Peanut Agriculture and Production Technology

Integrated Nutrient Management

Zafar Abbas | Arvind Kumar | Anoop Kumar

PEANUT AGRICULTURE AND PRODUCTION TECHNOLOGY

Integrated Nutrient Management

Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

PEANUT AGRICULTURE AND PRODUCTION TECHNOLOGY

Integrated Nutrient Management

Zafar Abbas

*PG Department of Botany, GF College (M. J. P. Rohilkhand
University), Shahjahanpur-242001, UP, India*

Arvind Kumar

*Department of Botany, Swami Brahmanand Degree College,
Agampur, Shahabad, Hardoi-241124, UP, India*

Anoop Kumar

*PG Department of Botany, GF College (M. J. P. Rohilkhand
University), Shahjahanpur-242001, UP, India*

Apple Academic Press Inc.
3333 Mistwell Crescent
Oakville, ON L6L 0A2 Canada

Apple Academic Press Inc.
9 Spinnaker Way
Waretown, NJ 08758 USA

© 2018 by Apple Academic Press, Inc.

Exclusive worldwide distribution by CRC Press, a member of Taylor & Francis Group

No claim to original U.S. Government works

Printed in the United States of America on acid-free paper

International Standard Book Number-13: 978-1-77188-613-0 (Hardcover)

International Standard Book Number-13: 978-1-315-16687-2 (eBook)

All rights reserved. No part of this work may be reprinted or reproduced or utilized in any form or by any electric, mechanical or other means, now known or hereafter invented, including photocopying and recording, or in any information storage or retrieval system, without permission in writing from the publisher or its distributor, except in the case of brief excerpts or quotations for use in reviews or critical articles.

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission and sources are indicated. Copyright for individual articles remains with the authors as indicated. A wide variety of references are listed. Reasonable efforts have been made to publish reliable data and information, but the authors, editors, and the publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors, editors, and the publisher have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged, please write and let us know so we may rectify in any future reprint.

Trademark Notice: Registered trademark of products or corporate names are used only for explanation and identification without intent to infringe.

Library and Archives Canada Cataloging in Publication

Abbas, Zafar (Senior associate professor), author
Peanut agriculture and production technology : integrated nutrient management / Zafar Abbas (PG Department of Botany, GF College (M. J. P. Rohilkhand University), Shahjahanpur-242001, UP, India), Arvind Kumar (Department of Botany, Swami Brahmanand Degree College, Agampur, Shahabad, Hardoi-241124, UP, India), Anoop Kumar (PG Department of Botany, GF College (M. J. P. Rohilkhand University), Shahjahanpur-242001, UP, India).

Includes bibliographical references and index.

Issued in print and electronic formats.

ISBN 978-1-77188-613-0 (hardcover).--ISBN 978-1-315-16687-2 (PDF)

1. Peanuts--Nutrition--India. 2. Peanuts--Physiology--India. 3. Peanuts--Harvesting--India. 4. Nitrogen fertilizers--India. 5. Peanut industry--India. I. Kumar, Arvind (Assistant professor of botany) II. Anoop, Kumar (Botany researcher) III. Title.

SB351.P3A23 2017

635'.6596

C2017-905901-7

C2017-905902-5

Library of Congress Cataloging-in-Publication Data

Names: Abbas, Zafar, author.

Title: Peanut agriculture and production technology / authors: Zafar Abbas, Arvind Kumar, Anoop Kumar.

Description: Waretown, NJ : Apple Academic Press, 2017. | Includes bibliographical references and index.

Identifiers: LCCN 2017040136 (print) | LCCN 2017044725 (ebook) | ISBN 9781315166872 (ebook) |

ISBN 9781771886130 (hardcover : alk. paper)

Subjects: LCSH: Peanuts.

Classification: LCC SB351.P3 (ebook) | LCC SB351.P3 A23 2017 (print) | DDC 633.3/68--dc23

LC record available at <https://lccn.loc.gov/2017040136>

Apple Academic Press also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic format. For information about Apple Academic Press products, visit our website at www.appleacademicpress.com and the CRC Press website at www.crcpress.com

CONTENTS

<i>About the Authors</i>	<i>vii</i>
<i>List of Abbreviations</i>	<i>ix</i>
<i>Foreword</i>	<i>xi</i>
<i>Preface</i>	<i>xiii</i>
1. Introduction	1
1.1 Agro-Techniques: Introduction	1
1.2 Focus on Crop Production.....	1
1.3 Present Scenario of the Research	6
1.4 Methodology and Plan of Work	12
1.5 Data Tabulation and Analysis.....	26
1.6 Data Interpretation and Justification in Context to Groundnut Agriculture.....	80
2. Integrated Nutrient Management	87
2.1 Introduction.....	87
2.2 Balanced/Organic Nutrition Supplements in Peanut Crop Agro-Physiology	94
2.3 Present Scenario of the Research	96
2.4 Methodology and Plan of Work	114
2.5 Data Tabulation and Analysis (Experimental Results).....	122
2.6 Conclusion: Crop Yield Potential.....	179
<i>References</i>	<i>189</i>
<i>Index</i>	<i>199</i>

Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

ABOUT THE AUTHORS

Zafar Abbas, PhD

*Senior Associate Professor and Chairman,
PG Department of Botany, GF College (M. J. P.
Rohilkhand University), Shahjahanpur, Uttar Pradesh,
India*

Zafar Abbas, PhD, is currently Senior Associate Professor and Chairman in the PG Department of Botany at GF College (M. J. P. Rohilkhand University) in Shahjahanpur, Uttar Pradesh, India. He has 40 years of research experience in plant and crop physiology, with a specialization in plant nutrition. He has attended several national and international seminars and conferences. At present, eight PhD students have completed their doctorate degrees under his supervision. Dr. Abbas is a life member and member of editorial boards of several Indian and international journals and societies, and he has authored a book and has published over 30 articles.

Arvind Kumar, PhD

*Assistant Professor of Botany, S. B. N. Degree
College, Shahabad, Hardoi, Uttar Pradesh, India*

Arvind Kumar, PhD, is Assistant Professor of Botany at the S. B. N. Degree College in Shahabad Hardoi, Uttar Pradesh, India. He is the recipient of an R. G. N. Research Fellowship from the University Grants Commission, New Delhi. He has five years of teaching experience and has attended several national and international seminars and conferences. He has published several articles in international peer-reviewed journals.

Anoop Kumar, PhD

*Botany Researcher, Botany Department, GF College,
Shahjahanpur, Uttar Pradesh, India*

Anoop Kumar, PhD, is a botany researcher in the PG Department of Botany at GF College, Shahjahanpur, UP, India. Dr. Kumar has 10 years of research experience and has attended several national and international seminars and conferences. His research has focused on sugarcane nutrition. He has published 15 research papers. He received his PhD in Botany from M. J. P. Rohilkhand University, Bareilly, Uttar Pradesh, India.

LIST OF ABBREVIATIONS

mg	microgram
%	percentage
*	significant
AICRPO	All India Coordinated Research Project on Oilseeds
ANOVA	analysis of variance
BDH	British Drug House
BHC	benzenehexachloride
CBS	cultured bacterial solution
C.D.	critical difference
cm	centimeter
CPE	cummulative pan evaporation
D	optical density
DAP	days after planting
DAS	days after sowing
DDW	double distilled water
D.F.	degree of freedom
DMA	dry matter accumulation
DOR	Directorate of Oilseeds Research
EC	electrical conductivity
F Test	F-test is a method to compare variance of two different sets of values
FLD	field legistative directorate
FYM	farm yard manure
gm	gram
ha	hectare
I	irrigation water
ICOC	Indian Central Oilseeds Committee
ICRISAT	International Crop Research Institute for Semi Arid Tropics
IU	International Units

K	potassium
l	litre
LAI	leaf area index
<i>m</i>	oil content
m	meter
m_0	weight of seed sample
mg	milligram
ml	milliliter
MSS	mean sum of the square
NARC	National Agricultural Research Centres
N.S.	non-significant
O.D.	optical density
ODC	Oilseeds Development Council
P	phosphorus
PIRCOM	Project for Intensification of Regional Research on Cotton, Oilseeds and Millets
PSB	phosphate solubilizing bacteria
PSM	phosphorus solubilizing microorganisms
RDF	recommended dose of fertilizer
S Em	standard error mean
S.S.	sum of the square
SPM	sulphinated pressmud
sq m	square meter
SSP	single super phosphate
t	ton
TDM	total dry matter
TMO	Technology Mission on Oilseeds
USDA	U.S. Department of Agriculture
V	final volume of 80% acetone
w	fresh weight of the sample

FOREWORD

The groundnut is the fourth most important source of edible oil and an equally important source of protein in the world. In the Indian context it is the most important oil seed crop, being grown over 55 lakh hectare area with a production of over 61 lakh tons. In view of the shortage of vegetable oils in the country, it is one crop that can meet our requirement of oil seeds, thereby offsetting volatility in vegetable oil prices. This crop has a great potential in a country like India where it can be grown under different agroclimates including marginal lands, which are available in abundance in the country. It is all the more important to expand its cultivation in view of its high energy conversion efficiency and high biological nitrogen fixation potential that will replenish the fast declining carbon reserves of our soils. What is more striking is its ability to not only sustain the adverse impact of climate change but also improve productivity despite high temperatures and rising CO₂ levels.

Although India is the second largest producer of groundnut in the world, its productivity is far below China and USA. Within India also, its productivity varies from state to state, being highest in Tamil Nadu and lowest in Karnataka and Uttar Pradesh. The differences are almost three times in the productivity of these states. Therefore, our immediate task should be to analyze the reasons for these wide differences in productivity and try to narrow them down by overcoming the factors involved. Even though we have come a long way in expanding the area and production of groundnut in the country by way of developing many high-yielding varieties, production, and protection technologies, much needs to be done on many fronts, which include developing short duration high-yielding varieties, identifying new plant types with higher harvest index, disease and pest forecasting, improving water saving technologies, and looking at yield gap analyses and ways and means to bridge them. Many more such need-based interventions at regional and local level are needed as well.

I am happy to note that a very sincere effort has been made by the authors (Dr. Zafar Abbas and coworkers) in generating a vast pool of data on agrotechniques, which are always the bottleneck in improving the productivity of any crop, including groundnut at local level. The information generated and presented in this book will prove useful to the growers of the region and elsewhere of similar agroclimatic zones of India and abroad. The methodology used in generating this information is robust, and the researchers will find it useful in carrying out their research work on any field crop. Therefore, the book is going to be very useful for both the line departments, postgraduate and PhD students, and the scientists. My sincere appreciation to the authors for their excellent work.

—Dr. Bir Pal Singh

*Central Potato Research Institute
(Indian Council of Agricultural Research)
Shimla-171001, Himachal Pradesh, India*

PREFACE

The present book, *Peanut Agriculture and Production Technology: Integrated Nutrient Management*, focuses on agricultural techniques and integrated nutrient management of peanuts (*Arachis hypogaea* L.). Peanuts are the second most important oil crop of India, occupying 5.7 million hectares, with an average production of 0.8 ton/ha, which is 23.5% of India's total oil seed production. Worldwide annual production of shelled peanuts was 42 million metric tons in 2014. It is the world's fourth most important source of edible oil and the third most important source of vegetable protein.

This book caters to the needs of students in advanced-level programs in agriculture, horticulture and allied sciences. It will also be valuable for agricultural scientists (plant and crop physiology), agronomists, soil scientists, farm owners, managers, researchers, etc., and for the agricultural sector as a whole.

Normal physiology is maintained under ideal environmental conditions. However, plants seldom exist under just the right conditions. Usually something is lacking, and often several factors are far from ideal. Because of the fact of competition, plants often live at the limit of their capability to survive one or more sub-normal conditions. This creates considerable hungers in the organism, which reacts by various biochemical and physiological mechanisms to surpass the sub-optimal effects by managing the development of plants in proper suitable conditions for special needs. In this context peanut growing in the rainy (kharif) season under different sources and methods of nitrogen applications as well as influence of different sowing dates and population densities to harvest its full yield potential (Part A) as well as on balanced nutrition integrated with organic manures in groundnut *Arachis hypogaea* L. (Part B) to enhance yielding ability, have been considered in the present book.

I am extremely thankful to, firstly, my parents, my wife S. Sultana Rizvi, my children Shuja, Farah, Unsa, and Faraz, and my sweet

granddaughter Sahrish, for their co-operative and moral supports. In addition, Apple Academic Press must be praised for their active work and support for our effort.

We are sure that readers of this book—scientists, researchers, professors etc.—will find it interesting and useful.

Above all, I am thankful to the Almighty.

—*Dr. Zafar Abbas*

CHAPTER 1

INTRODUCTION

CONTENTS

1.1	Agro-techniques: Introduction	1
1.2	Focus on Crop Production	1
1.3	Present Scenario of the Research	6
1.4	Methodology and Plan of Work	12
1.5	Data Tabulation and Analysis	26
1.6	Data Interpretation and Justification in Context to Groundnut Agriculture	80
	Keywords	85

1.1 AGRO-TECHNIQUES: INTRODUCTION

Groundnut (*Arachis hypogaea* L.), belonging to family Fabaceae, is an important annual legume in the world for oilseed, food, and animal feed. Being a soil nitrogen-fixing crop, it is safe, cheap, and eco-friendly for the soil environment. It is a good source of vegetable oil and protein for humans. It is an exhaustive crop and therefore, its proper crop husbandry has become a must. In this chapter, we will consider the significance and importance of the crop with different sources and methods of nitrogenous fertilizers as well as sowing dates and population densities (seed rates), based on intensive field experimentations under local conditions.

1.2 FOCUS ON CROP PRODUCTION

In India (during 2013–2014), groundnut (*Arachis hypogaea* L.) is cultivated in an area of 5.53 m ha with a production of 9.67 million tons and a

productivity of 1,750 kg/ha. The seeds contain 45–50% edible oil, which is used in the preparation of vanaspati, soaps, cosmetics, and cold creams in addition to common cooking oil. According to Das (1997), groundnut oil is good from both the nutritive and culinary perspective, as it contains high oleic acid (40–50%) and linoleic acid (25–35%). The remaining 50% of the kernel has high quality protein (on an average 25.3%), which is about 1.3 times higher than meat, 2.5 times higher than eggs; carbohydrates (6–24.9%); and minerals and vitamins. The productivity is low as compared to the United States and China due to imbalanced fertilization, uncertainty of monsoons, and poor cultural practices adopted by farmers (Kumar, 2012). Being a leguminous crop efficacy of different sources and methods of nitrogen fertilizers as well as sowing dates and population densities were considered to harvest its optimum yielding ability, as these affect different growth and physiological parameters (Kumar, 2012).

Groundnut is an oilseed crop with 40–50% oil content and grown in nearly 100 countries. The remaining seed protein can be used as a meal for food or feed (25–30% protein) (Ahmed et al., 2007). Groundnut is the thirteenth most important food crop of the world (Hatam and Abbasi, 1994). It is the world’s fourth most important source of edible oil and third most important source of vegetable protein. Groundnut seeds contain high quality edible oil, easily digestible protein, and carbohydrates.

Groundnuts are rich in essential nutrients. Ozcan (2010) explained that among the common cooking and salad oil, the groundnut oil contains 46% of monosaturated fats (primarily oleic acid), 33% of polyunsaturated fats (primarily linoleic acid), and 17% of saturated fats (primarily palmitic acid).

The remaining 50% of the kernel has high quality protein (on an average 25.3%), which is about 1.3 times higher than meat and 2.5 times higher than eggs; carbohydrates (6–24.9%); and minerals and vitamins. The *United States Department of Agriculture* (2014) provides the following data:

Nutritional value of groundnut per 100 g (3.5 oz)

Energy	2,385 kJ (570 kcal)
Carbohydrates	21 g
Sugars	0.0 g
Dietary fiber	9 g

Fat	48 g
Saturated	7 g
Monosaturated	24 g
Polyunsaturated	16 g
Protein	25 g
Tryptophan	0.2445 g
Threonine	0.859 g
Isoleucine	0.882 g
Leucine	1.627 g
Lysine	0.901 g
Methionine	0.308 g
Cystine	0.322 g
Phenylalanine	1.300 g
Tyrosine	1.020 g
Valine	1.052 g
Arginine	3.001 g
Histidine	0.634 g
Alanine	0.997 g
Aspartic acid	3.060 g
Glutamic acid	5.243 g
Glycine	1.512 g
Proline	1.107 g
Serine	1.236 g
Vitamins	
Thiamine (B1)	0.6 mg
Riboflavin (B2)	0.3 mg
Niacin (B3)	12.9 mg
Pantothenic acid	1.8 mg
Vitamin B6	0.3 mg
Folate (B9)	246 ug

Vitamin C	0.0 mg
Vitamin E	6.6 mg
Minerals	
Calcium	62 mg
Iron	2 mg
Magnesium	184 mg
Manganese	2.0 mg
Phosphorus	336 mg
Potassium	332 mg
Zinc	3.3 mg
Other constituents	
Water	4.26 g

The United States Department of Agriculture (2014),
<http://ndb.nal.usda.gov/ndb/foods/show/4831>.

Units: ug = microgram, mg = milligram, IU = International Units.

It is grown on 26.4 million ha worldwide with a total production of 36.1 million metric tons, and an average productivity of 1.4 metric tons per hectare (FAO, 2004). China leads in production, followed by India as shown in the following table (Anonymous, 2015).

Rank	Countries	Production
1	China	17.0
2	India	9.5
3	Nigeria	3.0
4	United States	1.9
5	Myanmar	1.4
Total	World	46

In India, groundnut is grown on 5.7 million ha with a production of 4.7 million tons and an average productivity of 0.8 tons/ha during the rainy season. Anantpur district of Andhra Pradesh is the largest producer of groundnut with 0.74 million ha of area under cultivation (ICRISAT, 2008). Groundnut haulms (vegetative plant parts) provide excellent hay for feeding livestock, being rich in protein and have better palatability and digestibility than other fodder (Singh et al., 2010). Apart from health care, source of fodder, and improved soil fertility, production of groundnut provides a means of livelihood to scores of people. It is also eco-friendly. Moreover, these crops can be intercropped compatibly with sugarcane (a long-term exhaustive crop), as they increase microbial biomass, control weeds and increase nitrogen (N) availability (Suman et al., 2006). This intercropping will also increase the margin of profit and the economic security of small and marginal farmers in sugarcane-dominant districts and state (Singh et al., 2006).

Modern agriculture is based, to a large extent, on the efficient use of inputs and maximization of yields through proper manipulation of some of the physical factors (agro-techniques) within a given environment. The productivity of groundnut in India is low as compared to the United States and China due to imbalanced fertilization, uncertainty of monsoons, and poor cultural practices adopted by farmers (Kumar, 2012). Keeping in view the importance of this kharif (summer) crop, the author decided to test this crop from the point of view of (i) impact of sources and methods of nitrogen application, and (ii) improvement of agro-techniques (seed rate and dates of sowing) to lend ample scope for intercropping, to promote the needs of farmers, and to maintain long-term soil health—a study not formerly done under local conditions. Two field experiments were conducted on groundnut, between 2008 and 2011, with the following aims and objectives:

1. To study the effect of different sources and methods of nitrogen application on growth, leaf nutrient (NPK) content, pod yield, and oil of groundnut (*Arachis hypogaea* L.).
2. To study the effect of different seed rate/population density, dates of sowing and their interaction on growth, leaf nutrient (NPK) content, pod yield, and oil of groundnut (*Arachis hypogaea* L.).

Both experiments were properly replicated, and the data analyzed statistically. The conclusions drawn have been discussed in light of the findings of other researchers in this book.

1.3 PRESENT SCENARIO OF THE RESEARCH

1.3.1 REVIEW OF LITERATURE

1.3.1.1 Nitrogen Use in *Arachis hypogaea* L.

Nitrogen recoveries from applied fertilizers can be increased by modifying crop geometry and sources and timings of nitrogen application in most of the crops. The importance of nitrogen as an essential plant nutrient need not be overemphasized. It is an integral part of a large variety of biological molecules, most of which are essential for one physiological process or the other. Thus, amino acids, structural proteins, enzymes, coenzymes, purines, pyrimidines, nucleosides, nucleotides, phosphoproteins, lipoproteins, nucleic acids, and protoplasm itself all have nitrogen as an integral element in them (Salisbury and Ross, 2000; Devlin and Witham, 2005; Verma, 2007). In fact, it is difficult to name a basic property of cells in plants that does not at some point make contact with their nitrogen metabolism (Steward and Durzan, 1965).

Groundnut (*Arachis hypogaea* L.) is the major kharif oilseed crop of India. It is an exhaustive crop and removes a large amount of nutrients from the soil. Higher seed yield is mainly attributed to greater biomass, pod weight, 100-seed weight, shelling percent, and harvest index in different genotypes (Singh et al., 2010), for which nitrogen is of prime importance (Kumar et al., 1994; Varalakshmi et al., 2005).

Singh and Ahuja (1985) made a field experiment with groundnut var. T 64 at RBS College research farm, Bichpuri, Agra in the kharif of 1978 and 1979. They reported that nitrogen increased dry matter production at all the growth stages. Application of 25 kg N/ha produced significantly higher dry matter and increased the nutrient uptake as compared to inoculum alone. The nitrogen also increased the yield of nuts and kernels significantly in both years. Inoculation alone gave the lowest yield. Thus, application of 25 kg N/ha proved superior to inoculation alone.

Selamat and Gardner (1985) reported that groundnut (*Arachis hypogaea* L.) normally uses symbiotically fixed N_2 for growth and development, but limitations inherent in the symbionts or environment may result in N deficiencies. Limitations can be corrected by N fertilization, which is a common practice in commercial groundnut production. Ball et al. (1983) found that N application increased total plant and pod yields of “argentine” and “florigiant” peanut cultivars in both 1978 and 1979, but reduced the harvest index, i.e., the vegetative component was increased more in proportion to the fruit. Wynne et al. (1979) showed an increase in both biomass yield (47%) and pod yield (32%) of peanut cultivars on a sandy soil fertilized with N at monthly intervals. On a sandy loam soil, N fertilization reduced seed yield; 100-seed weight of inoculated plants improved with increased seed yield compared with increased seed yield in inoculated plants (Reddy et al., 1981). Groundnut growers commonly believe that high yields require N fertilization at seeding despite effectiveness of biological N_2 fixation in peanut. Nitrogen fertilization may improve seedling vigor, competition against weeds, and correct possible deficiencies in growth.

Selamat and Gardner (1985) further reported the effects of N fertilization on growth, N uptake, and N partitioning in nodulating and non-nodulating groundnut genotypes during 1982 in the field and a greenhouse at the University of Florida, Gainesville. Three lines, florunner (FL), early bunch (EB), and a non-nodulating line ($M4^{-2}$) were grown in the field on a Lakeland sandy soil (hyperthermic coated thermic Quartzipsamment) at four N rates (0, 6, 12, and 24 gm^{-2} N) and in pots in the greenhouse at N rates at a factor of 0.05, 0.50, 0.95, and 1.40 N-strength of Hoagland no. 2 solution, modified to adjust the other nutrients at 0.50 strength. In the field experiment, only the biomass crop growth rate (CGR) and leaf area index (LAI) of all genotypes were significantly increased by N rates. An LAI of 3.0 was achieved at 60 days after planting (DAP) when 6 $g\ m^{-2}$ N or more was applied on the nodulating genotypes. For the non-nodulating genotype ($M4^{-2}$), 120 days at 6 $g\ m^{-2}$ N or 85 days at 24 $g\ m^{-2}$ N were required to achieve LAI of 3.0. The vegetative and reproductive responses of $M4^{-2}$ to N increments were highly positive and essentially linear. Pod and seed yields of nodulated genotypes in field-grown plants were not significantly influenced by N fertilization. Pod yield was increased in pot-grown plants in the greenhouse, but nodule number and weight were

reduced. A genotype $\times$ N rates interaction for plant component yield, leaf N concentration, and N content was observed due primarily to the differential response to N between the nodulating and non-nodulating lines. Photoassimilate partition to pods was generally reduced by N fertilization, probably due to vegetative growth stimulation. FL cultivar biologically fixed more N₂ than EB; the amount in FL exceeding the seed requirement (12.2 m⁻²) if fertilizer N rate was low. These studies suggest that the practice of N fertilization of nodulated groundnut does not increase pod or seed yield and is economically counter-productive.

Hadwani and Gundalia (2005) indicated that the pod and haulm yield of groundnut significantly increased with increasing levels of NP K (nitrogen, phosphorus, and potassium). The application of NP increased the pod and haulm yield by 5.7, 14.0, and 26.4 and 34.9% with the application of R₁₀₀ and R₁₅₀, respectively over control (R₀). Oil and protein yields of groundnut also increased significantly over control. Increase in the yields with increasing level of N and P could be ascribed to the overall improvement in plant growth and vigor as this plays an important role in plant metabolism, resulting in better yield attributes and yields. The results are in accordance with Patel et al. (1994).

The effect of N, P, and K significantly increased total uptake of NPK by groundnut. The highest total uptake of N (155.9), P (14.54), and K (29.4) kg ha⁻¹ was noted under the treatment combination R₁₅₀ $\times$ K₁₀₀. There was a synergistic effect of N and P $\times$ K interaction on the total uptake of NPK, which was obvious and directly related to the increasing yield as well as their concentration in the plants. Patra et al. (1995) reported that total uptake of NPK increased due to the combined application of various levels of NPK. The application of NP significantly increased the protein content, 100-seed weight, and shelling percentage over control (R₀).

1.3.1.2 Seed Rate/Population Density in *Arachis hypogaea* L.

Change in inter- and intra-row spacings affect the crop growth and yield variations due to acute competition between the crop plants. Fewer plants approach more closely their potential yield. Humans while trying to grow successful, healthy field crops, create such an intense competition that the

individual plants are in qualitative terms markedly subnormal (Hasan and Abbas, 2007b).

Singh and Ahuja (1985) studied (*Arachis hypogaea* L.) cv. T 64 at RBS College research farm, Bichpuri, Agra in kharif 1978, 1979 for dry matter accumulation, oil content, and nutrient uptake as affected by fertilizers and plant density. Among three plant densities (111 thousand plants/ha, 148,000 plants/ha), significantly higher yields of nuts and kernels were recorded at a medium density of 148,000 plants/ha. The dry matter production/plant increased with each reduction in plant density at all the stages.

A lowest density of 111 thousand plants/ha recorded significantly higher dry matter/plant than medium and high plant densities.

At high plant density, plants competed from early stage on; thus, growth rate was reduced which became progressively more marked as competition intensified.

Azu and Tanner (1978) also reported corroborative results. At the 40 days stage, plant density also influenced the nodule weight significantly. Low density produced significantly higher dry weight of nodules as compared to medium and high densities. Increasing inter-plant competition by increasing plant density adversely affected the nodule size and nodule weight. This inverse relationship of plant density to nodule weight was also observed by Bhan and Misra (1970). The highest yield were recorded with low density (111 thousands plant/ha) but the highest with medium plants density (148 thousand plant/ha). In both cases, further increase in density caused significant reduction in yield.

Regarding nutrient uptake, Singh and Ahuja (1985) noted that among the plant densities, medium density of 148 thousand plants/ha recorded significantly higher total uptake than high and low densities. A significant increase in total uptake of nutrients was recorded with each increase. The protein and oil percentages of seed significantly decreased by every increase of plant densities in both the years in *Arachis hypogaea* L. (groundnut).

1.3.1.3 Date of Sowing in *Arachis hypogaea* L.

Amongst oilseed crops, groundnut occupies a predominant position in terms of acreage and total production. Under assured irrigation conditions,

advance planting (prior to onset of monsoon) enhances productivity of this crop owing to least exposure to adverse situations (Gill and Kumar, 1995; Kumar et al., 2003). However, there is need to assess feasibility of different planting dates and its impact on productivity under prevailing agro-climatic conditions. Change in date of sowing induces the crop growth period to face different temperatures at different stages automatically and naturally. Temperature plays an important role in all aspects of plant growth and development (Went, 1953; Hasan and Abbas, 2007b).

Ketring (1984) reported that optimum temperature for growth of most groundnut (*Arachis hypogaea* L.) genotypes is near 30°C. During the 1980 growing season in the United States, temperatures ranged from 35 to 40°C for many days in the groundnut producing regions, and drought occurred. Experiments were initiated to determine the effect of temperature separate from drought on groundnut development. Plants were grown in controlled environments at 30/25°C, 12/12 h light/dark temperature to obtain a population of plants with uniform development. Measurements of individual leaf areas, leaf dry weights, and seedling height were made 21 days after planting to establish plant growth state. Then temperature treatments, based on temperatures expected to occur during the summer groundnut growing season in the south west United States, were begun. Temperature during the dark period was held constant at 22°C for all treatments. Temperatures during the light period were 30, 32, and 35°C. The 35°C treatment decreased individual leaf areas and dry weight at both 63 and 91 days after planting. Plants harvested at 91 days after planting showed reduced total leaf area; stem elongation was decreased in two experiments at 35°C. The highest temperature treatment significantly reduced the number of subterranean pegs. Mature seed weight was reduced and significantly so in two of three experiments, once for each cultivar tested. Thus, a temperature of 35°C was shown to have an inhibitory effect on groundnut development even when plants were grown in well-watered conditions. An evaluation of eight peanut genotypes showed genotypic variation in response to the 35°C temperature treatment. Thus, selection of peanuts with improved heat tolerance may be possible.

Talwar et al. (1999) found among abiotic factors, high temperature is one of the major constraints to adaptation of groundnut (*Arachis hypogaea* L.) in tropical and subtropical areas. The aims of their study were (i) to

evaluate three genotypes (ICG 1236, ICGS 44, and Chico) of groundnut for their heat acclimation potential (HAP), and (ii) examine whether the growth, yield, and photosynthetic responses of these genotypes to temperature related to HAP. HAP was defined as the change in leaf tolerance based on plasmalemma thermostability at 40 to 60°C measured by electrolyte leakage after acclimation at 35/30°C day/night temperature. Initially, plants were raised in a glasshouse maintained at 25/25°C day/night temperature. One half of the plants were shifted to another glasshouse maintained at 35/30°C after the appearance of the third leaf. Heat killing time (HKT), defined as the time required to cause 50% relative injury, indicated that the three genotypes acclimated to high temperature stress, with significant variations in HAP. All genotypes maintained greater vegetative growth and higher photosynthetic rates when grown under the higher temperature regime and genetic differences in photosynthetic rate were related to HKT. However, the higher temperature regime affected the reproductive growth adversely by increasing flower abortion and decreasing seed size. Differences in chlorophyll fluorescence and membrane thermo-stability between growth temperatures were found only after incubating the leaf tissue at temperatures of 50°C or higher. Genetic differences in HAP were small and unrelated to growth differences.

Kumar et al. (2003) conducted a field experiment during the kharif seasons of 1997 and 1998 at the Agricultural Research Station, Durgapura, Jaipur, to assess impact of advance sowing on groundnut (*Arachis hypogaea* L.) productivity. Amongst yield components, sowing dates failed to bring about perceptible variation in pods setting index, kernel pod, shelling percent, and seed index, but number of pods and their weight/plant were significantly improved under advance planting on June 1 over the rest. The crop sown on June 1 recorded significantly higher productivity in terms of pod, kernel, and haulm yield (30.81, 20.38, and 48.78 q/ha), representing an increase of 21.58, 25.88, and 21.50% and 40.23, 49.85, and 48.20% over June 16 and July 1 sowing, respectively.

Carley et al. (2008) found that determining when to dig groundnut (*Arachis hypogaea* L.) is complicated because of its indeterminate growth habit. Pod mesocarp color is often used as an indicator of pod maturation. However, this process is time consuming and is usually based on a relatively small subsample of pods from groundnut fields. Research was conducted

in 2003–2005 to determine if reflectance of the groundnut canopy, using multispectral imaging (350–2500 nm), could be used as an indicator of pod maturation. The cultivars VA 98R and NC-V II were planted beginning in early May through early June in each year with reflectance and the percentage of pods at optimum maturity (percentage of pods with brown or black mesocarp color) determined in mid-September. The highest yield observed for VA 98R across the three years of the experiment was noted when peanut was planted in mid-May rather than early or late May or when planted in early June when groundnut was dug based on optimum pod maturity using pod mesocarp color. Pod yield for the cultivar NC-V II did not differ when comparing planting dates. For cultivar VA 98R, Pearson's correlations were significant in all bandwidth categories except the normalized difference vegetation index (NDVI) when reflectance was compared with percentage of mature pods. Reflectance for NC-V II was not significant for any of the correlations though significant differences in the percentage of mature pods were noted in mid-September when comparing planting dates. These data suggest that canopy reflectance could potentially aid in predicting pod maturation, but more research is needed to determine feasibility of this approach.

1.3.2 CONCLUDING REMARKS AFTER LITERARY REVIEW

It may be concluded that, in view of groundnut (*Arachis hypogaea* L.) being an important cash crop and new genotypes being available with improved agro-techniques, the literature is not only meager but also patchy. Moreover, as this kharif crop may act as an income-generating crop for household nutrition and economic security, various aspects of its cultivation merits intensive study.

1.4 METHODOLOGY AND PLAN OF WORK

1.4.1 MATERIAL AND METHODS

1.4.1.1 General

The experiments included in the present study were conducted in the field during the kharif (summer) season of the years 2008–2010 at the Botanical

Garden and Agricultural Farm, G.F. College, Shahjahanpur, Uttar Pradesh. TG 37-A variety of groundnut (*Arachis hypogaea* L.) was selected for the purpose. The study is comprised of two field experiments, and the detail of the experiments with performed and prevailing conditions are given in the following sections.

1.4.1.2 Agro-Climatic Conditions, Soil Characteristics, and Locality

Shahjahanpur is located at latitude 27°53' N, longitude 79°4' E, and at altitude 154.53 meters above sea level (Figure 1.1). It has the semi-arid and sub-tropical climate of the Tarai region with hot dry summers and cold winters. The average precipitation in the years 2008, 2009, and 2010 was 412.18 mm, 560 mm, and 748.7 mm, respectively. Most of this annual precipitation was received during the two months of June and July. The temperature touched 38.5, 39.1, and 40.2°C during the crop growth period; although, it occasionally fell to as low as 8.2, 6.7, and 9.3°C, respectively, in the three years. The meteorological data for the period of the investigation, recorded by the Meteorological Observatory, U.P. Council of Sugarcane Research, Shahjahanpur, U.P. have been presented (Figures 1.2–1.7).

After preparation of the field, soil samples were collected randomly at a depth of 15 cm from each of the experimental field in the three years and analyzed for physico-chemical properties. The data are given in Table 1.1.

1.4.2 PREPARATION OF THE FIELD

Before beginning each field experiment, the field was thoroughly ploughed to ensure maximum aeration. Plots of 5.0 sq.m. size were prepared in which uniform recommended basal dose of farmyard manure 20 q/ha was applied in each experiment area to ensure better soil environment. Standard agricultural practices recommended for the groundnut crop by state agricultural universities/research institutes were followed.

FIGURE 1.1 Showing location and details of Shahjahanpur district (west U.P.).

FIGURE 1.2 Showing temperature, relative humidity and rainfall (monthly basis) from January to June 2008.

FIGURE 1.3 Showing temperature, relative humidity and rainfall (monthly basis) from July to December 2008.

1.4.3 PROCUREMENT OF SEEDS

Authentic seeds of groundnut (*Arachis hypogaea* L.) variety TG 37-A were obtained from C.S.A. University of Agriculture and Technology, Kanpur (U.P.).

FIGURE 1.4 Showing temperature, relative humidity and rainfall (monthly basis) from January to June 2009.

FIGURE 1.5 Showing temperature, relative humidity and rainfall (monthly basis) from July to December 2009.

1.4.4 EXPERIMENT 1

This first field experiment was conducted on groundnut (*Arachis hypogaea* L.) var. TG 37-A during the kharif (summer) season of 2009 in a factorial randomized block design. The seeds were sown with 30 × 10 cm row to plant distances and treated with 3 g thiram per kg before sowing to make them disease free. The physico-chemical soil analysis of the

FIGURE 1.6 Showing temperature, relative humidity and rainfall (monthly basis) from January to June 2010.

FIGURE 1.7 Showing temperature, relative humidity and rainfall (monthly basis) from July to December 2010.

experiment field is given in the [Table 1.1](#). The seeds were sown on June 3, 2009. This experiment on groundnut was conducted to study the effect of nitrogen sources (S1 = urea, S2 = ammonium sulfate, S3 = calcium ammonium nitrate, and S4 = diammonium phosphate) @ 50 kg N/ha applied with different methods of applications (T1 = full soil, T2 = full foliar, T3

TABLE 1.1 Physico-Chemical Analysis of Soil of the Experimental Fields 2008 and 2010

Characteristics	Experiment 1 (2009)	Experiment 2 (2010)
Texture	Sandy loam	Sandy loam
Particle size distribution:		
Sand	70.0	65.0
Silt	15.0	20.0
Clay	15.0	15.0
pH	7.10	7.50
E.C. dS/m	0.30	0.40
Organic Carbon (%)	0.25	0.20
Available N (kg/ha)	196.0	270.0
Available P (kg/ha)	14.10	12.70
Available K (kg/ha)	110.00	115.00
Calcium Carbonate	Nil	Nil

= 2/3 soil + 1/3 foliar, T4 = 1/3 soil + 2/3 foliar, T5 = 1/4 soil + 3/4 foliar, and T6 = 3/4 soil + 1/4 foliar) on growth characters; leaf chlorophylls and carotenoid content; leaf nutrient (NPK) content sampled at pre-flowering (50 days), flowering (70 days), and post-flowering (90 days) stages, as well as at harvest; yield characteristics; and pod and oil yield (%) of each treatment replicated thrice. An aqueous 1% nitrogen solution was sprayed foliarly 40 days after sowing, where required. A uniform dose of 40 kg, each of P and K was applied during field preparation through calcium super phosphate and muriate of potash along with farmyard manure. The crop was irrigated when required. The harvesting was done on October 20, 2009. The summary of treatments is given in [Table 1.2](#).

1.4.5 EXPERIMENT 2

This second field experiment was conducted on *Arachis hypogaea* L. (groundnut) variety TG 37-A to determine the effect of agro-techniques, different seed rates (row to plant distances) and dates of sowing (at one month intervals) and their interaction in a factorial randomized design in the kharif (summer) season of 2010. Each treatment was replicated thrice.

References

- Abbas, Z. , & Kumar, S. (1987). Response of sonalika wheat and triticale varieties to timings of nitrogen application coinciding with irrigation schedule. *Geobios*, 14, 27–30.
- Abbas, Z. , Samiullah , Afridi, M. M. R. K. , & Inam, A. (1980). Effect of different levels of nitrogen on the fodder yield of five varieties of rainfed sorghum. *Comp. Physiol. Ecol.*, 5, 143–145.
- Adhikari, J. , Samanta, D. , & Samui, R. C. (2003). Effect of gypsum on growth and yield of confectionary groundnut (*Arachis hypogaea*) varieties in summer season. *Indian Journal of Agricultural Sciences*, 73, 108–109.
- Agasimani, C. A. , & Hosmani, M. M. (1989). Response of groundnut to FYM, nitrogen and phosphorus in rice fellow in coastal sandy soil. *Journal of Oilseeds Research*, 6(1), 360–363.
- Ahmad, N. , Mohammad, R. , & Khan, U. (2007). Evaluation of different varieties seed rates and row spacings of groundnut planted under agro-ecological conditions of Malakand Division. *J. Agron*, 6, 385–390.
- Alam, A. T. M. M. (2002). Yield and quality of groundnut as affected by hill density and number of plants per hill. *Pakistan Journal of Agronomy*, 1, 74–76.
- Anandswarup, A. , Reddy, D. , & Prasad, R. N. (1998). Long-term soil fertility management through integrated plant nutrient supply. *Bulletin, All-India Coordinated Research Project on Long-term fertilizer experiment*, Indian Institute of Soil Science, Bhopal.
- Anonymous "Palm kernel meal as feed for poultry, 1. Composition of palm. *Journal of Animal feed science*, 2015c. Retrieved 25 May 2015 .
- Anonymous . "How peanut are grown – Harvesting – PCA". Peanut Company of Australia. 2008.
- Anonymous . "Meds & Food for Kids: Medika Mamba". Mfkhaiti. Org. 2015b.
- Anonymous . "Nutrition facts for oil, peanut, salad or cooking, USDA Nutrient Data". Conde Nast, USDA National Nutrient Database, version SR-21. 2014.
- Anonymous . "Production and trade data for groundnuts (peanuts)". FAOSTAT, Food and Agricultural Organization of the United Nations, Statistics Division. 2015a.
- Anonymous . 7CFR 2011: Part 996a. 2011.
- Arnon, D. I. (1949). Copper enzymes in isolated chloroplasts, polyphenol oxidase in *Beta vulgaris* . *Plant Physiol*, 24, 1–15.
- Azu, J. N. , & Tanner, J. W. (1978). Effect of plant density on growth yield and grade of Spanish peanuts. *Proc. Amer. Peanut Res. Edu. Asso., Inc.*, 10(1), 72.
- Babiker, E. A. (2004). Effect of sowing date and intra-row spacing on growth and yield on groundnut. *Gezira Journal of Agricultural Science (Sudan)* 2, 26–36.
- Ball, S.T. , Wynne, J. L. , Elkan, G. H. , & Schneeweis, T. J. (1983). Effect of inoculation and applied nitrogen on yield, growth and nitrogen fixation of two peanut cultivars. *Field Crops Res. Int.*, J. 6, 85–91.
- Bandyopadhyay, A. , Ghosh, P. K. , & Mathur, R. K. (2000). Groundnut situation in India. The present scenario and future strategies. *Indian farming*, 50, 13–20.
- Bao, Y. , Jiali, J. H. , Frank, B. , Edward, G. L. , Stampfer, M. J. , Willett, W. C. , et al. (2013). "Association of Nut Consumption with total and cause-specific mortality," *England Journal of Medicine*, 369, 2001–2011.
- Belletini, N. M. T. , & Endo, R. M. (2001). Compartimento doamendvin (*Arachis hypogaea* L.) sob diferentes (e) densidades (di) sameadura. *Acta scientiatium Universidade-Estadual de-marniga*, 23(5), 1249–1256.
- Bhan, S. , & Misra, D. K. (1970). Water utilization by groundnut (*Arachis hypogaea* L.) as influenced due to plant population and soil fertility levels under arid zone conditions. *Indian J. Agron*, 15, 258–263.
- Bhattacharya, P. , & Chakraborty, G. (2005). Current status of orgnic farming in India and other countries. *Journal of Fertilizers*, 1(9), 111–123.
- Bhattacharya, P. , & Gehlot, D. (2003). Current status of organic farming at international and national level. *Agrobios farming at international and national level. Agrobios Newsletter*, 4, 7–9.
- Bhattacharya, P. , & Ghosh, P. (2001). Phosphorus use efficiency in brinjal with FYM and sulphur. *Journal of Indian Society of Soil Science*, 49 (3), 456–462.

Bheemaih, G. , Subrahmanyam, M. V. R. , Ismail, S. , Sridevi, S. , & Radhika, K. (1999). Effect of integrated application of green leaf manures and fertilizers on growth and yield of summer groundnut under different cropping systems. *Indian J. Agric. Sci.*, 69 (10), 735–737.

Björkman, O. , Badger, M. R. , & Armond, P. A. (1980). Response and adaptation to temperature. p. 239–249. In: N.C. Turner , and P.J. Kramer (Ed.). *Adaptation of plants to water and high temperature stress*. John Wiley & Sons, New York.

Boote, K. J. (1982). Growth stages of groundnut. *Peanut Science*, 9, 35–39.

Carley, D. S. , Jordan, D. L. , Dharmasri, L. C. , Sutton, T. B. , Brandenburg, R. L. , & Burton, M.G. (2008). Peanut response to planting date and potential of canopy reflectance as an indicator of pod maturation. *Agron. J.*, 100, 376–380.

Chavan, A. P. , Jain, N. K. , & Mahadkar, V. V. (2014). Direct and residual effects of fertilizers and biofertilizers on yield, nutrient uptake and economies of groundnut (*Arachis hypogaea* L.) – rice (*oryzasiliva*) cropping system. *Indian J. Agron*, 59(1), 53–58.

Chawale, V. V. , Bharad, G. M. , Kohle, S. K. , & Nagdeva, M. B. (1995). Effect of N and FYM on yield, quality and nitrogen uptake of summer groundnut under microsprinkler irrigation. *Research Journal, Punjabrao Krishividyaapeeth*, 19(2), 171–172.

Das, P. C. (1997). *Oilseeds Crops of India*, Kalyani Publishers, Ludhiana, Punjab, India. pp. 80–83.

Devakumar, M. , & Giri, G. (1998). Influence of weed control and doses and time of gypsum application of yield attributes, pod and oil yields of groundnut (*Arachis hypogaea* L.). *Indian Journal of Agronomy* 43(3), 453–458.

Devlin, R. M. , & Witham, F. H. (2005). “Plant Physiology”, 5th edition, CBS Publishers & Distributors, Delhi (India) PP. 140.

Dosani, A. A. K. , Talashikar, S. C. , & Mehta, V. B. (1999). Effect of poultry manure applied in combination with fertilizers on the yield, quality and nutrient uptake of groundnut. *Journal of Indian Society of Soil Science*, 47(1), 166–169.

Dutta, D. , & Mondal, S.S. (2006). Response of summer groundnut (*Arachis hypogaea* L.) to moisture stress, organic manure and fertilizer with and without gypsum under lateritic soil of West Bengal. *Indian Journal of Agronomy*, 51(2), 145–148.

F.A.O. , Food and Agricultural Organization, Special report, 2004.

Fida, K. (2000). Effect of soil amendments on the varietal evaluation of groundnut under rainfed conditional Peshawar valley. *Peshawar (Pakistan) NAUP*, p. 82.

Fiske, C. S. , & Subba Row, Y. (1925). The colorimetric determination of phosphorus. *J. Biol. Chem.*, 66, 375–400.

Fortanier, E. J. (1957). De beïmoeding van de bloei bij *Arachis hypogaea* L. Doctoral Thesis of Agric., Univ. of Wageningen, 57, 1–116.

Gill, O. P. , & Kumar, Y. (1995). Effect of sowing dates and varieties on the pod yield of irrigated peanut in Rajasthan, India. In: *Proceedings of 82nd Indian Congress, Part IV Late Abstracts*, 12, pp. 124.

Giller, P. , & Morvan, B. A. (1984). In: “Plant analysis in the control of the nutrition and tropical plants”, groundnut (leaf analysis), Martin – Parvel, P. , Gagnard, J. , & Gautier, P. (Eds.), Lavoisier, Paris (France), pp. 549–558.

Golakiya, B. A. (1988). A system approach to resolve P x Zn antagonism in different soil water conditions. PhD Thesis, Gujarat Agricultural University, Sardar Krushinagar.

Hadwani, G. J. , & Gundalia, J. D. (2005). Effect of N.P. and K levels on yield, nutrient content, uptake and quality of summer groundnut grown on typical haplustepts. *J. Indian Soc. Soil Sci.*, 53, 125–128.

Halward, T. S. , Tom, S. , Elizabeth, L. , & Kochert, G. (1992). “Use of single-primer DNA amplifications in genetic studies of peanut (*Arachis hypogaea* L.)” *Plant Molecular Biology* 18, 315–325.

Hasan, A. (2009). Effect of different sources of sulphur and Boron on growth, yield and quality of *Brassica juncea* L. (Mustard). PhD Thesis, M.J.P. Rohilkhand University, Bareilly.

Hasan, A. , & Abbas, Z. (2007a). Effect of different concentrations of some leaf-applied agro-chemicals on growth, yield and quality in mustard (*Brassica juncea* L.). Paper presented at Indo-Hungarian Workshop, held on 24 March, 2007 at I.V.R.I., Bareilly, sponsored by DST, New Delhi.

- Hasan, A. , & Abbas, Z. (2007b). Nutritional aspects of some selected crop plants. Inc. "Plant Physiology – current trends" (Ed.) P.C. Trivedi, Pointer Publishers, Jaipur, pp. 153–203.
- Hasan, A. , & Abbas, Z. (2008). Studies on the effects of Agrochemicals, boron and Sulphur on growth and quality of mustard (*Brassica juncea* L.). In: "Plant Physiology in Agriculture and Forestry" (Ed.) P.C. Trivedi, Aawishkar Publishers, Jaipur pp. 16–56.
- Hasan, A. , Kumar, A. , & Abbas, Z. (2009). Effect of different sources of sulphur and boron on yield characteristics and oil yield in *Brassica juncea* L. Life Science Bulletin, 6(2), 233–240.
- Hasan, A. , Kumar, A. , Kumar, P. , & Abbas, Z. (2007). Effect of nitrogen levels on growth, herb yield and essential oil content of *Ocimum basilicum* var. *garbratum* (sweet basil). Indian J. Trop. Biodiv., 15(2), 140–143.
- Hatam, M. , & Abbasi, G. Q. (1994). History and Economic importance of groundnut (*Arachis hypogaea* L.) In: "Crop Production" Bashir, E. , & R. Bantel (Eds.), Pub. NBF, pp 350–351.
- Hirano, S. , Shima, T. , & Shimada, T. (2001). "Proportion of aflatoxin B1 contaminated kernels and its concentration in imported peanut samples" Shokuhin Eiseigaku Zasshi., 42, 237–242.
- Holley, K. T. , & Hammons, R. O. (1968). Strain and seasonal effects on peanut characteristics, Univ. Georgia Agri. Expt. Stn. Res. Bull., 32, 1–27.
- Husted, L. (1936). "Cytological studies on the Peanut, *Arachis*, vol. II", Cytologia, 7, 396–423.
- Ismail, S. , Melewar, G. U. , Rege, V. S. , & Yelvikas, N. V. (1998). Influence of FYM and gypsum on soil properties and yield of groundnut grown in vertisols. Agropedology, 8, 73–75.
- Jambhekar, H. A. (1992). "Use of earthworm as a potential source to decompose of wastes" Proc. National Seminar on Organic Farming MPKV (PUNE), pp. 52–53.
- James, G. , & Hasibuan, M. A. (2002). "The composting of sugarcane factory byproducts" Sugarcane May/June (2002) pp. 24–30.
- Kachot, N. A. , Malavia, D. D. , Solanki, R. M. , & Sagarka, B. K. (2001). Integrated nutrient management in rainy-season groundnut (*Arachis hypogaea*). Indian Journal of Agronomy, 46(1), 516–522.
- Kadam, U. A. , Pawar, V. S. , & Pardeshi, H. P. (2000). Influence of planting, layouts, organic manure and levels of sulphur on growth and yield of summer groundnut. J. Maharashtra Agric. Univ., 25(2), 211–213.
- Kanaujia, S. N. (2008). Effect of different sources of soil and leaf applied (352) zinc and sulphur nutrients on growth and oil yield of Japanese mint (*Mentha arvensis* L.). PhD thesis, M.J.P. Rohilkhand University, Bareilly.
- Kanwar, J. S. , Nighawan, H. L. , & Raheja, S. K. (1983). Groundnut Nutrition and Fertilizer Response in India. Pub. ICAR, New Delhi.
- Karpovikas, A. , Gregory, A. , & Walton, C. (1994). Taxonomia del genero *Arachis* (Leguminosae) Bonplandia, 8, 1–186.
- Karpovikas, A. , Gregory, A. , & Walton, C. (2007). Taxonomy of the genus *Arachis* (Leguminosae), IBONE, 16 (Supl), 1–205.
- Ketring, D. L. (1984). Temperature effects on vegetative and reproductive development of peanut. Crop Sci., 24, 877–882.
- Kishor, B. (2006). Effect of pyridoxine and nitrogen on growth, yield, essential oil and Biochemical components of *Mentha piperita* L. under salt stress. PhD thesis, M.J.P. Rohilkhand University, Bareilly.
- Kishor, B. , & Abbas, Z. (2003). Effect of pyridoxine on the growth, yield, oil content and amino: nitrogen content of *Mentha piperita* L. Proc. Nat. Symp. on "Plant Biology and Biodiversity in changing Environment", held on Dec 29–31, Jamia Hamdard University, New Delhi, p. 58.
- Kishor, B. , Kanaujia, S. N. , & Abbas, Z. (2006). Effect of vitamin B6 (Pyridoxine) on the growth, yield, oil content and biochemical components of peppermint *Mentha piperita* L. Nat. Jour. Life Sci., 3(3), 215–220.
- Kochert, G. , Thomas, S. H. , Marcos, G. , Leticia, G. , Romero, L. C. , & Moore, K. (1996). RFLP and Cytogenetic Evidence on the origin and Evolution of Allotetraploid Domesticated peanut, *Arachis hypogaea* (Leguminosae) Am. J. Bot., 83, 1281–1291.
- Kumar, A. (2009). Effects of soil-applied rice bran and foliarly-applied its extracts on carbohydrate and protein metabolism, during ripening and maturity in *Saccharum officinarum*

L., PhD Thesis, M.J.P. Rohilkhand University, Bareilly.

Kumar, A. (2012). Effect of different sources and methods of nitrogen applications, seed rate and dates of sowing on growth, yield and quality of *Ocimum basilicum* L. (sweet basil) and *Arachis hypogaea* L. (groundnut), PhD Thesis, M.J.P. Rohilkhand University, Bareilly, India.

Kumar, A. , Kumar, A. , & Abbas, Z. (2014). Effect of pyridoxine and gibberellins sprays on growth, yield and quality of sugarcane (*Saccharum officinarum* L.) J. Biol. Chem. Research., 31(1), 349–354.

Kumar, A. , Kumar, A. , Kumar, P. , & Abbas, Z. (2009b). Effect of soil-applied rice bran on germination percentage and cane yield of ten sugarcane (*Saccharum officinarum* L.) cultivars. Life Science Bulletin, 6(3), 161–164.

Kumar, A. , Sajjad, A. , Kumar, A. , Verma, N. , & Abbas, Z. (2011). Effect of different transplanting dates on herb and oil yield content and uptake of plant nutrients in (*Ocimum basilicum* L.) (Sweet basil). J. Func. Env. Bot., 1, 119–121.

Kumar, A. , Shukla, S. K. , & Abbas, Z. (2009a). Effect of soil-applied rice bran and pyridoxine soaking on sugarcane yield. Sugarcane International (The Journal of Cane Agriculture), U.K., 27(5), 210–211.

Kumar, A. , Verma, N. , Kumar, A. , & Abbas, Z. (2010). Crop growth period and population density variations in relation to leaf nitrogen, floral initiation and pod yield of groundnut (*Arachis hypogaea* L.), Life Science Bulletin, 7(2), 193–195.

Kumar, S. (2008). Salinity induce percent seed germination and seedling growth, oil yield of sunflower (*Helianthus annus* L.). PhD thesis, M.J.P. Rohilkhan University, Bareilly.

Kumar, S. , & Abbas, Z. (1992). Studies on different sources and methods of zinc application on wheat and triticale. Geobios, 19, 156–159.

Kumar, S. , Ahmad, A. , & Masood, A. (2007). Salinity induced percent seed germination and seedling growth of Brassica napus cv. Agami. Indian J. Trop. Biodiv., 15, 90–93.

Kumar, S. , Ahmad, A. , & Masood, A. (2008a). Salinity induced percent seed germination and seedling growth, oil yield of sunflower (*Helianthus annuus* L.). cv. PAC-3776. Research on Crops, 9, 274–277.

Kumar, Y. , Shaktawat, M. S. , Singh, S. , & Gill, O. P. (2003). Effect of sowing date and weed control methods on yield attributes and yield of groundnut (*Arachis hypogaea* L.) Indian J. Agron., 48, 56–58.

Lagatu & Maume (1930, 1934) In: Plant Physiology – A Treatise, vol. III. Steward, F. C. (ed.), Academic press, New York, 1963.

Latha, H. S. , & Sharanappa (2014). Production potential, nutrient use efficiency and economics of groundnut (*Arachis hypogaea* L.) and (*Allium cepa*) cropping system under organic nutrient management. Indian J. Agron., 59(1), 59–64.

Lindner, R. C. (1944). Rapid analytical methods for some of the more common inorganic constituents of plant tissue. Plant Physiol., 19, 76–89.

Lourduraj, C. A. (2000). Effect of irrigation and manure application on the growth and yield of groundnut. Acta Agronomica Hungarica, 18(1), 83–88.

Lourduraj, C. A. , Geethalakshmi, V. , Devsnath, P. , & Nagarajan, P. (1996). Drought management in rainfed groundnut. Madras Agriculture Journal, 83(4), 265–266.

Lundegardh, H. (1951). "Leaf analysis," Translated by R.L. Mitchel , Hilger Division, London.

Maity, S. K. , Giri, G. , & Deshmukh, P. S. (2003). Effect of phosphorus, sulphur and planting methods on growth parameters and total yield of groundnut (*Arachis hypogaea* L.) and sunflower (*Helianthus annuus* L.) Indian J. Plant Physiol, 8(4), 377–382.

Manoharan, V. , Sethapathi, R. , Ramalingam , & Sivaran, M. R. (1988). Correlation studies in Virginia bunch groundnut (*Arachis hypogaea* L.) Indian Journal of Oilseed Research, 5(2), 150–152.

Mishra, C. M. (2001). Effect of farmyard manure and chemical fertilizers on the yield and economics of groundnut (*Arachis hypogaea* L.) under rainfed condition. Madras Agriculture Journal, 87, 517–518.

Mohapatra, A. K. B. , & Dixit, L. (2010). Integrated nutrient management in rainy season groundnut (*Arachis hypogaea* L.). Indian J. Agron, 55(2), 123–127.

Moretzsohn, M. C. , Gouvea, E. G. , English, P. W. , Soraya, L. , Valls, J. F. M. , & David, J. (2013). "A study of the relationship of cultivated peanut (*Arachis hypogaea* L.) and its most closely related wild species using intron sequences and microsatellite markers". Annals of

Botany, 111, 113–126.

Murthy, S. K. , Krishna , & Rao, Yogeswara (2000). Correlation between weather parameters at different phenophases and growth and yield parameters of groundnut (*Arachis hypogaea* L.), Annals of Arid Zone, 39, 29–33.

Nambiar, K. K. M. , & Ghosh, A. B. (1984). Long term fertilizer experiment, Research Bulletin, Indian Agricultural Research Institute, New Delhi, pp. 101.

Nautiyal, P. C. , Ravindar, V. , & Joshi, Y. C. (1999). Net photosynthetic rate in peanut (*Arachis hypogaea* L.) Influence of leaf position, time of day and reproductive sink. Photosynthetica, 36, 129–138.

Nawlawade, P. P. , & Patil, B. P. (2000). Sowing time and seed bed modification for yield maximization in groundnut in north Konkan. Journal of Agricultural Meteorology, 2, 152–157.

Ozcan, M. M. (2010). "Some nutritional characteristics of kernel and oil of peanut (*Arachis hypogaea* L.)". J Oleo Sci., 59, 1–5.

Pacharne, D. P. , Tumbare, A. D. , & Dhonde, M. B. (2016). "Productivity, profitability and nutrient uptake in groundnut (*Arachis hypogaea*)-based cropping systems under different nutrient-management practices. Indian J. Agron., 61, 161–167.

Palaniappan, S. P. , & Annadurai, K. (1985). In: Organic-farming-theory and practice, pp. 53–73.

Panchaksharaiah, S. (1999). Effect of nitrogen and iron on growth and yield of groundnut. J. Farming Systems, 1, 9–13.

Panse, V. G. , & Sukhatme, P. V. (1967). Statistical Methods for Agricultural Workers, ICAR, New Delhi. pp. 137–174.

Panwar, A. S. , & Singh, N. P. (2003). Effect of conjunctive use of phosphorus and bioorganics on growth and yield of groundnut (*Arachis hypogaea* L.). Indian J. Agron., 48(3), 214–216.

Patel, M. S. , Gundalia, J. D. , Davaria, R. L. , & Patel, B. D. (1994). Effect of potassium and hormones under normal and higher levels of N and P on yield and uptake of nutrients by summer groundnut Gujarat Agricultural University Research Journal, 20, 23–38.

Patra, A. K. , Tripathi, S. K. , & Samui, R. C. (1995). Physiological basis of yield variation in rainfed groundnut. Indian J. Plant Physiol., 38, 131–134.

Ramesh, R. , Shanthamulliah, N. R. , Jayadeva. H. H. , & Hiramath, R. R. (1997). Growth and yield of irrigated groundnut as influenced by phosphorus farmyard manure and phosphate solubilizing micro organism. Current Research, 26(1), 196–198.

Ramesh Babu, N. , Reddy, S. R. , & Raghaiah, R. V. (1985). Studies on nutrient utilization by groundnut. Indian J. Agron., 30, 120–121.

Rao, S. S. , & Shaktawat, M. S. (2001). Effect of organic manure, phosphorus and gypsum on growth, yield and quality of groundnut (*Arachis hypogaea* L.). Indian J. Plant Physiol, 6(3), 306–311.

Rao, S. S. , & Shaktawat, M. S. (2002). Effect of organic manure, phosphorus and gypsum on groundnut (*Arachis hypogaea* L.) production under rainfed condition. Indian J. Agron., 47(2), 237–241.

Ravi Kumar, A. , Raghavalu, P. , Reddy, G. V. , Subbaiah, G. V. , & Rao, G. V. H. (1994). Effect of dose and time of nitrogen and gypsum application on dry matter production and yield of groundnut (*Arachis hypogaea* L.). Indian J. Agron, 39, 323–325.

Ray, S. P. , Chaudhary, B. P. , & Chaudhary, I. B. (1997). A report on outreach research on groundnut (1996/97), Sarlahi (Nepal). Oilseed Research Programme (n.p.).

Reddy, B. S. , Reddy, S. R. , & Subbiah, G. (1981). Effect of supplemental nutrition during post flowering phase of groundnut. The Andhra Agric. J., 38, 4–7.

Reddy, M. S. S. , Reddy, S. R. , Reddy, M. G. , & Reddy, M. G. R. K. (1991). Residual effect of organic matter and fertilizer applied to groundnut and maize on succeeding groundnut and groundnut-maize-groundnut sequence. Indian J. Agron, 86, 298–300.

Reddy, S. R. (2004). "Groundnut": In: Agronomy of Field Crops, Chapter 9. Kalynani Publishers, New Delhi, pp. 381–419.

Sajjad, A. , Kumar, A. , Kishor, B. , & Abbas, Z. (2011). Morphophysiological performance of seedling of three varieties of chickpea (*Cicer arietinum* L.). Life Science Bulletin, 8(1), 79–81.

Salama, N. E. , Hanna, F. R. , & Ahmad, A. (1994). Flower production and yield of groundnut under various concentrations of organic manure and water amounts. Ann. Agric Sci. (Egypt)

Salisbury, F. B. , & Ross, C. N. (2000). Plant Physiology, 5th Indian Reprint, Cengage Learning India Pvt. Ltd., New Delhi.

Sarawagi, S. K. , Tiwari, S. K. , & Tripathi, R. S. (1998). Nitrogen fixation, balance sheet and yield of winter soyabean as affected by divergent nutrients. *Annals of Agricultural Research*, 9(4), 379–385.

Sarkar, R. K. , Chakraborty, A. , & Bala, B. (1998). Analysis of growth and productivity of groundnut (*Arachis hypogaea* L.) in relation to micro nutrient application. *Indian J. Plant Physiol*, 3(3) (N.S.) 234–236.

Seijo, G. , Graciela, I. L. , Fernandez, A. , karpovickas, A. , Ducasse, D. A. , David, J. , et al. (2007). 'Genomic relationships between the cultivated peanut (*Arachis hypogaea*, Leguminosae) and its closed relatives revealed by double GISH'. *Am. J. Bot.*, 94, 1963–1971.

Selamat, A. , & Gardner, F. P. (1985). Growth, Nitrogen uptake, and partitioning in nitrogen fertilized nodulating and non nodulating peanut. *Agron. J.*, 77, 862–867.

Sharma, A. (2007). Ethno-botanical studies on the Tharu tribe of Udham Singh Nagar, Uttaranchal. Ph. D., thesis, M.J.P. Rohilkhand University, Bareilly.

Shukla, S. K. (2010). Effect of some agro-chemicals on sugar accumulation and quality in early and late maturing sugarcane cultivars. PhD Thesis, M.J.P. Rohilkhand University, Bareilly.

Sims, J. T. (1986). Phosphorus fractionation, adsorption and description studies with-heavily manured and fertilized atlantic coastal plain soils. *Agronomy Abstracts* p. 172 Fidc. *Advances in Agronomy* 52, 1994.

Singh, B. , & Singh, N. Y. (2002). Concepts in nutrient management. In: *Recent Advances in Agronomy* (Singh, G. , Kolar, J. S. , & Sekhon, H. S. Eds.) pp. 92–109. Indian Society of Agronomy, New Delhi.

Singh, K. P. , & Ahuja, K. N. (1984). Dry matter accumulation, oil content and nutrient uptake in groundnut (*Arachis hypogaea* L.) cv. T64 as affected by fertilizers and plant density. *Indian J. Agron.*, 30, 411–445.

Singh, S. , Kumar, Y. , & Gill, O. P. (2003). Growth characteristics of summer groundnut (*Arachis hypogaea* L.) as influenced by sulphur levels, irrigation schedules and organic manures. *Annals of Biology (Hissar)*, 19(2), 135–139.

Singh, S. , Singh, A. L. , Kalpana, S. , & Misra, S. , Genetic Diversity for growth, yield and quality traits, 15(3), 267–271.

Singh, S. B. , Singh, M. P. , Matamber ., & Nidhi, Katiyar . (2006). Microbial composting of pressmud and its impact on soil productivity. "Seminar on efficient practices in sugarcane" held on 25 Dec U.P. Council of Sugarcane Research, Shahjahanpur. U.P. India 2006.

Singh, S. R. , Nayar, G. R. , & Singh, U. (2007). Productivity and nutrient uptake of soyabean (*Glycine max*) as influenced by bio-inoculants and farmyard manure under rainfed conditions. *Indian J. Agron.*, 52(4), 325–329.

Steward, F. C. (1963). *Plant Physiology* (Ed) vol. III, A treatise, Academic Press, New York.

Steward, F. C. , & Durzan, D. J. (1965). Metabolism of nitrogenous compounds. In: Steward, F.C. (Ed.). *Plant Physiology: A treatise*. Vol. IV, p. 381, Academic Press, New York, USA.

Suman, A. , Lal, M. , Singh, A. K. , & Gaur, A. (2006). Microbial biomass turnover in Indian sub-tropical soil under different sugarcane intercropping systems. *Agron. J.*, 98, 698–704.

Survase, D. N. , Dongale, J. H. , & Kadrekar, S. B. (1986). Growth, yield, quality and composition of groundnut as influenced by FYM, calcium, sulphur and boron in lateritic soil. *J. Maharashtra Agric. Uni.*, 11, 49–51.

Talwar, H. S. , Nagaswar Rao, R. C. , & Nigam, S. N. (2002). Influence of canopy attributes on the productivity of groundnut. *Indian J. Plant Physiol.*, 7(3), 215–220.

Taufiq, A. , & Sudaryono . (1998). Sulphur and organic manure fertilization on groundnut in high pH of alfisol Balai penelitian Taman Kacang Kacangan dan umbi umbian, Malang (Indonesia), Bali kabi, pp. 198–208.

Taylor, C. L. (2003). "Qualified Health Claims": Letter of Enforcement Discretion – Nuts and Coronary heart disease (Docket No 02P-0505). Center for Food Safety and Applied Nutrition, FDA.

Trivedi, B. S. , Bhatt, P. M. , Patel, J. M. , & Gami, R. C. (1995). Increased efficiency of fertilizers through addition of organic amendment in groundnut. *Journal of Indian Society of*

Soil Science, 43(4), 627–629.

Varalakshmi, L. R. , Srinivasa, Murthy, C. A. , & Bhaskar, S. (2005). Effect of integrated use of organic manures and inorganic fertilizers or organic carbon available N.P.K. in sustaining productivity of groundnut finger millet cropping system. J. Ind. Soc. Soil Sci., 53, 315–318.

Venkaiah, K. (1985). Effect of bulk density of growth and yield of groundnut. Indian J. Agron., 30, 278–280.

Verma, N. (2011). Studies on balanced nutrition integrated with organic manures in groundnut (*Arachis hypogaea* L.) PhD Thesis, M.J.P. Rohilkhand University, Bareilly.

Verma, P. K. , Sharma, G. D. , Dhindsa, K. S. , & Sangwan, N. K. (1984). Effect of spacing on growth attributes and oil contents in palmarosa (*Cymbopogon martinii* var. motia) grass Indian J. Plant Sci., 2, 45–49.

Verma, V. (2007). “Textbook of Plant Physiology” New Edition, Emkay pub. Books India, New Delhi, pp. 211–212.

Went, F. W. (1953). The effect of temperature on plant growth. Ann. Rev. Plant Physiol., 4, 347–362.

Wood, I. M. W. (1968). The effects of temperature at early flowering on the growth and development of peanuts. Aust. J. Agric. Res. 19, 241–251.

Wynne, J. C. , Ball, S. T. , Elkan, G. H. , & Schneeveis, T. J. (1979). Cultivar, inoculum, and nitrogen effects on nitrogen fixation of peanuts. Agron. Abstr. American Society of Agronomy, Madison, W.L.

Yadav, D. V. (2001). “Recycling of sugar factory pressmud in agriculture”. Proc. Seminar on sugarmill waste based vermicompost and biofertilizers Organized by U.P. Ganna Kisan Santhan 11 Butler Road, Tilak Marg, Lko., held on 30 Sept–01 October pp. 91-106 2001.

Yakabri, M. , & Satyanarayan, V. (1995). Dry matter production and uptake of nitrogen, phosphorus and potassium in rainfed groundnut. Indian J. Agron., 40, 325–327.