNP (Figure 1), which consisted in two sample points, the Claro River area and its associated lagoon. The second type of wetland was located at an altitude of 3200 m. in Chingaza NNP (Figure 2). Table 1 summarizes the general characteristics of the evaluated wetland points under study (IDEAM, 2002). Batimetric data were recorded in each system based on points selected in the transects laid out over the total area of each wetland.

Figure 1: Spatial location of the Nevados NNP: Claro River watershed (1) and Claro River lagoon (2). Source: (UNIVALLE-IDEAM, 2008).

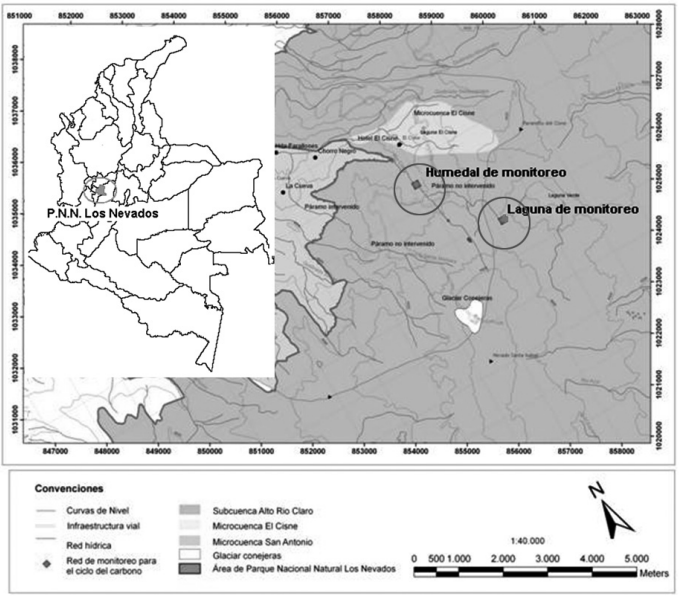


Figure 2: Spatial location of Chingaza NNP: Calostros River watershed (3) at the monitoring point of the selected wetland. Source: (UNIVALLE-IDEAM, 2008).

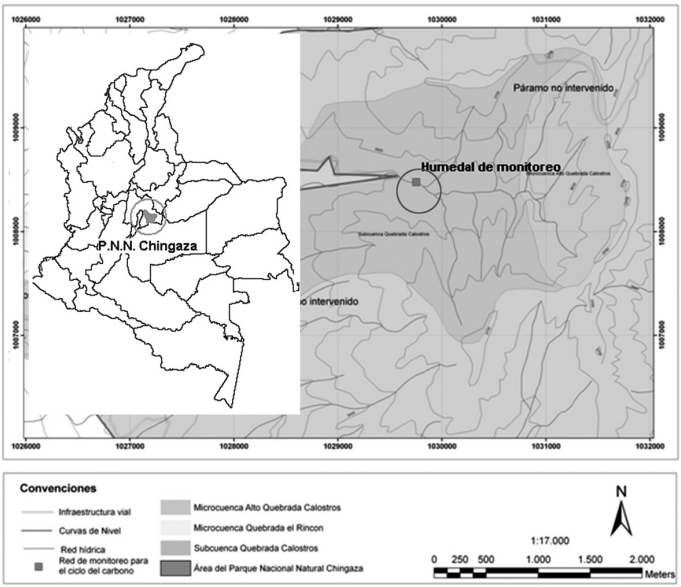


Table 1: General characteristics of the wetlands monitored for each study site.

Study Site	*Jurisdiction*	*Name*	*Geographic Coordinates (g/m/s)*	*Elevation (masl)*	*Avg. Annual Temp. (°C)*	*Avg. Annual Rainfall (mm)*	*Area (m^2)*
Nevados NNP (1)	Rural community El Páramo, Municipality of Villamaría (Caldas Province)	Claro River wetlands	N 4° 50' 57" W 75° 22' 19"	4080	9.2	2000	55872.6
Nevados NNP (2)		Claro River lagoon	N 4° 49' 54.2" W 75° 21' 33.5"	4456	9.2	2000	464.62
Chingaza NNP (3)	Rural community Mundo Nuevo, municipality of La Calera (Cundinamarca Province)	Calostros River wetlands	N 4° 40' 31.7" W 73° 48' 36"	3200	12.5	3322	158328

2.2 Physicochemical analyses of the water

In each of the wetlands studied, three samples were collected of water, were collected in 1-liter jars in order to conduct physicochemical tests of their quality. Measurements of dissolved (DOC) and total organic carbon (TOC) were done using the equipment TOC-5050 (Shimadzu). Curves for measuring DOC and TOC concentrations were calculated for each wetland, based on the relation between area and carbon concentration in accordance with the methodology proposed by Wetzel and Likens (2002). For the analyses of hardness and alkalinity, lab analyses were done using the EPA protocol; and the results were expressed as ppm (mg/L) $CaCO_3$. The Winkler method (Wetzel and Likens, 2002) was used to measure the dissolved oxygen (DO).

2.3 Carbon in plant biomass

In the selected transects, 1-m^2 quadrats were placed to determine the organic carbon of the plant biomass. In total 18 quadrats were established for the wetlands studied. The biomass was collected using a machete for the tall vegetation and manually for the ground-level and submerged vegetation. The samples were placed in sacks in order to transport them and were then weighed fresh, using an industrial platform-type scale (Bosche IPS-C). The plant material was then dried in ovens at an average temperature of 40-45°C for approximately two weeks until it was totally dry. The dry weight was measured with an electronic scale (Nobelsound NS-SM 788). The dry weight values of the plant biomass were then multiplied by a factor of 0.5 to obtain the amount of carbon present. This factor is based on the principle that the plant matter of any ecosystem contains 50% carbon in its biomass once the water has been removed. (Vallejo *et al.*, 2005).

2.4 Leaf nitrogen and phosphorus content

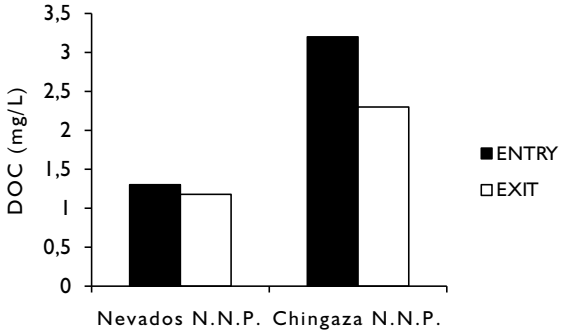
Leaf material of the plant species in the selected quadrats was submitted to P and N analyses using the procedure stipulated by ICONTEC under Standard Specification 5167 (norm for N and P analyses).

3 Results and Discussion

3.1 Water quality

The data obtained for dissolved (DOC) and total (TOC) organic carbon were significantly lower in the Claro River wetlands (Nevados NNP) than in the Calostros River wetlands (Chingaza NNP): 1.2 mg/L vs. 2.8 mg/L, respectively (Figure 3).

Figure 3: Relation between the DOC values for the entrance and exit points of the water in the wetlands of the two sites (Nevados and Chingaza).



The highest DOC and TOC concentrations (4.2 mg/L for both) were found in the Claro River lagoon (Nevados NNP) (1) (Table 2). Similarly within the wetlands the DOC and TOC concentrations were greater at the entrance sampling point than at the exit point of the water.

Table 2: General characteristics of the wetlands monitored for each study site.

Study Site	*Name*	*Sampling Points*	*Location*	*TOC (mg/L)*	*DOC (mg/L)*	*Hardness $\mathrm{CaCO_3}$ (mg/L)*	*Acidity $\mathrm{CaCO_3}$ (mg/L)*	*DO (mg/L)*	*pH*	*Temp. (°C)*
Nevados NNP (1)	Claro River Lagoon	P1	N 04° 49' 53.9" W 075° 21' 3.0"	4.4	4.4	0.044	—	1.1	6.8	5.3
		P2	N 04° 49' 54.0" W 075° 21' 33.1"	4.2	4.2	0.031	0.02	1.1	6.7	5.6
		P3	N 04° 49' 54.2" W 075° 21' 33.4"	4.0	4.0	0.034	0.02	1.1	6.7	5.8
		P4	N 04° 49' 53.8" W 075° 21' 33.2"	—	—	—	—	1.1	6.6	5.5
		P5	N 04° 49' 54.3" W 075° 21' 33.0"	—	—	—	—	1.1	6.8	5.5

The DO levels between the Claro River lagoon and wetlands (Nevados NNP) were different, with values of 1.1 and 6.46 mg/L, respectively. With respect to hardness-acidity, pH and temperature, there were no clear differences among the study sites; hardness-acidity values averaged 0.031 and 0.02 mg/L respectively. The pH values reflected relatively neutral waters (6.6-6.9) and low temperatures (4.3-5.8°C) (Table 2).

According to the morphological characteristics found in the wetlands under study, these can be considered swamps or peatlands-type of wetlands (Duque and Restrepo, 2008; Duque and Carranza, 2008). This type of systems is usually formed at the bottom of a glacial valley, where the slopes are less than 10%. These characteristics relate them directly to the lagoons formed in glacial cirques or areas dug out by blocks of ice, such as is the case of the Nevados (Duque and Restrepo, 2008). These are probably ancient lagoons that have been silted, whose areas are generally larger than 10 ha and are supplied by extensive watersheds (Duque and Restrepo, 2008).

The DOC, which is found in all ecosystems, is an important component in the global carbon cycle in aquatic flows (Giesler *et al.*, 2007). The processes of mineralization of the DOC have received special attention due to the effect of carbon dioxide (CO_2), as a gas related to the greenhouse effect and its role in global warming (Suhett *et al.*, 2007). The reservoirs and concentration of carbon is associated with the transformation of the organic matter, particularly in the case of water, either by exogenous processes (material from runoff) or by endogenous processes derived from the transformation of the biological matter existing in the water column (Wetzel, 2000). The results obtained with the dissolved (DOC) and total (TOC) organic carbon in the water column in the wetlands studied (Nevados and Chingaza) had relatively low values ($<$ 5mg/L) in comparison with other similar ecosystems, where values from 20 up to 60 mg/L have been recorded (Blodau, 2002; Giesler *et al.*, 2007; Suhett *et al.*, 2007). These differences could be based on the factors that determine the concentrations of DOC and TOC, where the temperature regulates the transformation of DOM, either by decomposition of plant litter/humus or by bacterial necromass). This latter factor has been considered to be the principal process that contributes to the concentrations of DOC and TOC in the wetlands (Giesler *et al.*, 2007).

Consequently the low temperatures in the study sites are the factors that regulate the DOC and TOC concentrations and also explain the low contents of these values in the ecosystems studied (Moore and Dalva, 2001). This can be evidenced taking into account the average temperature in the water column from all the study sites such as the case of the Claro River wetlands, which had the lowest concentrations of DOC and TOC (1.1-1.3 mg/L). The highest temperatures were recorded in the Claro River lagoon (5.3-5.8°C), which also had the highest concentrations of DOC and TOC (4.0-4.4 mg/L). In natural freshwaters, bicarbonates are the principal form of alkalinity and an indicator of the transformations of the carbon cycle in the ecosystem. Various studies have reported that hardness and/or alkalinity are very important with respect to the concentrations of carbon present in the water column because they can alter biological processes as a result of the toxic effect on the communities found therein (Sutin *et al.*, 2008). Normal concentrations of hardness and alkalinity in aquatic and semiaquatic

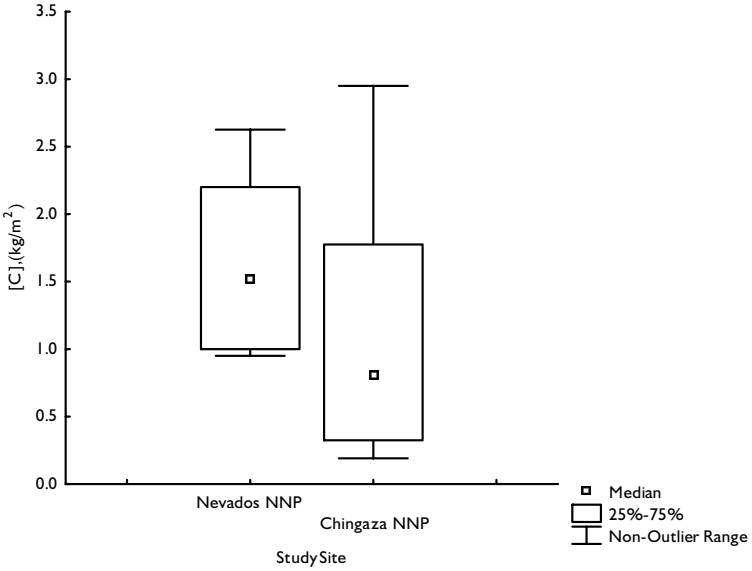
ecosystems range from 3-200 mg/L (Sutin *et al.*, 2008). The values obtained in the study sites do not surpass 0.06 mg/L for hardness and 0.03 mg/L for acidity; thus the concentrations of hardness and alkalinity-acidity in the water column do not have an important effect on the transformation of carbon in the ecosystems studied.

Similarly, the rates of mineralization of the carbon depend on the availability of oxygen, associated with water column depth and temperature (Blodau, 2002). The dynamics of the DO involve complex interactions between physical and biogeochemical processes; for example, (1) vertical and horizontal mixtures, (2) exchange of aeration (3) nutrient loads (4) the demand for oxygen in the water column and sediment, and (5) the chemical demand for oxygen (Lee and Lwiza, 2008). The DO concentrations in these high-altitude wetlands are low and decrease with the fall in temperature (Lee and Lwiza, 2008). In the lagoon values under 2-3 mg/L were recorded, which reflects hypoxia, the exhaustion of DO (Lee and Lwiza, 2008).

3.2 Carbon dynamics in plant biomass

The concentrations of carbon in the Claro River wetlands (the Nevados) were higher than for the Calostros River wetlands (Chingaza) (Figure 4). Similarly, differences in the carbon concentrations can be seen with respect to the transects marked for both wetlands, where they were highest at the entrance of the water, followed by Transect 2 and lastly by the transect farthest from the entrance point of the water. For the Claro River lagoon the concentrations of carbon in plant biomass were higher in the emerging plants (0.0925 kg/m^2) than in those that were submerged (0.015 kg/m^2).

Figure 4: Relation between concentrations of carbon (kg/m^2) at the study sites (Nevados and Chingaza).

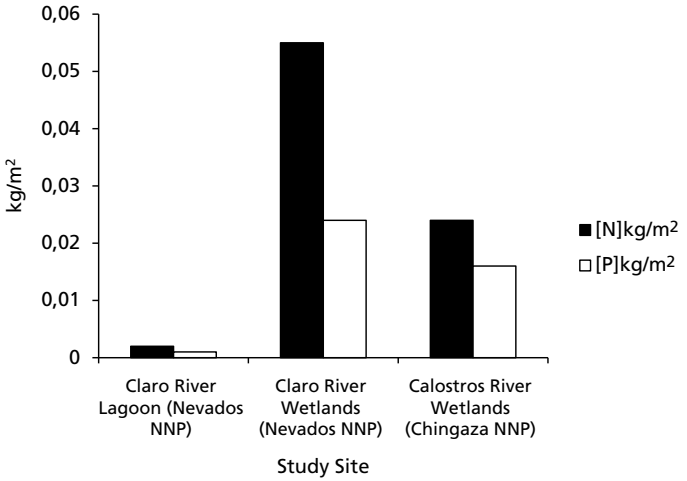


Plants participate in the balance and sequestration of carbon through two processes (SALAS and INFANTE, 2006) based on (a) the area of their biomass and (b) the decomposing material (necromass) of the biomass that can be accumulated in the soil in the form of plant litter and roots (SCHROEDER and WINJUM, 1995). In both wetlands there was a gradient in the distribution of the vegetation with a dominance of mountain bamboo (*Chusquea* sp.) observed in the water entrance zone (Transect 1), where the highest average concentration of carbon in the biomass was obtained (1.6 kg m^2); vs. the exit zone (Transect 3) with a dominance of herbaceous vegetation, where the lowest average of carbon in the biomass (0.2 kg m^2) was obtained. In comparison with the study sites, the levels of carbon in the Claro River wetlands (1.5 kg/m^2) were higher than the concentration of carbon in the Calostros River wetlands (0.7 kg/m^2). Consequently, an extrapolation of the data would make it possible to predict that within the wetlands under study, the plant biomass reaches sequestration levels of 7-15 t of carbon ha^{-1}, being much greater than that described by HEATHWAITE (1993). Levels of 0.5-0.7 t of carbon sequestered ha^{-1} in similar ecosystems evidence the great importance of the high Andean wetlands with respect to the sequestration and storage of carbon and as buffers of the global warming effect.

3.3 Phosphorus and nitrogen in the plant biomass

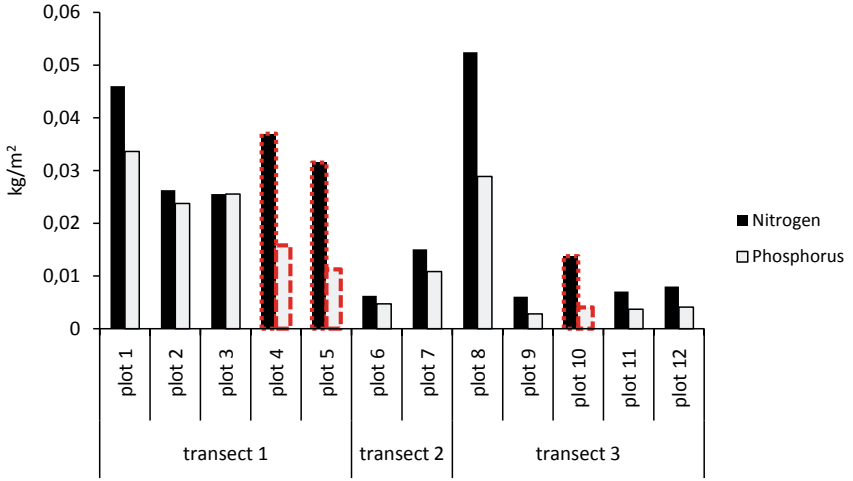
The concentrations of N reached values higher than 0.05 kg/m^2, whereas for P the highest value did not surpass 0.02 kg/m^2 (Figure 5). Similarly, significant differences were found between the N and P concentrations in relation to the study sites, being highest in the Claro River wetlands (Nevados), followed by the Calostros River wetlands (Chingaza) and the Claro River lagoon (Nevados).

Figure 5: Relation between the concentration of N and P (kg/m^2) and the study sites (p=0.013, CI = 95%).



For the Calostros River wetlands (Chingaza), no considerable differences were found in the N and P concentrations in relation to the type of quadrats established, both ground-level and submerged (submerged plots: T1-3S, T1-4S and T3-2S, marked with red) (Figure 6).

Figure 6: Concentration of N and P (kg/m^2) in the biomass collected for each plot and transect in the Calostros River wetlands (Chingaza NNP). The bars framed with red dots represent the plots with submerged vegetation.

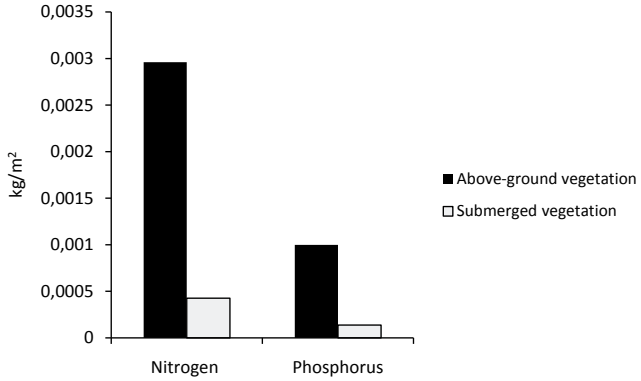


In the case of the Claro River lagoon (Nevados NNP), however, there were considerable differences with respect to the type of vegetation, where the N and P concentrations were greater in the ground-level or emerging biomass than in the submerged plants (Figure 7).

The N and P values in the plant biomass for the sites studied had ranges similar to those of other ecosystems (Blodau, 2002; Blodau *et al.*, 2004), averaging 0.032 kg N/m^2 and 0.016 kg P/m^2. The higher N and P concentrations in the wetlands vs the lagoon are partly due to the fact that the wetlands have greater plant biomass density as they are not totally flooded by the water column; whereas in the lagoon the sheet of water covers the whole area, which hinders dense growth of the vegetation, except for a few emerging and submerged plants.

In general the plant biomass of the wetlands under study can concentrate an average of up to 329 kg of N ha^{-1} and 125 kg of P ha^{-1} every year vs only 17 kg N ha^{-1} and 6 kg P ha^{-1} in the lagoon, evidencing concentrations for these types of ecosystems. In relation to forest ecosystems, these concentrations are much higher for both N and P (Bragazza *et al.*, 2006). It has been argued that the high-altitude wetlands have low biomass productivity despite concentrating high levels of N and P (HEATHWAITE 1993). However, it is necessary to validate the dynamics of the carbon flux in these

Figure 7: Concentration of N and P (kg/m^2) in the ground-level and submerged biomass in the Claro River lagoon (Nevados NNP).



types of wetlands, as principal reservoirs of carbon in high Andean zones based on the evaluation of the rates of productivity and decomposition of the plant biomass and other compartments of the ecosystem in particular.

4 Concluding Remarks

According to the morphological analysis, the studied systems can be considered peatland-type of wetlands, which are usually formed at the bottom of a glacial valley, where the slopes are less than 10%. The observed data of the water quality parameters s and the dynamics of the plant biomass reflected the significance of both components in the carbon cycle in both systems, especially the wetlands area covered by vegetation and the decomposing material (necromass) accumulated in the soil in the form of plant litter and roots. The total organic carbon in the systems concentrated in a range between 329 kg of N ha^{-1} and 125 kg of P ha^{-1} every year vs only 17 kg N ha^{-1} and 6 kg P ha^{-1} in the water column of the limnetic zone in the wetland, evidencing spatial differences in carbon concentrations for these types of ecosystems. Consequently, results revealed that these systems participate in the balance and sequestration of carbon in the Colombian Andes.

References

Blodau, C.; Carbon cycling in peatlands — A review of processes and controls; *Enviorn. Rev.*; 10(2):111–134; 2002.

Blodau, C., Basiliko, N. and Moore, T. R.; Carbon turnover in peatland mesocosms exposed to different water table levels; *Biogeochem.*; 67(3):331–351; 2004.

Bragazza, L., Siffi, C., Iacumin, P. and Gerdol, R.; Mass loss and nutrient release during litter decay in peatland: The role of microbial adaptability to litter chemistry; *Soil Biol. & Biochem.*; 39:257–267; 2006.

Duque, A. and Carranza, J. A.; Los humedales: Conceptos y contextos; in: *Los Humedales en Risaralda: Una Perspectiva Ecosistémica. 1ª ed.*, edited by Duque, A. and Carranza, J. A.; 17–33; Universidad Tecnológica de Pereira, Pereira, CO; 2008.

Duque, A. and Restrepo, S.; Los humedales del Parque Nacional Natural Los Nevados en la vertiente occidental de la Cordillera Central (Risaralda y Caldas); in: *Los Humedales en Risaralda: Una Perspectiva Ecosistémica. 1ª ed.*, edited by Duque, A. and Carranza, J. A.; 51–73; Universidad Tecnológica de Pereira, Pereira, CO.; 2008.

Giesler, R., Högberg, M., Strobel, B., Richter, A., Nordgren, A. and Högberg, P.; Production of dissolved organic carbon and low-molecular weight organic acids in soil solution driven by recent tree photosynthate; *Biogeochem.*; 84(1):1–12; 2007.

Gorham, E.; Northern peatlands: Role in the global carbon cycle and probable response to climate warming; *Ecol. Appl.*; 1:182–193; 1991.

van der Hammen, T. and Hooghiemstra, H.; Interglacial–glacial Fuquene-3 pollen record from Colombia: An Eemian to Holocene climate record; *Global and Planetary Change*; 36(3):181–199; 2003.

Heathwaite, A. L.; Disappearing peat-regenerating peat? The impact of climate change on British peatlands; *Geogr. J.*; 159(2):203–208; 1993.

IDEAM; *Páramos y ecosistemas alto andinos de Colombia en condición hot spot y global climatic tensor. Cap. I.*; IDEAM (Instituto de Meteorología, Hidrología y Estudios Ambientales), Bogotá, CO.; 2002.

Lee, Y. J. and Lwiza, K.; Characteristics of bottom dissolved oxygen in Long Island Sound, New York; *Estuarine, Coastal and Shelf Sci.*; 76:187–200; 2008.

Maltby, E. and Immirzi, P.; Carbon dynamics in peatlands and other wetland soils, regional and global perspectives; *Chemosphere*; 27:999–1023; 1993.

Moore, T. R. and Dalva, M.; Some controls on the release of dissolved organic carbon by plant tissues and soils; *Soil Sci.*; 166:38–47; 2001.

Salas, R. J. and Infante, A.; Producción primaria neta aérea en algunos ecosistemas y estimaciones de biomasa en plantaciones forestales; *Rev. For. Lat.*; 40:47–70; 2006.

Schroeder, P. E. and Winjum, J. K.; Assessing Brazil's carbon budget: II. Biotic fluxes and net carbon balance; *Forest Ecology and Management*; 75(1-3):87–99; 1995.

Suhett, A. L., Megali, A. A., Prast, E., Esteves, A., Farjalla, F. and Fortes, V.; Seasonal changes of dissolved organic carbon photo-oxidation rates in a tropical humic lagoon: The role of rainfall as a major regulator; *Can. J. Fish. Aquat. Sci.*; 64(9):1266–1272; 2007.

Sutin, S., Pollar, M., Jaroensutasinee, M. and Jaroensutasinee, K.; Spanner Bard at Thepchana Waterfall Khao Nan National Park, Thailand; *Int. J. Math., Phys. Eng. Sci.*; 2(1):6–9; 2008.

UNIVALLE-IDEAM; *Informe Final Contrato 147-2006. Consultoría para la validación del protocolo para la caracterización de los ciclos de agua y carbono en ecosistemas de alta montaña y diseño, instalación y puesta en operación de la red de monitoreo para*

determinar los impactos del cambio climático en dichos ciclos. 456p.; Universidad del Valle, Cali, CO.; 2008.

Vallejo, M. I., Londoño, A. C., López, R., Galeano, G., Álvarez, E. and Devia, W.; *Establecimiento de parcelas permanentes en bosques de Colombia*; Métodos para Estudios Ecológicos a Largo Plazo; No. 1; Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Bogotá D. C., Colombia. 310 p.; 2005.

Wetzel, R. G.; Fundamental processes within natural and constructed wetland ecosystems: short-term versus long-term objectives; *Water Sci. Tech.*; 44(11-12):1–8; 2000.

Wetzel, R. G. and Likens, G. E.; *Limnological Analyses. 3rd ed.*; Springer-Verlag, NY. 429 p.; 2002.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 110, No. 2, 2009, pages 127–135

A Study on the RAPD and SCAR Molecular Markers of Piper Species

Shi Jiang [*1], **Xin Jianhua** [2] and **Xin Li** [3]

Abstract

In order to compare the genetic relationships among Kava, Pepper and it's wild relatives and to distinguish Kava from Pepper and it's wild relatives, we conducted research on Kava by using RAPD and SCAR molecular markers. 20 random primers selected from 80 random primers were used for RAPD amplification to identify the genetic relationships among Kava, Pepper and it's wild relatives. Total 170 bands were amplified by 20 random primers, in which 20 bands were polymorphic (12%). Cluster analysis grouped the 28 accessions into six groups at similarity coefficient of 0.36, where 6 materials of Kava formed a group, indicating that Kava was distantly relation to Pepper and its wild relatives. Kava had 562 bp and 355 bp specific fragments amplified by primers OPQ-02 and OPQ-03, respectively, were recycled for cloning and sequencing analysis, and then converted to SCAR markers. Two pairs of specific SCAR primers for Kava, P4.1 and P4.2, P8.1 and P8.2 were designed. PCR amplification of 28 test materials were performed using the two pairs of the specific primers respectively, the specific bands of 562 bp and 355 bp with expected sizes were amplified in 6 Kava materials but not in other materials. The results showed that primers P4.1 and P4.2, P8.1 and P8.2 might be used as specific SCAR primers for Kava germplasm resources identification. This research provided the basis for selecting rootstocks, molecular identification and the fingerprint construction of Kava.

Keywords: Kava (*Piper methysticum* Forst. f., *Piperaceae*), Pepper (*Piper nigrum* L., *Piperaceae*), Random Amplified Polymorphic DNA (RAPD), Sequence-characterized amplified region (SCAR)

1 Introduction

First: The history of the use of Kava has 3000 years, which form a unique "Kava culture" in the local (Vincent *et al.*, 1992). The geographical distribution of Kava is limited

* corresponding author

[1] Associate Prof. Dr. Shi Jiang, College of Agriculture, Department of Biotechnology, Henan University of Science & Technology, 471003 Tianjin Road, Jianxi District, Luoyang, Henan province, China. E-mail: shijiang66@21cn.com; shijiang66@126.com; shijiang@mail.haust.edu.cn, Phone: 86-379-64280115, Fax: 86-379-64282340

[2] College of Agriculture, Shihezi University, Shihezi, 832000, China;

[3] College of Food and Bioengineering, Henan University of Science & Technology, Luoyang, 471003, China

to the South Pacific island nation. Because Kava plays a decisive role in the export, it is regarded as national treasure material by the local nation. Kava has a significant effect in treatment of anxiety disorder, depression, to promote and improve the sleep quality, and also has a very good role for ease the mental stress and relax the body. And the poison or negative effects are small (LEBOT and LEVESQUE, 1989). Second *Piper methysticum* Forst. f. commonly known as Kava or Kawa, which is a wild or planted perennial medicinal bush plants of *Piper* L., *Piperaceae* in Vanuatu, Fiji, Tonga, Papua new Guinea and the Solomon Islands and other South Pacific islands. South Pacific island nation's residents prefer to use Kava roots and stems to prepare drinks which could relax the body and emotions, improve sleep and restore the strength of the body. They often set up Kava feast especially in the religious activities, a major festival celebrations and banquet guests. Kava is the indispensable beverages in the ceremonial and social activities, and it also is an essential everyday goods. Kava was praised as the Pacific longevity medicine by the local people. Third: In 2001, Kava cultivation technology had been listed as China's "Tenth Five-Year" Scientific and Technological Project. In the process of introduction and cultivation of Kava, it was difficult to distinguish among the seedlings of Kava, Pepper (*Piper nigrum* L., *Piperaceae*) and it wild relatives which was similar in morphology. How to distinguish among them was a problem. Kava belongs to a Pepper plant, but the genetic relationships among Kava, Pepper and it wild relatives was not clear. The molecular tagging technology such as RAPD and SCAR could solve these problems.

RAPD markers have been widely used in many plants and crops to assess phylogenetic relationships such as potato, *Dalbergia*, olives, *Phytophthora sojae*, *Leymus*, Safflower, *Rehmannia glutinosa*, etc. RAPD technology became popular because of its simplicity and ease of use in a moderately equipped laboratory and the assay does not require any sequence information. However, RAPDs are often criticized for their lack of reliability among laboratories (GOSSELIN *et al.*, 2002). SCAR markers were widely used in some morphology which were difficult to distinguish from the different economic value of species, identification and evaluation of germplasm such as to distinguish between *M. boninensis*, *M. acidosa* and their hybrids (WANG *et al.*, 2001), for *Bambusa balcooa* and *Bambusa tulda* identification (NAOKI *et al.*, 2003), for identification in bamboo (DAS *et al.*, 2005), in genotype identification of 26 olive cultivars (MATTEO *et al.*, 2006). Compared with the RAPD markers, SCAR primers are longer, and primer sequence and the template DNA fully complementary to each other, so the amplification results possess good stability and strong repeatability. But very little work has been done about these markers in Kava (*Piperaceae*), Pepper (*Piperaceae*) and it wild relatives (*Piperaceae*). The objectives of this study were to compare the genetic relatedness among Kava, Pepper and it wild relatives and to distinguish them during the seedling period. To achieve this goal, we first analysed genetic relatedness among Kava, Pepper and it wild relatives using the RAPD technique, and then converted Kava-specific fragments into SCAR markers suitable for identifying Kava.

2 Materials and Methods

2.1 Plant Materials

Twenty-eight accessions of Kava, Pepper and it wild relatives were studied. Five Kava accessions from the Pacific island countries were provided by the State Key Biotechnology Laboratory for Tropical Crops at Hainan (China). *Peperomia pellucida* kunth.(*Piperaceae*) was provided by South China University of Tropical Agriculture at Hainan (China). Other Pepper and it wild relatives accessions were provided by Xinglong tropical botanical garden at Hainan (China). All samples used in this study were planted in greenhouse and authenticated in the State Key Biotechnology Laboratory for Tropical Crops, Hainan Province, China (Table 1).

2.2 DNA extraction

Total genomic DNA was extracted from freshly young leaves of individual seedlings by using CTAB method (WANG and FANG, 2002). DNA concentration was assessed by taking absorbance at 260 nm. Working samples were prepared to a concentration of 20 ng μl^{-1}.

2.3 RAPD assay

All RAPD primers used in this study were random sequence, 10-base, oligonucleotide primers with C+G contents ranging from 50 to 80%. One set of primers was obtained from Operon Technologies Inc. (Almada, CA, USA) and an additional set from Shanghai Sangon Company(Shanghai, China). Eighty RAPD primers were chosen for preliminary amplification of 28 test materials. In primer screening, DNA amplifications were repeated at least twice for each primer. Twenty primers (Table 2) that gave always reproducible and scoreable amplifications were selected for the analysis of all the 28 accessions. Protocol for PCR was optimised by varying the concentration of $MgCl_2$, dNTP, primers, *Taq* polymerase and template genomic DNA (XIN and SHI, 2005). PCR reactions (20 μl) contained 20 ng of genomic DNA, 1 unit of *Taq* DNA polymerase (TAKARA Biotechnology (Dalian) Company LTD.), 2 μl of 10$\times$ *Taq* DNA polymerase buffer, 2 mM $MgCl_2$, 200 μM of each dNTPs and 0.2 μM of random primer. DNA amplification was carried out in a GeneAmp PCR System 2400 or 2700 (Perkin-Elmer) for 40 cycles. The thermal profile was as follows: denaturation at 94°C for 5 min, followed by 40 cycles of denaturation at 94°C for 1 min, annealing at 37 °C for 1min and extension at 72 °C for 2 minutes, finished with final extension at 72 °C for 7 minutes and a subsequent incubation at 4°C followed. Approximately 10 μl of completed amplification reaction was run in 1.5% agarose gels containing ethidium bromide (0.5 μg ml^{-1}) and photographed under UV light using a computer printer. Reproducibility of each experiment was confirmed at least twice.

2.4 Data analysis

Only the RAPD primers which gave consistent profiles across the populations and also those that appeared to have diagnostic markers were chosen for further analysis. The presence and absence of bands were scored as 1 or 0 respectively. Faint bands were

Table 1

Species	*Registration No.*	*Origin*
Piper hancei Maxim	2003-P-01	Hainan Bawangling (Hainan, China)
Peperomia pellucida kunth.	2003-P-02	South China University of Tropical Agriculture (Hainan, China)
Piper betle L.	2003-P-03	South China University of Tropical Agriculture (Hainan, China)
Piper sarmentosum Roxb.	2003-P-04	South China University of Tropical Agriculture (Hainan, China)
Piper methysticum Forst.f. No.1	2003-K-01	Fiji
Piper methysticum Forst. f. No.2	2003-K-02	Fiji
Piper methysticum Forst.f. No.3	2003-K-03	Fiji
Piper methysticum Forst.f. No.4	2003-K-04	Fiji
Piper methysticum Forst. f. No.5	2003-K-05	Fiji
Piper methysticum Forst.f. No.6	2003-K-06	Fiji
Lampong Type	2003-P-011	Hainan Xinglong tropical botanical garden
Banniyueer-1	2003-P-12	Hainan Xinglong tropical botanical garden
Kuching	2003-P-13	Hainan Xinglong tropical botanical garden
Dashan	2003-P-14	Hainan Xinglong tropical botanical garden
Piper hancei	2003-P-15	Hainan Xinglong tropical botanical garden
Hybrid 1	2003-P-16	Hainan Xinglong tropical botanical garden
Hybrid 3	2003-P-17	Hainan Xinglong tropical botanical garden
Hybrid 5	2003-P-18	Hainan Xinglong tropical botanical garden
Hybrid 6	2003-P-19	Hainan Xinglong tropical botanical garden
Hybrid 7	2003-P-20	Hainan Xinglong tropical botanical garden
Hybrid 8	2003-P-21	Hainan Xinglong tropical botanical garden
Yinjian 45	2003-P-226	Hainan Xinglong tropical botanical garden
Ban 293	2003-P-23	Hainan Xinglong tropical botanical garden
Banjianni	2003-P-24	Hainan Xinglong tropical botanical garden
Banyunda	2003-P-25	Hainan Xinglong tropical botanical garden
Yuanxuan 1	2003-P-26	Hainan Xinglong tropical botanical garden
Dashan×Yinni	2003-P-27	Hainan Xinglong tropical botanical garden
Jianyin 93	2003-P-28	Hainan Xinglong tropical botanical garden

Table 2

Primer	*Sequence (5′→3′)*	*Primer*	*Sequence (5′→3′)*
OPA—08	GTGACGTAGG	OPQ—07	CCCCGATGGT
OPA—10	GTGATCGCAG	OPQ—10	TGTGCCCGAA
OPA—14	TCTGTGCTGG	OPQ—11	TCTCCGCAAC
OPA—15	TTCCGAACCC	OPQ—13	GGAGTGGACA
OPA—16	AGCCAGCGAA	OPQ—14	GGACGCTTCA
OPA—17	GACCGCTTGT	OPQ—15	GGGTAACGTG
OPA—20	GTTGCGATCC	S265	GGCGGATAAG
OPQ—02	TCTGTCGGTC	S273	CACAGCGACA
OPQ—03	GGTCACCTCA	S278	TTCAGGGCAC
OPQ—06	GAGCGCTTG	S279	CAAAGCGCTC

not recorded for analysis and the data were analyzed using the method of Nei and Li (1979). Cluster analysis was then performed to create a dendrogram using UPGMA by the software MVSP3.13f.

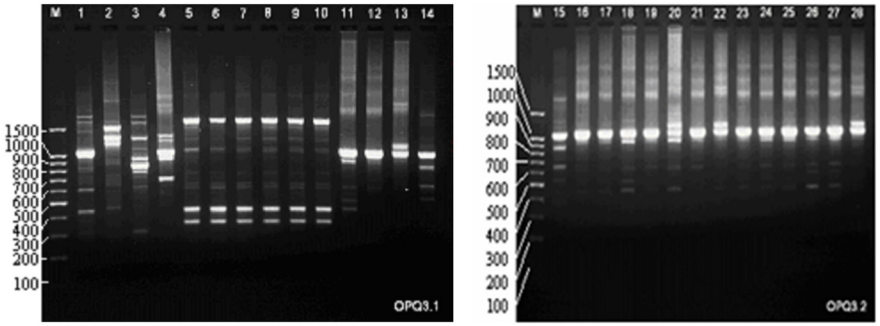
2.5 Cloning and sequencing

The target DNA fragments ($OPQ-02_{562}$ and $OPQ-03_{355}$) in the RAPD reactions were extracted from agarose gels using the QIAquick^{Gel} Extraction kit (Qiagen). The fragments were cloned into the pMD18-T vector (Promega) . *Escherichia coli* XL-1 blue competent cells were transformed with the recombinant vectors and were then plated onto LB/ampicillin/IPTG/X-Gal plates. Positive colonies were determined by blue/white screening. Plasmids from randomly selected white colonies were extracted using the lysis by alkali protocol from Joseph and David (2001) and *Hin*dIII and *Eco*RI double digestion was conducted to confirm the size of the inserted fragment. The vectors containing the fragments of the correct size were sequenced. For each sequence, a pair of target primers flanking the insert region was designed and synthesized. Each primer contained the original 10 bases of the RAPD primer plus the next 10-18 internal bases from the end. The primer pairs were used to amplify Kava, Pepper and it wild relatives DNA to identify Kava-specific SCAR markers.

3 Results

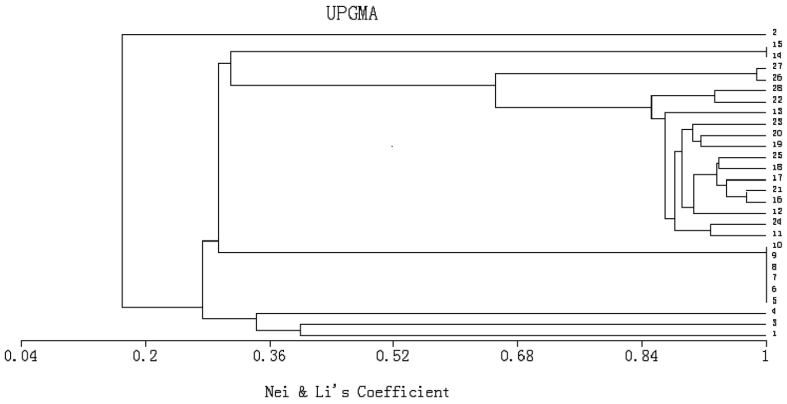
While 80 random primers were screened, out of them 20 primers produced clear and distinct patterns across all samples (Table 2, Fig. 1). PCR amplification with each of these 20 primers was done twice before scoring them. These primers generated a total of 170 bands ranging in size from roughly 300 bp to 2000 bp whereas the range with individual primers was 2–15 bands. This gave an average of 8 bands per primer. Out of 170 bands, 20(12%) of which were polymorphic for one or more species, 16 bands were monomorphic and rest 4 bands were Kava unique.

Figure 1: Agarose gel electrophoresis of OPQ-03 showing Kava's specific band at 355 bp. M is molecular marker lane (see table 1 = here include).



The data analysis and cluster analysis were conducted by using software MVSP3.13f. The clustering result of 28 accessions by using RAPD markers was shown in Figure 2.

Figure 2: Dendrogram of the genetic relationships among Kava, Pepper and it wild relatives (see table 1 = here include).



The similarity index values ranged from 0.125 to 1 indicating the presence of enormous genetic diversity at molecular level. The tested materials were classified into two clusters in similarity coefficient of 0.2. The first group had the 2nd material *Peperomia pellucida* kunth., which belonged to *Peperomia*, *Piperaceae*. The second group 2 contained the 27 materials of *Piper* L., *Piperaceae*, which meant that the materials of the different genera in the same family could be distinguished at the similarity coefficient of 0.2. It showed that the intergeneric difference was greater than that of intragenus. The 28 test materials were classified into six clusters at similarity coefficient of 0.36. Group 1 had *Piper hancei* Maxim (*Piperaceae*) and *Piper betle* L. (*Piperaceae*), Group 2 contained *Piper sarmentosum* Roxb. (*Piperaceae*), Group 3 was Kava, Group 4 was

Pepper, Group 5 was Dashan (*Piperaceae*) and *Piper hancei* (*Piperaceae*), Group 6 was *Peperomia pellucida* kunth. (*Piperaceae*), indicating a higher degree of genetic divergence among Kava and Pepper, Kava and Pepper wild relatives.

In order to increase the specificity and reproducibility of RAPD markers, the two RAPD markers ($OPQ-02_{562}$, $OPQ-03_{355}$) were converted to SCARs. Two SCAR markers were designed based on the sequences of $OPQ-02_{562}$, $OPQ-03_{355}$. The SCAR primers had been designed for $OPQ-02_{562}$ with a forward sequence of 5'-TCT GTC GGT CGT GAA CAA AAA GAA TG-3' and a reverse sequence of 5'-TCT GTC GGT CAT TTA ATT GGT TAA TTG T-3' and for $OPQ-03_{355}$ with a forward sequence of 5'-GGT CAC CTC AAA CCA AGC TTA ATC AAG-3' and a reverse sequence of 5'-GGT CAC CTC ATA ATA CAA ACT TGC AAG C-3'. The validity of the two SCAR markers were confirmed by PCR amplification of the 28 DNA samples (Fig. 3,4). The SCAR primer pairs designed for $OPQ-02_{562}$, $OPQ-03_{355}$ amplified the target fragments(562 bp, 355 bp) exclusively, which indicated that the two SCAR primers were kava-specific SCAR markers which could be used for the molecular identification of Kava germplasm resources.

Figure 3: Agarose gel showing SCAR markers amplified for the primer $OPQ-02_{562}$. M is molecular marker lane. Lanes 5-10 are Kava accessions.

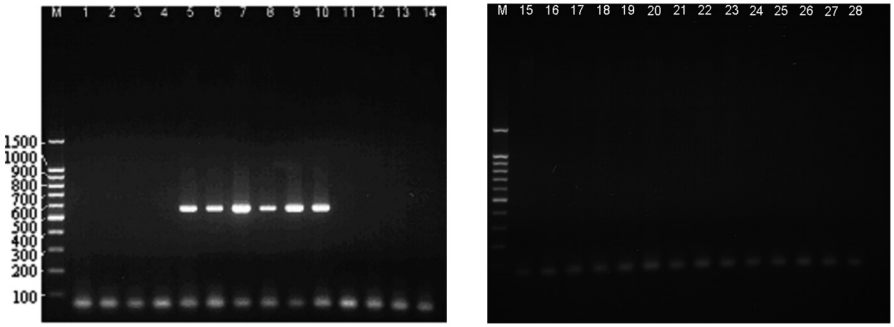
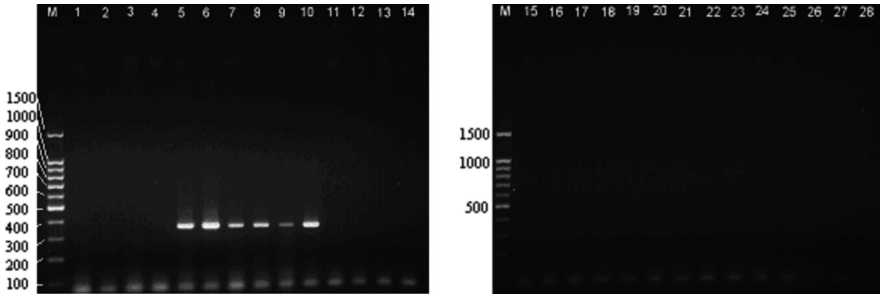


Figure 4: Agarose gel showing SCAR markers amplified for the primer $OPQ-03_{355}$. M is molecular marker lane. Lanes 5-10 are Kava accessions.



4 Discussion

Although Kava and Pepper belong to Pepper genus, the similarity coefficient between Kava and Pepper in our study was 0.36 indicating a higher degree of genetic divergence among Kava and Pepper. Jaramillo and Manos (2001) have suggested that, based on a phylogenetic analysis of sequences of the internal transcribed spacers (ITS) of nuclear ribosomal DNA, the genus Piper could potentially form three monophyletic groups: Asia clade, the South Pacific clade, and the Neotropics clade, and Kava could belong to the South Pacific clade which indicated that the level of genetic relatedness appears to be high between Kava and Asia clade. We obtained the same conclusion on this point. Kava's populations No. 5 to 10 grouped in the same cluster all the time and its similarity coefficients were 1. However, from appearance, 6 plants of Kava could be classified into three kinds of types. The 1st Kava and the 2nd Kava were green stems, the 3rd Kava and the 4th Kava were also green stems but slightly swelling internode, the 5th Kava and the 6th Kava were red stems. Why there was no reflected in the RAPD analysis of three kinds Kava appearance differences. We considered that whether the testing sites were enough to detect the genome by only using 20 random primers selected from 80 random primers. Or might be due to that Kava had no seeds, and took a long time cutting propagation, which caused the relevant unduly narrow of it genetic basis.

The similarity coefficients of Pepper population ranged from 0.612 to 0.989. This showed that genetic difference within Pepper population was relatively small, which related that Pepper was non-origin of my country, few introduction resources, limited geographical cultivation, as well as the long-term adoption of cutting propagation mainly.

SCAR markers have obvious advantages over RAPD markers because the band signals are more prominent and their amplification is less sensitive to reaction conditions. The SCAR markers developed in this study allowed us to distinguish among Kava, Pepper and it wild relatives. This research could provide references for the rootstocks selection in the grafting of *P. methysticum*, the molecular identification on its authenticity and the construction of its fingerprints.

It was reported that *Piper wichmannii* C. DC. and Kava are very similar in morphology, it is a common thing to confuse the two in the laboratory and field (Lebot and Levesque, 1989). Whether Kava-specific SCAR primers could be used to distinguish between *Piper wichmannii* C. DC. and Kava need to be further studied.

In our SCAR study of Kava and its related species, a total of four pairs of Kava specific SCAR markers were designed in which there were two pairs of primers could be used for molecular identification of Kava species and the success rate was of 50%. This loss of polymorphism during RAPD to SCAR conversion was most likely due to flanking site difference at the original RAPD primer binding site.

Acknowledgements

Thanks are duo to Prof. Zheng Xue-qin, State Key Biotechnology Laboratory for Tropical Crops, for the revision of this manuscript. Financial support by China's "Tenth Five-Year" Scientific and Technological Project (No. 2001BA707B02).

References

Das, M., Bhattacharya, S. and Pal, A.; Generation and characterization of SCARs for species-specific marker development in bamboo; *Annals of Botany*; 95:835–841; 2005.

Gosselin, I., Zhou, Y., Bousquet, J. and Isabel, N.; Megagametophyte-derived linkage maps of white spruce (*Picea glauca*) based on RAPD, SCAR and ESTP markers; *Theoretical and Applied Genetics*; 104:987–997; 2002.

Jaramillo, M. A. and Manos, P. S.; Phylogeny and patterns of floral diversity in the genus *Piper* (*Piperaceae*); *American Journal of Botany*; 88(4):706–716; 2001.

Joseph, S. and David, W. R.; *Molecular Cloning: A Laboratory Manual*; New York: Cold Spring Harbor Laboratory Press; 3rd edn.; 2001.

Lebot, V. and Levesque, J.; The origin and distribution of Kava (*Piper methysticum* Forst. f. and *Piper wichmannii* C.DC., *Piperaceae*): A phytochemical approach; *Allertonia*; 5:223–280; 1989.

Matteo, B., Luca, S. and Corrado, F.; Development of SCAR Markers for Germplasm Characterisation in Olive Tree (*Olea europea* L.); *Molecular Breeding*; 17(1):59–68; 2006.

Naoki, T., Takayuki, K., Hiroshi, Y. and Yoshio, H.; Development of SCAR markers distinguishing pure seedlings of the endangered species *Morus boninensis* from *M. boninensis* × *M. acidosa* hybrids for conservation in Bonin (Ogasawara) Islands; *Conservation Genetics*; 4(5):605–612; 2003.

Nei, M. and Li, W. H.; Mathematical model for studying genetic variation in terms restriction endonucleases; *Proceedings of the National Academy of Sciences*; 76:5269–5273; 1979.

Vincent, L., Mark, M. and Lamont, L.; *Kava - The Pacific Elixir*; Vermont: Rochester Healing Arts Press; 1992.

Wang, G. L. and Fang, H. J.; *Plant Genetic Engineering, edition;* (in Chinese); Beijing: Science Press; 2nd edn.; 2002.

Wang, J., Ha, W. Y., Ngan, F. N., But, P. P. and Shaw, P. C.; Application of sequence characterized amplified region (SCAR) analysis to authenticate Panax species and their adulterants; *Planta Medica*; 67:781–783; 2001.

Xin, L. and Shi, J.; Study on the RAPD amplification system of Kava (in Chinese); *Biotechnology*; 15(4):32–34; 2005.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 110, No. 2, 2009, pages 137–145

Performance of Different Tomato Genotypes in the Arid Tropics of Sudan during the Summer Season. I. Vegetative Growth

A. H.A. Abdelmageed [*1], **N. Gruda** [2] and **M. M. A. El-Balla** [3]

Abstract
Selected, eleven tomato genotypes of diverse origin were grown in a glasshouse of the Humboldt University of Berlin, Germany during 2002 and under field conditions in Shambat, University of Khartoum, Sudan for two successive seasons (2002/2003, 2003/2004). High temperatures under field conditions resulted in poor stand and stunted growth of tomato plants. Highly significant differences were encountered among the different genotypes for leaf area, leaf area ratio, leaf weight ratio, stem fresh and dry weight and leaf fresh and dry weight. Based on results obtained from this study, the genotype 'Summerset' proved to be more tolerant under high temperature conditions in comparison to other investigated genotypes and may be useful for exploitation under arid tropical region of Sudan.

Keywords: tomato, genotypes, heat tolerance, high temperature, vegetative growth

1 Introduction

Tomato is one of the major vegetable crops grown worldwide. Under open field conditions in arid regions like North Sudan, high temperatures ($\geq$ 35°C) can prevail for days and may extend into a portion of the dark period of the 24-h light-dark cycle (Abdalla and Verkerk, 1968). Heat stress adversely affects the vegetative growth and reproductive development of the tomato plants and ultimately reduces yield and fruit quality (Abdul-Baki, 1991).

Most of the presently cultivated varieties in Sudan are very much sensitive to hot climate and due to summer conditions with high temperature, their production and supply is limited almost to winter.

Hall (1992) reported that the genetics and physiology of heat tolerance in reproductive tissues in many crops have received comparatively little attention, so a better understanding of the way that heat stress affects plants would help in the development of improved and better production systems to reduce the effects of high temperatures.

* corresponding author
[1] Dr. Adil H.A. Abdelmageed, Department of Horticulture, University of Khartoum, Sudan
[2] Dr. agr. habil. Nazim Gruda, Institute for Horticultural Sciences, Humboldt University of Berlin, Germany
[3] Dr. Mustafa Mohamed Ali El-Balla[1]

Introduction of tomato genotypes of a promising nature has been important to the vegetable industry. Because of such efforts, new varieties have enriched and advanced the horticulture of many countries. The productivity in vegetables depends upon plant growth that is greatly influenced by heat stress.

The objectives of this study were to investigate the effect of high temperature on tomatoes growth and to evaluate the different tomato genotypes for their response to high temperature under open field conditions during summer in Sudan. To have a full picture of the behavior of these genotypes, they were firstly evaluated under glasshouse conditions in Germany.

2 Materials and Methods

2.1 Glasshouse experiment

Eleven tomato genotypes with known differences in sensitivity to heat stress were used: 'CLN2413R' (tolerant), 'CLN2026D' (tolerant), 'CLN2116B' (tolerant) and 'CL5915-93D4-1-0-3'(tolerant) from Asian Vegetable Research and Development Center, (Taipai, Taiwan). 'Strain B (tolerant), 'Peto 86' (sensitive) and 'UC 82-B' (sensitive) from Peto Seed, Co. Inc (USA). 'Maverick F_1' (tolerant), 'Kervic F_1' (tolerant) and 'Drd 85 F_1' (tolerant) from De Ruiter Seed Company, the Netherlands. Summerset (tolerant) and Omdurman (tolerant) as local cultivars bred by the National Institute for Exports of Horticultural Crops, University of Gezira, Sudan.

They were evaluated in the glasshouse at the Institute for Horticultural Sciences, Humboldt University of Berlin, Germany (Latitude 52° 30' N, Longitude 13° 25'E) in the period mid-May-August, 2002. Tomato seeds were sown in flat trays filled with a standard peat mixture substrate for germination (C200) from Stender AG, Company, Germany. Substrate contained 0.5 g l^{-1} NPK fertilizer, had an electrical conductivity (EC) of 0.25 dS m^{-1} and a pH of 5.0-6.0. Fifteen days after sowing (DAS), the seedlings were transplanted into 9 cm containers filled with standard peat mixture substrate (C700) from the same company. Substrate contained 1 g l^{-1} NPK fertilizer, had an EC of 0.53 dS m^{-1} and pH 5.8. Tomato seedlings at 30 DAS were transferred into 14 cm diameter pots filled with same substrate. At 40 DAS the seedlings were transferred into Tube-like single-plant-pots 50 cm long by 25 cm diameter. The pots were closed in one end by perforated cover, which allowed free drainage of excess water. The pots had a volume of 8 l each and were filled with the same substrate (C700). Temperature and relative humidity were continuously recorded using hygrothermographs (Belfort Instrument, Baltimore, MD). Night temperature was 20-21 °C, and remained constant within this range, the maximum day temperature was 25-31 °C, with occasional days exceeding these limits. Relative humidity was 70-80%. The glasshouse conditions are referred herein as normal temperature. Tomato plants were watered every two days. Twice a week 40 ml of 0.2% soluble fertilizer (12% N – 4% P – 6% K) were applied to each pot.

The experiment was set up in a complete randomized block design with three replicates and with five plants for each genotype.

2.2 Field experiment

The same eleven genotypes used in the glasshouse experiment were cultivated under field conditions during summer in Sudan for two successive seasons. In the first season tomato seedlings were transplanted on 25 February 2003 and in the second season on 1 March 2004 to the experimental field of the Department of Horticulture Orchard, Faculty of Agriculture, University of Khartoum, Shambat, Sudan (Latitude 15° 40'N and longitude 32° 32' E).

Tomato seeds were sown in trays filled with peat moss substrate imported from the Netherlands by Fresh Flower Company, Sudan. Four weeks old seedlings were hardened by direct exposure to sunlight for two weeks prior to field setting. Six weeks old seedlings were transplanted to the field on both sides of a flat ridge (bed) during late afternoon and irrigated immediately. The area of each plot was 4×4 meters during both seasons and each plot consisted of two flat ridges; spacing was 140 cm between rows and 40 cm between the plants along the row. The irrigation interval was every 5 days. All the necessary cultural practices and protection measures were adopted in the nursery and the field. The experiment was set up in a complete randomized block design with three replicates. Ten plants in each plot were randomly selected for data collection. OLIVER (1965) described the climate of Khartoum Province as arid tropical. The rainy season is between July and October, with a peak in August. The soil is a cracking heavy clay.

Monthly mean temperature and relative humidity were obtained from the meteorological station at Shambat (Table 1).

Table 1: Mean monthly temperature (°C) and relative humidity (RH %) during the experiment period.

Month	*2002/2003*				*2003/2004*			
	Temperature			*RH %*	*Temperature*			*RH %*
	Maximum	*Minimum*	*Mean*		*Maximum*	*Minimum*	*Mean*	
March	35.80	18.60	27.20	15	37.20	18.10	27.65	23
April	40.50	21.30	30.90	16	40.90	21.00	30.95	16
May	41.90	25.80	33.85	20	44.00	23.80	33.90	19
June	40.90	27.00	33.95	33	41.30	26.10	33.70	28
July	37.30	25.20	31.25	34	40.30	26.30	33.30	34

Source: Shambat Agrometeorological Station

2.3 Data collected

(1) Leaf area (cm^2): The leaf area was measured with an electronic leaf area meter, Type LI-COR Model 3100 (Lincoln, NE-USA) with a precision 0.01 cm^2.

(2) Stem fresh and dry weight (g $plant^{-1}$): Fresh weight of the stem was determined and then oven dried to a constant weight at 70 °C for a minimum of 72 h.

(3) Leaf fresh and dry weight (g $plant^{-1}$): Fresh weight of the stem was determined and then oven dried to a constant weight at 70 °C for a minimum of 72 h.

The following parameters were derived from the measured leaf area:

(4) Leaf area ratio (*LAR*) was calculated as leaf area divided by shoot dry weight for the glasshouse experiment and total plant dry weight for the field experiment according to RADFORD (1967).

(5) Specific leaf area (*SLA*) was calculated as leaf area divided by leaf dry weight according to RADFORD (1967).

(6) Leaf weight ratio (*LWR*) was calculated as leaf dry weight divided by shoot dry weight for the glasshouse experiment and total plant dry weight for the field experiment according to RADFORD (1967).

2.4 Data analysis

Analysis of variance was carried out according to the procedure described by GOMEZ and GOMEZ (1984) for the randomized complete block design to determine the significance of variation among the different genotypes. Mean separation was done by Duncan's multiple range test for $P \leq 0.05$.

3 Results

The performance of different tomato genotypes under field during summer in Sudan and glasshouse conditions in Germany was investigated. The results under open field conditions are means of measurements for two seasons.

3.1 Glasshouse experiment

Concerning the glasshouse experiment, there was a wide range of variation among the different genotypes for leaf area. The heat tolerant genotype 'Summerset' had the highest leaf area, while the heat sensitive genotype 'UC 82-B' had the lowest value (Table 2). The other genotypes were intermediate.

Stem fresh and dry weight and leaf fresh and dry weight showed the same tendency. However, the genotype 'Drd 85 F_1' showed the bigger dry weight (Table 3).

LAR, *SLA* and *LWR* are presented in Table 2. 'Strain B' had the highest *LAR* compered to the other genotypes and 'CLN-16B' had the lowest one. Maximum *SLA* was found in the heat tolerant genotype 'Summerset' and the minimum values were obtained by 'CLN-16B' and 'UC 82-B'. There was a highly significant difference among the different genotypes for *LWR* (Table 2).

Table 2: Leaf area ratio (*LAR*), specific leaf area (*SLA*) and leaf weight ratio (*LWR*) of Diverse tomatoes grown under glasshouse conditions.

Genotype	*Leaf area (cm^2)*	*LAR ($cm^2\ g^{-1}$)*	*SLA ($cm^2\ g^{-1}$)*	*LWR ($g\ g^{-1}$)*
CLN-1-0-3	7124.21 ^{b*}	104.39 ^{b}	191.83 ^{ab}	0.55 ^{def}
CLN-16B	5330.95 ^{c}	64.09 ^{c}	120.40 ^{d}	0.54 ^{def}
CLN-26D	5920.10 ^{bc}	91.03 ^{abc}	179.99 ^{abc}	0.53 ^{ef}
CLN-13R	5588.32 ^{bc}	76.81 ^{bc}	131.15 ^{cd}	0.59 ^{cde}
Strain B	6190.13 ^{bc}	111.55 ^{a}	166.38 ^{abcd}	0.67 ^{bc}
Maverick F_1	5916.98 ^{bc}	79.40 ^{bc}	128.19 ^{d}	0.62 ^{cd}
UC 82-B	3705.29 ^{d}	90.99 ^{abc}	120.90 ^{d}	0.75 ^{a}
Drd $85F_1$	6504.13 ^{bc}	82.62 ^{abc}	139.09 ^{cd}	0.60 ^{cde}
Kervic F_1	6345.91 ^{bc}	86.94 ^{abc}	140.78 ^{cd}	0.62 ^{cd}
Omdurman	5190.05 ^{c}	91.59 ^{abc}	146.39 ^{bcd}	0.63 ^{c}
Summerset	8674.52 ^{a}	103.63 ^{ab}	210.38 ^{a}	0.49 ^{f}
Mean	6031.28	91.28	152.66	0.61

* Means followed by the same letter(s) within each column are not significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 3: Stem fresh weight, stem dry weight, leaf fresh weight, and leaf dry weight of diverse tomatoes grown under glasshouse conditions.

Genotype	*Stem fresh wt (g)*	*Stem dry wt (g)*	*Leaf fresh wt (g)*	*Leaf dry wt (g)*
CLN-1-0-3	256.63 ^{ab*}	31.62 ^{abc}	289.98 ^{bcde}	36.92 ^{abc}
CLN-16B	263.33 ^{ab}	37.99 ^{ab}	313.28 ^{bcd}	45.27 ^{abc}
CLN-26D	213.61 ^{bc}	32.19 ^{abc}	314.35 ^{bcd}	35.32 ^{bc}
CLN-13R	259.59 ^{ab}	29.81 ^{bc}	322.03 ^{bc}	42.83 ^{abc}
Strain B	145.24 ^{de}	19.01 ^{d}	232.29 ^{ef}	38.27 ^{abc}
Maverick F_1	201.03 ^{c}	29.53 ^{bc}	310.46 ^{bcde}	47.05 ^{ab}
UC 82-B	79.68 ^{f}	11.18 ^{d}	190.47 ^{f}	33.26 ^{c}
Drd 85 F_1	216.26 ^{bc}	32.56 ^{abc}	335.69 ^{ab}	49.08 ^{a}
Kervic F_1	184.95 ^{cd}	28.98 ^{c}	312.43 ^{bcd}	47.16 ^{ab}
Omdurman	101.31 ^{ef}	28.30 ^{c}	258.94 ^{cde}	35.68 ^{abc}
Summerset	270.96 ^{a}	39.54 ^{a}	387.79 ^{a}	41.29 ^{abc}
Mean	191.57	27.98	293.30	40.82

* Means followed by the same letter(s) within each column are not significantly different at $P \leq 0.05$, according to Duncan's multiple range test.

3.2 Field experiment

There was a significant difference among the genotypes for leaf area. The heat tolerant genotypes 'Summerset' and 'Omdurman' had the highest leaf area. 'Kervic F_1', 'UC -82-B', 'Strain B', and 'CLN -1-0-3' were intermediate, while the other genotypes had the lowest values (Table 4).

The differences in stem fresh and dry weights among the genotypes were highly significant. The heat tolerant genotypes 'Summerset' and 'Omdurman' exhibited the highest values for stem dry weight. 'Omdurman' exhibited an intermediate value for stem fresh weight, while 'CLN-16B' had the lowest value (Table 5). The same tendency was observed for leaf fresh and dry weight (Table 5).

For growth analysis parameters, there were highly significant differences among the genotypes for these parameters under field conditions (Table 4). 'CLN-1-0-3' had the highest *LAR*, while 'Maverick F_1' had the lowest value (Table 4).

Regarding *SLA* and *LWR*, 'CLN-1-0-3' showed the highest values. 'UC 82-B' exhibited the lowest values; the other genotypes were in between (Table 4).

Table 4: Leaf area ratio (*LAR*), specific leaf area (*SLA*) and leaf weight ratio (*LWR*) of diverse tomatoes grown under field conditions.

Genotype	*Leaf area (cm^2)*	*LAR ($cm^2\ g^{-1}$)*	*SLA ($cm^2\ g^{-1}$)*	*LWR ($g\ g^{-1}$)*
CLN-1-0-3	935.39 ^{bc} *	104.77 ^{a}	173.66 ^{a}	0.64 ^{a}
CLN-16B	154.57 ^{c}	55.91 ^{bc}	158.85 ^{ab}	0.43 ^{b}
CLN-26D	513.83 ^{c}	80.30 ^{ab}	127.21 ^{abc}	0.63 ^{a}
CLN-13R	326.64 ^{c}	51.84 ^{bc}	93.83 ^{abc}	0.55 ^{ab}
Strain B	687.80 ^{bc}	49.13 ^{c}	75.80 ^{bc}	0.65 ^{a}
Maverick F_1	335.41 ^{c}	46.06 ^{c}	75.32 ^{bc}	0.62 ^{a}
UC 82-B	797.25 ^{bc}	47.54 ^{c}	72.51 ^{c}	0.67 ^{a}
Drd 85F_1	493.73 ^{c}	48.74 ^{c}	83.28 ^{bc}	0.59 ^{a}
Kervic F_1	826.02 ^{bc}	48.78 ^{c}	77.38 ^{bc}	0.63 ^{a}
Omdurman	1430.43 ^{ab}	49.48 ^{c}	76.20 ^{bc}	0.66 ^{a}
Summerset	2073.06 ^{a}	76.18 ^{bc}	140.04 ^{abc}	0.55 ^{ab}
Mean	779.47	59.88	104.92	0.60

* Means followed by the same letter(s) within each column are not significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 5: Stem fresh weight, stem dry weight, leaf fresh weight, and leaf dry weight of diverse tomatoes grown under field conditions.

Genotype	*Stem fresh wt (g)*	*Stem dry wt (g)*	*Leaf fresh wt (g)*	*Leaf dry wt (g)*
CLN-1-0-3	27.08 ^{bc} *	3.28 ^{bc}	16.58 ^{b}	7.60 ^{bcd}
CLN-16B	4.76 ^{d}	1.53 ^{c}	3.11 ^{b}	1.27 ^{d}
CLN-26D	8.03 ^{cd}	2.39 ^{bc}	9.25 ^{b}	4.03 ^{cd}
CLN-13R	9.32 ^{cd}	2.62 ^{bc}	6.63 ^{b}	3.30 ^{cd}
Strain B	13.98 ^{cd}	4.54 ^{bc}	21.49 ^{b}	8.43 ^{bcd}
Maverick F_1	11.57 ^{cd}	2.77 ^{bc}	15.26 ^{b}	4.47 ^{cd}
UC 82-B	18.24 ^{bcd}	5.62 ^{b}	26.35 ^{b}	10.82 ^{bc}
Drd 85 F_1	12.68 ^{cd}	4.15 ^{bc}	13.37 ^{b}	5.86 ^{cd}
Kervic F_1	7.95 ^{cd}	4.75 ^{bc}	27.63 ^{b}	9.03 ^{bcd}
Omdurman	35.41 ^{b}	10.18 ^{a}	64.01a	15.08 ^{ab}
Summerset	65.33 ^{a}	12.28 ^{a}	77.52 ^{a}	19.03 ^{a}
Mean	19.48	4.92	25.57	8.08

* Means followed by the same letter(s) within each column are not significantly different at $P \leq 0.05$, according to Duncan's multiple range test.

4 Discussion

The response of vegetative growth to temperature varied considerably between glasshouse and field studies. These results were due to differences in the environmental factors such as wind speed and light intensity, as well as biological factors like insects and diseases. As result, the relative stimulation in response to temperature in the current glasshouse was much larger than that observed under open field conditions.

4.1 Glasshouse experiment

In general, the different tomato genotypes that were grown under glasshouse conditions showed a vigorous vegetative growth compared to that grown under field conditions in Sudan. This might be due to the favorable environmental conditions encountered in the glasshouse.

Regarding the vegetative growth, there were some variations among the different genotypes. The heat tolerant genotype 'Summerset' had the highest leaf area, while the heat sensitive genotype 'UC 82-B' had the lowest. Also, stem fresh weight, stem dry weight and leaf fresh weight showed the same tendency. Thus, the heat tolerant genotype showed a higher rate of vegetative growth than the heat sensitive genotype. The difference may be attributed to the genetic make of these genotypes (Hussain *et al.*, 2001) and confirm the findings of Rainwater *et al.* (1996) who reported that different genotypes of tomato exhibited considerable variation in their sensitivity to heat stress.

4.2 Field experiment

High air temperatures combined with leaf curl disease during the growth period led to a poor stand and stunted growth on most of the cultivated genotypes. This is in agree-

ment with earlier investigation. Infection by leaf curl was shown by YASSIN (1984) and GOMEZ *et al*. (2004) resulted in foliar curling and yellowing, reduced leaf area and plant stunting.

High temperature under open field conditions markedly decreased the leaf area of the plants. However, the heat tolerant genotype 'Summerset' showed the largest leaf area under open field conditions and 'UC 82-B' the lowest. The differences may be attributed to the genetic make of these genotypes. This result corroborates that of NKANSAH and ITO (1994) who found that heat tolerant cultivars had a higher leaf area than heat sensitive ones under high temperature conditions.

Further, high temperature and infection of the plants by leaf curl disease encountered under field conditions drastically reduced the stem fresh and dry weight as well as leaf fresh and dry weight of the different genotypes tested, which may be related to the depletion of reserve starch and other carbohydrates by respiratory losses due to high night temperature. Similar results were obtained by ABDELMAGEED and GRUDA (2007, 2009a). The authors reported that the higher the temperature, the lower the dry weight of the vegetative parts. In the present study, in agreement with results for leaf area, most of the heat tolerant genotypes demonstrated a better stem fresh and dry weight than the heat sensitive genotype 'UC 82-B'. This might be due to its ability to produce more carbohydrates than the heat sensitive genotype (NKANSAH and ITO, 1994).

In order to explain differences in growth between the heat tolerant and heat sensitive genotype, growth analysis was carried out. A high temperature under open field conditions significantly reduced the *LAR*, *SLA* and *LWR* for most of the genotypes. Leaf area ratio (*LAR*), is used in assessing effects of environmental conditions on the relative size of the assimilatory part (NKANSAH and ITO, 1994). The capacity of plants to accumulate dry matter depends to a large extent on the size of the leaf area to the overall size of the plant. In general, differences were found among the genotypes for the *LAR*, *SLA* and *LWR*. 'Summerset', a heat tolerant cultivar, had thicker leaves as compared to those of 'UC 82-B', a heat sensitive one. GOSSELIN and TRUDEL (1984) reported that the increase in shoot dry weight might have resulted from larger leaf areas and higher plant photosynthetic rates.

In general, growth analysis in this study indicated that greater partitioning might contribute to an improvement of crop productivity by increasing total carbohydrate production (NKANSAH and ITO, 1994).

Based on results obtained from this study, the genotype 'Summerset' proved to be more tolerant under high temperature conditions in comparison to other investigated genotypes. However, correlation analyzes between the vegetative and generative parameters need to be examined further.

The results for generative development will be presented in a second paper (ABDELMAGEED and GRUDA, 2009b).

Acknowledgment
The German Academic Exchange Service (DAAD) is acknowledged for providing a scholarship for the first author.

References

Abdalla, A. A. and Verkerk, K.; Growth, flowering and fruit set of the tomato at high temperature; *Netherlands Journal of Agricultural Science*; 16:71–76; 1968.

Abdelmageed, A. H. A. and Gruda, N.; Influence of heat shock pretreatment on growth and development of tomatoes under controlled heat stress conditions; *J. Appl. Bot. Food Qual.*; 81:26–28; 2007.

Abdelmageed, A. H. A. and Gruda, N.; Influence of grafting on growth, development and some physiological parameters of tomatoes under controlled heat stress conditions; *European Journal of Horticultural Science*; 74(1):16–20; 2009a.

Abdelmageed, A. H. A. and Gruda, N.; Performance of different tomato genotypes in the arid tropics of Sudan during the summer season. II. Generative development; *Journal of Agriculture and Rural Development in the Tropics and Subtropics*; 110(2):147 – 154; 2009b.

Abdul-Baki, A. A.; Tolerance of tomato cultivars and selected germplasm to heat stress; *Journal of the American Society of Horticultural Science*; 116(6):1113–1116; 1991.

Gomez, K. W. and Gomez, A. A.; *Statistical Procedures for Agricultural Research; 2nd Ed.*; John Wiley and Sons, Inc., New York.; 2 edn.; 1984.

Gomez, O., Pinon, M., Martinez, Y., Quinones, M., Fonesca, D. and Laterrot, H.; Breeding for resistance to begomovirus in tropic-adapted tomato genotypes; *Plant Breeding*; 123:275–279; 2004.

Gosselin, A. and Trudel, M. J.; Interactions between root-zone temperature and light levels on growth, development, and photosynthesis of *Lycopersicon esculentum* Mill. Cultivar 'vendor'; *Scientia Horticulturae*; 23:313–321; 1984.

Hall, A. E.; Breeding for heat tolerance; *Plant Breeding Reviews*; 10:129–167; 1992.

Hussain, S. I., Khokhar, K. M., Mahmood, T., Laghari, M. H. and Mahmud, M. M.; Yield Potential of Some Exotic and Local Tomato Cultivars Grown for Summer Production; *Pakistan Journal of Biological Sciences*; 10(4):1215–1216; 2001.

Nkansah, G. O. and Ito, T.; Relationship between some physiological characters and yield of heat-tolerant and non-tolerant, and tropical tomato cultivars grown at high temperature; *Journal of Japanese Society for Horticultural Science*; 62(4):781–788; 1994.

Oliver, J.; The climate of Khartoum province; *Sudan Notes and Records*; 46:90–120; 1965.

Radford, P. J.; Growth analysis formulae - their use and abuse; *Crop Science*; 7:171–175; 1967.

Rainwater, D. T., Gossett, D. R., Mollhollon, E. P., Hanna, H. Y., Banks, S. W. and Lucas, M. C.; The relationship between yield and the antioxidant defense system in tomatoes grown under heat stress; *Free Radical Research*; 25:421–435; 1996.

Yassin, A. M.; Leaf curl epidemic in tomato and possible control strategies; *Acta Horticulturae*; 143:457–468; 1984.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 110, No. 2, 2009, pages 147–154

Performance of Different Tomato Genotypes in the Arid Tropics of Sudan during the Summer Season. II. Generative Development

A. H.A. Abdelmageed [*1] and **N. Gruda** [2]

Abstract
Eleven tomato genotypes of diverse origin were grown in Shambat, University of Khartoum, Sudan, in a randomized block design with three replications for two successive seasons (2002/2003, 2003/2004). The same genotypes were firstly evaluated under glasshouse conditions at the Humboldt University of Berlin, Germany during 2002. Highly significant differences were encountered among the different genotypes for most of the generative characters, such as number of days to flowering, number of flowers per plant, number of fruits per plant, fruit fresh weight per plant and fruit set percentage. Based on results obtained from this study, the genotype 'Summerset' proved to be high yielding under high temperature conditions in comparison to other genotypes.

Keywords: tomato, genotypes, heat tolerance, high temperature, vegetative growth

1 Introduction

Heat stress is a major abiotic factor that limits tomato production during summer season in Sudan. High temperature negatively affects plant growth and survival and hence crop yield (Boyer, 1982). According to a recent study, each degree centigrade increase in average growing season temperature may reduce crop yield by up to 17% (Lobell and Asner, 2003).

Lack of tolerance to high temperature in most tomato genotypes presents a major limitation for growing an economic crop in regions where the temperature during part of the growing season, even for short durations, reaches 38 °C or higher (Abdul-Baki, 1991). Moreover, most of the presently cultivated varieties in Sudan are very much sensitive to hot climate and due to summer conditions with high temperature, their production and supply is limited almost to the winter period.

Hall (1992) reported that the genetics and physiology of heat tolerance in reproductive tissues have received comparatively little attention. A better understanding of the way that heat stress affects plants would help in the development of improved and better production systems to reduce the effects of high temperatures.

* corresponding author
[1] Dr. Adil H.A. Abdelmageed, Department of Horticulture, University of Khartoum, Sudan
[2] Dr. agr. habil. Nazim Gruda, Institute for Horticultural Sciences, Humboldt University of Berlin, Germany

Introduction of tomato genotypes of a promising nature has been important to the vegetable industry throughout the world. New varieties have enriched and advanced the agriculture of many countries.

The objectives of this study were to analyze the performance of different tomato genotypes in the arid tropics of Sudan during summer in order to investigate the effect of high temperature on the generative development. To have a full picture of the behavior of these genotypes, they were firstly evaluated under glasshouse conditions.

2 Materials and Methods

2.1 Field experiments

The experiments with eleven tomato genotypes of different origins were conducted for two successive seasons in the Department of Horticulture Orchard, Faculty of Agriculture, University of Khartoum, Shambat, Sudan (Latitude 15° 40'N and longitude 32° 32' E). The cultivation data are described by ABDELMAGEED *et al.* (2009).

2.2 Glasshouse experiment

The same eleven genotypes used in the field experiment were firstly studied in the glasshouse at the Institute for Horticultural Sciences, Humboldt University of Berlin, Germany (Latitude 52° 30' N, Longitude 13° 25'E) in the period mid-May-August, 2002. For more details, see ABDELMAGEED *et al.* (2009).

2.3 Data collected

Number of days to flowering, number of flowers per plant, number of fruits per plant, percent of fruits setting and fruit fresh weight (g plant^{-1}) were recorded according to ABDELMAGEED and GRUDA (2007, 2009b).

2.4 Data analysis

Analysis of variance was carried out according to the procedure described by GOMEZ and GOMEZ (1984) for the randomized complete block design to determine the significance of variation among the different genotypes. Mean separation was done by Duncan's multiple range test for $P \leq 0.05$.

3 Results

The performance of different tomato genotypes under field during summer in Sudan and glasshouse conditions in Germany was investigated. The means under open field conditions are combined measurements of two seasons.

3.1 Glasshouse experiment

With regard to the number of days to flowering, there were significant differences among the different tomato genotypes (Table 1). The earliest genotypes were 'CLN-1-0-3','CLN-13R', 'CLN-16B'and 'Summerset', respectively and the latest genotypes were

'Drd 85 F_1', 'Kervic F_1' and 'Maverick F_1', respectively. The other genotypes were intermediate. There was a wide range of variation among the different genotypes for number of flowers under glasshouse conditions. 'CLN-1-0-3' produced the highest number of flowers per plant, while 'Omdurman' and 'UC 82-B' produced the lowest ones, respectively (Table 1).

Table 1: Number of days to flowering, number of flowers per plant, number of fruits per plant, fruit fresh weight per plant and fruit set percentage of diverse tomatoes grown under glasshouse conditions.

Genotype	*No. of days to flowering*	*No. of flowers plant^{-1}*	*No. of fruit plant^{-1}*	*Fruit fresh weight plant^{-1} (g)*	*Fruit set percentage*
CLN-1-0-3	47.00 ^{g*}	104.72 ^{a}	50.70 ^{a}	542.98 ^{e}	48.46 ^{b}
CLN-16B	50.20 ^{def}	83.44 ^{b}	52.26 ^{a}	792.77 ^{cde}	64.18 ^{a}
CLN-26D	49.60 ^{ef}	69.30 ^{c}	30.94 ^{b}	599.48 ^{de}	44.41 ^{bc}
CLN-13R	49.20 ^{f}	56.42 ^{def}	20.02 ^{de}	565.40 ^{de}	35.35 ^{cd}
Strain B	52.40 ^{bc}	57.54 ^{def}	18.98 ^{de}	830.90 ^{bcde}	32.98 ^{d}
Maverick F_1	57.20 ^{a}	62.58 ^{def}	17.94 ^{e}	994.29 ^{abc}	28.71 ^{d}
UC 82-B	51.80 ^{bcd}	53.62 ^{fg}	27.04 ^{bc}	858.34 ^{bcd}	50.63 ^{b}
Drd 85 F_1	55.60 ^{a}	63.28 ^{cd}	21.06 ^{de}	1110.52 ^{ab}	33.33 ^{d}
Kervic F_1	56.40 ^{a}	60.48 ^{def}	18.20 ^{e}	976.05 ^{abc}	30.19 ^{d}
Omdurman	52.00 ^{bc}	48.58 ^{g}	17.16 ^{e}	1058.87 ^{abc}	35.34 ^{cd}
Summerset	51.20 ^{bcde}	61.18 ^{def}	28.34 ^{bc}	1193.04 ^{a}	46.30 ^{b}
Mean	52.15	64.65	27.23	865.69	41.25

* Means followed by the same letter(s) within each column are not significantly different at P $\leq$ 0.05, according to Duncan's multiple range test.

Regarding the number of fruits per plant, more fruits were produced from 'CLN-16B'and 'CLN-1-0-3'. 'CLN-26D', 'Summerset' and 'UC 82-B' gave a medium number of fruits per plant, while the other genotypes produced a low number of fruits (Table 1). There was a wide range of variation among the genotypes for fruit set percentage. 'CLN-16B' had the highest fruit set percentage, while 'UC 82-B', 'CLN-1-0-3', 'Summerset' and 'CLN-26D' were intermediate. The other genotypes had the lowest fruit set percentage (Table 1).

For fruit fresh weight, 'Summerset' exhibited the highest fruit fresh weight followed by 'Drd 85F_1', 'Omdurman', 'Kervic F_1' and 'Maverick F_1', while the other genotypes were either intermediate or low (Table 1).

3.2 Field experiment

A significant variation in number of days to flowering occurred among the different tomato genotypes (Table 2). The earliest genotypes were 'Omdurman', 'Summerset' and 'CLN-1-0-3', respectively and the latest genotypes were 'Maverick F_1', 'Drd 85 F_1' and 'Kervic F_1', respectively. The other genotypes were intermediate. There was a wide range of variation among the genotypes for the number of flowers grown under open field conditions during summer. 'Summerset' produced the highest number of flowers, while 'Drd85 F_1' the lowest one, the other genotypes were intermediate (Table 2).

Table 2: Number of days to flowering, number of flowers per plant, number of fruits per plant, fruit fresh weight per plant and fruit set percentage of diverse tomatoes grown under field conditions.

Genotype	*No. of days to flowering*	*No. of flowers plant^{-1}*	*No. of fruit plant^{-1}*	*Fruit fresh weight plant^{-1} (g)*	*Fruit set percentage*
CLN-1-0-3	50.33 ^{d*}	43.67 ^{bc}	9.67 ^{b}	58.96 ^{bc}	22.01 ^{ab}
CLN-16B	49.00 ^{de}	27.33 ^{bcd}	2.00 ^{cd}	6.45 ^{c}	6.01 ^{bc}
CLN-26D	51.67 ^{cd}	27.33 ^{bcd}	2.40 ^{cd}	27.21 ^{c}	8.59 ^{bc}
CLN-13R	51.00 ^{cd}	30.67 ^{abcd}	2.67 ^{cd}	18.90 ^{c}	8.33 ^{bc}
Strain B	57.33 ^{b}	26.00 ^{cd}	6.00 ^{bcd}	53.92 ^{bc}	26.76 ^{a}
Maverick F_1	59.00 ^{ab}	22.67 ^{cd}	0.67 ^{cd}	8.11 ^{c}	6.67 ^{bc}
UC 82-B	53.67 ^{c}	38.00 ^{abcd}	0.00 ^{d}	0.00 ^{c}	0.00 ^{c}
Drd 85 F_1	59.00 ^{ab}	21.00 ^{d}	3.33 ^{cd}	20.88 ^{c}	16.60 ^{abc}
Kervic F_1	61.00 ^{a}	32.67 ^{abcd}	1.67 ^{cd}	3.25 ^{c}	4.17 ^{bc}
Omdurman	47.00 ^{e}	48.67 ^{ab}	7.00 ^{bc}	58.97 ^{bc}	14.81 ^{abc}
Summerset	49.00 ^{de}	52.00 ^{a}	16.00 ^{a}	246.02 ^{a}	31.59 ^{a}
Mean	53.45	33.64	4.67	45.67	13.23

* Means followed by the same letter(s) within each column are not significantly different at P $\leq$ 0.05, according to Duncan's multiple range test.

The number of fruits produced under open field conditions was observed to be zero in the heat sensitive genotype 'UC 82-B'. The heat tolerant genotype 'Summerset' produced the highest number of fruits. 'CLN-1-0-3' was intermediate, while the other genotypes produced low number of fruits per plant (Table 2).

Concerning fruit set percentage, there was a significant difference among the different genotypes (Table 2). 'Summerset' showed the highest fruit set percentage, while 'UC 82-B' the heat sensitive genotype produced no fruits. The other genotypes were low. 'CLN-1-0-3' was intermediate (Table 2).

For fruit fresh weight per plant, 'Summerset' had the highest fruit fresh weight per plant, while the other genotypes were either intermediate or low (Table 2).

4 Discussion

Temperature affects chemical reactions and physical properties of plants (GRUDA, 2005). It was recognized that the response of generative growth to temperature varied considerably between glasshouse and field studies. These results were due to differences in the abiotic factors such as temperature, wind speed and light intensity as well as biotic factors like insects and diseases. As consequence, the relative stimulation of reproductive development of tomatoes in response to temperature in the current glasshouse was much larger than that observed under open field conditions.

4.1 Glasshouse experiment

According to DORAIS *et al.* (2004) temperature is the most important climatic factor influencing sink strength and consequently photo-assimilate partitioning between plant organs.

There was a wide range of variation among the genotypes for the number of days to flowering and the number of flowers in this experiment. The difference may be attributed to genetic make of genotypes. Similar results were obtained by LOHAR and PEAT (1998) and HUSSAIN *et al.* (2001).

'CLN-16B'and 'CLN-1-0-3' produced the highest number of fruits. But, there was no significant difference between the heat tolerant genotype 'Summerset' and the heat sensitive genotype 'UC 82-B'. Fruit set percentage showed the same trend as in the number of fruits per plant, 'CLN-16B' had the highest fruit set percentage, while 'Summerset', 'UC 82-B' and 'CLN-26D' were intermediate. This may be due to genetic factors (HUSSAIN *et al.*, 2001). Fruit fresh weight per plant is not in line with the previous results of the number of fruits per plant, this may be due to the small size of the fruits of the genotypes that had the highest number of fruits per plant.

4.2 Field experiment

Prolonged periods of high temperature and hot dry wind under field conditions led to poor plant growth, deformities and abnormalities in flower structure during summer. In addition, excessive drying and browning of the stigma and style elongation were observed. These were probably responsible for the poor fruit set on most of the genotypes and lack of fruit set in the heat sensitive genotype 'UC 82-B' tested in this study. SATTI and ABDALLA (1984) and DANE *et al.* (1991) showed similar observations.

Consistent genotypic differences in sensitivity to high temperatures under field conditions were exemplified by the genotypes tested here for most of the characters. This confirms the early findings of RAINWATER *et al.* (1996) who reported that different cultivars of tomato exhibited considerable variation in their sensitivity to heat stress.

LOHAR and PEAT (1998) reported that delays in flowering can lead to delays in fruit production. Thus, earlier flowering in heat tolerant genotypes as compared to the heat sensitive genotype can be considered as a good character for heat tolerance, as it enables heat tolerant genotypes to produce earlier crop. In addition, earliness can help in

avoiding the problems associated with high temperature. In this study, the heat tolerant genotypes were earlier in flowering.

The number of flowers produced under field conditions was very low in most of the genotypes. Such effectiveness of high temperature is mainly due to the decrease in flower production and /or to bud and flower drop. This result falls in line with that of EL-AHMADI and STEVENS (1979) who reported a similar finding wherein a heat sensitive genotype produced only aborted flowers at high temperature.

The number of fruits per plant and fruit set percentage was either low or completely lacking due to high temperature under open field conditions. 'Summerset' produced the highest number of fruits per plant, while 'UC 82-B' produced no fruit. Other genotypes were intermediate. This may be attributed to the genetic make of these genotypes (HUSSAIN *et al.*, 2001). In addition, this is in accordance with the results obtained by SATO *et al.* (2004) who reported that the primary factor affecting fruit set under high temperature stress was the disruption of male reproductive development.

Fruit fresh weight in this study was more or less low and this can be attributed to the reduction in the fruit set. This result confirms earlier findings of EL-AHMADI and STEVENS (1979), SATO *et al.* (2000) and ABDELMAGEED and GRUDA (2009a).

The relative position of the flower on the plant is also important, as fruit set declines with time even under favorable conditions. Thus, flower abortion or lack thereof should not be used as the only indication of high temperature tolerance (SATO *et al.*, 2002). In addition, high temperature significantly increased the proportion of parthenocarpic fruit, undeveloped flowers, and aborted flowers. The primary factor affecting seeded fruit set under high elevated temperature stress in 'UC 82-B' was considered to be a disruption of male reproductive development (SATO *et al.*, 2002, 2004). Most of the genotypes grown under open field conditions during summer failed to give any significant economic yield. This marked reduction in yield may be attributed to diminished fruit set and fruit weight.

In conclusions, the heat tolerant genotypes offer opportunities as a genetic source of heat tolerance for breeding cultivars adapted to high temperature stress. They may also be useful in the study of the physiological basis of heat tolerance. In addition, according to this work and that from HALL (1992), it may be effective to screen for several morphological traits conferring heat tolerance. Furthermore, based on results obtained from this study, the genotype 'Summerset' proved to be high yielding under high temperature conditions in comparison to other genotypes.

Acknowledgment
The German Academic Exchange Service (DAAD) is acknowledged for providing a scholarship for the first author.

References

Abdelmageed, A. H. A. and Gruda, N.; Influence of heat shock pretreatment on growth and development of tomatoes under controlled heat stress conditions; *J. Appl. Bot. Food Qual.*; 81:26–28; 2007.

Abdelmageed, A. H. A. and Gruda, N.; Growth and gas exchange rate of some tomato cultivars under controlled heat stress conditions; *European Journal of Horticultural Science*; 74(4):152–159; 2009a.

Abdelmageed, A. H. A. and Gruda, N.; Influence of grafting on growth, development and some physiological parameters of tomatoes under controlled heat stress conditions; *European Journal of Horticultural Science*; 74(1):16–20; 2009b.

Abdelmageed, A. H. A., Gruda, N. and El-Balla, M. M. A.; Performance of different tomato genotypes in the arid tropics of Sudan during the summer season. I. Vegetative growth; *Journal of Agriculture and Rural Development in the Tropics and Subtropics*; 110(2):137 – 145; 2009.

Abdul-Baki, A. A.; Tolerance of tomato cultivars and selected germplasm to heat stress; *Journal of the American Society of Horticultural Science*; 116(6):1113–1116; 1991.

Boyer, J.; Plant productivity and the environment; *Science*; 218:443–448; 1982.

Dane, F., Hunter, A. G. and Chambliss, O. L.; Fruit set, pollen fertility, and combining ability of selected tomato genotypes under temperature field conditions; *Journal of the American Society of Horticultural Science*; 116(5):906–910; 1991.

Dorais, M., Demers, D. A., Papadopoulos, A. P. and van Ieperen, W.; Greenhouse tomato fruit cuticle cracking; *Hort. Reviews*; 30:163–173; 2004.

El-Ahmadi, A. B. and Stevens, M. A.; Reproductive responses of heat-tolerant tomatoes to high temperatures; *Journal of the American Society of Horticultural Science*; 104(5):686– 691; 1979.

Gomez, K. W. and Gomez, A. A.; *Statistical Procedures for Agricultural Research; 2nd Ed.*; John Wiley and Sons, Inc., New York.; 2 edn.; 1984.

Gruda, N.; Impact of Environmental Factors on Product Quality of Greenhouse Vegetables for Fresh Consumption; *Crit. Rev. Plant Sci.*; 24(3):227–247; 2005.

Hall, A. E.; Breeding for heat tolerance; *Plant Breeding Reviews*; 10:129–167; 1992.

Hussain, S. I., Khokhar, K. M., Mahmood, T., Laghari, M. H. and Mahmud, M. M.; Yield Potential of Some Exotic and Local Tomato Cultivars Grown for Summer Production; *Pakistan Journal of Biological Sciences*; 10(4):1215–1216; 2001.

Lobell, D. B. and Asner, G. P.; Climate and management contributions to recent trends in US agricultural yields; *Science*; 299:1032; 2003.

Lohar, D. P. and Peat, W. E.; Floral characteristics of heat tolerant and heat sensitive tomato (*Lycopersicon esculentum* Mill.) cultivars at high temperature; *Scientia Horticulturae*; 73:53–60; 1998.

Rainwater, D. T., Gossett, D. R., Mollhollon, E. P., Hanna, H. Y., Banks, S. W. and Lucas, M. C.; The relationship between yield and the antioxidant defense system in tomatoes grown under heat stress; *Free Radical Research*; 25:421–435; 1996.

Sato, S., Peet, M. M. and Gardner, R. G.; Altered flower retention and developmental patterns in nine tomato cultivars under elevated temperature; *Scientia Horticulturae*; 101:95–101; 2004.

Sato, S., Peet, M. M. and Thomas, J. F.; Physiological factors limit fruit set of tomato (*Lycopersicon esculentum* Mill.) under chronic, mild heat stress; *Plant, Cell and Environment*; 23:719–726; 2000.

Sato, S., Peet, M. M. and Thomas, J. F.; Determing critical pre- and post–anthesis periods and physiological processes in (*Lycopersicon esculentum* Mill.) exposed to moderately elevated temperatures; *Journal of Experimental Botany*; 53(371):1187–1195; 2002.

Satti, S. M. E. and Abdalla, A. A.; Temperature and nitrogen fertilization in relation to flowering and fruit set in tomatoes under arid conditions of the Sudan; *Acta Horticulturae*; 143:289–297; 1984.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 110, No. 2, 2009, pages 155–168

Vitamin E Supplementation to Sows and Effects on Fertility Rate and Subsequent Body Development of their Weanling Piglets

D. O. Umesiobi *[1]

Abstract

The aim of this study was to evaluate the effects of dietary supplementation of vitamin E to sows on sow fertility and serum α-tocopherol, growth and physiological state of their weanling pigs. A total of 60 Large White gilts were randomly allotted to three groups (20 gilts per group) from coitus to lactation phases over a two-parity period to evaluate the effects of dietary vitamin E on fecundity rates and litter size of sows. Each of the three dietary vitamin E treatment combinations involved 0, 40 or 70 IU/kg of dl- α-tocopheryl acetate/kg of diet, and parity 1 and 2. Sow serum α-tocopherol and Selenium (Se) were collected at 30 day *post coitum*, 99 day of gestation and 21 day lactation. Serum α-tocopherol and Se were collected from piglets at 1 day *post natum* and on day 21 (weaning age). Data relating to sow fecundity and litter size were also recorded. Results indicate that body weights and body weight gains of sows and their litters increased significantly ($P < 0.01$) by parity, increasing more from parities 1 to 2, mostly when dietary vitamin E was increased from 40 to 70 IU/kg diet. The highest number of total piglets and number of piglets born alive (12 ± 8.9 vs. 11 ± 0.1) were obtained at parity 2 when dietary vitamin E was increased to 70 IU/kg diet. There was an increase in weights of the piglets when dietary vitamin E was increased in sow's diet. There was a dramatic increase in serum α-tocopherol and Se concentrations following 40 and 70 IU/kg of vitamin E supplementation during the 30 and 99 day gestation and 21 day lactation periods as parity increased. Se concentrations were about 3 fold higher in the 70 IU/kg vitamin E supplemented group in parity 2 compared to the other groups. In both parities, female piglets had higher serum α-tocopherol and Se concentrations at both 2 day *post natum* and on day 21 (weaning) compared to the male piglets. Results from this study suggest that supplementing 70 IU/kg α-tocopheryl acetate in sow's diets appears to enhance growth of their weanling piglets.

Keywords: Litter size, dl- α-tocopheryl acetate, physiological status, pigs, South Africa

1 Introduction

In South Africa like in most parts of the world, swine breeders lack site-specific information on the exact level of vitamin supplements that are to be supplied in sows' diet to

* corresponding author

[1] School of Agriculture and Environmental Sciences, Central University of Technology, Free State, Private Bag X20539, Bloemfontein 9300, South Africa

optimise litter size, and subsequent body development and general wellbeing of weanling pigs. Most estimates on vitamin E supplementation are based on the minimum level required to overcome a deficiency symptom and not necessarily to promote productivity or indeed, to enhance immunity (Umesiobi, 2008). The supplemental level of vitamin E necessary to attain maximum litter size has not yet been ascertained, but it is considered to be within 10 to 22 IU/kg of diet (NRC, 1998). Higher dietary vitamin E levels may be necessary when diets contain high-moisture grain (Prasad and Kalra, 1993; McDowell, 2002) or unsaturated fat (McDowell, 2001). The immense importance of vitamin E in optimising fecundity rates and litter size in sows is demonstrated by the fact that maximal early growth and general wellbeing in weanling pigs, depend amongst other factors, on correct vitamin E supplementation to their sows pre and *post coitum* (Capper *et al.*, 2005). Consequently, when swine diets have been fortified with vitamin E, an increased litter size at birth has generally been demonstrated (Marin-Guzman *et al.*, 2000; Stuart and Kane, 2004).

Dietary supplementation of vitamin E is required during gestation and lactation to prevent reproductive failures (Wolf, 2005; McDowell, 2002; Umesiobi, 2008). Vitamin E is a fat soluble chemical found in the diet in varying amounts. Vitamin E usually refers to all tocol (α, β, γ and δ) and trienol (α, β, γ and δ) derivatives. All these substances are found in plants and have vitamin E activity, but alpha-tocopherol is the most active form of vitamin E. In the animal body, vitamin E is present primarily as alpha tocopherol. Vitamin E is essential for growth and mostly, during critical periods of embryonic development to enhance embryo survival (Stuart and Kane, 2004), it also acts as an intracellular antioxidant (Dufrasne *et al.*, 2000; Umesiobi, 2008). Vitamin E is also a precursor of certain thromboxanes, prostaglandins, leukotrienes and immunoglobulins (Håkansson *et al.*, 2001; Le Dividich *et al.*, 2005).

Vitamin E deficiency has been shown to affect growth development and health status of weanling pigs (Flachowsky, 2000), cattle (McDowell, 2001, 2002; Waller *et al.*, 2007) and several other animal species (Pehrson *et al.*, 2001; McDowell, 2002), resulting in foetal death and resorption (Sivertsen *et al.*, 2007), with a concomitant reduction in profitability of pig husbandry. Consequently, increasing dietary vitamin E intake during gestation or intramuscular injection of vitamin E resulted in an increase in litter size and a reduction of pre-weaning piglet mortality (Allan and Bilkei, 2005; Fragou *et al.*, 2006). However, the optimal level of vitamin E needed to improve the reproductive parameters has not been determined because of several interfering factors such as the composition of the diet, feed consumption, the rate of animal growth and living conditions or stress (Prasad and Kalra, 1993; McDowell, 2001, 2002). Moreover, the way of actions of vitamin E in enhancing litter size in sows and general wellbeing of the weanling pigs is still unclear. According to reports (Capper *et al.*, 2005), antioxidant properties as well as an immuno-modulating effect may be the reasons, and may also be important for the general wellbeing of weanling pigs. Interestingly, vitamin E supplementation during early development has important immediate and short-term effects on growth, body composition and body functions in weanling pigs (Oldfield, 2003; Stuart and Kane, 2004). In addition, various reports by Barker (1994) and

Burrin (2001) indicate that long-term vitamin E supplementation during critical time periods of development affected later physiological and metabolic processes of weanling pigs, a phenomenon referred to as 'metabolic programming' (Barker, 1994; Burrin, 2001).

Since no behaviour or other parameters in relation to this study, were recorded that could be effectively related to the wellbeing of pigs in the South African environment, the aim of this study was to assess the adequacy of present feeding regimes in the South African pig industry with respect to vitamin E status for sows and its effects on litter size and subsequent body development of their weanling piglets.

2 Methodology

2.1 Study area

Large White gilts (n = 60) were obtained and maintained from a private swine farm at Rodenbeck Bleomfontein, South Africa, located at an altitude of 1351 m i.e.l. on latitude 29°06' South and longitude of 26°18' East. These animals were second generation gilts raised under confinement conditions and fed formulated diets composed of corn and soybean meal. They were selected at 30 kg body weight (BW), and reared in groups of 15 per confinement pen. Pre-treatment diets for the gilts consisted of corn-soybean meal admixture formulated to meet the NRC (1998) nutrient requirements with dietary supplementations of 0.1 ppm of Se as sodium selenite and 10 IU of dl- α-tocopheryl acetate/kg of diet. Diets were provided on *ad libitum* basis in feeding stalls from 30 to 130 kg BW.

2.2 Diet compositions and management protocols

At 130 kg BW, gilts were randomly allotted to each of the three dietary vitamin E treatment combinations involving 0, 40 or 70 IU/kg of dl- α-tocopheryl acetate/kg of diet, and parity I and II. These treatment diets were provided during both gestation and lactation phases following the procedures of Wuryastuti *et al.* (1993); Mahan (1994); Marin-Guzman *et al.* (2000); Umesiobi (2008). The litters from all treatment groups were fed a fortified semi-purified creep diet and water *ad libitum* from 2 days *post natum* until the end of the study. The feeders were cleaned daily. The piglets were weaned and weighed at 21 days of age. No supplemental vitamin E or Se was added to both the creep and weaning diets so as to evaluate and deplete the piglets' body reserves of vitamin E or Se. The diets were provided in sequence within each treatment group, meeting the NRC (1998) nutrient requirements for each production phase except for the nutrient being investigated.

2.3 Gilt oestrus induction and artificial insemination

Oestrus was synchronised in the experimental gilts by a single subcutaneous injection of P.G. 600® (400 IU PMSG with 200 IU HCG/5 mL dose/animal; Intervet Inc., Millsboro, DE). Gilts were checked for oestrus twice daily by providing them with fence-line contact with a teaser boar, for a minimum of 15 minutes beginning 12 hours after the injection of PG600. About 72 hours after the P.G. 600®, all gilts were given 1000

Table 1: Percentage composition of experimental diets, on dry matter basis.

Ingredient	*Gestation* [a]	*Lactation* [b]
Corn	75.30	65.90
Soybean meal (45% CP)	20.00	25.00
Lard[c]	-	4.50
Dicalcium phosphate	2.60	2.50
Limestone	0.75	0.75
Se premix[d]	0.15	0.15
Trace minerals[e]	0.50	0.50
Vitamin premix[f]	0.20	0.20
Vitamin E premix[g]	+	+
Antibiotics[h]	0.50	0.50

[a] Calculated analysis: 14% CP, 0.65% lysine, 1.00% Ca, and 0.80% P.

[b] Calculated analysis: 16.5% CP, 0.95% lysine, 1.00% Ca, and 0.80% P.

[c] Animal-vegetable fat admixture obtained from Bloemfontein Abattoir.

[d] Sodium selenite in a limestone carrier provided 0.3 ppm of dietary Se.

[e] Supplied per kilogram of diet: 8 mg Copper, 120 mg Iron, 0.2 mg Iodine, 15 mg Manganese, 120 mg Zinc, and 5.5 g Sodium chloride.

[f] Supplied per kilogram of diet: 4, 000 IU vitamin A, 220 IU vitamin D3, 3 mg vitamin K, 3.5 mg riboflavin, 14.5 mg pantothenic acid, 18 mg niacin, 20 μg vitamin B12, 330 mg of choline, and 0.2 mg biotin.

[g] Vitamin E premix contained 44, 000 IU dl- α-tocopheryl acetate/kg diet and was added at the appropriate level to supply: 30, 60 or 90 IU /kg of dl- α-tocopheryl acetate/kg of diet at the expense of corn.

[h] Supplied per kilogram of diet: 110 mg of chlortetracycline, 110 mg sulfamethazine, and 55 mg penicillin.

IU of HCG (Intervet Inc., Millsboro, DE), to induce ovulation to occur at 40 hours (Willenburg *et al.*, 2003). After the onset of oestrus, gilts of each treatment were artificially inseminated using semen from the same boars and collections. All experimental females received inseminations of 3 $\times$ 109 sperm/80 ml at 12 and 24 hours after onset of oestrus. All females were inseminated using a spirette catheter (Minitube Inc., Verona, WI).

Inseminated gilts were fed 2.0 kg of their diet once daily and individually housed in gestation pens with dwarf walls and concrete floors through the first gestation. The lactation diet was increased by approximately 0.8 kg/d from parturition to 7 d *postpartum*,

on *ad libitum* basis through to 21 days of lactation. Animals were weighed at breeding; 110 days *post coitum*, at parturition and weaning (42 day *postpartum*). Piglets from each treatment groups were weighed at birth and on day 21 *post natum*. In terms of feeding patterns, vitamin E and Se supplementation as well as other management procedures, the second parity was identical to the first parity. The sows were re-bred approximately 32 days post weaning as recommended by UMESIOBI and ILOEJE (1999). During the second parity, sow and litter parameters were evaluated in the same way as in the first parity. In order to minimise feed wastage by both sows and piglets, 2 weeks to weaning the sows were fed a restricted quantity (1 kg/d) of their treatment diet but they remained with their lactation diet and in their pen.

2.4 Serum evaluation

For the evaluation of concentrations of vitamin E and Selenium equivalents in the blood serum, all the sows were bled (8 mL/sow) by puncture of the jugular vein or the anterior Vena cava during both reproductive cycles (parity I and II). Samples were collected at 30 day *post coitum*, the 99 day of gestation and on day 21 of lactation. Four piglets per litter (two males and two females) were bled via cardiac puncture (5 mL) into heparinized vacuum tubes (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ) on days 1 4, and 8 *post natum* and at weaning (day 21) to evaluate haematological (Lymphocytes, Neutrophils and Neutrophil / Lymphocyte ratio) and α-tocopherol concentrations. Blood samples were drawn from the marked pigs in both parities, resulting into $60 \times 2 \times 2 = 240$ samples, and body weights were recorded. Approximately 120 mL of the harvested serum was used for the determination of haematological status of the piglets. Aliquots of the blood samples (lymphocytes and neutrophils) were analyzed with an automated hematology analyzer, ADVIA 120 (Bayer, Tarrytown, USA) using commercial reagent kits (ADVIA® 120 PEROX 1, 2 & 3 reagents, Bayer, USA). The remainder (n = 120 mL serum) was frozen at -25°C for subsequent laboratory analysis of α-tocopherol concentrations. The following parameters were investigated for each litter: the total number of piglets born, the number of piglets born alive, the number of stillborn (defined as the number of piglets which were alive at the initiation of farrowing, but died *intrapartum*), mortality during the lactation period, the litter size at weaning, the average body weight of piglets at birth and at weaning following the procedures of MAHAN (1991), WURYASTUTI *et al.* (1993), UMESIOBI (2004) and UMESIOBI (2008).

Feed and serum were analyzed for vitamin E spectrophotometrically applying with the procedures of MARIN-GUZMAN *et al.* (2000). Selenium level was determined by the method of MAHAN (1994) using a spectrofluorometer. Glutathione peroxidase (GSH-Px) activity was determined as described by MAHAN (1991). Diarrhoea was evaluated only when it occurred, using a 1-5 point scale.

2.5 Statistical analyses

Litter size and serum concentrations of vitamin E and Se were statistically evaluated as a 2×3 factorial treatment in a randomized complete block design with sows in treatment groups between parity as repeated measures. Individual sows or litters, respectively,

were considered the experimental unit. Main effects least squares means of vitamin E levels and parity are presented in the tables. Statistical analyses were performed using the General Linear Model (GLM) procedure (SAS, 2002). Data were reported as least-square means (± s.e.). Differences between treatment means were tested for significance using the procedures of McDonald (2008).

3 Results and Discussion

3.1 Sow and litter weight

Mean sow and litter weight after vitamin E supplementation to sow over a two-parity period are displayed in Tables 2 and 4, respectively. Gilt weights at first breeding averaged 135.3 ± 0.6 kg. The 99-day *post coitum* weights increased dramatically ($P < 0.01$) from parity 1 to 2. Body weight gains increased from parity 1 to 2, with the highest gain recorded at parity 2, following 70 IU/kg of vitamin E supplementation (188.1 ± 0.6 kg). There was a greater lactation weight increase ($P < 0.01$) of sows from parity 1 to 2 as dietary vitamin E level increased from 0 to 70 IU/kg. Sow farrowing and weaning weights increased ($P < 0.01$) from parity 1 to 2 following 70 IU/kg of vitamin E supplementation. Lactation weight increased from parity 1 to 2; the greatest sow weight gain occurred during the second lactation. A significant ($P < 0.01$) sow weight gain was noticed during the first and second lactation period, with the highest sow weight gain observed at parity 1 following 70 IU/kg of vitamin E supplementation ($P < 0.01$).

Table 2: Average weight of sows after vitamin E supplementation over a two-parity period.

Parameters over two parity periods	*Reproductive cycles*						*SEM*
	Parity I Vitamin E (IU/kg)			*Parity II Vitamin E (IU/kg)*			
	0	*40*	*70*	*0*	*40*	*70*	
Body weight at breeding (kg)	135.3^a	135.3^a	135.3^a	165.3^a	172.6^a	188.1^a	0.6
Body weight at 99 day gestation (kg)	181.5^a	200.7^b	215.1^c	182.3^a	208.0^d	211.9^c	2.4
Body weight gain (g/d during 99 days)	16.2^a	35.4^b	49.8^c	16.6^a	42.7^d	46.6^e	0.2
Farrowing weight (kg)	156.5^a	158.4^b	166.5^c	171.2^d	184.9^e	195.1^f	0.8
Weaning weight (kg)	156.9^a	160.2^b	169.5^c	175.8^d	190.1^e	204.3^f	0.3
Body weight gain (g/d, during × days)	0.4^a	1.8^b	3.0^c	4.6^d	5.2^e	9.2^f	0.2

Means with different superscripts within rows ($^{a\ b\ c\ d\ e\ f}$) differ at $P < 0.01$
SEM = Standard error of the means.

Table 3: Mean sow reproductive performance after vitamin E supplementation over a two-parity period.

Parameters over two parity periods	*Reproductive cycles*						*SEM*
	Parity I Vitamin E (IU/kg)			*Parity II Vitamin E (IU/kg)*			
	0	*40*	*70*	*0*	*40*	*70*	
Weaning-to-oestrus interval (days)	5.3^a	4.1^b	3.2^c	5.4^a	2.2^d	1.0^e	0.4
Returns to oestrus per sow (n)	0.3^a	0.1^b	0.02^c	0.3^d	0.02^c	0.01^e	0.04
Farrowing-to-farrowing interval (days)	153^a	149^b	144^c	152^d	145^e	136^f	0.01
Farrowing rate (%)	40.9^a	53.1^b	67.5	79.1	88.3^c	91.5^c	4.1
Total piglets born/litter (n)	6^a	8^a	12^{ab}	8^a	10^c	12^d	4.7
Piglets born alive/litter (n)	4^a	6^b	10^c	5^d	9^e	11^f	0.5
Stillborn piglets/litter (n)	1.7^a	0.7^a	0.5^a	1.4^a	0.5^a	0.5^a	1.02
Litter size at weaning (n)	3.2^a	5.9^b	9.6^c	3.7^a	7^e	10^f	0.7

Means with different superscripts within rows ($^{a\ b\ c\ d\ e\ f}$) differ at $P < 0.01$
SEM = Standard error of the means.

Table 4: Mean growth, diarrhoea score and haematological characteristics of piglets after vitamin E supplementation of their sows over a two-parity period.

Parameters over two parity periods	*Reproductive cycles*						*SEM*
	Parity I Vitamin E (IU/kg)			*Parity II Vitamin E (IU/kg)*			
	0	*40*	*70*	*0*	*40*	*70*	
Piglet body weight at birth/litter (kg)	1.2^a	1.6^a	2.1^b	1.3^a	2.3^b	2.5^b	0.2
Piglet body weight/litter on day 21, weaning (kg)	7.0^a	7.8^b	9.5^c	7.5^d	7.8^b	12.5^e	0.2
Weight gain (g/d until weaning)	276.2^a	295.2^b	352.4^c	295.2^b	262^d	476.2^e	6.2
Diarrhoea score/litter until weaning (1-5 scale)	5.1^a	3.4^b	2.0^c	5.5^a	2.1^c	0.7^d	0.3
Dead piglets until weaning (n)	1.5^a	1.1^b	0.8^c	1.6^a	0.5^d	0.5^d	0.07
Lymphocytes, %	33.5	30.3	27.5	33.8	29.3	26.3	6.8
Neutrophils, %	59.5	61.8	63.5	61.3	64.5	65.1	3.8

Means with different superscripts within rows ($^{a\ b\ c\ d\ e\ f}$) differ at $P < 0.01$
SEM = Standard error of the means.

As indicated in Table 4, feeding diets supplemented with vitamin E to sows significantly increased (P<0.01) the weaning body weight gain of piglets compared to the control diet, with the highest body weight (12.5 ± 0.2 kg) and average daily weight gain (476.2 ± 6.2 g) obtained in weanling pigs farrowed by sows receiving 70 IU/kg of vitamin E supplementation. Even though the litter size was higher in the supplemented groups, this did not have a negative effect on the birth weight of the piglets and on their weight at weaning. A considerable increase in birth and weaning weigh is in agreement with the findings of Le Dividich *et al.* (2005). Mahan (1991) and Pehrson *et al.* (2001) reported that increasing the vitamin E level of sow's diet over the generally considered adequate led to increased titers of serum antibodies to *Escherichia coli* bacteria. This reason could be attributed for better survival and birth and weaning weigh gain of the piglets.

3.2 Sow fecundity parameters

The main effects of dietary vitamin E level and parity on sow reproductive performance and litter sizes are presented in Table 3. In this study farrowing rate was determined by percentage of pregnant sows that farrowed litters within the experimental period. There were significant ($P < 0.01$) effects due to parity and dose of vitamin E on weaning-to-oestrus interval, number of returns to oestrus per sow and farrowing-to-farrowing interval. The shortest weaning-to-oestrus interval (1.0 ± 0.4), lowest number of returns to oestrus per sow (0.01 ± 0.04) and shortest farrowing-to-farrowing interval (136 ± 0.01) were obtained at parity 2 following 70 IU/kg of vitamin E supplementation. Additionally, the number of piglets born alive per litter was greater in the groups which received 70 IU/kg of vitamin E and this difference was significant between parities. Similar results were also reported by Flachowsky (2000), Oldfield (2003) and Umesiobi (2008). Research in sows has shown that vitamin E supplementation increases the immunogenic capacity of reproductive sows (Wuryastuti *et al.*, 1993; Moreira and Mahan, 2002) which is important for the embryonic development and survival (Tarín, 2002; Pinelli-Saavedra and Scaife, 2005).

Litter size referred to the total number of piglets born per litter per female. As shown in Table 3, parity and vitamin E supplementation elicited significant differences ($P < 0.01$) in parturition and postnatal litter parameters exemplified by farrowing rate (FR) and litter size (LS) of AI sows. There was a tendency for a higher total number of piglets born to parity 2 groups, especially in the group supplemented with 70 IU/kg of vitamin E (12 ± 4.7). Moreover, the number of piglets born alive was higher ($P < 0.01$) at parity 2 compared with parity 1 and the LS at weaning was found to be higher at parity 2 in the groups treated with 40 and 70 IU/kg of vitamin E respectively, compared with parity 1 groups. However, the supplementation of vitamin E to the sows' diet did not influence ($P > 0.01$) the number of stillborn piglets/litter, although the lowest number of stillborn piglets/litter was obtained with 40 and 70 IU/kg of vitamin E supplementation to sows' diets. The greater number of weaned piglets observed in the group supplemented with 70 IU/kg of vitamin E is probably due to the greater number of piglets born alive per litter. These results are in agreement with those of Pinelli-Saavedra and Scaife

(2005), who reported that although the body weights of piglets at birth and at 21 days of age differed amongst groups, supplementation of vitamin E to sows enhanced the average daily weight gain of piglets/litter.

3.3 Diarrhoea score and haematological characteristics of piglets

As illustrated in Table 4, the diarrhoea score of piglets until weaning was influenced by the supplementation of vitamin E to sows' diet during the two parities, with the highest (best) values obtained when vitamin E was supplemented to the sows' diets at parity 2. On the other hand, no significant treatment differences in blood parameters (concentrations of lymphocytes and neutrophils in blood) were obtained through supplementation of vitamin E to the sows' diet (Table 4). Dietary supplementation of vitamin E to sows' diet may have resulted in the significant reduction ($P < 0.01$) in the diarrhoea score during lactation/litter and in piglet mortality during lactation. These results are in line with findings of Wolf (2005) who observed that supplementation of vitamin E to the diet of sows could alleviate a diarrhoea-like condition and at the same time maintain the growth rate of their piglets. The results on lymphocyte and neutrophil concentrations in blood of piglets compare favourably to those obtained by Wuryastuti *et al.* (1993) who reported that vitamin E restriction affected both neutrophils and lymphocytes profile, and hence, if gestating sows do not obtain adequate vitamin E, they and their piglets will be more susceptible to disease processes in the *peripartum* period.

3.4 Sow and piglet serum compositions

Tables 5 and 6 highlight the mean serum α-tocopherol concentrations (μg/mL) of the sows and litters after vitamin E supplementation of sows over a two-parity period. There were significant effects ($P < 0.05$) due to supplementation of vitamin E at the two parities. Serum α-tocopherol at 30 and 99 day *post coitus* increased ($P < 0.05$) as dietary vitamin E increased during first and second parity. There was a dramatic increase in serum α-tocopherol concentration following 40 or 70 IU/kg of vitamin E supplementation during the 30 and 99 day gestation and 21 day lactation periods from parity 1 to parity 2. Serum α-tocopherol levels during gestation and lactation were substantially higher when sows were fed diets containing 70 IU/kg of vitamin E supplements. Serum Se concentrations were significantly affected ($P < 0.05$) by the dietary vitamin E level. On day 30 and 99 of gestation and day 21 of lactation, Se concentrations were about 3 fold higher in 70 IU/kg vitamin E supplemented sows in parity 2 compared to parity 1 and control groups, respectively. In all treatment groups, the highest Se concentrations were noticed on day 21 of lactation. Certainly, a positive correlation between nutritional intake of vitamin E and serum vitamin E levels has been established (Capper *et al.*, 2005), and a relationship between dietary levels of vitamin E and its concentrations in the liver has been shown (Brigelius-Flohé and Traber, 1999; Yoon and McMillan, 2006). According to Stuart and Kane (2004) a slight increase in the levels of α-tocopherol in the blood of animals that received supplemental vitamin E could be enough to show beneficial effects during critical periods of embryonic development, thus enhancing embryo survival. Results from this current study conducted over 2 parity periods indicated that dietary supplementation of vitamin E influences serum levels of α-

tocopherol and thus have a beneficial effect on some important reproductive parameters in sows and subsequent improvements in growth of their weanling pigs.

Table 5: Average serum parameters of sows with and without vitamin E supplementation over a two-parity period.

Parameters over two parity periods	*Reproductive cycles*						*SEM*
	Parity I			*Parity II*			
	Vitamin E (IU/kg)			*Vitamin E (IU/kg)*			
	0	*40*	*70*	*0*	*40*	*70*	
Serum α-tocopherol concentrations (μg/mL):							
Day 30 *post coitus*	0.11^a	0.35^b	1.51^c	0.11^a	2.73^d	4.04^e	0.2
Day 99 of gestation	0.13^a	0.25^b	1.84^c	0.12^a	3.01^d	4.17^e	0.2
Day 21 of lactation	0.33^a	0.52^b	2.55^c	0.38^a	4.55^d	5.05^e	0.3
Serum Se concentrations (ppm):							
Day 30 *post coitus*	0^a	0.44^b	0.62^c	0^d	0.47^e	0.68^f	0.02
Day 99 gestation	0.35^a	0.41^b	0.40^b	0.38^b	0.54^c	0.62^d	0.03
Day 21 of lactation	0.31^a	0.28^b	0.45^c	0.32^a	0.35^d	0.55^e	0.03

Means with different superscripts within rows ($^{a\ b\ c\ d\ e\ f}$) differ at P < 0.01
SEM = Standard error of the means.

Piglets' serum α-tocopherol concentrations on day 2 and 21 were significantly influenced (P < 0.05) by parity and level of vitamin E supplementation. Female piglets had higher serum α-tocopherol concentrations at both day 2 and day 21 compared to the male piglets. These differences were more pronounced at parity 2 with 70 IU/kg of vitamin E supplementation. On day 2 and day 21, serum Se concentrations of piglets were also affected (P < 0.05) by dietary vitamin E levels fed to the sows. Serum Se contents increased from parities 1 to 2, with highest values observed at 70 IU/kg of vitamin E supplemented in parity 2. Also, female piglets had higher serum Se concentrations on day 2 and day 21 compared to the male piglets. The significant increases noticed in the serum α-tocopherol concentrations in 2-day old and weanling pigs support the reports by Marin-Guzman *et al.* (2000) and Tao *et al.* (2004) who indicated that concentrations of plasma α-tocopherol were higher in piglets born from gilts fed vitamin E supplemented diets. This implies that piglets from nursing sows fed higher dietary vitamin E levels received more α-tocopherol during the latter part of lactation and thus were in a better vitamin E status at weaning than pigs from sows fed the lower dietary level. The activity of the selenium-dependent enzyme glutathione peroxidase in the serum of piglets was very low on day 2 *post natum* in both groups despite the fact that the sows' feed had been supplemented with 0.15 mg selenium/kg. This indicates that the selenium status of newborn piglets might be more critical for their health than their vitamin E status. However, no behavioural parameters were recorded in this study that could be effectively related to the wellbeing of the piglets of vitamin E supplemented sows in the South African environment.

Table 6: Average concentrations of α-tocopherol and Se in piglets' serum as influenced by vitamin E supplementation of their sows over a two-parity period.

Parameters over two parity periods	*Reproductive cycles*						*SEM*
	Parity I			*Parity II*			
	Vitamin E (IU/kg)			*Vitamin E (IU/kg)*			
	0	*40*	*70*	*0*	*40*	*70*	
Piglets' serum α-tocopherol concentrations (μg/mL):							
Male piglets							
Day 2 *post natum*	0.42^{a}	1.81^{b}	3.43^{c}	0.71^{d}	3.85^{e}	5.35^{f}	0.4
Day 21 (weaning age)	0.95^{a}	1.36^{b}	3.09^{c}	1.25^{b}	4.61^{d}	5.35^{e}	0.4
Female piglets							
Day 2 *post natum*	1.17^{a}	1.85^{b}	3.51^{c}	1.32^{d}	4.81^{e}	5.81^{f}	0.1
Day 21 (weaning age)	1.40^{a}	1.91^{b}	4.15^{c}	1.88^{b}	5.55^{d}	6.26^{e}	0.3
Piglets' serum Se concentrations (ppm):							
Male piglets							
Day 2 *post natum*	0.055^{a}	0.065^{b}	0.071^{c}	0.058^{d}	0.074^{c}	0.085^{e}	0.004
Day 21 (weaning age)	0.059^{a}	0.073^{b}	0.075^{b}	0.061^{c}	0.078^{b}	0.092^{d}	0.003
Female piglets							
Day 2 *post natum*	0.057^{a}	0.070^{b}	0.079^{c}	0.062^{d}	0.075^{e}	0.085^{f}	0.003
Day 21 (weaning age)	0.063^{a}	0.077^{b}	0.082^{c}	0.065^{d}	0.083^{c}	0.095^{e}	0.003

Means with different superscripts within rows ($^{a\ b\ c\ d\ e\ f}$) differ at $P < 0.01$
SEM = Standard error of the means.

4 Conclusion and Recommendation

Based on the results of the present study on improved body weight gains of vitamin E supplemented sows and their weanling piglets, improved sow fertility parameters, piglet survival and haematological status of sows and piglets, it is concluded that supplementing sows' diets with 70 IU/kg α-tocopheryl acetate appears to be most beneficial. It seems that the vitamin E requirements of reproducing sows are higher than currently recommended and that the progeny of animals fed higher dietary levels of vitamin E are in a better vitamin E status at weaning. Therefore following concrete recommendations are made:

- Gestation and lactation diets of sows should be supplemented with at least 70 IU/kg α-tocopheryl acetate so as to enhance litter size and subsequent body development of the piglets.

- There should be a routine check on the activity of the selenium-dependent enzyme glutathione peroxidase in the serum of piglets, during the first two days after birth. This seems imperative since the selenium status of newborn piglets might be more critical for their health than their vitamin E status.

References

Allan, A. and Bilkei, G.; Oregano improves reproductive performance of sows; *heriogenology*; 63(3):716–721; 2005.

Barker, D. J. P.; *Mothers, Babies and Disease in Later Life*; BMJ Publishing London; 1994.

Brigelius-Flohé, R. and Traber, M. G.; Vitamin E: function and metabolism; *The FASEB Journal*; 13:1145–1155; 1999.

Burrin, D. G.; Nutrient requirements and metabolism; in: *Biology of the Domestic Pig*, edited by Pond, W. G. and Mersmann, H. J.; 309–389; Cornell University Press, Ithaca New York; 2001.

Capper, J. L., Wilkinson, R. G., Kasapidou, E., Pattinson, S. E., MacKenzie, A. M. and Sinclair, L. A.; The effect of dietary vitamin E and fatty acid supplementation of pregnant and lactating ewes on placental and mammary transfer of vitamin E to the lamb; *British Journal of Nutrition*; 93:549–557; 2005.

Dufrasne, I., Marche, C., Clinquart, A., Hornick, J. L., van Eenaeme, C. and Istasse, L.; Effects of dietary vitamin E supplementation on performance and meat characteristics I fattening bulls from Belgian Blue Breed; *Livestock Production Science*; 65:197–201; 2000.

Flachowsky, G.; Vitamin E-transfer from feed into pig tissues; *Journal of Applied Animal Research*; 17:69–80; 2000.

Fragou, S., Balaskas, K., Fegeros, A. and Politis, I.; Effect of Vitamin E supplementation on lymphocyte distribution in gut-associated lymphoid tissues obtained from weaned piglets; *Journal of Veterinary Medicine. A, Physiology, pathology, clinical medicine*; 53(7):327–333; 2006.

Håkansson, J., Hakkarainen, J. and Lundeheim, N.; Variation in vitamin E, glutathione perroxidase and retinol concentrations in blood plasma of primiparous sows and their piglets, and in vitamin E, selenium and retinol contents in sows' milk; *Acta Agriculturae Scandinavia Section A, Animal Science*; 51:224–234; 2001.

Le Dividich, J., Rooke, J. A. and Herpin, P.; Nutritional and immunological importance of colostrum for the new-born pig; *The Journal of Agricultural Science*; 143:469–485; 2005.

Mahan, D. C.; Assessment of the influence of dietary vitamin E on sows and offspring in three parties: Reproductive performance, tissue tocopherol and effects on progeny; *Journal of Animal Science*; 69(6):2904–2917; 1991.

Mahan, D. C.; Effects of dietary vitamin E over a five parity period; *Journal of Animal Science*; 72:2870–2879; 1994.

Marin-Guzman, J. D., Mahan, C. and Whitmoyer, R.; Effect of dietary selenium and vitamin E on the ultrastructure and ATP concentration of boar spermatozoa, and the efficacy of added sodium selenite in extended semen on sperm motility; *Journal of Animal Science*; 78:1544–1550; 2000.

McDonald, J. H.; *Handbook of Biological Statistics*; Baltimore, Maryland: Sparky House Publishing; 2008.

McDowell, L. R.; Vitamin nutrition of livestock species; *Nutrition Abstract and Reviews*; 71(11):33R–41R; 2001.

McDowell, L. R.; Recent advances in mineral and vitamin nutrition of cows; *Pakistan Journal of Nutrition*; 1(1):8–19; 2002.

Moreira, I. and Mahan, D. C.; Effect of dietary levels of vitamin E (all-rac-tocopheryl acetate) with or without added fat on weanling pig performance and tissue α-tocopherol concentration; *Journal of Animal Science*; 80:663–669; 2002.

NRC; *Nutrient Requirement of Swine*; National Research Council, National Academy Press, Washington, USA; 1998.

Oldfield, J. E.; Some recollections of early swine research with selenium and vitamin E; *Journal of Animal Science*; 81:E145–E148; 2003.

Pehrson, B., Holmgren, N. and Trafikowska, U.; The influence of parenterally administered α-tocopheryl acetate to sows on the vitamin E status of the sows and suckling piglets and piglets after weaning; *Journal of Veterianry Medicine Series A*; 48(9):569–575; 2001.

Pinelli-Saavedra, A. and Scaife, J.; Pre- and postnatal transfer of vitamins E and C to piglets in sows supplemented with vitamin E and vitamin C; *Livestock Production Science*; 97(2-3):231–240; 2005.

Prasad, K. and Kalra, J.; Oxygen free radicals and hypercholesterolemic atherosclerosis; *Effects of vitamin E*; 125:958–973; 1993.

SAS; Statistical Analysis Systems; Statistical Analytical Institute Inc., Cary, North Carolina, USA; 2002.

Sivertsen, T., Vie, E., Bernhoft, A. and Baustad, B.; Vitamin E and selenium plasma concentrations in weanling pigs under field conditions in Norwegian pig herds; *Acta. Vet. Scand.*; 49(1):1; 2007.

Stuart, R. L. and Kane, E.; Vitamin E form, source may be important for swine; *Feedstuffs*; 76(34):11–14; 2004.

Tao, Y., Zhou, B., Xia, G., Wang, F., Wu, Z. and Fu, M.; Exposure to L-Ascorbic Acid or α-Tocopherol Facilitates the Development of Porcine Denuded Oocytes from Metaphase I to Metaphase II and Prevents Cumulus Cells from Fragmentation; *Reproduction in Domestic Animals*; 39(1):52–57; 2004.

Tarín, J.; Oral administration of pharmacological doses of Vitamins C and E reduces reproductive fitness and impairs the ovarian and uterine functions of female mice; *Theriogenology*; 57(5):1539–1550; 2002.

Umesiobi, D. O.; Functional integrity of boar spermatozoa and sow fertility using raphia (*Raphia hookeri*) palmwine plus 'Nche' (*Saccoglotis gabonensis*) Urban extender; *Journal of Applied Animal Research*; 26:13–16; 2004.

Umesiobi, D. O.; Effects of Sexual Restraint and Stimulation of Boars on Fertility and Fecundity Rate in Sows; *The Philippine Agricultural Scientist*; 91(1):379–385; 2008.

Umesiobi, D. O. and Iloeje, M. U.; Effect of sexual teasing and diurnal period of semen collection on reaction time and semen characteristics of Large White boars; *Journal of Sustainable Agriculture and Environment*; 1(2):231–235; 1999.

Waller, K. P., Sandgren, C. H., Emanuelson, U. and Jensen, S. K.; Supplementation of RRR–Tocopheryl Acetate to Periparturient Dairy Cows in Commercial

dairy farm; *Journal of Dairy Science*; 90:3640–3646; 2007.

Willenburg, K. L., Miller, G. M. and Rodriguez-Zas, S. L.; Effect of boar exposure at time of insemination on factors influencing fertility in gilts; *Journal of Animal Science*; 81:1–8; 2003.

Wolf, G.; The Discovery of the Antioxidant Function of Vitamin E: the contribution of Henry A. Mattill; *Antillean Journal of Nutrition*; 153(3):363 – 366; 2005.

Wuryastuti, H., Stowe, H. D., Bull, R. W. and Liller, E. R.; Effects of vitamin E and selenium on immune responses of peripheral blood, colostrum and milk leukocytes of sows; *Journal of Animal Science*; 71:2462–2472; 1993.

Yoon, I. and McMillan, E.; Comparative effects of organic and inorganic selenium on selenium transfer from sows to nursing pigs; *Journal of Animal Science*; 84(7):1729 – 1733; 2006.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 110, No. 2, 2009, pages 169–170

Buchbesprechungen

Heather Dugmore & Ben-Erik van Wyk; 2008

Muthi and Myths from the African Bush
128 pages, numerous colourful pictures, published by Marula Books, Pretoria, South Africa, 2008. ISBN 978-0-9584954-9-3; Price: R 199.00 (15,30 €)

The authors, Heather Inez Dugmore, a journalist and Ben-Eric van Wyk, a professor of Botany, endeavour to bring to light a fundamental part of indigenous African knowledge which has been passed on orally over generations, and which may be partially or totally lost in due course, if not documented. Medicinal plants, i.e. muthi, and myths which go along with them, are closely associated with healing practices applied by medicine men or women all over Africa for times immemorial. They are an important part of African culture, and, as such, enjoy growing interest in western societies, today. A total of fifty-two medicinal plants are mentioned in the book. A small portion, though, out of thousands endemic to African natural environments, but the associated cures and effects, along with the stories and beliefs behind them, allow an interesting insight into traditional African culture and indigenous knowledge.

The stories are easy to read and nicely supported by numerous colourful photographs. The book may be of interest to scholars of anthropology as well as of natural sciences medicine, and others.

Eckhard Baum, Witzenhausen

Richard Wiens; 2009

Giheke Kitabu
Aus dem Innenleben Afrikas oder Entwicklung ohne Kooperation?
334 Seiten, keine Abbildungen, Novum Verlag, Neckenmarkt, ISBN 978-3-85022-696-7, 18,40 €

Das Buch beschreibt das Entwicklungshilfeprojekt „Einführung des kleinbäuerlichen, genossenschaftlichen Teeanbaus“ im ländlichen Raum. Ein Drittel des Buches geht auf Entwicklungspolitik, Land der tausend Hügel, Lebensbedingungen und –weisen, sowie Entwicklung ein. Dem Projekt ist die Hälfte des Buches mit: Das Projekt, Projektplanung, Implementierung, Das dritte Jahr, Das vierte Jahr, Das fünfte Jahr und *Annus horibilis*, gewidmet. Rund fünfzig Seiten behandeln Hoffnung, Nekrolog und Anmer-

kungen. Entwicklungspolitik mit ihrem theoretischem Ansatz und in der praktischen Durchführung, eine kritische Auseinandersetzung damit, dies ist hier beispielhaft dargestellt. Eine Hommage an die Leistung der Frauen und der Bauern, aber kein Ruhmesblatt für die Politik, sowohl des Landes als auch der Entwicklungspolitik. Dies wird sehr detailliert, jeweils mit weiterführenden Hinweisen in den Anmerkungen, aufgeführt. Ein sehr persönlich geschriebenes Buch. Besonders lesenswert für alle, die in der Entwicklungszusammenarbeit tätig sind oder tätig sein werden.

Hans Hemann, Witzenhausen

Beate und Leopold Peitz; 2009

Hühner halten
7. überarbeitete Auflage, Eugen Ulmer KG Verlag, Stuttgart, ISBN 978-3-8001-5901-7
176 Seiten, 50 Farbfotos, 46 Zeichnungen, 19 Tabellen, 29,90 €

Hühner zu halten ist in unserem dicht besiedelten Lebensraum oft die einzige Möglichkeit, – „Ein Stück echtes Landleben, von dem so mancher Zeitgenosse träumt, in den heimischen Garten zu holen " – das ist das starke, beherzte Anliegen der Autoren. Bei den zu überzeugenden Hühnerhaltern steht neben dem Gedanken der Selbstversorgung vor allem die Freude an der Kreatur und dem hautnahen Erleben von Werden und Vergehen.

So wird denn der potenzielle Hühnerhalter mit dem notwendigen Fachwissen ausgestattet, ausgehend von der Kulturgeschichte des Haushuhnes und seinen körperlichen und sozialen Eigenheiten, dem Ausdrucksverhalten (gute Farbabbildungen!) und den Faktoren für eine artgemäße und tiergerechte Haltung - unterlegen die mit dem Text beigeordneten Zeichnungen.

Dieses Buch, dem vieljährige Erfahrung zugrunde liegt, gibt Anstöße und praktische Anregungen zur Förderung und dem Aufbau von Hühnerhaltungen auch für tropische Gebiete, wo eigene Kreation mit Berücksichtigung lokaler Kenntnisse von Nutzen ist.

Detlef W. Fölsch, Witzenhausen

Notes to authors

The Journal of Agriculture in the Tropics and Subtropics publishes papers and short communications dealing with original research in the fields of rural economy and farm management, plant production, soil science, animal nutrition and animal husbandry, veterinary hygiene and protection against epidemics, forestry and forest economy.
The sole responsibility for the contents rests with the author. The papers must not have been submitted elsewhere for publication. If accepted, they may not be published elsewhere without the permission of the editors.
Manuscripts are accepted in German, English, French, and Spanish. Papers may not be published in the order of receipt, those that require minor amendments, only are likely to appear earlier. Authors are advised to retain one copy of the manuscript themselves as the editors cannot accept any responsibility for damage or loss of manuscripts.

1. *Contents of the manuscripts*

Findings should be presented as brief as possible. Publication of a paper in consecutive parts will be considered in exceptional cases.
The following set-up is recommended:
The introduction should be as brief as possible and should concentrate on the main topics of the paper. Reference should be made to recent and important literature on the subject, only.
Materials used and methods applied should be explained briefly. Well-known or established methods and procedures should not be described. New or important methods should be explained. With all its brevity, this part should enable the reader to assess the findings adequately.
Tables and Figures should be used to effectively present the results. Explanations and other remarks on the results can be included in the text.
Discussion of results should also refer to relevant literature on the topic and lead to clear conclusions. Recommendations with respect to further research needed on the respective subject will increase the value of the paper.
The summary should concentrate on the main results and conclusions to highlight the author's contribution. It should be suitable for information storage and retrieval.

2. *Form of the manuscripts*

Manuscripts should be typed double-spaced with a wide margin.
Documents should be submitted as standard word processing formats: OpenDocument Format (OpenOffice.org .odf), LaTeX or Microsoft Word (97-2003 .doc). Alternatively, the manuscript can be submitted as a simple text/rtf file together with a printed version or PDF file of the original format.

Please do not use automated or manual hyphenation.
Title, headings and references (names of authors) should *not* be in capitals.
Tables and figures should be attached at the end of the document or separately.
The preferred position for the insertion of tables and figures should be marked on the margin of the text.

The manuscript should not be longer than 15 typed pages including tables, figures and references.
The title of the paper is followed by the name(s) and address(es) of the author(s).
The abstract should be followed by a list of keywords (up to eight).
For each paper, a summary must be submitted in the same language (not more than 20 lines) and in English, if the paper is written in an other language.

Tables should not be prepared with blanks and should fit on a DIN A5 page (max. width: 12cm (landscape: 18.5cm) with a minimum font-size of 7pt.).
All tables should have captions and should be numbered consecutively.

Figures should be black&white/greyscaled and suitable for reproduction (if possible, vector formats: svg or postscript). Photos should be high-gloss prints of good contrast, maximum size 13 by 18 cm, line drawings with Chinese ink on white or transparent paper. All figures should be numbered consecutively. A separate list of captions for illustrations has to be added.

S.I. (System International) units have to be used throughout.
References in the text should be made by the name of the author and the year.
Each paper should have an alphabetical list of references giving name and abbreviated first name of the author(s), title of the paper, name of the journal, number of the volume, year, page numbers; for books: title, place of publication, and year.
On publication, each author will receive two copy of the Journal

Manuscripts and communication should be addressed to:
Journal of Agriculture and Rural Development in the Tropics and Subtropics, formerly
Der Tropenlandwirt/Beiträge zur tropischen Landwirtschaft und Veterinärmedizin
Editorial Board
Steinstrasse 19,D-37213 Witzenhausen
E-mail: tropen@wiz.uni-kassel.de , Fax (0) 5542 981313

April 2007