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Full Length Research Paper

Capacity for research and outreach on climate change agricultural adaptation in the Faculties of Agriculture of Universities in southeast Nigeria

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The study examined research and outreach capacities on climate change agricultural adaptation in the faculties of agriculture in southeast, Nigeria. One hundred and twenty (120) randomly selected academic staff of faculties of agriculture were used. Data were collected using questionnaire and analyzed by descriptive statistics. The results show poor investment in equipment (18.7%) and human capacity building (25.8%); limited department/faculty (43.3%) and university/university (28.3%) linkages for climate change research and outreach. Only 25.0% of the respondents expressed the existence of outreach and fund for climate change activities. The personal activities of staff were attendance to conference (62.5%), and involvement in researches (91.7%) on climate change. Capacities for research and outreach on climate change were constrained by several factors namely high cost of TV, radio and newspaper adverts (M = 3.44), poor understanding/knowledge of climate change concepts (M = 3.36), limited grant for climate change research (M = 3.35) and others. The study recommends that government should enact favourable policies and institutional supports that could encourage, spur and stimulate capacity acquisition activities in the universities. The university system need to internally put in place activities, strategies and programmes that could attract external aids, collaboration and raise staff interest and motivation to acquire capacity on climate change agricultural adaptation.

Key words: Climate change, university, research, outreach, adaptation, agriculture.

INTRODUCTION

Climate change is any change in climate overtime due to natural variability and human activities (anthropogenic factors) with alteration in the composition of the global atmosphere (Inter-governmental Panel on Climate Change, IPCC, 2001, 2007). According to Organic Consumer Association (2008), the agricultural land use was responsible for approximately 15 to 20% of all anthropogenic green house gas (GHG) emissions. Thus, agriculture significantly contributes to climate change and in turn is affected by climate change. The IPCC (2007) predicted that in some African countries including Nigeria, yields from rain-fed agriculture will be reduced by up to 50% and a decrease of 30% in world food production. Moreover, between 75 and 250 million people in Africa will be exposed to water stress due to climate change and this will adversely affect livelihood in the region. This

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is attributed to wide range effects of climate change evidence as increase temperature, decrease rainfall in the continental interiors, drought, desert encroachment, melting ice, extreme weather, floods, sea level rise, sinking of Islands water scarcity, health and other agricultural problems (Odjugo, 2007, 2009; Adefolalu, 2007; Awake, 2008).

In Nigeria, there are increasing evidence of climate change with the attendant impacts and threats to rural communities and farmers in particular. Southeast agro-ecological zone of the country recorded remarkable increase in flooding, landslide and erosion which have led to loss of lives, houses, farmlands, properties, roads etc. (Agwu and Okhimamhe, 2009). Some States in the area such as Anambra and Enugu have consistently experienced sheet and gully erosion; with the worse hit areas in the Anatu-Agulu-Nanka axis, the areas around Nkisi River, Amawbia and Ozubulu areas of Anambra State. Soil productivity in many parts of the region has been badly impacted with considerable reduction in food productivity (Adesina and Odekunle, 2012). Bello et al. (2012) also observed that the area is currently confronted by irregularity in the rainfall pattern (delayed onset or early retreat of rains) leading to unsteady growing season and other soil-related problems. Thus, the challenge of building resilient society with capacity to adapt to the threats of climate change is an imperative.

Adaptation refers to adjustments in practices, processes or structures in response to projected or actual changes in climate (Ifeanyi-Obi et al., 2012), with the goal of maintaining the capacity to deal with current and future changes.

Agricultural adaptation to climate change aims at reducing and developing appropriate coping measures to address the negative impacts of climate change on crop production, soil management/conservation and animal husbandry. Adaptation and mitigation potential according to Lybbert and Sumner (2010) are nowhere more pronounced than in developing countries where agricultural productivity remains low; poverty, vulnerability and food insecurity remain high; and the direct effects of climate change are expected to be especially harsh.

Adaptation to climate change requires development of strong adaptive capacities, including provision of tools, technologies and/or information, raising awareness of adaptation options, educating society, professionals on climate change through education, research and community engagements. In other words, it calls for high climate science literacy, generation, effective diffusion and use of appropriate agricultural technologies by the public and farmers in particular. The magnitude of the challenge, particularly on the agricultural sector places universities and faculties of agriculture at the frontier of leadership in climate change adaption. In other words, through education and research, universities need to take leadership role in developing, testing and modeling solutions for meeting human needs in the face of rapid global change that threatens the viability of current systems (www.presidentclimatecommitmen.org.). In another hand, professionals and students through update to curricula need understanding of climate science, the way it affects their life and professions; and effectively contribute to building resilient community. Reports shows that as economic development drivers and infrastructure developers, as resources of expertise, student capacity and of leadership; and as advocates for specific policies at the local, state and national levels, colleges and universities have always played substantial roles in the effort to prepare communities and make them more resilient in the face of growing climate change impacts (www.presidentclimatecommitmen.org.). They could serve as “hubs” in communities on adaptation issues, creating, testing, and disseminating knowledge about regional climate projections and adaptation strategies, and work directly with local communities to explain the science and implement solutions. Rising to the above responsibilities demand capacities at individuals, organizations and systems levels in the universities and their faculties. Ideally, such capacities should include knowledge/skills and competencies, scientific, resources (human and institutional) required to generate, innovate, and disseminate information, knowledge or technology for agricultural adaptation to climate change.

Therefore, this study aimed to assess the extent to which the requisite capacities exist in the faculties of agriculture of the universities. The objectives were to: 1) assess the research capacities on climate change agricultural adaptation in the faculties of agriculture; 2) examine the capacities for outreach on climate change agricultural adaptation and 3) determine the factors that constrained the capacities for research and outreach in the faculties of agriculture on climate change agricultural adaptation.

METHODOLOGY

The survey was conducted in southeast agro-ecological zone of Nigeria. Southeast is located between latitudes 04°17’ N and 07°06’ N and longitudes 05°23’ E and 09°28’ E (Macmillan, 2009). The area comprises the geographical location of five States namely Abia, Anambra, Ebonyi , Enugu, and Imo (Figure 1). The climate of southeast Nigeria is generally tropical with two clear identifiable seasons: the wet and dry seasons with average highest annual rainfall at 1952 mm and temperature pattern-mean daily and annual temperature at 28 and 27°C, respectively (Igbokwe et al., 2008). It is primarily an agricultural zone with sandy, mostly loose and porous soil, hence its vulnerability to climate change. Three States namely Abia, Anambra and Enugu out of five States were purposively selected because of the presence of Federal and State universities/faculties of agriculture. All academic staff within the faculties of agriculture constituted the population for the study. In each State, two universities (State and Federal) were purposively selected as follows: Abia State (Michael Okpara University of Agriculture (MOUA), Umudike, and Abia State University (ABSU) Uturu); Anambra State (Nnamdi Azikiwe University (UNIZIK) Awka and Anambra State University (ANSU), Uli); Enugu State [University of Nigeria, Nsukka (UNN) and Enugu State University of Science and Technology (ESUT), Enugu]. Simple random sampling

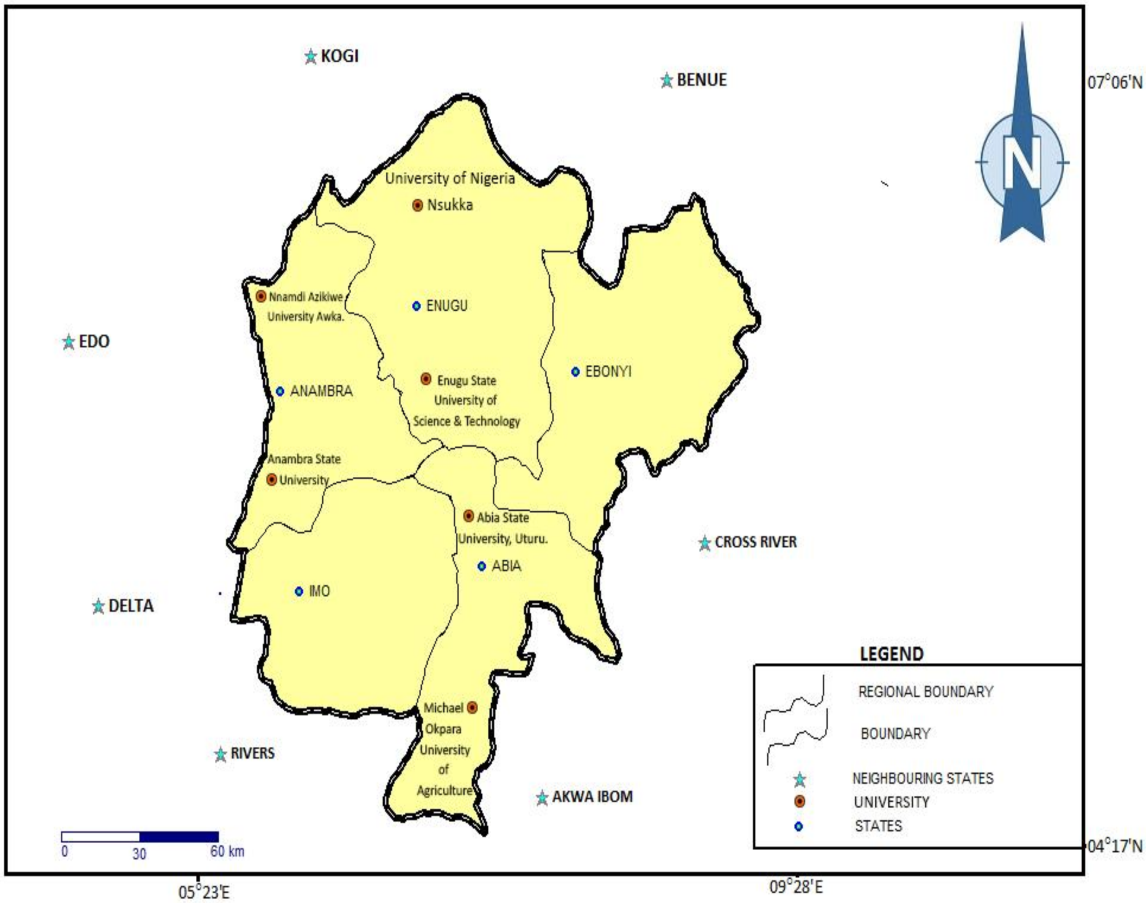

Figure 1. Map of southeast Nigeria showing the study area and the selected universities. **Source:** Macmillian Atlas series (2009).

technique was used to select five staff across the departments in the faculty/college of agriculture of each university. An exception was made at the Nnamdi Azikiwe University Awka, where five staff of the faculty was selected because the faculty was not yet fully departmentalized. The total sample size for the study was 130 respondents. Questionnaire was used for data collection and only 120 questionnaires were found analyzable. Capacities of universities for research on climate change adaptation were assessed by asking respondents to indicate investment/efforts that have taken place by the universities in the areas of equipment, staff training, linkages within institution, with relevant institutions and researches carried out, among others. Outreach capacities were measured in terms of its existence, methods and/or strategies adopted for outreaches and others. The respondents were asked to indicate the channels (example: use of radio programmes/jingles on climate change issues, use of television, posters, fliers, farm visits, public lectures etc) employed for climate change outreach and whether they have participated in State/National discuss on climate change. Information on constraints to research and outreach capacities of the universities were elicited using 16 possible constraint items such as inadequate fund, lack of favourable policy, poor infrastructural facilities and others. Respondents indicated the extent to which the items constrained capacities of the universities on a four point Likert-type scale of: no extent (1), little extent (2), great extent (3) and very great extent (4). Data were analyzed using descriptive statistics. Mean scores ≥2.5 were considered as major constraints. Data were presented with histograms.

RESULTS AND DISCUSSION

Capacities for research on climate change agricultural adaptation in the faculties of agriculture

The issues discussed here include: investment in equipment and human development, linkages and collaboration with institutions/agencies, and conferences attended on climate change, etc.

Investment in equipment and human development in faculties of agriculture

About 19.0% of the respondents indicated that they had invested on equipment for research on climate change adaptation in the universities (Figure 2). Personal observation and communication show that some of the investments on equipment are in the areas of library stocking, information communication technologies facilities and refurbishing of a Geographic information systems (GIS) laboratory used in accessing information in geographic systems. About 26% expressed that there

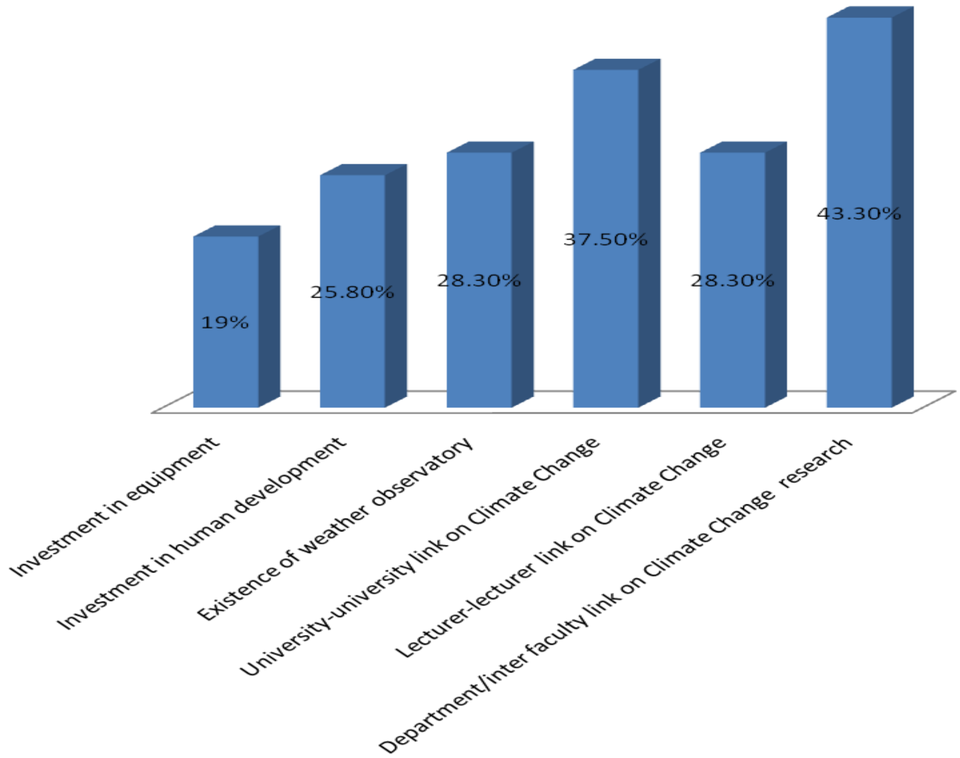

Figure 2. Investment and linkages on climate change.

were investment in human development for research on climate change adaptation. Further interview with the respondents however, revealed that they had received training on trans-disciplinary research methodology and update to curriculum in response to the need for adaption to climate change. Specifically, respondents from UNN had participated in trainings on climate change and sustainability, general knowledge on climate change, sensitization workshop/ trans- disciplinary climate change adaptation capacity, air and water pollution. Generally, the efforts so far made by the universities are insufficient to size the magnitude of the challenges posed by climate change. According to World Bank (2010), human development (level of education and specific skills) and technical capacity (type of equipment for climate data collection and monitoring, GIS, quality of information technology services, etc.) available within an institution to support activities for adapting and/or mitigating the impacts of climate variability and change on the agricultural sector remains paramount in curbing the challenges of climate change.

Furthermore, 28.3% of the respondents acknowledged the existence of weather observatory facilities in their faculties. Weather forecasting facilities are critical in addressing the challenges of climate change in the Universities. According to Mude et al. (2009), better and more timely information through weather facilities could help to forecast impending weather events such as flooding, drought, early and late rain etc more effectively and thereby improve response times and adaptation. Thus, its limited availability in the faculties of agriculture suggests poor climate science capacities in the system.

Linkages for climate change research

The respondents acknowledged the existence of weak departmental and faculty (43.3%), university-university (37.5%), and lecturer-lecturer (28.3%) linkages in the universities for climate change research (Figure 2). Largely, the findings agree with Orusha et al. (2012) that academic programs in agriculture tend to exist in isolation, with little collaborations between institutions, even among those in the same geographic area. This means that innovations, research activities and programs are conducted with limited linkages/collaborations, interactions and synergy across and within institutions and disciplines. The impacts of climate change cut across sectors and discipline; thus approaches, initiatives or research activities targeted at developing adaptive capacities should be inter and/or trans-disciplinary and participatory. In other words, resources, ideas, skills among universities, departments, faculties and lecturers should be harnessed for interdisciplinary research in the whole system. Such interaction expunge knowledge flow and expunge idea fertilization across disciplines on how

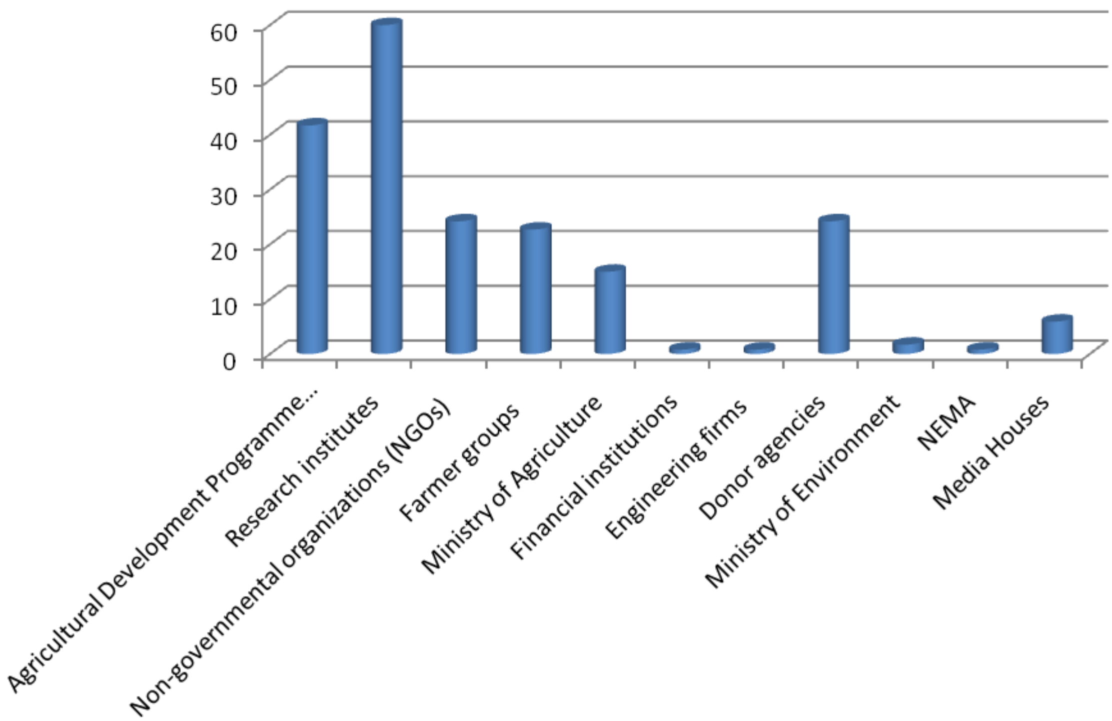

Figure 3. Percentage distribution of respondents by linkages with institutions on climate change.

best to tackle the challenge of agricultural adaptation to climate change. Above all, institutions shape and modify the capacity of one another; collectively prepare farmers, and all-dependent people to adapt their livelihoods to the context of climate change (FAO, 2010).

Linkage with other organizations on climate change agricultural adaptation

Figure 3 shows that majority (60 and 57.5%) of the respondents indicated the existence of linkages with research institutes and Agricultural Development Programmes (ADPs), respectively. Other areas of institutional linkages include: Non-governmental organizations (NGOs) (24.2%), farmer group (22.7%), Ministry of Agriculture (15.0%), financial institutions (0.8%), engineering firms (0.8%), donor agencies (24.2%), Ministry of Environment (1.7%), National Emergency Management Agency (NEMA) (0.8%) and media houses, (5.9%). Linkage particularly with research institutions and ADPs is more common probably due to interdependency in roles, functions and operations of the institutions; however, the strength, mechanisms and orientations may not be strong and effective. Generally, most linkage arrangements among institutions and agencies are dysfunctional, ad-hoc and inhibited by several economic, structural, organizational and institutional problems. However, linkage and collaboration on issues of public and global interest like climate change are crucial for evolution of multifaceted and holistic approaches to climate change adaptation needs. Though, each institution and agency has roles to perform but not in isolation. For instance, while education and research institutions are looked upon for generation/development of technologies, knowledge and skills; the ADPs, weather and environmental agencies, the media houses are critical actors in the dissemination of relevant information to the users for agricultural adaptation to climate change. Hence, World Bank (2010) recommended collaboration and communication with other agencies, bilateral/multilateral exchanges with other countries (south-south or north-south collaboration) on addressing climate variability and change.

Respondents' personal activities on climate change

Collaboration with agencies/organizations and supervision of climate change research

Figure 4 shows that only 5.0% of the respondents had personal collaboration with agencies and organizations on climate change issues. Twenty percent (20%) had supervised postgraduate students, while a lesser proportion (2.0%) had supervised undergraduate students on climate change research. The result reflects poor capacities and participation of the staff of faculties of

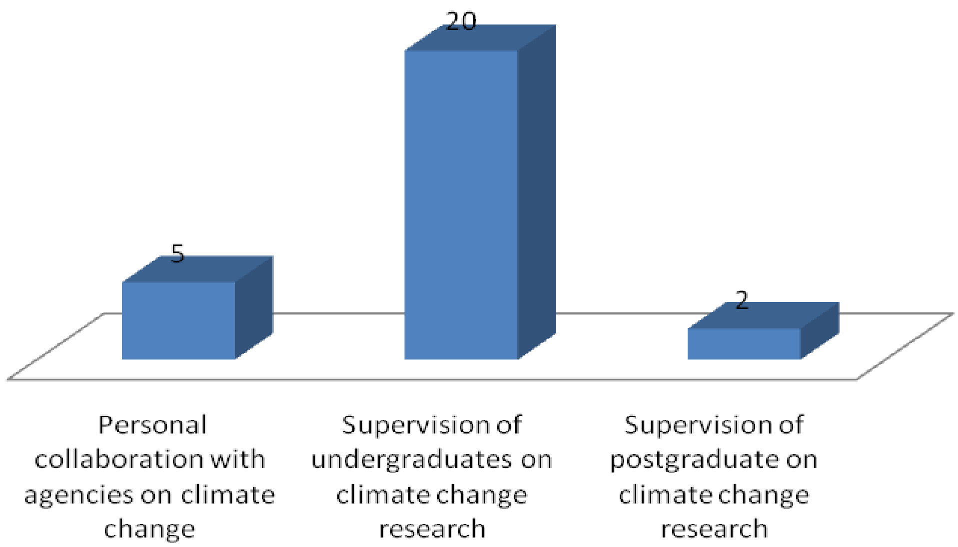

Figure 4. Percentage distribution of Staff by collaboration and supervision on climate change.

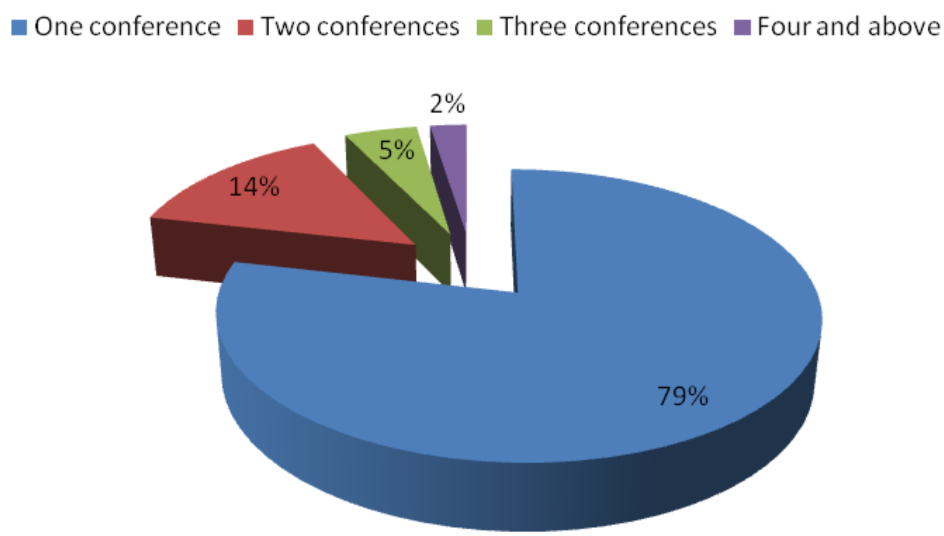

Figure 5. Percentage of respondents based on conferences attended on climate change.

agriculture in climate change research. It suggests poor commitment, orientation and perhaps lack of incentive for participation in climate change adaptation concern. Research and collaboration are interrelated activities critical for both development of technology, creation of knowledge, facilitation of interaction, exchange, and sharing of information for climate change adaptation. Interactions between actors on climate change according to Dominguez and Brown (2004), allow sharing of information, learning and boosting the capacities of researchers. This is because adaptation capacity demands incorporation of multi-stakeholders including climate science experts, agricultural practitioners and technicians, local communities/civil society, donors and policy makers (Asiedu et al., 2011).

Conferences attended on climate change in the last 3 years

Majority (62.3%) of the respondents attended one conference, while about 21 and 11.3% attended 2 and 3 conferences on climate change, respectively (Figure 5). Only 3.8 and 1.9% of the respondents had attended between 4 and 5 conferences on climate change, respectively. The average number of conferences

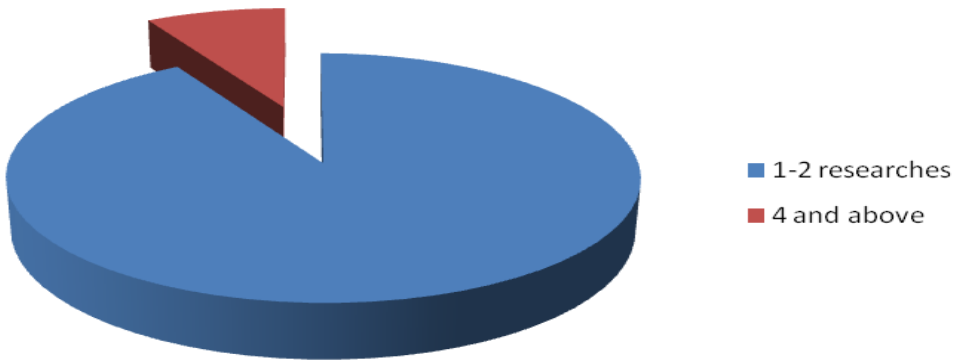

Figure 6. Percentage distribution of respondents based on researches carried out on climate change.

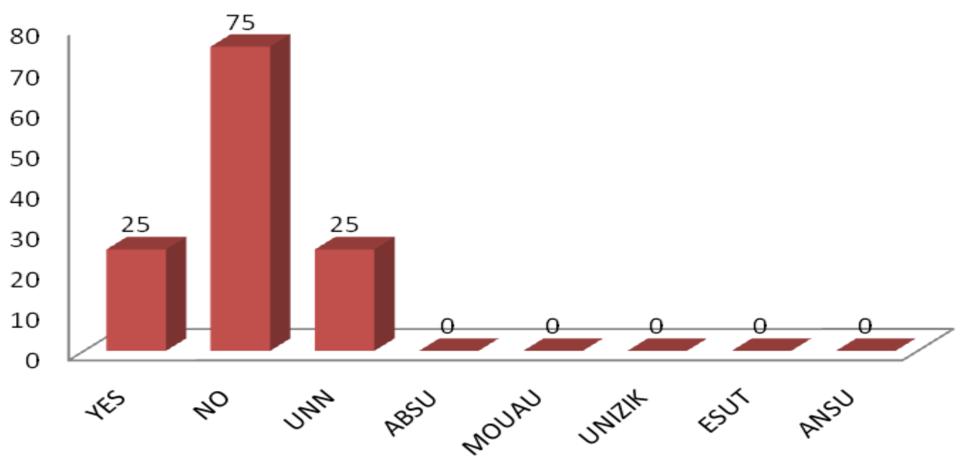

Figure 7. Percentage distribution of respondents based on availability of fund for climate change research.

attended in the last 3 years was 2. Relatively, this shows low exposure of the academic staff of the faculties to climate change issues. Attendance to professional conferences are expedient to facilitate exchange of ideas, encourage innovativeness; articulate and focus research priority to the need of the moment. This is even more pertinent for issues of global concern like climate change.

Researches carried out on climate change in the last 3 years

A greater proportion (91.7%) of the respondents had carried out 1 to 2 researches, while 8.4% had conducted 4 or more researches on climate change in the past 3 years (Figure 6). The average number of researches carried out by the respondents was 2. The results show that a considerable number of researches have been conducted on climate change in faculties of agriculture in the universities. Interview revealed that majority the researches were conducted at the University of Nigeria, Nsukka. This is not surprising because the University has organized a number of workshops on climate change and related issues. Many universities may not have had such novel opportunities and hence limited incentive and motivation for notable research efforts on climate change.

Availability of fund for climate change activities

Twenty-five percent (25%) of the respondents, specifically from University of Nigeria, Nsukka indicated availability of fund for climate change activities (Figure 7). Other universities expressed non-availability of fund for climate change activities. This appears to be one of the long aged and unabated problems in higher institution in Nigeria. According to Nigeria University Commission (NUC) (2000), Nigerian Universities have been underfunded especially in the area of capital development and research grant. Hence, researchers

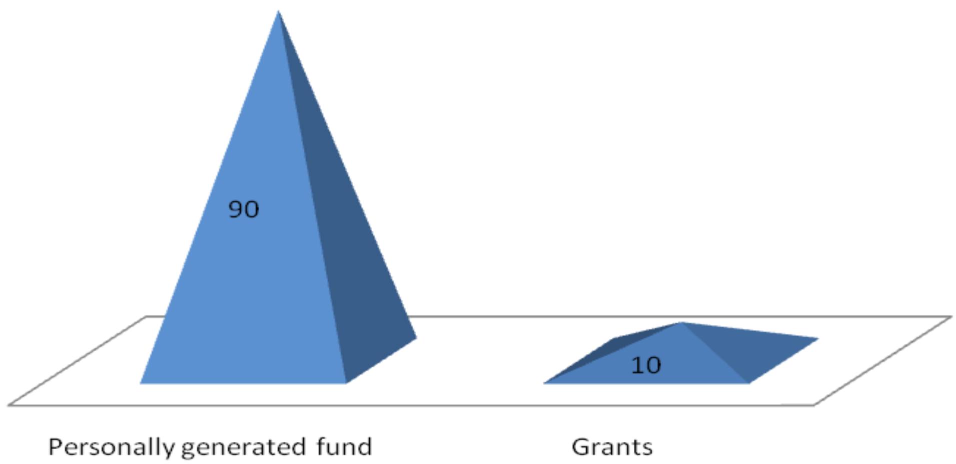

Figure 8. Percentage distribution of respondents based on sources of fund for climate change research.

rely mostly on limited external funding for a qualitative research. This is a strong disincentive and impediment to any meaningful efforts on capacity building in teaching, research, and outreach on climate change. As reported by FAO (2010), confronting the challenge of climate change creates new financing requirements in terms of both amounts and financial flows associated with needed investments, which will require innovative and institutional solutions.

Sources of funding for research on climate change

Majority (90.0%) of the respondents indicated that the universities depended on internally generated funds for research on climate change, while 10.0% indicated that funding was from grants (Figure 8). This suggests strong demonstration of commitment to research on climate change. However, dependence on internally generated fund may not be adequate and sustainable. Severally, scholars have sported out poor funding as one of the major constraints in tertiary institution (Chakaredza et al., 2008). Access and use of external/donor funds for research on climate change are necessary and cannot be over emphasized.

Area of funding on climate change adaptation

The areas of funding on climate change were library stocking with climate change text books (23.3%), research (20.8%), workshops (18.8%) and conferences (15.5%). Other areas include; symposiums (14.5%) and funding of staff travel (14.5%) for climate change- related issues (Figure 9). Many relevant activities for capacity acquisition are funded in the university, but the low responses of the respondents suggest inadequate investment and limited coverage. Climate change adaptation requires knowledge and capacity building across disciplines which requires adequate and sustainable funding.

Outreach programmes/extension on climate change

Only 25.0% of the respondents from the University of Nigeria, Nsukka indicated participation of the University in State or National discourse on climate change issues. Similarly, 25.0% of the respondents indicated the existence of outreach programme on climate change in the Faculty of Agriculture (UNN) (Table 1). Respondents revealed that the major outreach programme in the university is carried out by the 4th year students of the Faculty of Agriculture as part of the Student Internship Work Experience Scheme (SIWES). The outreach targets creating awareness, building knowledge and capacity of the rural farmers on climate change, sustainable adaptation strategies etc. It is also accepted as means of promoting collaboration between scientists and practitioners, and enhancing local adaptation capacity including the ability to draw on climate data (Open Society Foundation, 2012). Besides, the students as well as academic staff explore the opportunity to build critical mass of capacities on climate science and to respond appropriately in their professions.

Furthermore, Table 1 shows different media of outreach to rural communities on climate change. The medium used always were posters (10.0%), radio (9.2%), fliers (2.5%), newspaper (0.8%) and newsletter (0.8%). About 36% of the respondents indicated that the university sometimes used fliers as a medium of outreach on climate change. Other media sometimes used for

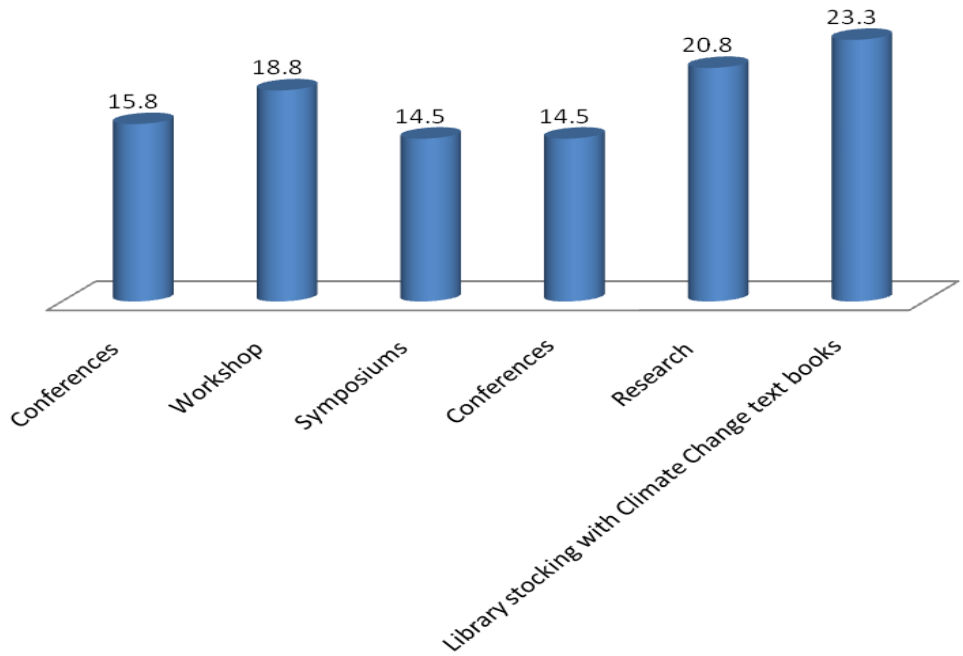

Figure 9. Percentage distribution of respondents based on activities on climate change funded

Table 1. Percentage distribution of respondents based on outreach/ medium of outreach and state/national discourse on climate change.

Outreach and medium	% (n = 120)	
Faculty outreach on climate change	25	
State/National discourse on climate change	25	
Medium of outreach	**Sometimes**	**Always used**
Radio programmes/jingles	15.1	9.2
Television	3.4	
Newspaper	10.3	0.8
Fliers	36.4	2.5
Posters	31.9	10.9
Newsletters	12.7	0.8
Pamphlet	8.5	-
Farmers' visit	18.3	5.8
Public lecture	10.1	19.3
Group discussion visits	12.6	14.3

outreach include; posters (31.9%), farm visit (18.3%), radio, (15.1%), newsletter (12, 7%), newspaper (10.3%), public lecture (10.1%), and pamphlet (8.5%). Many channels are used but the extent of use in communicating climate change information and technology is very poor. Indeed, the urgency of building climate change adaptation capacities, particularly in the agricultural sector requires adoption of multiple, but appropriate and effective channels of communication. FAO (2010) affirms that communication and equitable information access of rural people and institutions to information related to impacts of climate change variability and adaptation demands appropriate channels. Appropriateness however, is relative to the audience the messages are intended.

Perceived constraints to capacities for research and outreach on climate change

The major constraints to capacities of the universities for research and outreach on climate change were high cost

Table 2. Mean scores on constraints to capacity building for research and outreach on climate change.

Constraint factors	Mean	Standard deviation
Poor teaching material	2.67	0.643
Inadequate ICTs facilities	2.88	0.640
Lack of reliable weather forecasts/climate change information	2.79	0.592
Limited grant for climate change research	3.35	0.691
Lack of interest of staff and the public	1.88	0.977
Poor collaboration with other agencies	2.74	0.567
Lack of weather observatory	2.76	0.606
Lack of fund	3.36	0.653
Poor human resources capacity	2.65	0.691
Poor interest in climate change research	1.65	0.849
limited outreach on climate change	2.24	0.741
Poor technical and communication skill	2.74	0.567
Limited availability of media network	3.00	0.651
High cost of TV, radio and newspaper adverts on climate change	3.44	0.561
Lack of CC issues integrated in rural development	2.85	0.702
Corruption in the university system	2.65	0.646
Poor remuneration of staff	2.76	0.663
Lack of policies/policy implementation on climate change	2.85	0.558
Poor understanding of climate change concepts	3.36	0.603

of TV, radio and newspaper adverts (M = 3.44), poor understanding/knowledge of climate change concepts (M = 3.36), limited grant for climate change research (M = 3.35), limited availability of media networks (M = 3.00) and inadequate Information and Communication Technologies (ICTs) facilities (M = 2.88) (Table 2). Others include poor integration of climate change issues in rural development (M = 2.85), lack of policies/policy implementation on climate change (M = 2.85), and poor weather forecast/climate change information (M = 2.79), lack of functional weather observatory (M = 2.76), poor remuneration of staff (M = 2.76), poor collaboration with agencies (M = 2.74), poor technical and communication skill (M = 2.74), poor human resources capacity (M = 2.65), corruption in the university system (M = 2.65) etc. In other words, capacities for climate change adaptation research and outreach in the universities are inhibited by economic, technical, infrastructural and personnel-related factors. The results corroborates with Aiyamenkhue (2012) which reports that the Nigeria university system is bedeviled with the challenges of poor infrastructure (inadequate classrooms and teaching aids etc); paucity of quality teachers, poor or polluted learning environment and others. This presents a formidable challenge to the university system in positively and significantly contributing to addressing the problem of climate change. For instance, poor infrastructural base, human resource and environment could hinder teaching, research, technology generation, communication and dissemination of useful information on climate change adaptation. In turn, it could leads to poor adaptation to climate change as pointed out in Ozor et.al. (2010). Also, unfavourable government policies are inhibitors to the propagation and advancement of climate science and adaptation capacities in the institutions and the public in general. Ideally, government is expected to play the roles of setting priorities, participating and enacting laws that could enhance capacity and development needed for adaptation to climate change. Furthermore, lack of fund or grant for teaching, conducting research and outreach on climate change according to Obiora (2012) incapacitates the universities in taking leadership role for climate change adaptation in the country.

Conclusion

Results of the study show that capacities for research and outreach on climate change adaptation in the faculties of agriculture are weak. Relatively, no substantial programmes/workshops/conference, investment, researches and outreach have been implemented or carried out in the universities. Minimal responses and commitment to the challenges of climate change adaptation is only visible in one of the universities studied. Capacities for research and outreach are constrained by several issues ranging from economic, institutional, infrastructural and personnel related factors. Given the critical roles of universities as centers of learning, research and innovation, government should enact favourable policies, mandates and institutional supports that would encourage, spur and stimulate activities in the universities on climate change adaptation. The university system should internally put in place activities, strategies and programmes or projects that could attract external aids, collaboration and raise staff interest and motivation to acquire capacities and contribute to increase awareness, knowledge, skill and technology generation for agricultural adaptation to climate change.

Conflict of Interests

The authors have not declared any conflict of interests.

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Genetic characteristics and path coefficient analysis in ten groundnut varieties (*Arachis hypogaea* L.) evaluated in the Guinea Savannah agro-ecological zone

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Nine improved varieties of groundnut developed at the Institute of Agricultural Research, Samaru and one locally cultivated variety were evaluated for their breeding potentials in the Guinea Savannah agro-ecological zone. Considerable variability was observed for basal stem diameter, biological yield, days to first and 50% flowering, plant height, number of leaves/plant, branches/plant and100-seed weight, showing a wide scope for improvement through selection. Coefficient of variation at phenotypic and genotypic levels were close in magnitude for number of branches/plant, plant height, days to first flowering and grain yield suggesting the presence of additive gene effects. High heritability estimates coupled with genetic advance were noted for number of branches/plant, plant height, days to first flowering and grain yield. Correlation studies revealed that grain yield correlated positively with all except the phenological traits. The path analysis implicated biological yield, failed pegs/plant, number of leaves/plant, and basal stem diameter as having substantial influence on grain yield in groundnut. Thus, selection of breeding lines based on the biological yield, failed pegs, number of leaves/plant and basal stem diameter could give a better scope for maximum grain yield in groundnut. Considering the grain yield, four of the varieties, ICIAR, SAM NUT 22, SAM NUT 23, SAM NUT 21 and SAM NUT 11 were identified as promising in Makurdi environment.

Key words: Grain yield, *Arachis hypogaea* L., morphological traits, genetic advance.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the most important legume crops cultivated in the sub-Saharan Africa for cheap source of vegetable oil, good quality feedstuff, improvement of soil health through nitrogen fixation as well as a source of fuel for the rural population. In developing countries such as Nigeria where the cost of animal protein is prohibitive, groundnut serves as a good alternative source of animal protein for improving the nutritional status of Nigerians (Asibuo et al., 2008). Groundnut (also called peanut) is an ancient oilseed crop which belongs to the family, Leguminosae and subfamily Papilionoidae. Weiss (2000) reported that South America is credited as the primary centre of diversity of groundnut but presently, its production has spread to other parts of

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the world. Globally, the leading groundnut producers includes, India (33.4% of global production) China (27.80%), USA (9.3%), Senegal (4.2%), Indonesia (4.2%), Nigeria (3.3%), Myanmar (3.0%), Sudan (2.7%) and Argentina (2.0%) (Isleib et al., 1994). Groundnut is a bio-energy feedstock that supplies most of the important food components. Compared to other sources of food like milk (cow), egg (fowl), beef, mutton, redgram, processed groundnut gives protein (25.33%), carbohydrate (10.2%), fats (40.5%), and caloric value (5000 to 6000) (Wrenshall, 1949). Groundnuts are rich sources of vitamins such as Vitamin E and the members of the B-complex, especially thiamine, riboflavin, and nicotinic acids, but the amounts of Vitamins A, C, and D are negligible (Wrenshall, 1949; Talawar, 2003). Economic analyses of this crop revealed its prospects as a major source of income to farmers (Awoke, 2003; Taru et al., 2010).

Okolo and Utoh (1999) reported that the average yield of groundnut in Nigeria per ha is within the range of 500 to 3000 kg compared with China where the average ton per ha has reached 1.4 metric (FAO, 2004). One possible way to wean groundnut from subsistence farming and integrate it into a commercially important crop as in the days of groundnut pyramids (Echekwu, 2003), there is need to develop high yielding varieties to replace the existing traditional ones. In this regard, efforts have been made at the Institute for Agricultural Research, Samaru, Nigeria to develop some new varieties of groundnut but their yielding potentials have not been tested under the Guinea Savannah agro-ecological zone.

Knowledge of the genetic variability in a population and partitioning the variance into the components provides useful information for improvement of the desirable traits. Coefficient of variation at genotypic and phenotypic levels, heritability

and genetic advance have been calculated for different yield parameters in groundnut by several research workers (khan et al., 2000; Meta and Monpara, 2010; Zaman et al., 2011) and have shown the importance of these parameters in enhancing success in a planned breeding program. High heritability estimate coupled with high genetic advance for a character could serve as a better criterion for selection (Johnson et al., 1955). Correlation is a biometrical approach which brings out the intensity of the association between two pairs of characters and provides information on those components that could serve as criteria for selection of candidates in a breeding program. Traits that are positively correlated with yield are considered effective because selection for such traits would result in the simultaneous improvement in yield (Mahalakshmi et al., 2005; Zaman et al., 2011; Khan et al., 2000).

Path analysis provides an efficient way of partitioning the correlation coefficient into direct and indirect effect to allow the selection of traits that have direct implications for yield (Dewey and Lu, 1959). Khan et al. (2000) reported that the 100-kernel weight had the highest direct positive effect on pod yield, followed by pods per plant and sound mature kernel, whereas, the study by Zaman et al. (2011) showed that seed yield was influenced by number of mature pods per plant, followed by nut size, shelling percentage, days to 50% flowering and days to maturity.

The objective of the present study was to evaluate 10 groundnut varieties for genetic variability, genetic parameters, heritability and genetic advance to provide information that might be useful for groundnut breeding program.

MATERIALS AND METHODS

The experimental materials comprised nine improved varieties of groundnut viz, SAM NUT 10, SAM NUT 11, SAM NUT 21, SAM NUT 22, SAM NUT 23, ICIAR 19 BT, NC-7, GH 119-20, and ICGV 93030 were collected from Institute for Agricultural Research, Samaru, Zaria, and one local variety (OLAMU). These varieties were selected based on their promising agronomic attributes. Evaluation of the varieties was done during the 2010 cropping season at the Teaching and Research Farm of the University of Agriculture, Makurdi (Lat. 7°41' N, Long. 8°35' E), Nigeria. Makurdi falls within the Southern Guinea Savannah agro-ecological zone. The experiment was laid in a randomized block design with four replications. The plot size was 5 × 4 m, with four ridges in a plot, and the distance between one plant and another within a row and between rows was maintained at 0.30 and 0.50 m, respectively. Observations were taken randomly on four plants in the two middle rows. All standard agronomic practices (viz, weeding, fertilization, etc) and insect control were applied to ensure the full expression of the varieties potentials. Harvesting was done 116 days after planting, sun-dried for 5 days and the biological yield (grain weight plus Haulm weight) determined before the nuts were decorticated. Other observations taken included plant height (cm), number of leaves/plant, number of branches/plant, basal stem diameter (cm), pods/plant, 100-seed weight and grain yield/plant (g). Data collected on the following variables were subjected to analysis of variance (ANOVA) using Genstat Discovery Edition 3 software, and significant means separated using least significant difference as described by Obi (1996). Heritability was estimated using the procedure of Singh and Chaudhury (1979), genetic advance was calculated as a percentage of the mean at 5% selection intensity, while path coefficient analysis was calculated according to Dewey and Lu (1956) to partition the total correlation into direct and indirect effects using Analysis for Moment of Structures for Windows Version 16 (AMOS Development Corp., House, USA) software program.

RESULTS AND DISCUSSION

The result obtained from the ANOVA is presented in Table 1. The result showed significant differences among the varieties for all the characters studied except biological yield and failed pegs indicating the presence of large magnitude of genetic variability. Conversely, biological yield and failed pegs however showed no significant differences evidencing low variation in these traits. Our results are comparable with the reports of Saleh and Masiron (1994) who also found highly significant differences in pod yield, kernel yield, 100-seed weight, number of pods/plant and days to flowering and

Table 1. Characteristics of 10 groundnut varieties evaluated during 2010 planting season in Makurdi.

Variety	BSD	BY	DFF	D50%	FP	GY	HT	NOB	NOL	SPP	100-SW
SAM NUT 10	5.26	161.00	26.25	27.50	108.00	24.75	32.00	26.50	998.0	2.00	31.20
SAM NUT 11	5.50	175.00	24.25	25.25	209.00	34.00	45.78	22.00	758.0	2.00	48.70
SAM NUT 21	5.28	144.00	26.25	28.00	246.00	33.75	32.50	23.75	809.0	2.00	44.60
SAM NUT 22	6.18	170.00	24.50	25.25	206.00	38.75	59.25	23.25	993.0	2.00	44.60
SAM NUT 23	5.15	120.00	22.75	25.00	140.00	33.50	49.30	8.75	247.0	1.98	42.50
ICIAR 19 BT	5.85	390.00	23.25	25.00	62.00	39.00	75.00	7.88	222.0	2.00	35.00
NC-7	5.05	123.00	25.00	25.50	117.00	28.25	48.00	9.10	247.0	2.00	43.70
GH 119-20	5.45	91.00	24.25	24.75	82.00	21.25	73.25	7.70	213.0	2.00	30.00
ICGV	5.03	116.00	25.25	26.25	173.00	28.25	45.10	14.32	624.0	2.00	43.00
OLAMU	5.97	95.00	25.25	25.61	86.00	26.35	57.26	10.04	314.0	1.97	42.00
Mean	5.47	158.00	24.71	28.81	143.0	30.79	51.82	15.33	542.0	1.99	40.50
F-LSD$_{(0.05)}$	0.4898	NS	0.996	0.747	NS	6.875	6.819	1.875	221.3	NS	11.16
CV	6.20	107.30	2.00	2.00	64.10	15.40	9.10	8.40	26.80	1.10	18.90

BSD = Basal stem diameter (cm), BY = biological yield, DFF = days to first flowering, D50F% = days to 50% flowering, FP = failed pegs, GY = grain yield/plant (g), HT = plant height (cm), NOB = number of branches/plant, NOL = number of leaves/plant, SPP = seeds/pod, 100-SW = 100-seed weight (g).

no significant difference in shelling percentage among the entries evaluated. Similarly, findings were also reported by Meta and Monpara (2010) and Zaman et al. (2011).

Among the entries evaluated in the present study, ICIAR 19 BT gave the highest grain yield (39.0 g/plant). This was closely followed by SAM NUT 22 (38.75 g/plant), and SAM NUT 11 (34.0 g/plant), while GH119-20 (21.25 g/plant) had the least grain yield. Similarly, OLAMU (95.00 g/plant) and ICIAR 19 BT (390.0 g/plant) produced the least and highest biological yields, respectively. The variety, SAM NUT 11 had the heaviest kernel with average 100-seed weight of 48.70 g. This was followed by SAM NUT 21 and SAM NUT 22 with average 100-seed weight of 44.60 g each. Variety GH119-20 (30.0 g) recorded the lowest kernel weight when average 100-seeds weight was considered. A wide range of variation was observed for number of leaves/plant (180.0 to 1470.0), biological yield (71 to 1140.0) failed pegs/plant (24.0 to 464.0) and plant height (28.0 to 90.0) as shown in Table 1.

Coefficient of variation at both genotypic and phenotypic levels was relatively high for number of branches/plant, failed pegs/plant, biological yield/plant, plant height, number of leaves/plant, 100-seed weight, days to first flowering and grain yields/plant (Table 2), evidencing high variation in the material.

Apparently, grain yield/plant, number of branches/plant, days to first flowering as well as days to 50% flowering recorded genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) values that were comparable in magnitude suggesting the minimum influence of environment on the expression of these traits. This result indicates that the phenotypic variation observed in the material was largely due to genotypic effects. Whereas, the magnitude of PCV was considerably higher than GCV for biological yield and failed pegs/plant suggests the preponderances of environmental effects. Consequently, the relatively high environmental coefficient of variation (ECV) observed in biological yield, failed pegs, number of leaves/plant and 100-seed weight shows higher environmental influence than genetic factor controlling these characters.

Good estimate of heritability is a useful tool that helps the breeder to determine traits that can serve as criteria for selection of parental lines in a breeding program. According to Allard (1960), heritability is the proportion of the genetic variation that can be attributed to genetic causes. When considered alongside with genetic advance, heritability estimates give a better assessment of the reliability of the traits and allows for easy prediction of the genetic progress to be achieved in a breeding program (Johnson et al., 1955). In the present study (Table 2), number of branches/plant (97023) had the highest heritability estimate, followed by days to first flowering (96.30), plant height (90.43 cm), days to 50% flowering (81.69), grain yield (56.52 tons/ha), and basal stem diameter (56.0), in that order. Meta and Monpara (2010) reported high heritability in plant height and days to maturity. While 100-seed weight and number of leaves/plant gave moderate heritability values and low heritability was obtained for failed pegs and biological yield. Expectedly, number of branches/plant (101.11), plant height (54.51 cm), days to first flowering (28.60) and grain yield (27.13 g/plant) had high genetic advance suggesting the presence of additive gene effects. Effective selection is only possible when the additive gene effect is substantial and environment relatively low. Thus, these results showed that selection of breeding lines based on number of branches/plant, plant height, days to first flowering and grain yield would be more

Table 2. Basic statistics and estimates of genetic components for 10 groundnut varieties evaluated during 2010 planting season at Makurdi.

Character	Range	Mean	MS	δ^2_{ph}	δ^2_g	δ^2_e	PCV	GCV	ECV	H^2B (%)	GA
Basal stem diameter	4.50 - 6.40	5.47	0.65**	0.25	0.14	0.11	9.14	6.84	6.06	56.0	10.55
Plant height	28.0 - 90.0	51.82	853.75**	229.95	207.94	22.01	29.26	27.83	9.05	90.43	54.51
Number of leaves/plant	180.0 - 1470.0	542.0	432037**	26647	5520	21127	30.12	13.71	26.82	20.72	12.86
Number of branches/plant	6.0 - 28.0	15.33	234.56^{NS}	59.89	58.23	1.66	50.48	49.78	8.41	97.23	101.11
Days to 50% flowering	24.0 - 28.0	28.81	4.91**	1.42	1.16	0.26	4.14	3.74	1.77	81.69	6.96
Days to first flowering	22.0 - 27.0	24.71	5.34**	12.69	12.22	0.47	14.42	14.15	2.78	96.30	28.60
100-seed weight	30.0 - 60.0	40.50	155.96**	82.83	24.38	58.45	22.47	12.19	18.88	29.43	13.62
Failed pegs	24.0 - 464.0	143.0	15607^{NS}	10186	1807	8379	70.58	29.73	64.01	17.74	25.79
Seeds/pod	1.90 - 2.0	1.99	0.00^{NS}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biological yield	71.0 - 1140.0	158.0	30011^{NS}	30011	1072	28939	109.64	2.07	107.67	3.57	5.81
Grain yield/plant	13.0 - 48.0	30.79	138.73**	51.47	29.09	22.38	23.30	17.52	15.36	56.52	27.13

* and ** indicates significance at 5 and 1%, respectively. NS = Non-significance.

Table 3. Correlation coefficients of 10 groundnut varieties evaluated at Makurdi during the 2010 planting season.

Character	BSD	PHT	NOB	NOL	FP	DFF	D50F	100-SW	BY	GY
Basal stem diameter`(BSD)	1	0.55	0.06	0.11	-0.11	-0.19	-0.34	0.01	0.37	0.41
Plant height (PHT)		1	-0.67*	-0.61	-0.58	-0.66*	-0.81**	-0.35	0.38	0.11
Number of branches/plant (NOB)			1	0.98**	0.68*	0.60	0.67*	0.22	-0.18	0.19
Number of leaves/plant (NOL)				1	0.67*	0.58	0.61	0.22	-0.05	0.20
Failed pegs (FP)					1	0.30	0.42	0.72*	0.23	0.41
Days to first flowering (DFF)						1	0.84*	-0.01	-0.37	-0.41
Days to 50% flowering (D50F)							1	0.00	-0.14	-0.14
100-seed weight (100-SW)								1	-0.18	0.50
Biological yield (BY)										0.65*
Grain yield (GY)										1

* and ** indicates significance at 5% and 1%, respectively.

rewarding than using biological yield, days to 50% flowering which had low genetic advance. The tendency of some of the yield components that gave high heritability values as found in the present study to be utilized as the criteria for selection is espoused by the reports of other legume crops workers (Manggoel et al., 2012; Shaahu et al., 2012; Vange and Egbe, 2009).

The correlation coefficients of 10 varieties of groundnut are presented in Table 3. Grain yield was positively associated with all the traits except the phenological traits (days to first flowering and days to 50% flowering each. This result appears to suggest that grain yield is linearly related to all the traits that have positive correlation with it, and

Table 4. Direct and indirect effects of yield traits on grain yield of 10 groundnut varieties evaluated during 2010 planting season.

Character	1	2	3	4	5	6	7	Total indirect effects	Total correlations
Basal stem diameter (cm)	**0.44**	-0.23	-0.06	0.05	0.00	-0.09	0.30	-0.03	0.41
Plant height (cm)	0.24	**-0.41**	0.72	-0.28	-0.03	-0.45	0.31	0.51	0.11
No. of branches/plant	0.03	0.28	**-1.07**	0.45	0.02	0.53	-0.03	1.28	0.19
No. of leaves/plant	0.05	0.25	-1.05	**0.46**	0.02	0.52	-0.04	-0.25	0.20
100-seed weight (g)	0.00	0.14	-0.24	0.10	**0.07**	0.56	-0.15	0.41	0.50
Failed pegs	-0.05	0.24	-0.73	0.31	0.05	**0.78**	-0.19	-0.37	0.41
Biological yield/plant	0.16	-0.16	0.04	-0.02	-0.01	-0.18	**0.81**	0.17	0.65*

R = 0.29. Figures in bold print are the direct effects. *Significance at 5% probability.

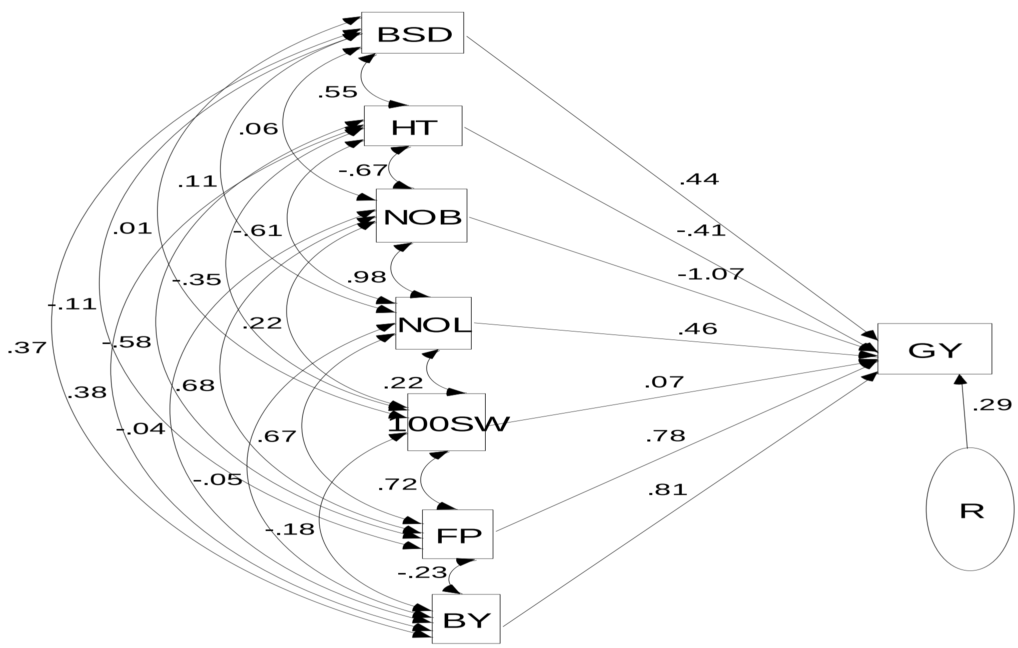

Figure 1. Path analysis showing the cause and effect relationship of yield and yield components of 10 groundnut varieties evaluated during the 2010 planting season.

illustrates the fact that increase in these traits would lead to increase in grain yield (Manggoel et al., 2012, Sadeghi and Niyaki, 2012; Zaman et al., 2011; Khan et al., 2000). This result on the interrelationship of traits appears to suggest that although the phenological traits gave high heritability estimates, however, its negative correlation with grain yield makes it a poor criterion for selection. This inference is further corroborated by the low genetic advance values obtained for these traits. Significant correlation was observed between grain yield and biological (r = 0.65*), indicating that selection based on this trait would improve grain yield. Kobraee et al. (2010) had reported significant correlation between grain yield and biological yield in Chickpea. Meta and Monpara (2010) also observed a negative association between grain yield and days to 50% flowering. Highly significant correlation was recorded for number of branches/plant and number of leaves/plant (r = 0.98**), whereas the association between branches/plant and plant height was negative (r = -0.67*). Other correlations between pairs of traits that are of some interest to the breeder are shown in Table 3.

The result of the path analysis showing the direct and indirect effects of characters on grain yield is shown in Table 1. Path analysis revealed that biological yield/plant (0.81), failed pegs/plant (0.78), number of leaves/plant (0.46), and basal stem diameter (0.44) exerted positive and highest direct influence to grain yield (Figure 1), indicating that selection based on these traits will be helpful in improving the grain yield of groundnut. While the contribution of 100 seed weight to grain yield was positive but negligible. This result is in contrast to the reports of Khan et al. (2000) and Manggoel et al. (2012) who reported that 100-seed weight has substantial influence on grain yield. However, number of branches/plant and plant height contributed negatively to grain yield, implying their poor association with grain yield.

Conflict of Interests

The authors have not declared any conflict of interests.

Conclusion

This study has revealed the extent of genetic variation inherent in the studied materials. This variation is sufficient to permit the start of a selection programme. Based on grain yield, five promising varieties have been identified for the Guinea Savannah agro-ecological zone. These varieties include ICIAR, SAM NUT 22, SAM NUT 23, SAM NUT 21 and SAM NUT 11. Further studies are needed especially multi-location trials to establish their breeding potentials.

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Short Communication

Evaluation of substrates for multiplication of bio-agent, *Trichoderma viride*

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An experiment was conducted using locally available substrates to mass multiply *Trichoderma viride* on different substrates. Experiment was conducted during June to August for 2 years (2011 and 2012). Result revealed that sporulation was observed after 5 days of incubation in cowdung, followed by all other substrates after 7 days of incubation. Maximum sporulation (51.50×10^8 cfu g^{-1}) was observed in cowdung on 15th day, which is followed by rice bran, talc powder, rice straw, banana leaf, arecanut leaf, coconut leaf, neem cake and vermicompost with 48.12×10^8, 44.5×10^8, 39.00×10^8, 29.00×10^8, 21.4×10^8, 18.2×10^8, 15.5×10^8 and 10.45×10^8 cfu g^{-1}, respectively. Nevertheless, up to 90 days of observation, significantly superior growth (39.1×10^8 cfu g^{-1}) was noticed on cowdung in comparison to other substrates.

Key words: *Trichoderma viride*, substrates, mass multiplication.

INTRODUCTION

Out of various strategies for management of diseases, chemicals have been so far found to be most dominating. Although this has resulted in increase in production of agricultural commodities but there is deleterious effects of chemical pesticides on crop ecosystems. Increase in public awareness about these problems, has stimulated research on biocontrol agents. Also, biological control of plant diseases has got momentum as it offers many advantages over the conventional methods of control (Mukhopadhyay, 1994). Among the biocontrol agents, *Trichoderma* spp. have shown exceptionally good promise in the management of a wide range of plant pathogens (Cook and Baker, 1983) and are acclaimed as effective, eco-friendly and cheap, nullifying the ill effects of chemicals. However, it is also known that these biocontrol agents should be native for their good efficacy against their target pathogens. But the utilization of these bioagents has been hampered mainly because of non-availability of effective methods of mass production technology. Different workers have used different substrates such as composted coir pith, coffee (Rukmani and Mariappan, 1993), coffee wastes and poultry manures (Sawant et al., 1995), neem cake, coir pith, farmyard manure (FYM), and decomposed coffee pulp (Saju et al., 2002), well-decomposed FYM, dried cowdung, gobar gas slurry (GGS), sorghum grain floor,

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Table 1. Effect of different substrates on the population of *Trichoderma viride*.

S/N	Substrates	Mean population ($\times 10^8$ cfu g^{-1})						Per cent decrease over initial population
		Days of incubation						
		15	30	45	60	75	90	
1.	Arecanut leaf	21.40^f	19.2^f	15.6^f	13.4^f	11.2^f	9.4^f	56.07
2.	Banana leaf	29.00^e	28.4^e	26.2^e	24.1^e	21.2^e	17.7^e	38.96
3.	Coconut leaf	18.2^g	16.7^g	15.7^g	12.8^g	9.3^g	7.3^g	59.89
4.	Cowdung	51.50^a	49.3^a	47.7^a	44.6^a	41.8^a	39.1^a	24.08
5.	Neem cake	15.5^h	14.9^h	13.3^h	11.5^h	9.2^h	6.5^h	58.06
6.	Rice bran	48.12^b	47.9^b	45.8^b	41.4^b	38.2^b	35.2^b	26.85
7.	Rice straw	39.00^d	37.2^d	35.9^d	32.7^d	29.3^d	25.4^d	34.87
8.	Talc powder	44.5^c	42.3^c	40.7^c	38.2^c	36.8^c	34.7^c	22.02
9.	Vermicompost	10.45^i	9.4^i	8.6^i	6.8^i	5.7^i	4.9^i	53.11
	SEd±	0.07	0.08	0.08	0.08	0.08	0.08	
	C.D.(0.05)	0.15	0.17	0.17	0.17	0.17	0.17	

wheat bran, groundnut shell, molasses, saw dust, wheatstraw, mushroom bed straw, neem cake, peat soil, fly ash and talc (Sangle and Bambawale 2005), cowdung, neem cake, coir pith, sorghum grain, saw dust, and rice bran (Rini and Sulochana, 2007), vegetable wastes, fruit wastes, crop wastes, FYM and poultry manure (Simon, 2011), vegetable waste, fruit juice waste, sugarcane baggase, rotten wheat grains (Babu and Pallavi, 2013) for mass production of *Trichoderma* spp.

The present study was therefore carried out to identify a suitable, cheaper and locally available substrate for mass multiplication of *Trichoderma viride*.

MATERIALS AND METHODS

The trial was conducted in the laboratory of Central Plantation Crops Research Institute, Research Centre, Kahikuchi, Guwahati. Nine substrates *viz*., arecanut leaf, banana leaf, coconut leaf, cowdung, rice bran, rice straw, neem cake, vermicompost and talc powder were evaluated for mass multiplication of *T. viride* using the procedure of Kousalya et al. (1990). Rice straw, arecanut, coconut and banana leaves were chopped into small bits (2 to 3 cm) and then pre-soaked for overnight as per the procedure of Kousalya et al. (1990). The treatments were maintained following a completely randomized block design with 20 numbers of packets for each treatment for 3 months. After incubation, the samples were drawn and population of *T. viride* was enumerated in *Trichoderma* selective medium (Elad and Chet, 1983). Colony forming units (cfu 10^8/g) were estimated by dilution plate technique (Pramer and Schimidt, 1956) after every 15 days interval and the data was analyzed statistically. The study was conducted during the period from June to August for 2 years (2011 and 2012).

RESULTS AND DISCUSSION

The growth of *T. viride* on different substrates is enumerated in the Table 1. Sporulation was observed after 5 days of incubation in cowdung as compared to 7 days after incubation, in all other substrates. Maximum sporulation (51.50×10^8 cfu g^{-1}) was observed in cowdung on 15th day, which was followed by rice bran (48.12×10^8 cfu g^{-1}). The result is in consistent with the findings of Saju et.al. (2002). Other substrates in order of merit were; by talc powder, rice straw, banana leaf, arecanut leaf, coconut leaf, neem cake and vermicompost with 44.5×10^8, 39.00×10^8, 29.00×10^8, 21.4×10^8, 18.2×10^8, 15.5×10^8 and 10.45×10^8 cfu g^{-1}, respectively. A significant difference was observed among all the substrates tried throughout the experiment period that is, starting from 15 to 90 days of incubation. The enhanced effect of cowdung might be due to the supplementation of NPK and other nutrients to the substrate. FYM was reported to be an effective substrate for growth and multiplication of both *Trichoderma harzianum* and *T. viride* (Kousalya and Jeyarajan, 1988). Sethuraman (1991) reported that the increase in *Trichoderma* population was due to application of organic amendments *viz*., rice bran and FYM in soil. Nevertheless, up to 90 days of observation, significantly superior growth (39.1×10^8cfu g^{-1}) was noticed on cowdung followed by rice bran (35.2×10^8 cfu g^{-1}), talc powder (34.7×10^8 cfu g^{-1}) and rice straw (25.4×10^8 cfu g^{-1}). Vermicompost recorded continually lower population as compared to other substrates (Table 1). The study also indicated that there is decreasing trend of population of *T. viride*. The decrease in population of *T. viride* was observed after 15 days onwards. In all the substrates, invariably, there was a reduction in the population at 90 days after incubation from initial level, which ranged between 22.02% in talc powder to 59.89% in coconut leaf.

The result of study indicated that the locally available substrates *viz*., cowdung, rice bran, rice straw, banana leaf and arecanut leaf has got immense potential for growth and sporulation of the antagonistic fungi, *T. viride,* which can be successfully used in agricultural field for management of soil borne diseases.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

A case study of rooftop rainwater harvesting of Renavi village in Sangli District of Western Maharashtra: New approach of watershed development in India

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The population in India is expected to stabilize around 1640 million by the year 2050, as a result, gross per capita water availability will decline from 1820 m^3/year in 2001 to as low as ~ 1140 m^3/year in 2050. Thus, the growing concern about water scarcity challenges us to think of alternative solutions to avoid the current problem of water scarcity. The micro-watershed development, which ensures availability of water for agriculture and domestic purpose and the roof-top rain water harvesting measures, which provide water for domestic consumption are often suggested as solutions for overcoming water shortage in drought prone areas of India. This article presents the success story of rooftop rain water harvesting program in Renavi village in Sangli District of Maharashtra, India. The potential assessment of the village revealed that, approximately 20 lakh liters of water collected from rooftops, will satisfy the demand of a population of 1300 for at least 78 days. This estimation is as per the United Nations standard, which prescribes the requirement of 20 liters of water (cooking and domestic uses) per person per day in India.

Key words: Roof top, rain water harvesting, water scarcity.

INTRODUCTION

A leaf stretched out from its branch, catches a drop of rain, channeling water towards the ground as its base, for millions of years; this simple rain collection technique has fueled life in many reaches of this planet (Neuman et al., 2007). Accordingly, roof-top rain water harvesting techniques are most simple, but neglected in the water harvesting programs. It requires two basic elements: a catchment, which is a broad surface to catch the rain and method or device for storing the captured rain (Thomas, and John, 1985). Roof top rain water harvesting has become inevitable as fresh and good quality water necessary for human consumption, social, economic and cultural needs and for environmental requirement is rapidly becoming scarcer.

In the 1950's only a handful of countries faced water shortages. In the nineties, the numbers of countries

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facing the water deficit has grown to 26 with the populations of 300 million (Abu-zeid, 1998). The population of India is expected to stabilize around 1640 million by the year 2050, as a result, gross per capita water available will decline from ~ 1140 m^3/year in 2050. Total water requirement of the country for various activities around the year 2050 has been assessed to be 1450 m^3/year. This is significantly more than the current estimate of utilizable water resources potential (1122 m^3/year) through conventional development strategies (Gupta and Deshpande, 2004).

In a bid to conserve rain water and recharge groundwater for drought proofing, the Indian government has mounted the watershed approach to rainwater harvesting and conservation in a big way. Over US$ 3.5 billion are being spent by the government, bi- and multi lateral agencies. However, droughts have kept pace with the investment increasing in frequency (Sharma, 2001). Rooftop rainwater harvesting is one of the optimistic and economically viable methods of rainwater harvesting. Rooftop rainwater is allowed to percolate in the ground and become helpful to increase ground water recharging groundwater aquifers.

In the case of India, it was found that the success stories of watershed program happen in villages where people's participation remains active. Peoples participation in socio-environmental issues remains key to community centered development, and has remained largely stuck in the 'you participate in my program mode' (Sharma, 2001). In this context, the people centered rooftop rain water harvesting movement play an important role in conservation of water resources in Renavi village of Khanapur block of Sangli District, Maharashtra, the village came into limelight during our study visit. The present study was conducted with the objectives below:

(1) To study rain water harvesting potential of Renavi village
(2) To understand the participatory approach of collective action of people in rooftop rainwater harvesting
(3) To provide remedies for sustainable benefits of rain water harvesting models.

METHODOLOGY

A general village survey was carried out to assess the rooftop area of houses; number of houses were collected through personal discussion with beneficiaries and Grampanchayat* records. The information related to the geographical location of Sangli district and monsoon collected from socio- economic review of Sangli District respectively. For the sake of reliability, the quantitative data was collected from a focus group discussion.

Background of study

The Sangli district is located around latitude 16° 51' 6" N and 74° 33' 36" E longitude. This region falls in the semi arid tract of Deccan plateau (Sankpal, 2003). The district comprising the Tasgaon, Kavathemahankal, Atpadi, Khanapur and Kadegaon block is grouped under the drought prone regions. In the early parts of 2001 – 2003 the ground water level dropped in an alarming rate in 494 villages out of 730 villages (67.67%) (Jalja, 2005). In same period, watershed development projects were carried out in the 100 villages, where peoples' participation play important role. During recent decades the planners the government, stake holders and donor agencies have perceived that the goal of social development cannot be achieved unless the beneficiaries participate in the entire process of preparation, implementation and follow up on the development of plans and programs (Robert, 1994). The people's participation remains considerably high (Table 1 and Figure 1).

Funding of rainwater harvesting program in Renavi village of Sangli District

Rainwater harvesting is a method raised as the optimistic and economically viable method of water harvesting became compulsory for buildings, apartments and entertainment centers etc. having rooftop area of >1000 m^2 for urban areas. The rural area of India and other nations also having wide chances to collect rainwater from the rooftops with low investment like the present case. The funding distribution is given in Table 3.

A total of Rs. 6, 04,000 was invested as contribution by Government agencies and villagers (Table 3). The capital cost for harvesting roof and surface water structures in Delhi is estimated at Rs. 2.5 crore per 4 million liters per day (mlpd) as compare to the average cost of Rs. 4 crore mlpd for water obtained from Himalaya reservoirs and Rs. 3 crore mlpd water received through canals (Bannerjee et al., 2001). This example simply proves that this technique is feasible in both assured as well as drought prone areas. The statistics of the tank construction as per water demand of family and economic viability is given in Table 4.

It is noted that as the construction cost of the 5000 L tank is only Rs.11, 700 (260 US Dollars) these costs are reduced with increasing capacity of the tank. The Government of Maharashtra granted limited finance to this activity. For the sustainability of the Rain Water Harvesting projects, the following components are essential for storage of the harvested water.

Rainfall data collection

Rainfall data was collected from the Jalja Report. The Renavi village is situated in the Khanapur block in the eastern part of Sangli District, whose annual rainfall is 558 mm (Jalja, 2005). For the present research, the annual rainfall of the year 2005 which was 527 mm have been considered for carrying out potential assessment.

Coefficient of runoff

Coefficient of Runoff (Cr) for any catchments is defined as "The ratios between volumes of water that runs off and that of total volume of rain that fall on the surface" (Gould and Nissen, 1999).The runoff coefficients for the different structures are given in Table 2. In the village survey, a maximum number of houses had *Chawl* (the perfectly finished sheets of soil) System. Taken into account the rooftops, the 0.8 Runoff Coefficient is taken as a standard for the present research.

$$\text{Cr} = \frac{\text{Volume of runoff water}}{\text{Volume of rain water that fall on the surface}}$$

The run off coefficient of Renavi village has been taken as 0.8

Table 1. Block-wise rainfall data (mm) of drought prone areas of Sangli District 2000-2006.

Block	Average annual rainfall (mm)
Miraj	487
Kavate-Mahankal	493
Tasgaon	461
Jat	415
Khanapur	558
Atapadi	237
Kadegaon	545
District	459

(Source: Jalja- Report on Sangli District Watershed Program, 2000-2006) (Jalja and Sangali, 2008).

Table 2. Coefficient of runoff.

S/N	Type of roof top	Runoff coefficient
01	Galvanized Sheets	0.9
02	Asbestos	0.8
03	Cement concrete	0.7
04	Grass	0.0

*Source-Government Resolution No./Govt. of Maharashtra VIDE LT. CHE/PP/36.

Table 3. Funding of Rainwater harvesting project in Renavi Village.

S/N	Government funding	Villagers funding	Total cost of the project
1	Rs. 5,30,000	Rs.74,000	Rs.6,04,000

(Source: Grampanchayat Records: 2004)

which is taken as standard for the designing of *pucca (well built up)* rooftop catchments system.

Potential of rain water supply

Potential is calculated by using the formula given below (Gould and Nissen, 1999):

P = R x A x Cr

Where R = mean annual rainfall in meter, A = catchment area in m^2, Cr = coefficients of runoff.

RESULTS AND DISCUSSION

Rain water harvesting at Renavi Village

The annual rainfall of the year 2005 of Khanapur block which is 557 mm is considered for the research work. The village survey revealed that the Renavi village has 231 houses and total population is 1300. Of the total houses 108 houses (46.98%) having traditional rooftops, not suitable for collecting rain water. A total of 123 houses had suitable rooftops to collect water, out of which 70 houses were selected for rainwater harvesting program. While 53 more houses having suitable rooftop were used to harness the rainwater, but not included in the program (Table 5).

At present the water harvested from rooftops of the seventy houses, which is estimated to be 11, 63,616 L is used for recharging the 17 bore-wells and 4 dug-wells located near the housing area. It is proposed that if collected water is stored in the tank, then it will help to fulfill the drinking and cooking water related needs of most of the entire population of 1300 persons, for at least 45 days. This estimation is as per United Nations standards, which prescribes the requirement of 20 L of water per person per day. It is also proposed to provide the water harvesting structures to additional 153 houses, which provide to additional 53 houses, which would enable collection of additional 8, 55,848 L of water, which will in turn fulfill the above said need of the entire

Table 4. Budget for Sump/Tank construction.

Component	5000 Lts	6000 Lts	7000 Lts	8000 Lts	9000 Lts	10000 Lts
Tank	7600	8090	9070	9470	10380	10835
Filter unit	350	350	350	350	350	350
Gutter	3000	3000	3000	3000	3000	3000
Down and flush pipe	750	750	750	750	750	750
Total Cost	11700	12190	13170	13750	14480	14935
Cost per Lts* (In Rupees)**	2.34	2.04	1.88	1.7	1.61	1.49

*Lts- Liters of water, ** 1 US dollar = 45 Rupees of Indian currency.

Table 5. Rain water harvesting at Renavi Village.

S/N	Roof-top surface area(m^2)	Average roof-top surface area (m^2)	No. of Houses	% of Houses	Estimated Roof-top area (m^2)	Estimate of water harvesting (Lakh liters)
Houses with roof top rainwater harvesting structures. (Annual rainfall 527 mm.)						
1	50-70	60	4	5.71	240	1,01,184
2	40-60	50	20	28.57	1000	4,21,600
3	30-50	40	23	32.85	920	3,87,872
4	20-40	30	16	22.85	480	2,02,368
5	10-30	20	5	7.14	100	42,160
6	00-20	10	2	2.85	20	8,432
	00-70	39.42	70	100	2760	11,63,616
Houses without roof top rainwater harvesting structures. (Annual rainfall 527 mm.)						
1	50-70	60	8	15.09	480	2,02,368
2	40-60	50	6	11.32	300	1,26,480
3	30-50	40	12	22.64	480	2,90,904
4	20-40	30	23	43.39	690	2,90,904
5	10-30	20	4	7.54	80	33,728
	10-70	38.30	53	100	2030	8,55,848

(Based on authors field survey).

population for 33 more days. It was found that water table had risen by 4.15 m (on average) in the bore-wells which were connected to harvesting structures, and no significant change occurred in the bore-wells which were not connected to the rooftops (Table 6). Thus, rain water harvesting technique is an effective tool for satisfying the demand of domestic water.

Ground water quality assessment from the open well and bore wells in the Renavi village

Thirteen water samples were collected including 3 water samples from bore-wells which were not connected to the roof-tops. The results were compiled with the WHO and ISI values of drinking water standards. Analysis shows that, the water values for pH is ranging between 7.6 to 8.6, pH values found quite safe for drinking of the bore well water. Total Dissolved Solids (TDS) is 301 mg/L which is within permissible limits of WHO and ISI standards. The parameters such as Ca (Calcium), Mg (Magnesium), and Na (Sodium) were found within limits of WHO standards (Table 7). The slightly alkaline pH value 8.6 is recorded for the one sample which is not connected to the rooftop structure. The TDS value is recorded at 1213 mg/L, which is slightly on a higher side but within permissible limits of the ISI standards. Overall results of the physico-chemical analysis show that the quality of bore-wells is very soft and within the limits of WHO and ISI standards. In the context of the heavy contamination of surface and sub-surface fresh water reservoirs, the present case is very important. The brief analysis is given in the Tables 7 and 8.

DISCUSSION

Roof top rain water harvesting measures need to be

Table 6. “t” value for ground water table recorded in the year 2004.

Water table in Bore wells	Total Bore wells undertaken to study	Before commissioning rain water harvesting system A	After commissioning rain water harvesting system B	Difference in water Table A-B
Houses with rain water harvesting models	17	17.24 m	13.09 m	4.15 m
Houses without rain water harvesting models	13	16.96 m	16.07 m	0.89 m

(Based on authors field survey.)

Table 7. Physico-chemical analysis of selected parameters**.**

S/N	1 pH	2.EC (umohs)	3.TDS (mg/L)	4.T/HAR (mg/L)	5.T/ALK (mg/L)	6.Ca (mg/L)	7.Mg (mg/L)	8.Na (mg/L)	9.K (mg/L)
1	8.3	470	301	116	124	35.2	6.804	50	1
2	8.5	487	312	172	200	27.2	25.272	29	0.5
3	7.6	623	399	248	144	27.2	43.74	26	1.1
4	7.9	868	556	300	168	54.4	39.852	55	0.4
5	8.6	567	768	972*	176	329.6*	101*	43	0.6*
6	8.2	783	499	800*	144	157*	121.5*	194*	0.8*
7	8.3	748	479	270	168	28.8	48.114	32	0.5
8	8.2	1838	1213	692*	184	249.6*	16.524	65	0.7
9	8	212	657	344	204	64	44.712	52	6
10	8.3	801	513	220	360	11.2	46.656	136	0.5
11	8.4	755	483	240	200	41.6	33.048	71	0.9
12	8.2	530	339	152	168	33.6	16.524	44	0.3
13	8.4	467	391	308	132	75.2	29.16	99	2.2

* The water samples collected from the bore-wells not connected to rooftops. Kranti Co-operative Sugar Mill, Soil and Water analysis Laboratory Report, 2010.

Table 8. Ground water quality assessment between of Rooftop connected and not connected bore wells with WHO and ISI standards.

Parameter	WHO standards		ISI Standards		Observed Values	
	P	E	P	E	Minimum	Maximum
pH	7	8.5	7	8.5	7.6	8.6*
EC	-	-	-	-	212	1838*
TDS	-	-	500	2000	301	755
T/HAR	-	-	300	600	116	972*
T/ALK	75	200	200	600	132	360
Ca	50	150	75	200	11.2	329.6*
Mg	200	-	30	100	6.8	121*
Na	-	-	150	-	26	194*
K	-	-	-	-	0.3	2.2

P- Permissible Limits, E-Excessive Limits.* The higher values recorded from the water sample which was not connected to rooftops.

given priority in the drought prone areas and should be incorporated in the watershed development programs. As illustrated by this case, roof top rain water harvesting measures helps in fulfilling the domestic water need as well improving the ground water level by few meters. On the other hand, in some states of India such as Andhra

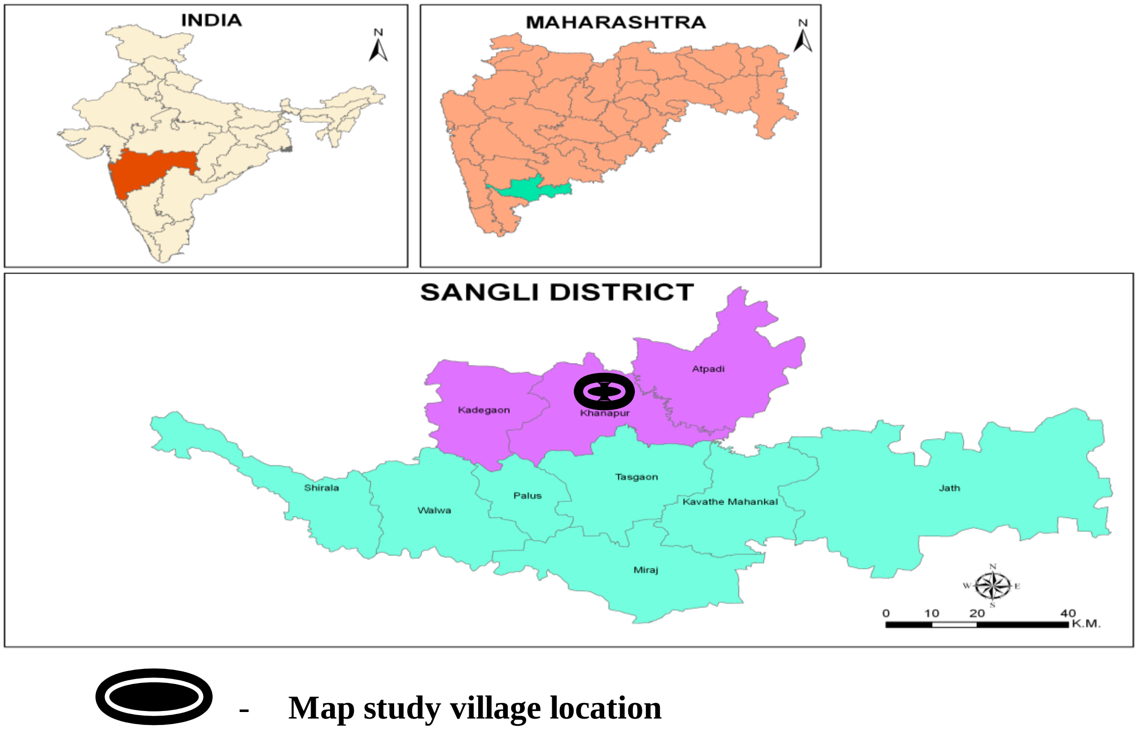

Figure 1. Map of study village location.

Pradesh, Madhya Pradesh, Gujrat and Rajashthan the level of fluoride in ground water is above the permissible limit (1.5 mg/L). In parts of the West Bengal of India and Bangladesh, the ground water also contains arsenic above the permissible limit of 50 micrograms / liter. In these situations also, roof water harvesting is desirable although there may be no shortage in groundwater. Rainwater is practically free of dissolved solids as well as arsenic and fluorides (report on rain water supply) (Athavale, 2003). Rain water harvesting techniques have the potential of reducing water scarcity. Technically, it is possible to drought proof the entire India, even if half of the average annual rainfall of 1170 mm is captured on 1.12 ha of land in each of the country's 5, 87,226 villages, then 6.57 million liters of rain water will be collected in each village, which can meet the annual cooking and drinking needs of a population of 1200 (The Ecological Foundation, 2003).

It is argued that due to consideration of gestation period and capital requirement, rainwater harvesting and water conservation measures must receive the highest priority followed by renovation and recycling to be followed by intra and then inter basin transfers in the last phase (Gupta and Deshpande, 2004). Across the globe, rainwater harvesting techniques are reappearing in a variety of individual, community and government projects .The government of Maharashtra VIDE LT. CHE/PP/36 dated 0.2002 has made compulsory for buildings, having area >1000 sq.km, to provide rainwater harvesting arrangements. Such provision plays vital roles in natural resource conservation. These types of models are highly practicable throughout countries where the region is faced with similar climatic conditions.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Allelopathic impact of aqueous extracts of *Eclipta alba* L. on germination and seedling growth of *Melilotus alba* Medik.

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Allelopathy refers to the beneficial or retardatory effect of one plant on another plant through the release of chemicals from plant parts by leaching, root exudation, volatilization, residue decomposition and other processes in both natural and agricultural system. Allelochemicals concentration in the producer plants may vary from each part. Allelopathic effect of different parts extract of *Eclipta alba* L. on seed germination and seedling growth of *Melilotus alba* Medik. was conducted under laboratory condition. The trial was replicated three times in completely randomized design with four concentrations (0.5, 1, 2 and 4%). Aqueous extracts of leaf, stem and root were prepared by soaking the powder of different parts in distilled water for a period of 24 h. The germination of seeds was recorded for 15 days and radical and plumule length were recorded. The result suggested that aqueous extract from leaves significantly inhibited not only the germination but also the radical and plumule length of seedlings. Stem and root extracts also suppress the germination and seedling growth as compared to control. However, treatment with higher concentration had negative effect on rate of germination, plumule length and radical length. Hence, it is suggested that *E. alba* L. has strong allelopathic potential and might be candidate for biological control of weeds.

Key words: Aqueous extract, biological control, *Eclipta alba* L., *Melilotus alba* Medik.

INTRODUCTION

Weeds are one of major constraints to plant production worldwide. Weeds affect crop growth and production that may be significantly reduced when weeds compete with them for light, water and minerals (Hussein, 2001). Existing weed control methods are either expensive or hazardous. Heavy use of chemical herbicides in most integrated weed management systems is a major concern since, it causes serious threats to the environment, public health and increase cost of crop production.

Therefore, alternative strategies against weed must be developed. Rice (1983) defined allelopathy as the effect of one plant on other plants through the release of chemical compounds in the environment. Brown et al. (1991) defined allelopathy as the direct or indirect harmful or beneficial effects of one plant on another through the production of chemical compounds that escape into the environment. Many of the phytotoxic substances that inhibit germination and growth have been identified from plant tissues and soils. These substances are termed

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allelochemicals (Whittaker and Feeny, 1977).

Allelochemicals not only govern various ecological processes such as productivity and vegetation patterning but are also important potential source for alternative agrochemicals, pharmaceuticals and biological control agents (Hirai, 2003; Cheema et al., 2004; Macias et al., 2007; Norton et al., 2008). Many plants have been studied for their allelopathy against crops and natural vegetation (Bais et al., 2003; Fujii, 2003; Weston and Duke, 2003; Kato-Noguchi, 2003; Hussain et al., 2004, 2005; Kato-Noguchi and Tanaka, 2006).

Uludag et al. (2006) reported that allelopathy involves both inhibitory and stimulatory effects. Borges et al. (2007) working on the allelopathic activity of *Virola surinamensis* suggested that radical and hypocotyls elongation of test species were more intensely inhibited than seed germination. The allelopathic properties of plants can be exploited successfully as tool for pathogens and weed reduction (Xuan et al., 2005). Carmo et al. (2007) reported that aqueous extracts from various parts of Brazilian sassafras (*Ocotea odorifera*) inhibited seed germination, root and shoot growth and chlorophyll content of sorghum seedlings. Le et al. (2008) observed the growth inhibitory effect of cucumber on various test species. Furthermore, it was also observed that inhibition increased with amplifying concentration of extract. Rua et al. (2008) tested foliar leaf extracts of *Sapium* against seed germination and seedlings growth and found that allelopathy does not contribute to Sapium's invasive success. Sisodia and Siddiqui (2007c) reported the phytotoxic or allelopathic effect of aqueous extract of weed, *Mikania micrantha.* Macias et al. (2007) suggested allelopathy as an alternate strategy for weed control. Siddiqui et al. (2009) observed the leaf extract of *Prosopsis juliflora* inhibited the germination, root length and shoot length of wheat Norton et al. (2008) stated that *Centurea* avoids grazing and gains competitive advantage due to allelopathy. It is obvious that allelopathy plays important role in natural and agro ecosystem. It can also be exploited for searching new bio-control agents for weeds and insects (Hirai, 2003; Carmo et al., 2007; Borges et al., 2007; Norton et al., 2008). The present study was conducted to explore the allelopathic potential of *Eclipta alba.*

MATERIALS AND METHODS

Preparation of aqueous extracts of leaf, stem and root of donor plant

Leaf, stem and root of *E. alba* were collected from the adjoining area of the University campus, Aligarh. The aqueous extract was prepared from fresh leaves, stem and roots of the donor plant (Kumari et al., 1985). The leaves stem and roots were shed dried and then stem cut into small pieces with knife and ground in a mixer for getting powder. The ground powder passes through 2 mm mesh sieve to get fine powder.

The leaf, stem and root powder were soaked in distilled water separately and kept for 24 h. Then, extract was filtered through Whatman No. 1 filter paper. The extract was diluted to obtain the concentrations of 0.5, 1, 2 and 4% while distilled water used as the control and stored in refrigerator in conical flasks until required.

Seed germination test (SGT)

Germination test was performed for the aqueous extracts of leaf, stem and root of donor plant. Healthy and uniform size of 10 seeds were selected and presoaked in distilled water for 24 h and then evenly placed on two layers of filter paper in sterilized Petri dish (9 cm diameter). 10 to 15 ml of aqueous extract of different concentration of aqueous extracts or distilled water for control treatment was added. The Petri dishes were placed in growth chamber (25°C). Treatments were arranged in a completely randomized design with three replications. Seeds were considered germinated upon radicle emergence. Germination was determined by counting the number of germinated seeds at 24 h intervals. Germination was recorded everyday for 15 days. Then, the root length and shoot length were recorded.

RESULTS AND DISCUSSION

In nature, many ecological ways are involved for releasing and transporting phytotoxins from allelopathic plants. Soaking in rain water, irrigation or even moist soil releases water soluble substances from living and/or dead plant parts that might have allelochemicals. The present study demonstrated the presence of allelochemicals in different parts of *E. alba* that strongly inhibited the germination and seedling growth (Figures 1 to 3). Maximum germination was reached in control (98%) and minimum (68%) was observed in 4% leaf extract. It was seen that different concentration of different parts of the donor plant significantly inhibited the germination of the test plant, especially by extracts obtained from leaves. This suggested that inhibitory effects on germination enhanced with increasing the concentration. The root and shoot growths of the test species were significantly reduced in all the treatments, especially in extract from leaf and those for higher concentration (Figures 2 and 3).

The minimum growth of root and shoot was 1.58 ± 0.03 and 4.36 ± 0.06, respectively. The results agree with those of Pereira et al. (2008) who observed that aqueous extracts of alfalfa leaves inhibited germination, radical and hypocotyls growth. El-Rokiek and Eid (2009) who found that the inhibitory effect of foliar extract of Eucalyptus on germination of some weeds was proportional to the concentration of the extract The similar result also observed by various authors in different plant species include (*Eucalyptus camaldulensis* (Dadkhah and Asaadi, 2010), *M. micrantha* (Sisodia and Siddiqui, 2007c), *Ageratum conyzoides* (Batish et al., 2002b; Singh et al., 2003b) and *Cyperus rotundus* (Quayyum et al., 2000). It was also observed that the toxicity of extract progressively increased with increasing the concentration. The germination, root and shoot growth of the test species were significantly decreased in all the treatments. The degree of different parts of *E. alba*

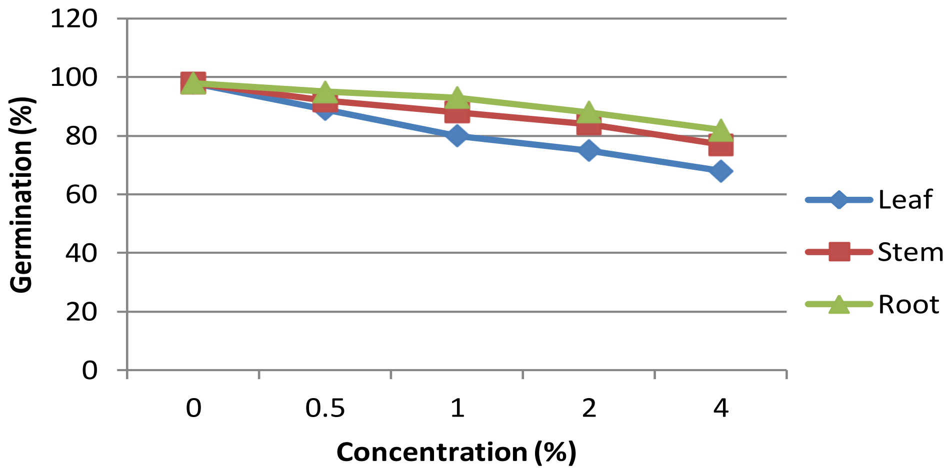

Figure 1. Allelopathic effect of *Eclipta alba* on germination of *Melilotus alba*.

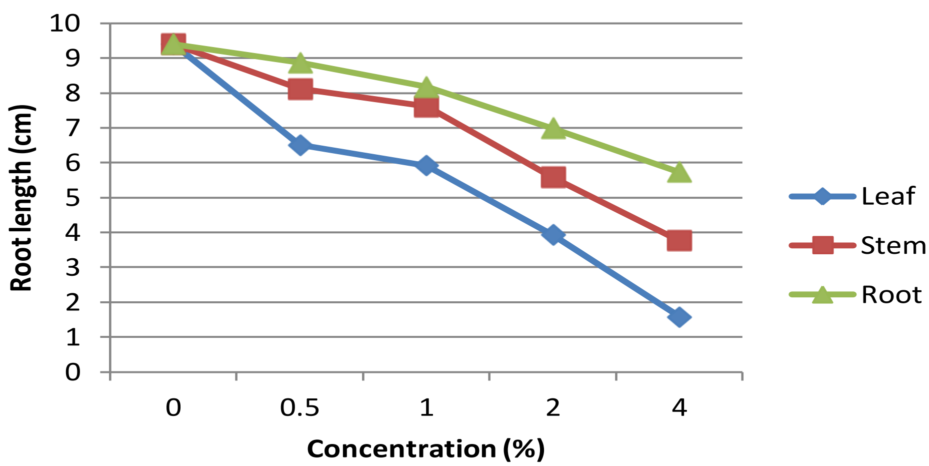

Figure 2. Allelopathic effect of *Eclipta alba* on Root length of *Melilotus alba*.

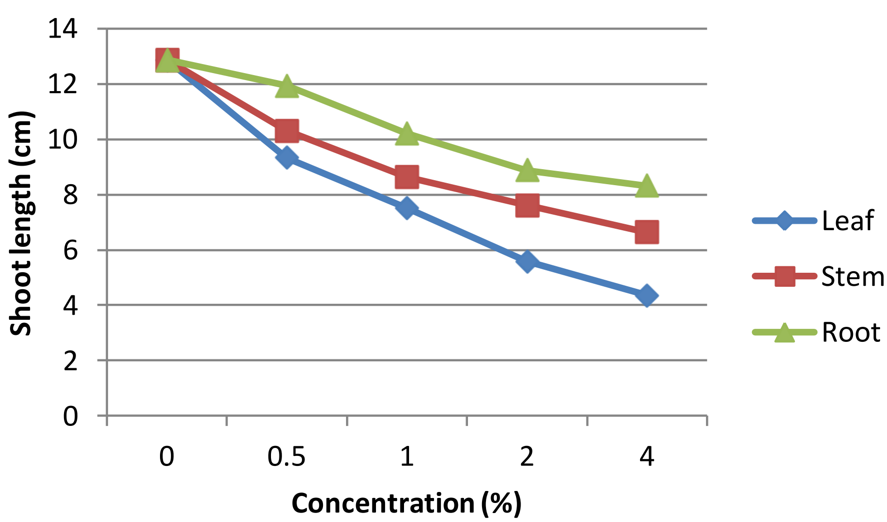

Figure 3. Allelopathic effect of *Eclipta alba* on Shoot length of *Melilotus alba*.

can be ranked in the following order of inhibition: leaves > stem > root.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Characteristics of a manganese-rich soil and metal accumulation in edible parts of plants in the region of Moanda, Gabon

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Moanda region in Southeastern Gabon is rich in manganese (Mn) ores. This study aimed to determine the physico-chemical properties of cultivated and uncultivated soils and the metal content in edible parts of 9 plants cultivated in this area. The studied soils had a sandy loam clay texture. Cultural practices induced a significant acidification, decrease in fertility and loss of metals from soils. Mn contents in soils varied from 8,672 to 17,956 mg.kg^{-1}, and were significantly higher in uncultivated than in cultivated soils. Concentration of metals in plants seemed to depend on the type of plant more than the concerned part. Except for Nkoumou (*Gnetuma fricanum*), Ca, Mg and K contents were in large amounts in all plants so they could be good sources of macronutrients for humans and animals. Mn levels in leaves of cassava and sorrel and Fe levels in the red sorrel leaves exceeded 1 g.kg^{-1}. Sorrel and amaranth showed the highest daily intake of nutrients.

Key words: Manganese-rich soil, metal nutrients, food plants, bioconcentration factor (BCF), daily nutrient intake.

INTRODUCTION

Metals naturally occur in the Earth's crust at variable concentrations and with few exceptions they undergo to biogeochemical cycles (Garrett, 2000). Among the most abundant elements, Al can be toxic to plants, animals and humans (Poschenrieder et al., 2008; Gonzalez-Muñoz et al., 2008), whereas others such as Mg and Zn are essential for growth and life of plants, animals and humans and insufficient level of essential elements cause serious human, animal and plant (Ebel and Gunther, 1980; Galdes and Vallée, 1983; Young-Eun et al., 2007).

In several world areas, metals accumulate to levels above levels of the Earth's crust and become mines exploited by men. Mining activities can lead to metal accumulation in biological tissues through inhalation, ingestion or absorption through the skin (De Miguel et al., 2007; Ferreira-Baptista and De Miguel, 2005; Lu et al., 2003). The populations in these regions sometimes practice agricultural activities for food. Leafy,

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Figure 1. Map of Moanda city location.

vegetables hold an important place in well-balanced diets, and increasing consumption of vegetable and fruits is advisable (Kawashima and Soares, 2003). Leafy vegetables represent an important source of proteins, vitamins and minerals for humans, and act as buffering agents for acidic products formed during the digestion process. However, vegetables may accumulate both essential and toxic elements (Akbar Jan et al., 2010) which may cause nutritional disorders and diseases, particularly in Africa (Odhav et al., 2007; Kwapata and Maliro, 1995) where approximately 300 million people go hungry and 31 million children less than 5 years are undernourished (Tchibambelela, 2009). Leafy vegetables are commonly edible as meals, mixed or not with fruiting vegetables and/or tubers (cassava, yam, and taro).

There is little information currently on food composition in Gabon and on metals contents in cultivated soils and their transfer to crops. The present work aims to assess the accumulation of seven major nutritional metals (Ca, Mg, K, Na, Fe, Mn, and Zn) and the non-essential metal Al, in food plants by the determination of their content in manganese-rich soil of Moanda and in the edible parts of these plants. This is complemented by the study of the impact of agriculture on the soils characteristics, by the calculation of bioconcentration factor (BCF) of metals in plants, and by the calculation of the daily nutrient intake of major nutritional metals.

MATERIALS AND METHODS

Study area

The study area is located in the areas of Moanda, Haut-Ogooué Province, South-east Gabon, 571 m [13°10' - 13°15' E, 1°25' - 1°35' S, (Figure 1)]. The area is covered by a mosaic of forest and secondary grassland savannah. The climate is transitional equatorial with an annual rainfall of 1800 to 2000 mm and an average temperature of 23 to 24°C and a small dry season (December to February) and a large dry season (June to September) (Guichard and Tercinier, 1979). Moanda is one of the most important manganese mining towns in the World, with an estimated 230 million tons of Mn, 20% of the World's deposits. The total Mn and ferromanganese ore reserve exceeds 200 Gt. They are confined to the Lower Proterozoic Franceville Formation that fills the intracratonic Franceville basin. The Franceville formation is composed of the dominant marine terrigenous rocks and the subordinate carbonate varieties, volcanics, and jaspilites. The rocks are virtually undeformed, but divided by faults into blocks. The formation is approximately 4000 m thick and is divided into several lithostratigraphic units (Kuleshov, 2011; Vizier, 1971).

Sampling and sample preparation

Soil and plants analyzed in this study were collected in the forest (control soil) and plantations located 15 km from Moanda. The soil was black, a characteristic of manganese-rich soil. The crops were grown in a deforested area in the following sequence: clearing, burning, cleaning and planting.

Samples of surface soil (0 to 10 cm) were collected in five different points, according to a cross pattern, in cultivated (soil in the root zone) and uncultivated parcels. They were air-dried. The aggregates were crushed and soils were sieved to 2 mm mesh and stored in polythene bags. A part of this fraction was crushed with a tungsten-carbide blade grinder and subsequently sieved with a 0.2 mm titanium mesh.

2 to 5 kg of the edible parts of each plant species were randomly selected and collected. All collected plant samples had reached the same degree of maturation. Samples were washed 3 times with distilled water first, and with de-ionized water thereafter. They were dried in a stove at 70°C until constant weight. Samples were finely ground (0.2 mm) and kept in polyethylene bags. The selected plants are listed in Table 1.

Physico-chemical characterization of the soils

Soil properties were assessed according to the Open Systems Interconnection (ISO) protocols (AFNOR, 1994). They included: particle size (3 fractions), pH_{water}, pH_{KCl}, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), available phosphorus ($P_{ass.}$), cation exchange capacity (CEC), and exchangeable bases (Ca_{exch}, Mg_{exch}, K_{exch}, and Na_{exch}). Considering that the average content of carbon in soil organic matter (OM) is equal to 58%, the conversion factor 1.724 was used to calculate the percentage of OM from the content of organic carbon (Abollino et al., 2002). The sum of exchangeable bases S was calculated.

Total metals concentrations in soils

Soil samples were mineralized in aqua regia (1/3 HNO_3 + 2/3 HCl) according the AFNOR NF X31 - 151 (AFNOR, 1994) standard using a microwave mineralizer. The mineralization products were filtered with a 0.45 µm mesh and the mineral concentrations determined by the Inductively coupled plasma atomic emission spectroscopy (ICP-AES) method (JobinYvon, Spectra 2000). Accuracy of the method was tested by analysing two reference soils (SCP-Science SS-2, Canada and SRM-2586, USA). Precision of results ranged from 3.9 to 7.6%.

Metals in plants

Plant samples were digested at 150°C for 1 h in a microwave

Table 1. Studied plants and consumed parts.

Usual name of plant	Part consumed	Scientific name of plant
Pimento	Fruits	*Capsicum frutescens*
Nkoumou	Leaves	*Gnetum africanum*
Okra	Fruits	*Abelmoschus calei*
Eggplant	Fruits	*Solanum melongena*
Lemon grass	Leaves	*Cymbopognon citratus*
Yam	Tubers	*Dioscorea* spp
Cassava	Leaves Tubers	*Manihot esculenta* Crantz
Amaranth	Leaves	*Amaranthus cruentus* L.
Sorrel with small red leaves	Leaves	*Hibiscus sabdariffa*
Sorrel with large green leaves	Leaves	*H. sabdariffa*

mineralizer using a mixture of nitric acid, hydrogen peroxide and ultra-pure water with a volume proportion ratio 2:1:1 (Nardi et al., 2009). The resulting solution was filtered with a 0.45 µm mesh and stored at 4°C before ICP-AES analysis for determination of metal concentrations.

Bioconcentration factor (BCF)

The capacity of plants to accumulate metals present in soils was assessed using BCF, defined as the ratio of their concentrations measured in plant tissues and soils, in dry weight (Komarek et al., 2007).

$$BCF = \frac{\text{Metal concentration in consumed part of plant}}{\text{Metal concentration in soil}}$$

Daily intake of metals (DIM)

The DIM was calculated by the following equation:

$$DIM = \frac{[M] \times K \times I}{W}$$

Where [M] represents heavy metal concentrations in plants ($mg.kg^{-1}$); K is conversion factor used to convert fresh part consumed of plant weight to dry weight, estimated to 0.085; I is daily intake of consumed plants (kg); W is average body weight.

The average adult and child body weights were considered to be 55.9 and 32.7 kg, respectively, while average daily vegetable intakes for adults and children were considered to be 0.345 and 0.232 kg/person/day, respectively (Arora et al., 2008; Wang et al., 2005).

Statistical analysis

The means and standard deviations were calculated for all data. The influence of agriculture on soil fertility parameters were analyzed through analysis of variance (ANOVA) statistical tests. Statistical significance was set at 95% ($p = 0.05$).

RESULTS AND DISCUSSION

Soil characteristics

The physico-chemical characteristics of the soils are reported in Table 2. The loam content is significantly higher in the control soil (uncultivated) than in cultivated soil ($p = 0.025$ and $F = 12.3$ - with F: variance). Furthermore, the sand concentration is significantly higher in the cultivated soil than in the control soil ($p = 0.035$ and $F = 9.8$). The cultivation increased the sand content by 41% and decreased the silt content by 24%. The loss in silt content and the gain in sand content were probably due to agricultural practices, erosion and illuviation (Igué, 2007). Several authors have also found that tillage of land affects positively or negatively the particle size of soil by ameliorating or reducing root growth, nutrient interception by roots, and soil aeration or compaction (Agoumé and Birang, 2009; Béliveau et al., 2009; Korkanc et al., 2008).

The uncultivated soil was slightly alkaline and its pH significantly higher compared with the cultivated soil pH. Soil acidification in cropping systems in the tropics is mainly due to depletion of soil base cations by leaching due related to the impact of rainfall (Khresat et al., 2008; Sa et al., 2009; Haynes et al., 2003) or due to through use of chemical fertilizers. The decrease in pH in the surface layer also may be associated with changes in particle size and with a relative loss of soil OM. The pH_{water} value was always higher than pH_{KCl}, indicating that the soil minerals were negatively charged and could retain the free cations in soil solution.

The TOC and available P contents in the cultivated soil decreased both by about 50% mainly due to the increased OM mineralization and leaching rates (Table 2).

Available P is influenced by the mineralogy and soil texture and is concentrated in the organic fraction of most

Table 2. Physico-chemical characteristics of soils.

Characteristics of soils		Uncultivated soil	Cultivated soil
Particle size	Clay ($mg.g^{-1}$)	275.1 ± 12.9[a]	234.3 ± 61.0[a]
	Loam ($mg.g^{-1}$)	332.3 ± 24.5[a]	252.7 ± 16.5[b]
	Sand ($mg.g^{-1}$)	361.1 ± 43.4[a]	511.3 ± 47.1[b]
pH	pH_{-water}	7.4 ± 0.8[a]	4.8 ± 0.3[b]
	pH_{-KCl}	6.3 ± 0.8[a]	3.7 ± 0.1[b]
	∆pH	1.1 ± 0.5[a]	1.1 ± 0.1[a]
Organic matter	TOC ($mg.g^{-1}$)	39.9 ± 5.8[a]	24.7 ± 1.3[b]
	OM ($mg.g^{-1}$)	69.0 ± 9.2[a]	42.7 ± 1.4[b]
	TKN ($mg.g^{-1}$)	2.9 ± 0.7[a]	2.6 ± 0.2[a]
	TOC/TKN	13.8 ± 0.3[a]	10.7 ± 1.2[b]
Phosphorus	$P_{ass.}$ ($mg.kg^{-1}$)	26.3 ± 0.6[a]	13.6 ± 0.1[b]
Basic exchangeable cations	Ca ($mg.kg^{-1}$)	4601 ± 837[a]	64.1 ± 12.6[b]
	Mg ($mg.kg^{-1}$)	460.9 ± 48.5[a]	18.2 ± 11.0[b]
	K ($mg.kg^{-1}$)	318.2 ± 41.4[a]	3.9 ± 1.4[b]
	Na ($mg.kg^{-1}$)	9.0 ± 1.5[a]	2.3 ± 0.6[b]
Cation exchange capacity	CEC (meq/100 g)	25.1 ± 2.9[a]	13.1 ± 2.9[b]
Sum of exchangeable basic cations	S (meq/100 g)	27.2 ± 2.6[a]	4.9 ± 0.7[b]

a, b: Means (±standard deviation) followed by different letters in a same line are significantly different at the 0.05 level.

tropical soils (McAlister et al., 1998; Kamprath and Watson, 1980). The predominant form of phosphorus in soils that contain clay minerals of type 1/1 and Fe- and Al-rich soils as soils of Moanda, is Al-phosphate which is transformed over time in Fe-phosphate (Sanchez, 1976) and reduces the availability of P by adsorption of this element on the large area of Fe-Al-(hydro) oxides (McAlister et al., 1998).

Exchangeable Ca, Mg, K and Na concentrations which also significantly decreased is higher as a result of agricultural practices. Indeed, there is a decreased by 74 to 98% in the cropped soils (Table 2). Base cation depletion of soils was related to acidification leading to a reduced availability of these essential nutrients for plant growth. In acid soils, most of the Ca^{2+} present would exist in soluble form, but both soluble and exchangeable Ca decreases with decreasing soil pH (Haynes and Ludecke, 1981). Furthermore, at low pH, the availability of Ca is further hampered in the presence of high Al concentrations (Bolan et al., 2003). Upon soil acidification, decreasing amounts of Mg remain in exchangeable form due to reduction in variable charge, and more is present in solution, liable to leaching losses. Also, since Mg is a poor competitor with Al and Ca for the exchange sites, it tends to accumulate in the solution phase and is therefore prone to leaching (Myers et al., 1988; Edmeades et al., 1985). The sum of exchangeable bases was low in cultivated soils compared to control soils (Table 2).

The CEC also significantly decreased in the cultivated soil (Table 2). The soil CEC is contributed by the SOM and clay minerals (Bewket and Stroosnijder, 2003), and therefore, soil acidification and SOM losses reduce the soil CEC.

Total metal concentration in soils

Concentrations of metals in soils are presented in Table 3. Concentrations of the measured metals were significantly higher in the uncultivated than in cultivated soil, except for Al and Fe. The Mn concentration in the uncultivated soil was larger than that of the cultivated soils. The Mn and Al concentrations along with the acidic pH value in cultivated soil could pose risks of toxicity of soil for plants (Kabata-Pendias and Mukherjee, 2007). In fact, at acidic pH free Al and Mn may be the predominant forms in soil solution, which could be readily available for plants (Gauthier, 2002; Pedro, 2007). Renella et al. (2005) reported that in Mn and Zn polluted soils, the Mn and Zn solubility was significantly higher in the presence of organic acids typically released by the plant roots than in water, thus suggesting that plants can mobilize trace elements by their root exudates.

Table 3. Total metals Concentrations in soils.

Metal ($mg.kg^{-1}$)	Uncultivated soil	Cultivated soil
Ca	36.823 ± 3.847[a]	178.6 ± 24.8[b]
Mg	4.380 ± 694[a]	1.037 ± 430[b]
K	14.940 ± 1.464[a]	8.796 ± 785[b]
Na	1.323 ± 319[a]	891.1 ± 247.2[a]
Al	14.823 ± 1.673[a]	36.529 ± 3.508[b]
Fe	15.210 ± 1.498[a]	20.869 ± 1.124[b]
Mn	15.725 ± 2.231[a]	10.070 ± 1.398[b]
Zn	463.3 ± 53.2[a]	248.3 ± 37.9[b]

a, b: Means (±standard deviation) followed by different letters in a same line are significantly different at the 0.05 level.

Fertility parameters of soils

Based on the classification of Landon (1991) of different parameters of agricultural tropical soils, levels of TOC and TKN in cultivated soils are still significant for a good agricultural performance (23 to 58 and 2 to 5 g/kg, respectively. However, all parameters indicated that cropping was not environmentally sustainable, leading to the lowering of important indicators of fertility such as TOC, OM, TKN, $P_{ass.}$, exchangeable base cations. This observation was also made by Guichard (1975) who analyzed soil samples from gardens in this study area. Fertilizers applied to soils are almost exclusively minerals, mainly urea and NPK. EdouEdou (2006) observed also that the organic fertility of cultivated land was renewed through an annual or temporary abandonment of cultivated area. This practice only occurred after the observation of infertility signs, including the decline in yield. The levels of OM and nutrients then could decrease greatly depending on the duration of the operation of the cultivated plot.

Ca mobility is more elevated than Mg mobility in cultivated soil. Exchangeable Ca and Mg represent about 36 and 2%, respectively of the total concentration of these elements in the cultivated soil. This is consistent with the results of Guichard and Tercinier (1979) and Guichard (1975), which showed that the proportion of illitic clays, manganese, calcium and magnesium carbonate complexes was important in these soils. In these complexes, Ca is relatively mobile, while Mg is poorly soluble (Legros, 2007).

Metal concentrations in plants

The concentrations of metals in edible parts of plants are shown in Figure 2. The ranking order of the measured metals in plants was: Ca > K > Mg > Mn > Na > Fe > Al > Zn. These concentrations seem to depend on the type of plants more than the edible part concerned. All plants accumulate significant amounts of Ca, Mg and K. Only Nkoumou accumulated small concentrations of metals, and had a very poor nutritive intake. The plants studied in the region of Moanda could be an important source for the intake dietary of these nutrients for humans and animals. Bartlett (1999) described Mn as a "key of life" because of its importance in photosynthesis, the vital link in a large amount of processes occurring in human or animal organism. The Mn levels in several parts of plants (Okra fruits, Cassava leaves, Amaranth leaves and Sorrel leaves) are higher than plant toxic level of 500 mg/kg proposed by Kabata-Pendias and Mukherjee (2007). Here, cassava and sorrel leaves accumulate values above 1000 $mg.kg^{-1}$ of Mn. Ascher et al. (2009) reported that Ca, P, Fe, Mn and Zn concentrations in the edible parts of lettuce grown on polluted soils depended on the pollution level and that soil remediation reduced the potentially toxic Mn and Zn concentrations in the edible parts of lettuce.

Bioconcentration factor (BCF)

The rate of elements absorption by the plant depends on the plant cultivated and soil properties such as pH, cation exchange capacity and distribution of metals in different soil fractions (Kos et al., 2003; Cui et al., 2004). The metal BCF in plants is used to describe the extent of the accumulation of a compound in a biological system identified. Table 4 presents the BCF values of metals in consumed parts of studied plants. Al and Fe are less accumulated than other elements. Their BCF ranged from 0.0003 to 0.0265 for Al and from 0.0010 to 0.0519 for Fe. Zn is more accumulated than other metals. Values of Zn BCF are in the ranges from 0.0306 to 0.6033. Nkoumou is the leafy vegetable that accumulates the least amount of metal. However, this traditional leafy vegetable is the most popular and most consumed by people in the Moanda region. The best accumulators are sorrel with small red leaves for Al, Fe and Mn, and sorrel with large green leaves for Zn. Ondo (2011) indicated that sorrel or *Hibiscus sabdariffa*, was a plant that preferentially

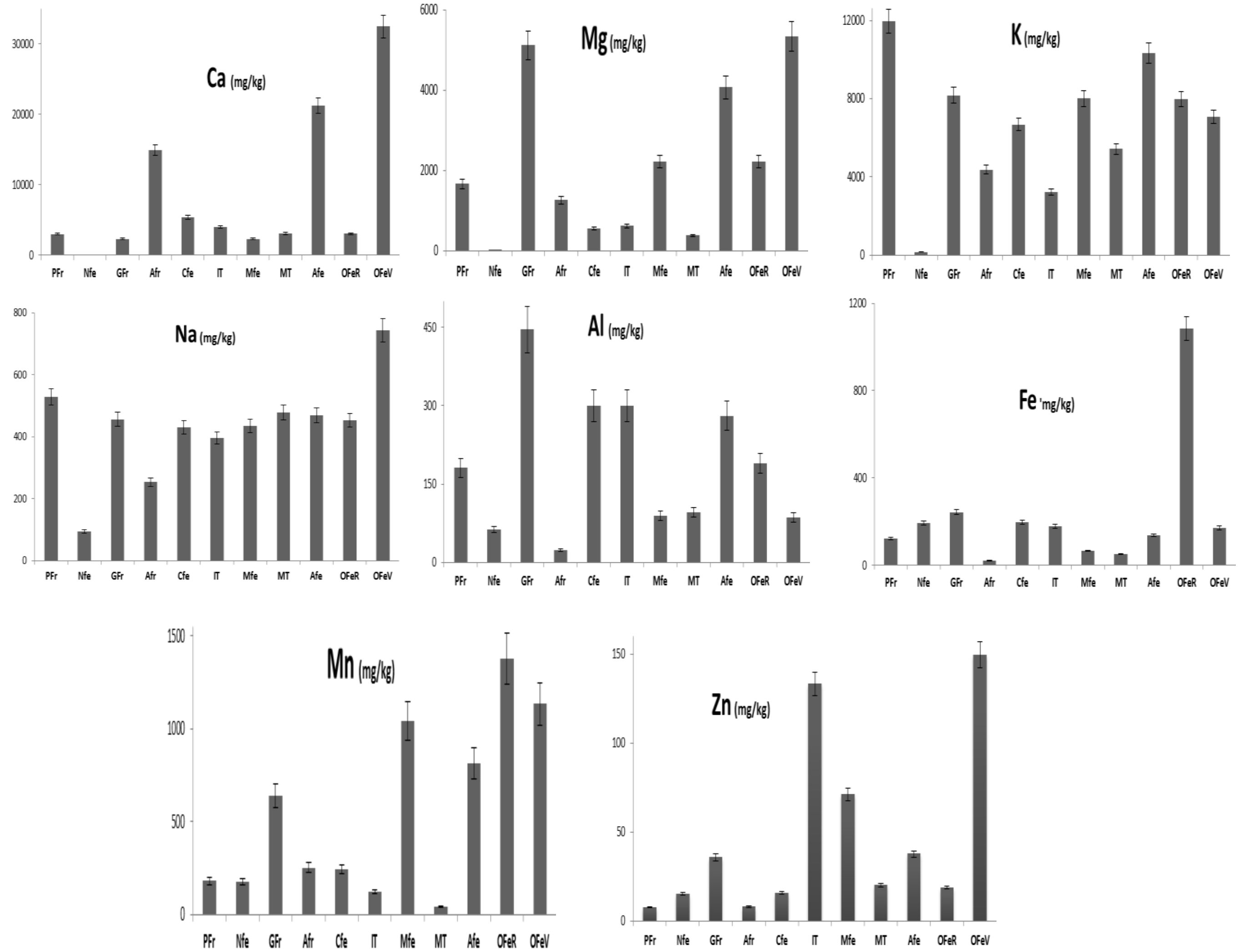

Figure 2. Metal concentrations in consumed parts of dry plants (mg.kg^{-1}). **PFr,** Pimento fruits; **NFe,** Nkoumou leaves; **GFr,** okra fruits; **AFr,** eggplant fruits; **CFe,** lemon grass fruits; **IT,** yam tubers; **MFe,** cassava leaves; **MT,** cassava tubers; **AFe,** Amaranth leaves; **OFeR,** Sorrel red leaves; **OFeV,** Sorrel green leaves.

Table 4. Bioconcentration factor of metal in consumed parts of plants.

Usual name of plant	Al	Mn	Fe	Zn
Pimento	0.0025	0.0220	0.0058	0.0306
Nkoumou	0.0009	0.0211	0.0093	0.0616
Okra	0.0062	0.0777	0.0116	0.1442
Eggplant	0.0003	0.0308	0.001	0.0322
Lemon grass leave	0.0042	0.0298	0.0093	0.0636
Yam	0.0042	0.0149	0.0086	0.5373
Cassava leave	0.0012	0.1265	0.0031	0.2872
Cassava tuber	0.0013	0.005	0.0024	0.0818
Amaranth	0.0039	0.0991	0.0066	0.1518
Sorrel with small red leaves	0.0265	0.1673	0.0519	0.0761
Sorrel with large green leaves	ND	0.1379	0.0081	0.6033

ND: Not determined.

Table 5. Estimated daily intake of nutritional metals.

Daily intake of nutritional metals		Pimento	Nkoumou	Okra	Eggplant	Lemon grass	Yam	Cassava leaves	Cassava tuber	Amaranth	Sorrel with small red leaves	Sorrel with large green leaves
Mn (mg.day^{-1})	Children	0.114	0.109	0.402	0.159	0.154	0.077	0.654	0.026	0.512	0.865	0.713
	Adult	0.095	0.091	0.335	0.133	0.128	0.064	0.545	0.021	0.427	0.721	0.594
Fe (mg.day^{-1})	Children	0.077	0.122	0.152	0.013	0.123	0.112	0.041	0.031	0.086	0.682	0.107
	Adult	0.064	0.101	0.127	0.01	0.102	0.094	0.034	0.026	0.072	0.568	0.089
Zn (mg.day^{-1})	Children	0.005	0.01	0.023	0.005	0.01	0.084	0.045	0.013	0.024	0.012	0.094
	Adult	0.004	0.008	0.019	0.004	0.008	0.07	0.037	0.011	0.02	0.01	0.079
Mg (mg.day^{-1})	Children	1.052	0	3.225	0.795	0.352	0.39	1.399	0.241	2.568	1.405	3.363
	Adult	0.877	0	2.69	0.663	0.293	0.325	1.166	0.201	2.142	1.172	2.804
Ca (mg.day^{-1})	Children	1.895	ND	1.465	9.404	3.404	2.506	1.445	1.931	13.363	1.904	20.447
	Adult	1.58	ND	1.222	7.843	2.838	2.09	1.205	1.611	11.144	1.587	17.052
K (mg.day^{-1})	Children	7.526	0.106	5.141	2.755	4.206	2.034	5.042	3.419	6.493	5.018	4.452
	Adult	6.277	0.089	4.287	2.297	3.508	1.696	4.205	2.851	5.415	4.185	3.713
Na (mg.day^{-1})	Children	0.333	0.059	0.286	0.159	0.271	0.249	0.273	0.301	0.295	0.285	4.673
	Adult	0.278	0.049	0.239	0.133	0.226	0.208	0.228	0.251	0.246	0.238	3.897

ND: Not determined.

concentrated metals in its leaves, the consumable part of the plant.

Daily intake of physiologically active metals

The daily intake of physiologically active was estimated (Table 5) and was compared with the recommended daily intakes (World Health Organization, 1996; Institute of Medicine from United States, 2007). Comparisons with the recommended daily intakes present results in the range of 0.53 to 21.62% for Mn, 0.06 to 3.41% for Fe and less than 2% for other nutritional metals. The highest contributions come from the sorrel and amaranth. The high potassium values for pimento were not significant because this fruit-vegetable is used only in very small quantities because of his prickly flavor. In general, these values are higher than those found by Arora et al. (2008). The results of this study suggest that daily intakes of physiologically active from plants cultivated in manganese-rich soils of Moanda are high, and could be free of risk because the recommended daily intakes were much higher: 270 to 1200 mg/day for Ca, 10 to 30 mg/day for Fe, 75 to 420 mg/day for Mg, 1 to 6 mg/day for Mn, 700 to 2000 mg/day for K, 200 to 500 mg/day for Na, 5 to 19 mg/day for Zn (World Health Organization, 1996; Institute of Medicine from United States, 2007).

Conclusion

The agricultural practices on manganese-rich soil of Moanda significantly led to a strong acidification, a reduction of fertility index and a loss of metals in soil. Mn concentrations in several consumed parts of plants are higher than toxic level for plants (500 $mg.kg^{-1}$). The increasing consumption of vegetables in the region of Moanda could be a significant source of essential metals for animals and humans. But dietary intake of food results in long-term low level body accumulation of heavy metals and the detrimental impact becomes apparent only after several years of exposure. The determination of more toxic metals in agricultural soils, like Pb or Cd, and their transfer in consumed plants, is thus necessary. Regular monitoring of these toxic metals in soils, plants and human or animal bodies are essential to prevent their excessive build-up in the food chain. Other studies, such as education on food requirements, tillage, and new methods of conservation and preservation of agricultural soils, are of prime importance to improve crop yields. Laboratory studies and experiments carried out in cultivated field would be necessary to determine the capacity accumulate toxic metals such as Pb or Cd of sorrel, the best accumulator plant in this study and because of his importance in the alimentation in West Africa.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Comparison of site selection of suitable lands for performance of pressurized irrigation by geography information system (GIS) in Kerman Plain, Southeast of Iran

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The different parameters such as water, soil and climate have an important effect in the decision making and performance of pressurized irrigation systems. The underground and surface water resources in per region have no unique quality and quantity. The Kerman Plain, which has about 7500 km^2, is located in the Kerman Province. The irrigation of this plain is done with using the underground water resources which are facing drop in the water level, due to over exploitation. Accordingly, the pressurized irrigation is suggested in order to the prevention of drop the loss trend and increasing irrigation efficiency. The aim of this research is to identify suitable lands for performance of pressurized irrigation system, with the help of remote sensing techniques and geography information system (GIS), in Kerman plain of southeast of Iran. In this research, 2 methods of site selection: logical overlay method –Boolean method- and Arithmetic overlay - proportion percent method are compared and evaluated. On the basis of Boolean site selection model 5% of desert lands for performance of sprinkle irrigation and 25% of lands for drip irrigation and on the basis of arithmetic overlay 15% of lands for performance of sprinkle irrigation and 20% of them for performance of drip irrigation reasonably were recognized. The comparison of these 2 methods with considering the condition of regions showed that arithmetic overlay site selection model is more suitable for recognizing the suitable zones for performance of pressurized irrigation systems.

Key words: Pressurized irrigation, geography information system (GIS), boolean model, proportion percent model, site selection.

INTRODUCTION

The limitation of water sources and ever –increasing population, has tended the world countries to increase of the agricultural products in unit of area and optimized productivity form water and soil sources by new methods irrigation for increasing irrigation efficiency and efficiency of used water.

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The quality of water, the climate of region, the situation of topography, characteristics of soil region, the quantity of water irrigation and kind of crops are the most important and effective factors in determination of various pressurized irrigation systems. Arba Minch University (2004) made a case by case study on the basis of Arabia CHAMOO in the area of irrigation proportion by geography information system (GIS).

Abrishamdar et al. (2005) researched in field of evaluation of site selection of performing of pressurized irrigation in different zones in Khuzestan province. Mirzaee (2007) spent his time to site selection of pressurized irrigation systems in central regions of Kermanshah province. Albaji et al. (2008) evaluated suitable lands by GIS for surface and drip irrigation in Shawer desert, in Iran.

Mamanpoosh and Tofangsaz (2009) did site selection of zones which have the ability of pressurized irrigation by assistance of geography information system for Barkhar desert in Esfahan.

Taghvaee and Sangooni (2008) evaluated the efficiency of satellite pictures in recognition of suitable lands for performance of aquifer projects in the Mashhad plain.

Albaji et al. (2009) evaluated the soil characteristics for different irrigation systems in Laly desert.

The aim of this research is to do a suitable site selection for performance of pressurized irrigation systems by remote sensing techniques with GIS. Considering the characteristics of soil and water, soil texture, electrical conduction , thickness of bicarbonate ,the slope of region , climate, the conditions of water quality, the proportion lands, the ability of lands which is Kerman desert with the comparison and evaluation of logical overlay- Boolean- and arithmetic overlay, the proportion percent that contribute to present the best overlay model.

MATERIALS AND METHODS

The process of site selection by GIS includes recognition steps, the collection of input data, determination of effective factors, compiling and preparing of data, the preparation of maps, weighting to maps, combination of maps and preparation of output maps. The province of Kerman, which has about 184.400 km^2 area, is located on the southern east of Iran, and it is the most extensive province of Iran. The geography position of this province is from 54°, 22' to 59°, 45' eastern latitude, and from 26°, 22' to a little more than 32° northern longitudes. The evaluations of statistical wind speed are shown in a long-term period which demonstrates that the moderate of strong winds in forecast station of Kerman region have 5.1, 2.4, 2.5, and 3.5 km/h speed in the spring, summer, fall and winter respectively, which illustrates that proportional tranquility is dominated in the region.

The majority of agriculture products are pistachio which is more compressed in northern desert, Zerand, Rafsanjan, and Sirjan. After collecting data which are related to condition of soil texture, types of lands, proportion of lands, and lands ability, maps that are related to soil texture, soil ability, and proportion of lands of region are prepared by GIS. Booth B, Mitchell A., 2011, Cuenca RH 1989.

In order to evaluate the quality of water irrigation, the results of chemical analytic of water resources on the basis of last excising statistics in 2008 were used. Electrical conduction, thickness of bicarbonate, sodium, and chlorine were the evaluated parameters.

The position of region slope is another important and effective factor in operating site selection of pressurized irrigation system that is prepared by digital elevation model (DEM) map and GIS technology (Mamanpoosh and Tofangsaz, 2009; Nikpoor, 2011). After gathering required data including state of soil texture, the ability of soil lands, the lands proportion, the condition of slope, the evaluation of water quality, the maps are classified into 2 groups: the logical Boolean model, and the proportion percent. The various methods and models are used in site selection which involves Boolean model, Fussy, and indexes overlay. In this research, Boolean site selection model and arithmetic overlay is used. In this, Boolean site selection model- Binary- the logical combination of map value is in 2 cases: Yes and No. It means that belonging to a series by ONE and not belonging to a series by ZERO is expressed.

However, the conclusion of arithmetic overlay method is a suitability map which is set on the basis of well-proportioned degree, and includes a variety of colors. This method is used when the severe effectiveness of each factor is to be determined. However, the impact of all factors should be considered the same in Boolean. In this research, to evaluate water quality, on the basis of the model mentioned, water sources of pressurized irrigation systems with limitations, such as electrical conductions and calcium bicarbonate –H CO_3– should be determined. Moreover, pistachio consists of the majority of cultivated field in Kerman Plain, and the number and limitations which are related to sensitivity of salty are not mentioned in this table considering the conditions of pressurized irrigation plans which are performed in the province. In the evaluation of the soil water of the province and considering high the electrical conduction in this region, the borders and limitations on the basis of Boolean method are E.C (µmos/cm)< = 8000 and Bicarbonate (meq/lit)< = 6 suitable value: (1). Also, E.C(µmos/cm)> 8000 and Bicarbonate(meq/lit)> 6 is considered not suitable value:(0).

The limiting factors in the sprinkle irrigation system were water quality, sodium, chlorine, and electrical conductions. The borders were determined by site selection Boolean model: E.C(µmos/cm)< = 2500, Sodiume(meq/lit)< = 9, and Cholorine(meq/lit)< =9 is considered suitable value: (1) Moreover, E.C (µmos/cm)> 2500, soduim (meq/lit)> 9 and Chlorine (meq/lit)> 9 is considered not suitable value:(0).

The interpolation of maps for site selection of pressurized irrigation systems -sprinkle and drip- is prepared. The interpolation is done on E.C, HCO_3 parameters in drip irrigation system and in the sprinkle irrigation is done on the E.C sodium and chlorine factors. The topography conditions of region showed that the spline method is used for interpolation.

The soil texture is the other limiting factor in performing pressurized irrigation system. The suitable and not suitable value of soil texture is shown on the basis of Boolean model. Fine coarse texture with E.C (µmos/cm)< 5000 is considered suitable value: (1), and coarse texture with E.C (µmos/cm)> 5000 is considered not suitable value: (0) in the drip irrigation. Also, fine texture shows suitable value: (1) and coarse texture is recognized not suitable value in the sprinkle irrigation (Amor et al., 2001; Ayers and Westcot, 1985).

After evaluation of effective factors in selection of pressurized irrigation system such as climate condition, topography, the characteristics of soil, the quality of irrigation water in selection of pressurized irrigation system, the layers of separate data are prepared separately for per parameters. Also, then with considering standards and numerical limitation which are in these parameters, interpolation was done. Consequently, weighting the map was done by two logical overlay method –Boolean-, and arithmetic overlay.

Figure 1. The position of Kerman plain in the satellite pictures of land sat.

After combination of maps, the suitable and not suitable locations in order to performing of pressurized irrigation system by 2 methods were recognized and compared and evaluated.

RESULTS

The result of logical overlay Boolean is a (0, 1) function:
1: suitable and 0: Not suitable, so just two colors are shown in the output Raster with the labels of (0, 1). However, the result of arithmetic overlay is a suitability map which has set on the basis of suitable degree, and include a variety of colors when a series of conditions is described for explanation of projects, logical overlay is used. A series of conditions means that for each condition, an amount is determined. Two groups of maps are prepared in this research:

The maps which are related to logical overlay (site selection Boolean model). The maps which are related to arithmetic overlay (proportion percent) without considering the percent affection which means the effect ion of all parameters consider the same.

After evaluation of effective factors in selection of pressurized irrigation system such as climate condition, topography, the characteristics of soil, the quality of irrigation water in selection of pressurized irrigation system, the layers of separate data are prepared separately for per parameters.

Finally, the separation of suitable and not suitable sites was done by Boolean logic in which the logical combination of a map is in Yes and No form (in zero and one form: zero shows not suitable regions and one is considered for suitable regions).

By combining of layer information's of soil texture, the ability of soil the slope of region, and the water quality with standards and especial limitations of sprinkle irrigation a map was prepared (Figure 4). Also by combining the layers information's which include soil texture the ability of soil the slope of region the water quality with standards and especial limitations of drip irrigation a map was drawn (Figure 4). These maps were drawn by logical Boolean (logicaloverlay) and proportion percent (arithmetic overlay).

Kerman desert has about 7.500 km^2 area, and 4.000 km^2 out of this area consists of proportion lands which have ability, and potential of irrigation: about 55% of them. After preparation and combination of data which are related to soil texture, the ability of lands proportion, the slope of lands, water quality and use of standards, and limitation in when design of drip irrigation is considered is prepared (Figures 1, 2 and 3).

After preparation and combination of data which are related to soil texture, the ability of lands proportion, the slope of lands, water quality and use of standards, and limitation in when design of sprinkle irrigation is considered, the suitable sites for sprinkle irrigation by Boolean and arithmetic overlay were recognized (Figures 4, 5, 6 and 7). The conclusion of Boolean method showed 25% of desert lands are suitable for performing of drip irrigation system, and 5% of them are suitable for

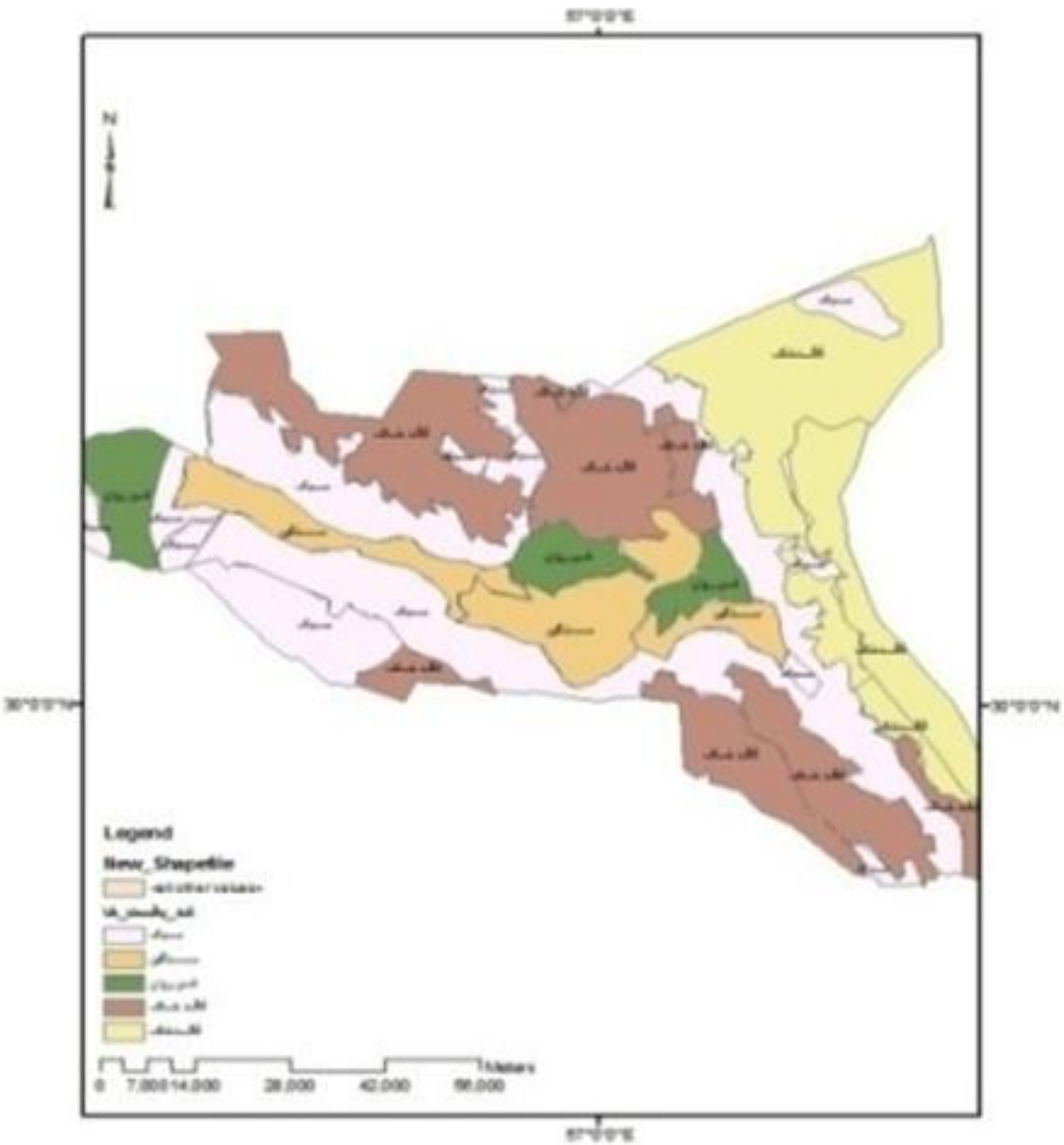

Figure 2. The condition of soil texture in Kerman Plain.

performing of sprinkle irrigation in the desert of Kerman. However, the arithmetic overlay method showed that 20% of desert lands are suitable for performing of drip irrigation and 15% of them can be used for sprinkle irrigation in the Kerman plain.

To sum up, the comparison of results and condition of the region showed that arithmetic overlay method is more suitable for recognizing and finding suitable locations to perform pressurized irrigation plans in Kerman Plain.It is noticeable that the logical overlay model, Boolean, because of simple logic and calculation, has fast and simple performance, but with considering the effect of other parameters on site selection process, this model cannot be used as a suitable model for combination of maps. Because not only the weight of all parameters isconsidered the same and equal in this model but also the possibility of classification of per parameter in separate classes for weighting per classification is impossible.

The unsuitable and untalented land for performance of drip irrigation includes about 80% of plain lands that 20% out of the unsuitable lands is located in Derakhtegan and Khenaman - section. The limiting factors in these regions involve the condition of topography and improper slope of land and kind of land region. The lands of this region include mountains and hills that have severe limitation because of having rocks out crop which is without soil. Fourthly percent of unsuitable lands are located in some

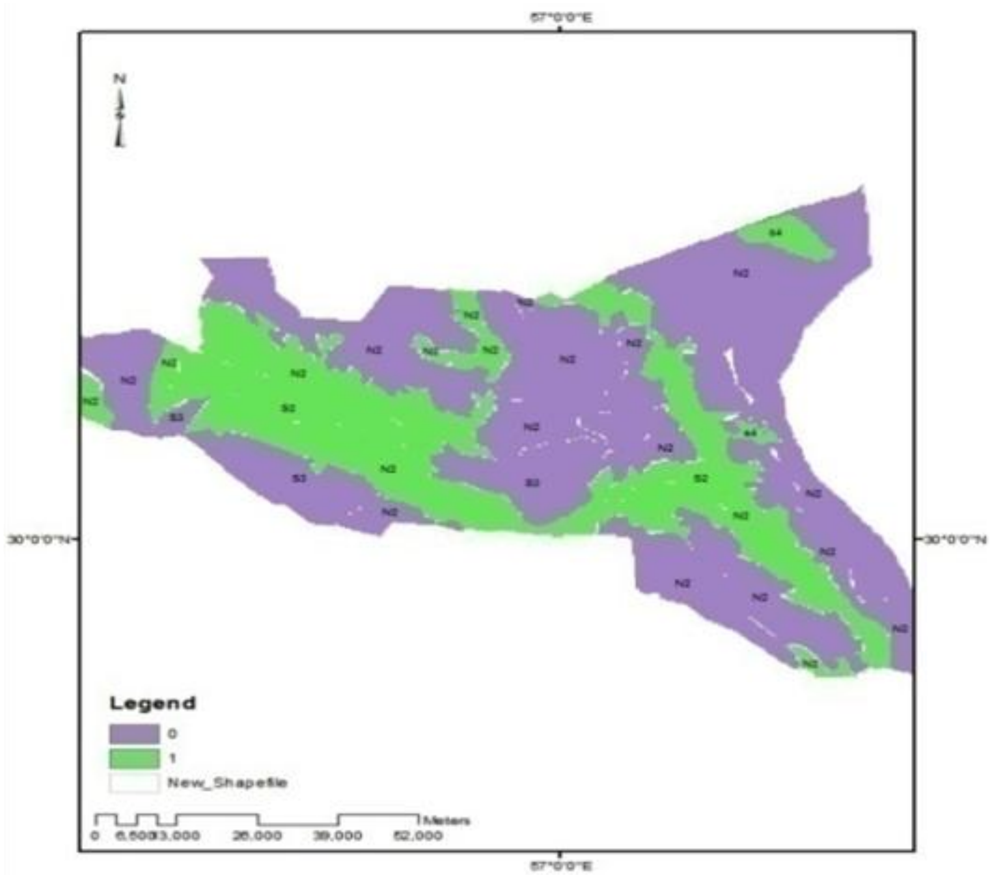

Figure 3. The classification of soil texture in the sprinkle irrigation with Boolean method.

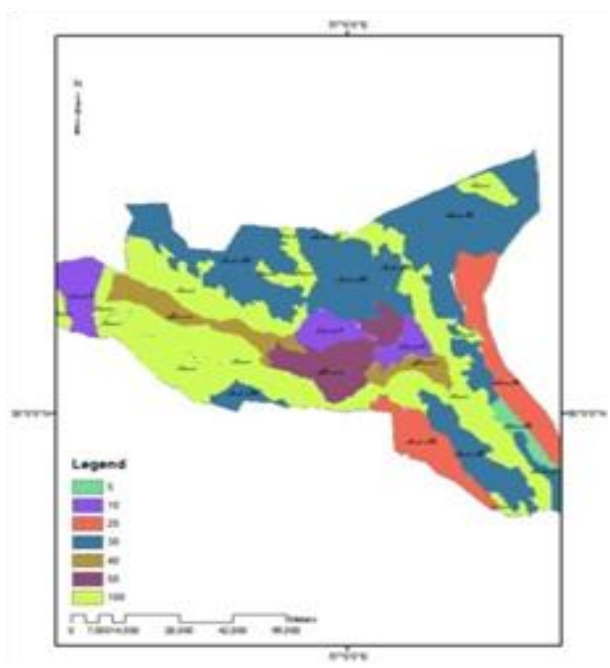

Figure 4. The classification of soil texture in the sprinkle irrigation with proportion % method.

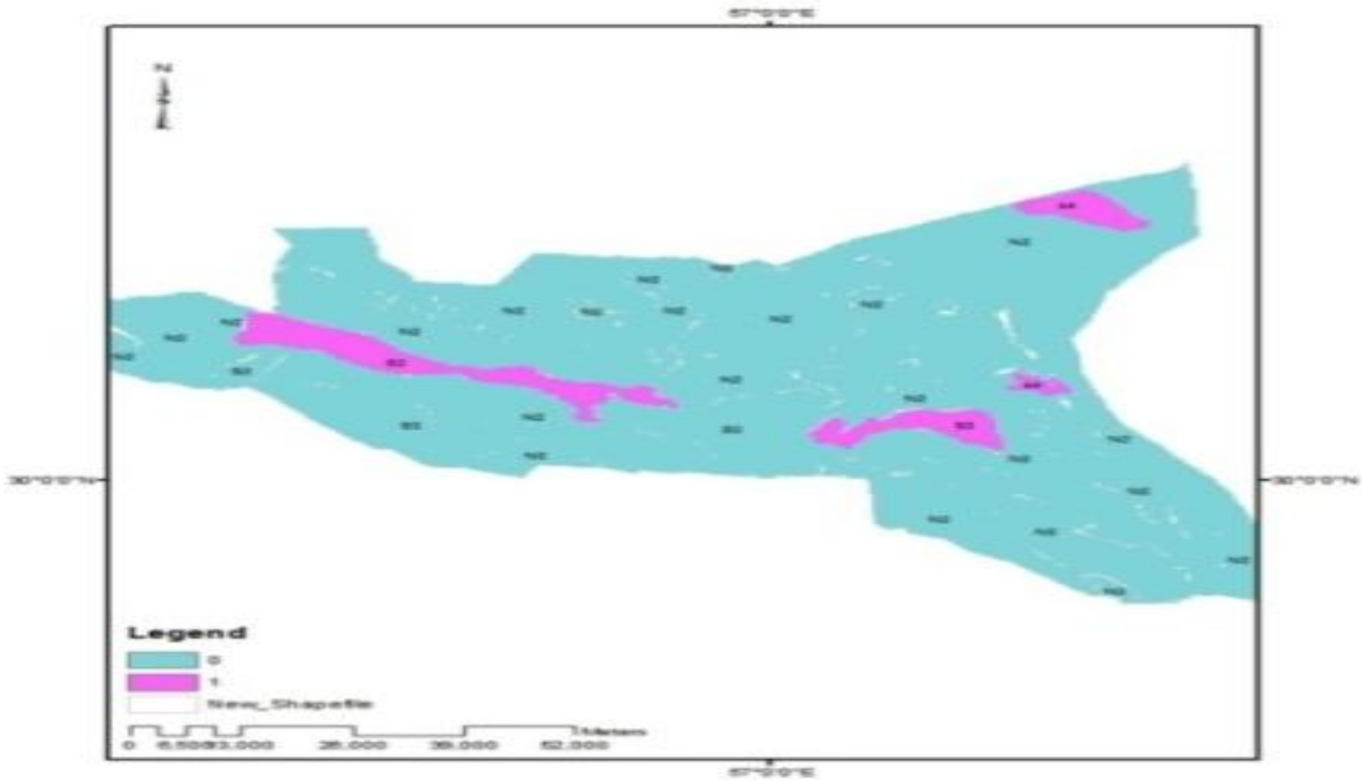

Figure 5. The proportion classification of Lands with Boolean.

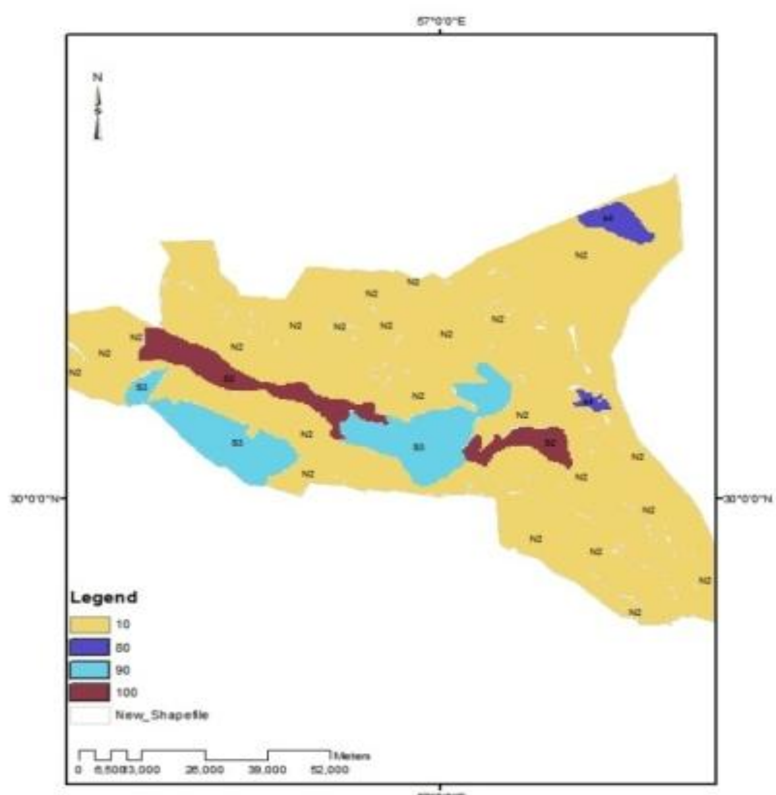

Figure 6. The classification of proportion Lands with proportion percent.

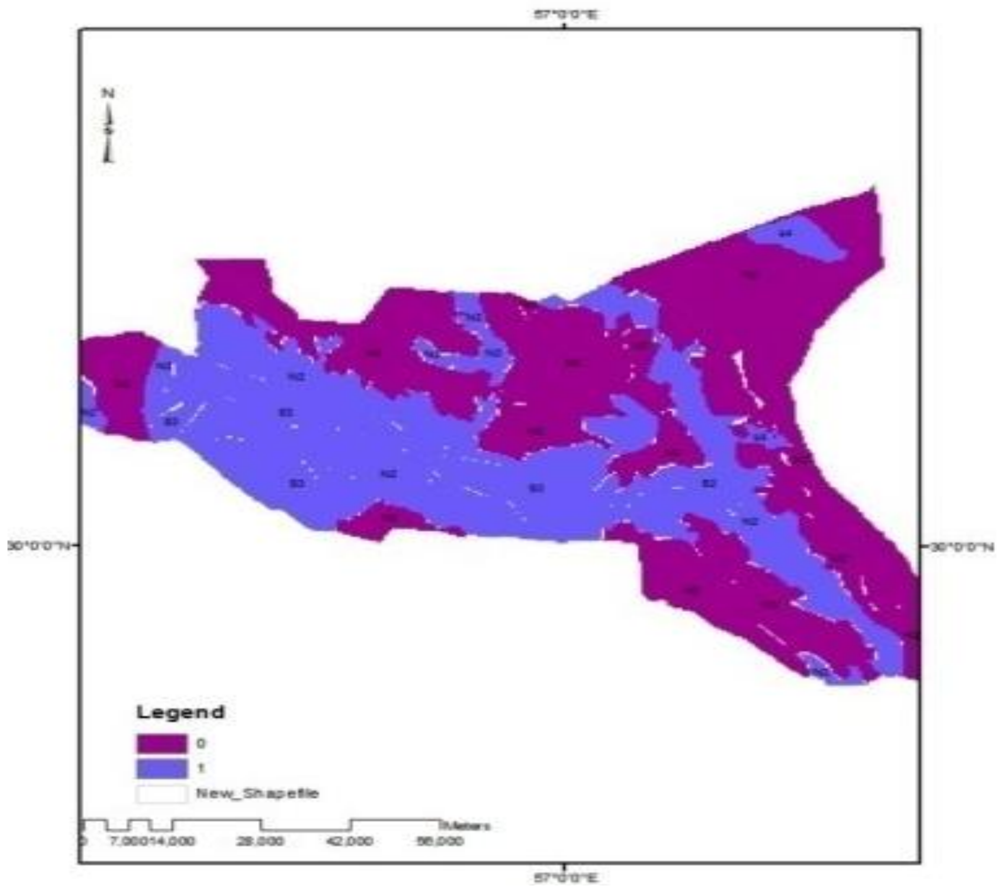

Figure 7. The classification of soil texture in the trickle irrigation with Boolean method.

parts of Baghin and Kabootarkhan region. The limiting factors in these regions include the improper quality of water because of having high electrical conduction (E.C > 8000) and thickness of bicarbonate of calcium (HCO_3 > 6). Also the kind of these regions includes the gravel fan colluviums and type and severity of them is because of many gravels and not keeping of moisture. Some lands of these regions belong to mountains and hills.

Type and severity of their limitation because of rocks out crop that have not soil and proper slope (slope> 10%). 20% of unsuitable lands of plain is located in some parts of Mahan region and Sare Asiabe Farsangi limiting factors in this regions are unqualified water and the improper condition of slope (slope > 10%).the unsuitable and untalented lands for performance of sprinkle irrigation include about 85% of lands of plan and 45% out of them are located in Baghin, Kabootarkhan, Khenaman and Derakhtegan and the soil texture is the most important problem.

Forty percent of unsuitable and untalented lands for performance of irrigation system in Kerman plain is located in some ports of Zangiabad, Ekhtiar Abad, Sare Asiabe Farsangi, Mahan and Ghenaghestan which have the limiting factor of water quality, the high ratio of sodium, chlorine or the high ratio of E.C.

DISCUSSION

The remote sensing techniques, GIS, and its analytic functions are applied and effective devices in site selection. There are different ways and models in quantitative , qualitative and drawing form for site selection .The potentials and abilities of a site is different according to concepts.

The indexes should be combined with standards on the basis of the performance in order to evaluate the potential of site. These indexes and standards are difference according to application, but all of them are centralized for selection of site. The using of these indexes requires the correct and complete information from the site, and achieving these information's needs on extensive and comprehensive researchers.

The Kerman plain has about 7.500 km^2 area and the well-proportioned and irrigation able lands include around 4.000 km^2 of this area, which is about 55%. 25% of plain lands are reasonably recognized for drip irrigation (Naseri et al., 2009; Omidvari and Sepahvand, 2005). The

Planning and Budget Organization (1997). The unsuitable and untalented lands for performing of drip irrigation are categorized into three zones:

The first zone

This zone covers the Deraklltecan region and parts of Khenaman, which have totally 1.380km^2 areas and include 20% of plain. The limiting factors in these regions are:

1). The condition of topography and slope On the basis of the map of slope region, the slope is more than 10% in these regions and according to Boolean logic; these regions were not reasonably recognized for the drip irrigation.
2). The lands of these regions belong to mountains and hills on the view of lands type. According to the proportion degrees of lands and limitations of these lands are severe because there is severe rocks out crop there , and they belong to N2(r) lands on the view of the proportion lands classification.

The second zone

The region covers some parts of Baghin, Kabootarkhan, Ekhtiarabad, and Zangiabad, and it involves 35% of unsuitable lands of plain. The limiting factors in these regions involve:

1). The quality of water: The limitation of these region is EC > 8000 and HCO_3 > 6 in some parts.
2).The ability of lands: The lands of this region belong to 1.3 and 8.1 lands. The 8.1 lands include the grovel colluvium on the view of lands type and many gravel colluviums, and the lack of keeping moisture are the reasons of kind and severe of limitation. They belong to s_4 (gw) lands on the view of lands classification, and 1.3 lands. The rocks out crop which have not soil are the reasons of their limitation and kind, and they belong to N_2(r) lands on the view of lands classification.
3). The unsuitable slope condition (slope >%10)
With paying attention to the lands slope, KABOOTAPKLAHN has unsuitable land.

The third zone

This region includes some parts of MAHAN and SARA ASIAB, which cover about 18% of plain lands.

The limiting factors of these regions are:

1). The unsuitable slope in the Mahan region (slope >%10).
2). The unqualified waterof some parts of Sarasiabefarsaci, and 5% of plain lands are reasonably recognized for sprinkle irrigation, so 95% of them are not suitable and talented.

On the view of existing limitation for performing of sprinkle irrigation in the Kerman plain, the lands are categorized into two zones:

The first zone

This region, which has about 3.650 km^{2,} covers BAGHIN, KABOOTARKHAN, KHENAMAN, and DERAKHTEGAN or it includes 48% of lands plain. The problem of these regions is soil texture.

The second zone

This region, which includes 47% of plain lands, covers some parts of Zangiabad, Ekhtiarabad, Sarasiabe Farasangi, Mahan, and Ghenaghestan, and it has the limiting factor of water quality high sodium,chlorine or high ratio EC.

Conclusions

1).The comparison of two methods: logical overlay and arithmetic overlay with the circumstances of the regions showed that the site selection arithmetic overlay model – the proportion percent- for recognizing the suitable lands in order to perform pressurized irrigation system is more suitable. On the basis of this method, 15% of desert lands for performing of sprinkle system and 20% of them for drip irrigation reasonably were recognized.
2). Principal management and correct programming and optimistic exploitation from the sources required exact and up to date from that site. In this direction, GIS plays an important role in achieving predetermined aims such as optimistic investment; for they have the ability of analysis of location, combination and digestion of map data, table data, reporting in according to standards format and decrease of cost.
3). The suitable site selection for performing of pressurized irrigation plans by study of all quantitative and qualified factors of water, soil, climate, and the topography of region which were done by GIS and satellite image that has high quality that finally with making analytic site selection and by related logical contribute to appropriate comprehension from region is a necessary issue in all regions. Because with existing limitation in sources of agriculture section the regions which have more adoption for performing of pressurized irrigation system should be determined so that to prevent to go to waste the sources of soil and water.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Effects of soil types and nutrient levels on early leaf development of maize, bean and sunflower crops

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Leaf area development at early stages of plant growth affects dry matter production because the former is the determinant for the amount of light intercepted, which then is used for photosynthesis. A pot experiment was conducted in a glasshouse to investigate the interacting effect of soil types and nutrient levels on leaf area and leaf dry weight at early development stages of maize, bean, and sunflower. The experiment was laid down in a randomized complete block design with three factors including plant species, nutrient levels and soil types. The latter two showed an interacting effect both on leaf area per pot and leaf dry weight, but the three way interactions were not significant. Leaf area and leaf dry weight per pot were high in pot soils and at 50% nutrient level for all the plant types. All plant types showed higher difference in leaf area and leaf dry weight per pot in pot soil than in quartz sand and sandy soils. Leaf area per pot and leaf dry weight per pot was high in pot soils. Maize and bean, and maize and sunflower interactions showed significantly higher difference in leaf area and leaf dry weight in pot soil than in quartz sand and sandy soils.

Key words: Pot soil, quartz sand and sandy soils, plant types.

INTRODUCTION

Maize, common bean and sunflower have long history of association with people. Leaf area development at early growth stages of a plant affects dry matter production because leaf area determined the amount of dry matter production (Gomez-del-Compo and Lisserague 2002). Effects of nutrient limitations on plant growth are mainly due to its effects on leaf area and to a lesser extend to its effects on photosynthesis (Marcelis, 2001).

Nutrients are available to plants as soil composition or supplemented to soil. Nutrient content of the soil is an important soil chemical property and different soil has different properties (Brye et al., 2004). Nitrogen deprivation reduces the leaf production, individual leaf area and total leaf area (Vos et al., 2005). High nitrogen (N) application resulted in high shoot dry mater production per plants. The difference in dry matter production is mainly attributed to the effect of N on leaf production by an individual leaf dry matter (Cechin and Fatima, 2004). The rate of dry matter accumulation is determined primarily by the amount of solar radiation intercepted (Cechin and

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Table 1. Analysis of the three soil types used in the experiment.

Materials	Quartz sand	Sandy soil	Pot soil
pH_{KCl}	5.60	5.40	5.90
Organic matter (%)	0.30	4.80	57.00
N-total (%)	0.11	0.14	0.69
P-total (%)	0.02	0.15	0.44
K_2O (mg/100 g)	1.00	24.00	68.00
MgO (mg/kg)	9.00	96.00	182.00

Table 2. Amount of nutrient needed per pot.

Mineral	Common concentrations (%)	Need per 12 g	Need at 50% (mg/pot)	To add at 50% (mg/pot)	M	To add at 50% (mmol/pot)
N	3.0	360	180	180	14.0	12.88
P	0.5	60	30	30	31.0	0.97
K	3.0	360	180	180	93.1	1.93
Mg	0.35	42	21	21	24.3	0.86
Ca				256.64	40.1	6.40
S				88.875	32.1	2.77

[1]N: Nitrogen, P: phosphorus, K: potassium, Mg: magnesium, Ca: calcium, S: sulphur.

Fatima, 2004). A good mixture of potting media offers a reliable environment for plant growth. Shoot dry mass and leaf area decrease as the size in diameter of the soil aggregate increases in a greenhouse pot experiment (Alexander and Miller, 1991). Leaf area development and leaf dry weight accumulation of maize, bean and sunflower increased when supplied with high nutrient levels, by planting on fertility soils and soils with good water holding capacity. However, nutrient levels may not have the same effect on different soil types; and this may be due to the inherent nature of the soil on which the nutrient is applied. The objective of this study was therefore to investigate the interactive effects of soil types and nutrient levels on leaf area, and leaf dry weight during early growth stages of maize, bean and sunflower.

MATERIALS AND METHODS

Experimental set up

The experiment was conducted in a glasshouse in a randomized complete block design in nine and ten block, respectively. The experimental units were a five litre pot in which 15 seeds of maize or common bean cv. or sunflower were sown. The three factors namely: soil types, nutrient levels and plant type were combined in each treatment. The three soil types were quartz sand, sandy soil and pot soil which differed in important chemical characteristics (Table 1). The nutrient levels used were 5 and 50% of the estimated amount of nutrients needed to produce 12 g plant dry matter at harvest. This was calculated by assuming that plant dry matter contains an average of 3% N, 0.5% P, 3% K and 0.35% Mg (Table 2). The 50% nutrient level solution was prepared by adding 415 ml distilled water in 485 ml stock solutions. In addition, 5% nutrient level solution was prepared by adding 10 ml of the 50% solution into 90 ml distilled water (Table 3).

Cultural practices

Sandy soil was sieved through two millimetre wire mesh sieve so as to remove the clods of the soil particles and other debris materials. The pots were filled to 4 cm of soil under the edge and pressed to level the top soil and all pots were labelled accordingly. Fifteen seeds of each plant type were sown 2 cm deep per pot in regular pattern. Two guard pots were included at the end of each block to give protection for the middle pots. The soil moisture level in pots was maintained at optimum to fulfil the water requirement of the plants and this was done in two irrigation regimes in a day using a standard watering hose.

Growing conditions of the plants

The average day and night temperatures in the glasshouse were 25 and 21°C, respectively, and the set temperatures for cooling and heating were 22 to 23°C, respectively. The relative humidity was set at 70% during the growing period of the experimental plants.

Data collection

After 13 days of plant age all plants were harvested and the parts of

Table 3. Compositions of nutrients prepared from stock solutions used in pot experiment.

Solution (undiluted)	Volume of undiluted solution needed per pot (ml)	Dilution	Volume per pot 50% nutrient (ml)
CALSAL	N: 1.37	1:10	125
MAGNESUL	Mg: 1.36	1:10	35
SULFAKAL	S: 0.45	1:25	105
BASKAL	K: 0.16	1:50	70
Phosphoric acid	P: 0.11	1:50	50
EDDHA3 (3%Fe)	: 1.24	1:50	55
Trace elements	5.00	-	45
Water			415
Total			900

Table 4. Effect of plant types and soil types on leaf area (cm^2/pot) over two nutrient levels.

Plant types	Quartz sand	Sandy soil	Pot soil
Maize	720[a1]	1292[b]	1765[c]
Bean	1894[c]	2243[d]	3373[e]

[1]Means followed by different letter(s) differ significantly (P < 5%) as established using the LSD-test (0.05) =203.5.

the harvested plants including leaf, aerial stem, underground stem and root; the roots were separated from the soil by carefully cleaning and washing them using distilled water. The stems close to the ground were also separated from the cleaned roots and dried separately. The plant parts were oven-dried at 105°C for 16 h to constant weight and then the leaf area per pot was determined with a leaf area metre.

Statistical analysis

Analysis of variance (ANOVA) was conducted using GenStat software and 5% level of probability was used to test the significant effects of treatments. Differences between treatment means were established using the LSD-test at 5% probability.

RESULTS

Effect of soil types and nutrient levels on leaf area

The three-way interactions among soil types, between nutrient levels and among plant types were not significant for leaf area per pot (p > 0.05) in both experiments (Table 4). However, the two-way interactions among plant types and soil types were very significant (p < 0.001 and 0.001) in both experiments. The interactions among soil types, nutrient levels and plant types were significant to very significant (p < 0.05) in both experiments. The leaf area per pot for common bean was higher than that of maize in all soil types. However, maize recorded highest leaf area per pot in a pot soil (Table 4) than the other two soil types. In addition, maize and bean had higher leaf area per pot in pot soil than in other two soil types. Results also indicated that there was no significant (p > 0.05) difference observed for maize in pot soil and for bean in quartz soil (Table 4). Referring to all the three plant types, leaf area per pot was higher in the order of pot soil, sandy soil and quartz sand (Tables 4 and 6).

The leaf area per pot increased with increase in nutrient levels for all soil types (Table 5). In 5 and 50% nutrient levels quartz sandy soil had lower leaf area per pot for all plant types than in other soil types. The leaf area per pot for maize was higher than for sunflower in both nutrient levels. However, the difference between maize and sunflower at 5% nutrient level was smaller than at 50% nutrient level (Table 7). The leaf area per pot increased with increase in nutrient level only in quartz sand and sandy soils, but not in pot soil (Table 8).

Effect of soil types and nutrient levels on leaf dry weight

In experiments one and two, the three-way interactions among soil types, nutrient levels and plant types were not significant (P >0.05) for leaf dry weight per pot. On the other hand, the two-way interactions among plant types and soil types resulted in leaf dry weight per pot which differed significantly (P < 0.001). Referring to plant types as maize, common bean, and sunflower, the leaf dry

Table 5. Effect of nutrient levels (5 and 50%) and soil types on leaf area (cm^2/pot). for two plant types.

Soil types	Nutrient levels	
	5%	50%
Quartz sand	1067[a1]	1535[b]
Sandy soil	1727[b]	1808[bc]
Pot soil	2384[d]	2754[e]

[1]Means followed by different letter(s) differ significantly (P < 5%) as established using the LSD-test (0.05) =203.5.

Table 6. Effect of plant types and soil types on leaf area (cm^2/pot) over two nutrient levels.

Plant types	Quart sand	Sandy soil	Pot soil
Maize	662[c]	1115[d]	1509[e]
Sunflower	298[a1]	505[b]	656[c]

[1]Means followed by different letter(s) differ significantly (P < 5%) as established using the LSD-test (0.05) =86.6.

Table 7. Effect of plant types and nutrient levels (5 and 50%) on leaf area (cm^2/pot) over three soil types.

Plant types	Nutrient levels	
	5%	50%
Maize	992[c]	1199[d]
Sunflower	44 [a1]	525[b]

[1]Means followed by different letter(s) differ significantly (P < 5%) as established using the LSD-test (0.05) =70.7.

Table 8. Effect of plant types and nutrient levels (5% and 50%) on leaf area (cm^2/pot) for two plant types.

Soil types	Nutrient levels	
	5%	50%
Quartz	327[a1]	633[b]
Sandy soil	750[c]	869[d]
Pot soil	1083[e]	1082[e]

[1]Means followed by different letter(s) differ significantly (P< 5%) as established using the LSD-test (0.05) =86.6.

weight per pot was higher in order of pot soil, sandy and quartz sand soils (Tables 9 and 11). Leaf dry weight per pot for common bean was the highest in all soil types compared with maize and sunflower, but the difference between maize and common bean in sandy soil was smaller than in the other soil types (Tables 9 and 11).Pot soil resulted in higher leaf dry weight per pot for common bean than in the other two soil types (Table 9). Leaf dry weight per pot for maize in all soil types was higher than sunflower, but the difference between maize and sunflower in quartz sandy soil was smaller than in the other soil types (Table 11).

The leaf dry weight per pot increased with increase in nutrient levels only in quartz sandy soil, but not in sandy and pot soils (Tables 10 and 12). Significant ($P < 0.05$) differences were observed between nutrient levels on quartz sandy soil, but not in sandy and pot soils (Tables 10 and 12).

Table 9. Effect of plant types and soil types on leaf dry weight (g/pot) over two nutrient levels.

Plant types	Soil types		
	Quartz soil	Sandy soil	Pot soil
Maize	2.04a1	2.94b	4.11c
Bean	5.32d	5.59d	7.68e

[1]Means followed by different letter(s) differ significantly (P< 5%) as established using the LSD-test (0.05) =0.411.

Table 10. Effect of plant types and nutrient levels (5% and 50%) on leaf dry weight (g/pot) over two crop types.

Soil types	Nutrient levels	
	5%	50%
Quartz sand	3.39a1	3.98b
Sandy soil	4.43b	4.09b
Pot soil	5.81c	5.98c

[1]Means followed by different letter(s) differ significantly (P < 5%) as established using the LSD-test (0.05) =0.411.

Table 11. Effect of plant types and soil types on leaf dry weight (g/pot) over two crop types.

Plant types	Soil types		
	Quartz sand	Sandy soil	Pot soil
Maize	2.26c	3.10d	4.17e
Sunflower	1.19a1	1.64b	2.05c

[1]Means followed by different letter(s) differ significantly (*P* < 5%) as established by the LSD-test (0.05) =0.231.

Table 12. Effect of nutrient levels (5% and 50%) and soil types on leaf dry weight (g/pot) over two crop types.

Soil types	Nutrient levels	
	5%	50%
Quartz sand	1.34a1	2.10b
Sandy soil	2.28b	2.46b
Pot soil	3.16c	3.06c

[1]Means followed by different letter(s) differ significantly (P < 5%) as established using the LSD-test (0.05) = 0.231.

DISCUSSION

Plant types and soil types; soil types and nutrient levels; and, nutrient levels and plant types showed interactions for leaf area per pot of maize, common bean and sunflower, but there was no interaction observed between the three factors on leaf area development and leaf dry weight accumulation. Plant types and soil types; and, soil types and nutrient levels also showed interactions for leaf dry weight, but there were no three-way interactions observed for the leaf dry weight. In this study, leaf area per pot increased in pot soil and at high nutrient level. This might be due to immediate availability of nutrients for plant uptake especially at the studied early growth stages of the crop. This findings suggest that at early stages of crop growth there is response in formation of canopy structure and results in increased vegetative development. Similar findings are also reported by Lebon et al. (2006).

The interacting effect of soil types and nutrient levels on leaf area and leaf dry weight might be related to the differences in nutrient composition of the soils and other properties of the studied soils. The findings of this study indicated that pot soil, which has high nutrient composition and water holding capacity enhanced leaf area development and leaf dry matter production compared with quartz sand and sandy soils. High nutrient level (50%) used in this study resulted in high leaf area development and leaf dry weight production. The highest differences in leaf area and leaf dry weight production among the three soil types were observed at the low nutrient level (5%). Similarly, sandy soil resulted in higher leaf area and leaf dry weight per pot than quartz sandy soil at the low (5%) and high (50%) nutrient levels. In addition, the low nutrient level (5%) resulted in lower leaf area production than in high nutrient level (50%). The latter observation is in corroboration with the findings of Gutierrez-Boem and Thomas (2001) who indicate that nutrient deficiency particularly phosphorus (P) resulted in low leaf area production.

The findings of this study indicated that the leaf dry weight of common bean was higher than for maize. This might be related to the leaf area per pot of common bean which was higher than that of maize. Further to that, the leaf dry weight of maize was higher than that of sunflower, which could be related to the leaf area per pot of maize which was higher than that of sunflower. In addition, the high nutrient level (50%) resulted in leaf dry weight production which was higher than that produced in low nutrient level (5%). This observation was similar to the findings of Cechin and Fatima (2004) on the photosynthesis of sunflower plants grown in the glasshouse as affected by nutrient supply. The findings of this study imply that soil types with good chemical and physical properties may have an increasing effect on leaf area and leaf dry matter production, an observation which is similar to the findings of Magdi et al. (2004). Magdi et al. (2004) reported significant contribution of compost application towards an increase in growth, yield, yield components and total crude protein of faba bean plants and this contribution is due to an improved properties of soil resulted by application of compost. Similarly, a study conducted by (Zakaria et al. 2014) to investigate the effect of different ratios of municipal solid waste compost on growth parameters and yield of Marigold also confirmed the potential of compost in improving growth parameters of crops.

Conclusion

Soil properties can be improved through organic soil amendment, since biofertilizers have the ability to improve properties of soil. Fertility status of the soil needs to be taken in to consideration before making fertilizer recommendation for a given soil. This is because application of nutrient to soils with high inherent fertility may not result in an increating performance or yield of crops.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Effects of fermented Indigo-Leaf (*Indigofera tinctoria* L.) extracts on yield and pest control in Chinese mustard and sweet basil

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The purpose of this study was to investigate the impact on yields and pest control of extracts from fermented Indigo leaves (*Indigofera tinctoria* L.) on Chinese Mustard (*Brassica chinensis* Jusl var parachinensis (Bailey) Tsen & Lee) and Sweet Basil (*Ocimum basilicum* L.) For Chinese mustard, comparing crop yields revealed that fermented indigo-leaf extracts of mixed (tea-coloured and blue), tea-coloured and blue varieties gave yields of 24,444.44, 19,222.25 and 19,111.13 kg ha^{-1}, respectively. The fermented indigo leaf extracts of mixed (tea-coloured and blue) variety could be most appropriate for preventing and eradicating *Phyllotreta sinuata* Steph. For Sweet basil, fermented tea-coloured, blue and mixed (tea-coloured and blue) indigo leaf extract gave yields of 20,333.31, 17,833.31 and 17,555.56 kg ha^{-1}, respectively. The differences were statistically significant. The tea-coloured indigo leaf extracts caused decreased population of natural predator (*Menochillus sexmaculatus* (F.)) in basil plantation.

Key words: Indigo-leaf extracts, yield, pest control, Chinese mustard, sweet basil.

INTRODUCTION

In Thailand, insect pests such as striped flea beetles (*Phyllotreta sinuata* Steph.) infesting Chinese Mustard and maggots in Sweet Basil are important concerns for growing these vegetables. Insect pests have caused problems for large amounts of exported agricultural produce of many kinds. In expanding to grow large quantities of vegetables, a recurring problem in the growing plots has been that they are struck down by pests. Thus, the farmers need to use chemicals to prevent and eradicate pests, and produce that might be harvested before it is ready. Residues frequently accumulate in the vegetables in amounts over the standard values allowed. In addition, the use of such chemicals affects the environment and human wellbeing.

One possible way to improve this situation is by growing vegetables using extracts of certain herbs that possess more than one active insecticidal ingredient. The chance for insects to produce an anti-agent against such a mix of ingredients is likely to be slim (Wongthong and Pimsaman, 2005). The extracts experimented within this study were derived from *Indigofera tinctoria* L. There are rotenoids from *Isatis tinctoria* L. that have the quality of preventing and eradicating insect pests (Kamal and Mangla, 1993). Rotenoids can be found in *Derris elliptica* Benth (Sugsawat, 2005; Perry et al., 1998) which is highly active for killing insects by touch and sucking

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(Ahmed et al., 1983).

Derris elliptica Benth have low toxicity to humans, other vertebrate animals and the environment. It is highly toxic to fish and insect pests, and break down quickly when exposed to sunlight and high temperature (Tuncho, 2008). Rotenoids from *I. tinctoria* L. are mostly found in the leaves. There are six kinds of rotenoids, namely dehydrodeguelin, deguelin, rotenol, rotenone, tephrosin and sumatrol (Royal Project, 2008).

A study of *I. tinctoria* L. should be conducted, especially with respect to controlling insects that are pests of vegetables grown for domestic consumption and export. Success in such studies could lead to a new way to bring domestic plant resources to their full potential and sustainability.

MATERIALS AND METHODS

Preparation of fermented extract from indigo leaves

Four kilograms of fresh leaves were put in a 50 L plastic container. The tank was then filled with 10 L of freshwater. The leaves were pressed to submerge them and soaked for 24 h. Then the dregs were separated out of the tank and the extract was filtered. There were microorganisms especially *Bacillus alkaliphylus* in aeration and indigo leaves (Chanayati, 2001). The filtered extract was divided into 2 parts. The first 5 L of the indigo-blue extract (indoxyl and glucose with acidity pH 4.8) (Chanayati, 2001) was employed for experiments in vegetable plots. The remaining 5 L of the fermented indigo extract was mixed with 100 g of lime in tap water. The fermented indigo extract was stirred until it became dark blue, then it was left for 24 h until the residue had sunk down to the bottom of the tank. The tea-coloured indigo extract was then poured out of the upper tank for experiments in vegetable plots. The tea-coloured indigo extract had substantial amounts of nutrient, lime and active rotenone and others (Preparation of fermented extract from indigo leaves by Local wisdom methods in Sakon Nakhon province)

Experiments to examine the effects of fermented indigo leaf extracts on yields and pest control in Chinese mustard and Sweet basil

Examination of the effects of the fermented indigo-leaf extracts on Chinese mustard and Sweet basil using a randomized complete block design (RCBD) comprised 4 treatments and 3 blocks: Treatment 1 (tea-coloured fermented extract), Treatment 2 (indigo-blue fermented extract), Treatment 3 (tea-coloured and indigo-blue mixed together), and Treatment 4 control (tap water) were paired with vegetables. Seedlings were raised in seed pans containing soil: compost mix (1:1 v/v). After germination the seedlings were maintained for two weeks. When the seedlings aged 15 days, they were transplanted into the seedling bag. After seedlings were maintained for 15 days, they were brought to grow in the growing plot. The growing plot size was 1.5×2 m^2 and elevated as high as 15 cm. Bogashi compost (hull and manure mixed together for 30 days), 5 kg/plot, was added after periods of 15, 30 and 45 days.

The tea-coloured fermented indigo extract was used to water the vegetables for prevention and eradication of insect pests in a ratio of 25 ml/10 L of water. The indigo-blue fermented extract was also used in a ratio of 25 ml/10 L of water. The tea-coloured and indigo-blue extracts were also mixed in a ratio of 25: 25 ml/ 10 L of water, and tap water was used as a control. All extracts were prepared for watering every one week. Absolute method was used. A yellow sticky trap was used and the insects were counted on the trap. Notes were taken by observation of the kinds of insect found; the numbers of insects found on vegetables before and after one week of watering with each extract were also counted. Chinese mustard was harvested 50 days and Sweet basil 55 days after planting in the plots. The quantity of each kind of vegetable produced per plot was weighed. The crop yields with each treatment were weighed, recorded and analysed and compared using analysis of variance; a pair wise comparison for a difference of means was done using Duncan's New Multiple Range Test (DMRT).

RESULTS AND DISCUTION

Investigating the effects of fermented indigo leaf extracts on yields of Chinese mustard

In comparing which fermented indigo leaf extract had more effects on yields of Chinese mustard with the three experiment which used the tea- coloured fermented extract, the indigo blue fermented extract and mixture of both, it was found that treatment using the mixture resulted in the highest yield, an average of 24,444.44 kg ha^{-1}. This average weight was significantly different from the yields obtained from using either the indigo tea-coloured fermented extract or the indigo blue-coloured fermented extract alone, which produced 19,222.25 and 19,111.13 kg ha^{-1}, respectively, ($p<0.05$); whereas tap water (control) yielded only an average of 12,777.75 kg ha^{-1}, (Figure 1). The indigo tea- coloured fermented extract was appropriate for Chinese mustard, yielding 24,444.44 kg ha^{-1}

It was evident that the yield of Chinese mustard using the mixture of both extracts was the highest, while using the tea-coloured extract and indigo-blue extract individually, produced successively lower yields, although still higher than the control plots. This is because as a plant of Papilionaceae, Indigo's root nodules carry *Rhizobium indigoferae* which have nitrogen-fixing capacity (Garrity et al., 1994). The plants, then, include food minerals that are essential for their growth. Their leaves had a high amount of nitrogen. Therefore the fermented indigo-leaf extracts had quantities of highly concentrated organic minerals. In a particular indigo leaf, the level of nitrogen was as high as 5.11% as well as diphosphorus penta-oxide 0.78% and potassium oxide 1.68% and calcium from lime (Royal Project, 2009; Tuncho, 2008; Reangrug and Tuntiwat, 1991). The Chinese mustard, then, could grow better.

The effects of fermented indigo-leaf extracts on pest control in Chinese mustard

During investigation of widespread insect pests in the Chinese mustard plots before use of the fermented indigo extract, striped flea beetles were found in the plots before the treatments on average 15.33, 15.67, 15.67 and 16.67

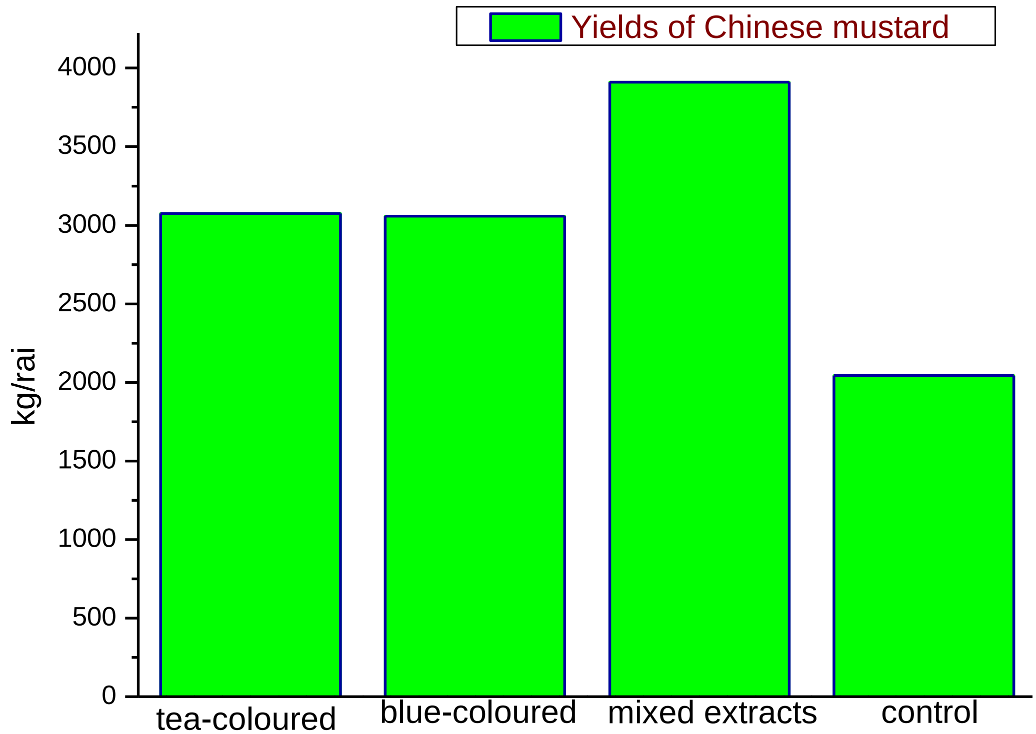

Figure 1. Comparing the yields of Chinese mustard with the tea-coloured, blue and mixed (tea-coloured and blue) fermented indigo-leaf extracts, and control.

Table 1. Average number of *P. sinuate* Steph. in Chinese mustard

Treatment	Average number of *P. sinuate* Steph.					
	Before treatment	**1 week**	**2 weeks**	**3 weeks**	**4 weeks**	**5 weeks**
Tea-coloured indigo extract	15.33	3.33[a]	1.00[a]	2.33[a]	1.67[a]	2.00[a]
Blue-coloured indigo extract	15.67	9.67[b]	8.00[b]	3.67[a]	2.33[a]	3.33[a]
Mixed of both	15.67	0.33[a]	0.00[a]	1.33[a]	0.67[a]	0.67[a]
Control	16.67	19.33[b]	12.67[b]	10.67[b]	8.33[b]	8.00[b]
F-test	ns	*	**	*	*	*

Note: Means in each column followed by the same letter are not significantly different . (P < 0.05) from each other according to DMR test.

fleas/plot were noted. There were no significant differences between the average numbers of striped flea beetles. By analysis of variance after the first watering after 1 week with the three treatments, it was found that the average number of striped flea beetles on the Chinese mustard growing plots showed significant differences (p<0.05) among all the treatments. After watering the Chinese mustard using the tea-coloured and indigo-blue mixed together, striped flea beetles were minimal, occurring on average only 0.33 flea/plot. After 2 weeks of watering the Chinese mustard with, the tea-coloured and indigo-blue mixed together and the indigo tea-coloured fermented extract, the average number of striped flea beetles for each treatment showed highly significant differences (p<0.01).

The striped flea beetles were not found in the growing plots that used the tea-coloured and indigo-blue mixed together, whereas in the plots with the indigo tea-coloured fermented extract, an average of only 1.00 flea/plot was found. After 3 to 5 weeks of watering with the indigo tea-coloured fermented extract, the indigo blue-coloured fermented extract, the tea-coloured and indigo-blue mixed together and control, the average numbers of striped flea beetles for each treatment were significantly different (p<0.05) shown in Table 1. In a nutshell, watering the fermented indigo extract 1 to 2

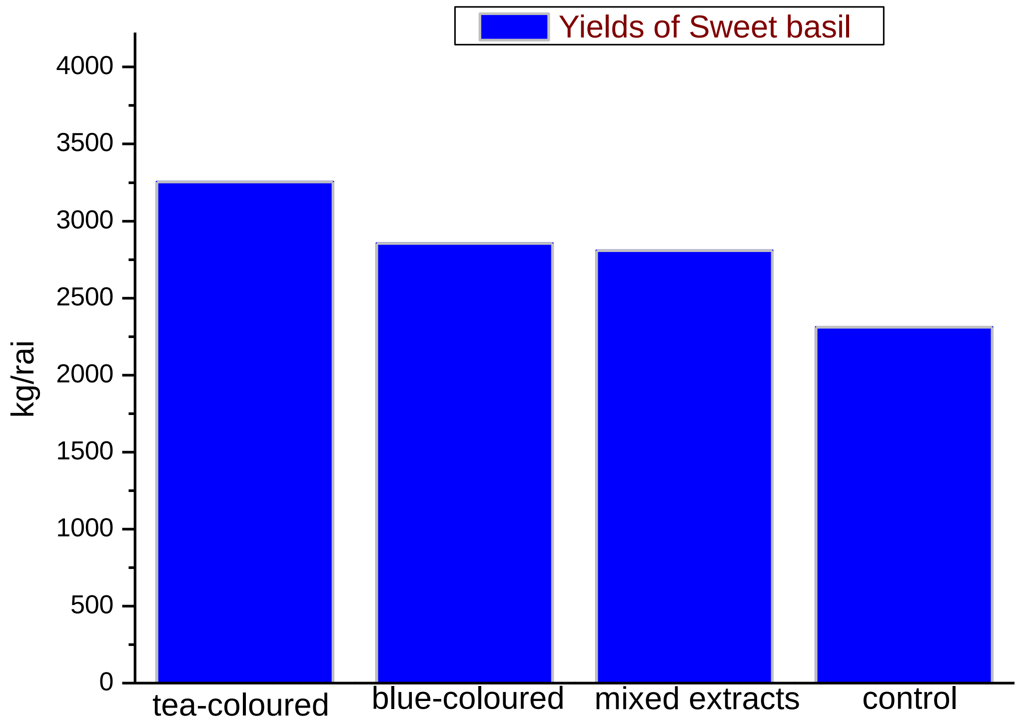

Figure 2. Comparing the yields of Sweet basil with the tea-coloured, blue, and mixed (tea-coloured and blue) fermented indigo-leaf extracts and control.

weeks could control number of striped flea beetles in Chinese mustard plots.

It was apparent that watering the Chinese mustard with indigo-blue and tea-coloured fermented extracts could be beneficial for prevention and eradication of insects. Since each kind of extract from the fermented indigo-leaves contained rotenoids, which have several active ingredients and an acidic quality, watering the Chinese mustard growing plots on which the striped flea beetles larvae and their matured maggots live by day with the fermented indigo-leaf extracts resulted in visible decreases in striped flea beetles after just one or two times.

The fermented indigo-leaf extracts could be used to prevent and eradicate insects that are pests of these vegetables (Wongthong and Pimsaman, 2005; Kamal and Mangla, 1993; Sugsawat, 2005; Royal Project, 2009; Reangrug and Tuntiwat, 1991). Using the fermented indigo-leaf extracts to water or spray the Chinese mustard 2 or 3 times with an interval of 5 to 7 days between each treatment reduced the numbers of striped flea beetles. Thus, fermented indigo-leaf extracts could be useful for controlling pest insects of these vegetables. The use of a mixture of tea-coloured and blue-coloured fermented indigo-leaf extract could produce the highest yield and most effective control of striped flea beetles in Chinese mustard followed by the tea-coloured and the blue-coloured fermented indigo-leaf extract, respectively.

The effects of the fermented indigo-leaf extracts on Sweet basil yields

When the effects of using the three kinds of fermented indigo-leaf extract were compared, it was found that the yields of Sweet basil with and without receiving treatment by the fermented indigo-leaf extracts showed a significant difference ($p<0.05$). Sweet basil treated with the tea-coloured indigo fermented extract produced the highest yield of 20,333.31 kg ha^{-1}on average; below this was the blue indigo fermented extract, the tea-coloured and indigo-blue mixed together and the control, with yields of 17,833.31 17,555.56 and 14,444.44 kg ha^{-1}, respectively, Figure 2. The tea-coloured indigo fermented extract was appropriate for Sweet basil, yielding 20,333.31 kg ha^{-1}

It was evident from the treatments that the Sweet basil watered with the tea-coloured fermented indigo-leaf extract produced the highest yield, and below this ranked the treatment with the indigo-blue extract and the treatment with a mixture of both extracts. This was because the fermented indigo-leaf extracts had high concentrations of organic elements and minerals, especially nitrogen, as high as 5.11% and high calcium from lime (Royal Project, 2009; Reangrug and Tuntiwat, 1991). That resulted in more growth of Sweet basil, the tea-coloured fermented indigo-leaf extract was suitable for watering garden vegetables for increasing their growth and keeping them free of disturbing insects.

Table 2. Average number of *M. sexmaculatus* Fabr. in Sweet basil.

Treatment	Average number of *M. sexmaculatus* Fabr.					
	Before treatment	1 week	2 weeks	3 weeks	4 weeks	5 weeks
Tea-coloured indigo extract	10.67	2.67[a]	1.67[a]	1.33[a]	2.00[a]	1.33[a]
Blue-coloured indigo extract	15.33	5.00[b]	3.67[a]	2.33[a]	1.67[a]	2.00[a]
Mixed of both	14.67	2.00[a]	2.00[a]	1.00[a]	0.67[a]	1.33[a]
Control	16.33	5.67[b]	6.33[b]	4.67[b]	5.33[b]	4.67[b]
F-test	ns	*	*	*	*	*

Note: Means in each column followed by the same letter are not significantly different (P < 0.05) from each other according to DMR test.

The effects of the fermented indigo-leaf extracts on insect control in sweet basil

From the results of counted insects found on the growing plots of Sweet basil, *M. sexmaculatus* Fabr. (Ladybird beetles) were found with a serrated pattern on their wings. Before watering the plants with the treatments, the counts of ladybird beetles on the plots of all the treatments intended to receive the tea-coloured indigo fermented extract, the blue indigo fermented extract, the tea-coloured and indigo-blue mixed together and the control plots showed the average numbers of 10.67, 15.33, 14.67 and 16.33 counts/plot, respectively. There were no significant differences between the average numbers of ladybird beetles.

By analysis of variance after first watering after 1 week with the three treatments, it was found that the average number of ladybird beetles on the Sweet basil growing plots showed significant differences (p<0.05) among all the treatments. After 2 to 5 weeks of watering with the tea-coloured fermented extract, the blue-coloured fermented extract, the tea-coloured and indigo-blue mixed together and the control, the average number of ladybird beetles showed significant differences (p<0.05), Table 2. In a nutshell, watering the fermented indigo leaf extract for 2 weeks had significant effects on the population of natural predator (*M. sexmaculatus* F.).

It was evident that with treatments of the tea-coloured extract itself, or a mixture of it with the indigo-blue extract just one or two times, the number of ladybird beetles decreased. It showed that the fermented indigo affected a number of nodes because in indigo leaves there are rotenoids which are active ingredients in preventing and eradicating insect pests of plants (Wongthong and Pimsaman, 2005; Kamal and Mangla, 1993; Sugsawat, 2005; Royal Project, 2009; Reangrug and Tuntiwat, 1991). This was in congruence with Perry et al. (1998); Ahmed et al. (1984) that in Indigo leaves, there are 6 rotenones which affects the number of nodes by contact. Thus, control over ladybird beetles on the Sweet basil plots using the mixture of tea-coloured and indigo-blue fermented indigo-leaf extracts or using the tea-coloured extract alone to spray two or three times on the plants with an interval of between five and seven days before the next spray resulted in a decreased number of ladybird beetles. This was in congruence with the Department of Agriculture which noted that substance rotenoid affects ladybird beetles. The fermented indigo leaf extract of tea-coloured and blue causes decrease in the population of natural enemies (*M. sexmaculatus* Fabr.) in Sweet basil plot. This was in congruence with Teanglum (2013) who noted that the fermented indigo leaf solutions of tea-colored and blue-colored extracts decreases the population of natural enemies (*Menochilus sexmaculatus* (F.)).

Conclusion

Application of the tea-coloured and indigo-blue extracts mixed together for prevention and eradication of *Phyllotreta sinuata* Steph on the Chinese mustard plots resulted in the highest yield, 24444.44 kg ha^{1}. Below this, were yields of 19222.25 and 19111.13 kg ha^{-1} obtained by using only the tea-coloured or the indigo-blue extracts alone, respectively. The tea-coloured fermented indigo extract gave the highest yield on Sweet basil, equalling 20333.31 kg ha^{-1}. Below this were Sweet basil yields of 17833.31 and 17555.56 kg ha^{-1} obtained by using the indigo-blue extract and the mix of both extracts, respectively. The tea-coloured and blue fermented indigo-leaf extracts caused a decrease in population of natural enemies (*Menochillus. sexmaculatus* Fabr.). In a nutshell, the application of extracts from indigo leaves for control of insect pests on vegetable plots is helpful for decreasing chemical residues in vegetables.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Hydrogen peroxide pre-treatment for seed enhancement in Cotton (*Gossypim hirsutum L.*)

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Seed germination and plant stand is a major problem in cotton especially under rain-fed cultivation. Various seed hardening treatments have been recommended in cotton for combating the moisture stress during germination. The role of H_2O_2 as a seed treatment for enhancing cotton seed performance has not been determined. The present study was therefore undertaken to study the effect of H_2O_2 on germination under moisture stress in comparison with the reported KCl treatment and water treatment with untreated control. The results suggested that seed priming with H_2O_2 at 80 mM is an effective method for obtaining superior germination and seedling growth under moisture stress condition. Lower values for electrical conductivity of seed leachates as well as malonaldehydes released during germination in the H_2O_2 treated seeds revealed the improved membrane stability of treated seeds. Parallely, an increase in activities of anti-oxidants viz. Peroxidase and Catalase as well as Malate dehydrogenase was also observed supporting the positive role of H_2O_2 in enhancing the seed germination of cotton.

Key words: Cotton, seed germination, H_2O_2 seed pre-treatment, antioxidant enzymes.

INTRODUCTION

Cotton is an important commercial crop of global significance and is cultivated under both irrigated and rain-fed conditions. Incomplete/improper plant population due to scanty/erratic rainfall which is a serious concern in rain-fed cultivation. Nearly 65% of the Indian cotton is grown under rain-fed which is a major cause for low cotton productivity in the country. Obtaining complete germination and establishing good plant stand is a prime requirement for cotton in India where high value seeds such as hybrids incorporated with transgene are sown in almost complete cotton acreage. Various seed hardening treatments to combat moisture stress during germination have been reported in cotton as reviewed extensively by Solaimalai and Subburamu (2004). These include soaking cotton seeds for various duration in water, succinic acid, potassium chloride, potassium dihydrogen phosphate, sodium or calcium salts etc. Seed priming is a technique widely used to overcome the germination related problems in different crops (Afghani et al., 2012; Dahamarudin and Arivin, 2013; Demir et al., 2012). Considerable interest have focused on seed priming since it also ameliorate stress tolerance by improving the activity of antioxidant enzymes which in turn decrease the adverse effects of reactive oxygen species (ROS). Hydro priming, osmopriming (using mannitol/PEG 6000) and halopriming (using KCl/KNO_3/Calcium salts) have been

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found effective for cotton seed establishment under unfavourable field conditions (Toselli and Casenave, 2005; Casenave and Toselli, 2007; Papstyliano and Karamanos, 2012; Mohammad et al., 2012).

It has been known for long that pretreatment of seeds with oxidants such as H_2O_2 (in a dose-dependent manner) leads to breaking, primary seed dormancy (Jann and Amen, 1977), secondary dormancy provoked by salinity, high temperature stresses (Kürsat and Kabar, 2010), or dormancy due to presence of germination inhibitors (Ogawa and Masaki, 2001). Hydrogen peroxide has been known to function as a stress signal in plants (Hung et al., 2005) and hence exogenously applied H_2O_2 in a dose-dependent manner has been reported to ameliorate seed germination in many crops (Patade et al., 2012; Gregario et al., 2010; Liheng et al., 2009; Azevedo et al., 2005). However, in cotton, Saeed (1974) reported that other than enhancing the germination rate, H_2O_2 pre-treatment of seeds neither increased the germination percentage nor the root length. There is limited information available on role of H_2O_2 in cotton seed germination. Therefore, the present study was carried out with a primary objective to evaluate seed treatment effect of H_2O_2 in comparison with the already reported KCl along with hydration on cotton seed germination and seedling growth under moisture stress condition. The second objective was to determine the biochemical changes occurring in treated seeds.

MATERIALS AND METHODS

Seed material

The premium cotton seeds with boll guard insect protection gene incorporated (Bt gene) into it and treated with imidacloprid was used. These seeds were further treated (primed) with KCl (2%), water and hydrogen peroxide (80 mM) by spraying over seeds uniformly followed by quick drying and used for further studies.

Experiments

Germination under controlled condition

Germination test was carried out using 50 seeds each in four replicates placed on rolled paper towels and incubated at 25°C for 7 days. The parameters observed during and after the experiment were 3rd, 5th and 7th day count. 10 normal seedlings selected on 7th day were subjected to data on shoot length, root length, fresh weight and dry weight.

Germination under moisture stress condition (pot study)

The pots filled with potting mixture (FYM + Sand and clay soil) were watered (quantity required was noted) till complete saturation for one day. The seeds were carefully placed in the soil at 15 seeds per pot during extreme summer month of the year. Subsequent watering was restricted to 40% of initial amount of water required for saturation in pots subjected to moisture stress and 80% in pots subjected to normal soil moisture condition. The seed germination was noted daily for two weeks. After 20 days, the experiment was terminated and seedling length, fresh weight and dry weight of five randomly selected seedlings in each treatment were recorded.

Seed quality assessment on the basis of solute leakage

Primed and non primed seeds (2.5 g) were soaked in 10 to 25 ml of distilled water and incubated at 25 to 30°C for 17 h (Hampton and Tekrony, 1995). The leachate was decanted. The electrical conductivity of leachate was observed in a bench conductivity meter (Eutech Instruments, Singapore).

Volatile aldehydes

Volatile aldehyde released was determined spectrophotometrically. 20 seeds (primed and non primed) were kept in 150 ml conical flask over moist blotter. Test tubes containing 5 ml of 0.2% MBTH was inserted inside the flask and incubatred at 25°C for 48 h in dark. After 48 h the flask was removed and 2.5 ml of 0.23% $FeCl_3$ solution was added to 1 ml of MBTH. This solution was incubated for 5 min, 6.5 ml of acetone was added to it and absorbance was measured spectrometrically at 635 nm (Wilson and Mc Donald, 1986).

Activity assessment of major enzymes involved in seed germination

Extraction and enzyme activity assays were carried out with both primed and non primed seeds. The seeds were kept for germination in Petri plate over moist blotter at 25°C in dark for 2 to 3 days. The germinated seeds (hypocotyls emerged) were taken as sample for enzyme extraction (Sadasivam and Manikam, 1992).

Peroxidase: The fresh plant tissue was ground in pre chilled mortar and pestle in 0.1 M phosphate buffer (pH-7.0). The homogenate was centrifuged at 18000 g at 4°C for 15 min and supernatant was used as enzyme extract. The reaction mixture containing phosphate buffer (0.1 M, pH 7.0), guiacol solution (20 mM), H_2O_2 solution (0.042%) and enzyme extract was made. The absorbance was recorded at 436 nm.

Catalase: The fresh plant tissue was homogenized in blender with phosphate buffer (pH 7.0) at 1-4°C and centrifuged. The supernatant was used as a source of enzyme extract. The reaction mixture containing phosphate buffer and enzyme extract was made as per the protocol and absorbance was recorded at 240 nm.

Malate dehydrogenase: The fresh plant tissue was ground in pre chilled mortar and pestle in grinding medium containing 50 mM Tris TCl (pH-8.0), 50 mM $MgCl_2$, 5 mM 2- mercaptoethanol and 1 mM EDTA and the filterate centrifuged at 3000 g for 20 min at 4°C and the supernatant was used as enzyme source. The reaction mixture was made as per the protocol and absorbance was recorded at 340 nm

Statistical analysis

All the data was subjected to statistical analysis with WEB AGRI STAT PACKAGE (WASP). Analysis of variance (ANOVA) was done to test different priming techniques. Multiple comparison tests were used to separate significant differences among all treatments at the 0.01 level. Standard error (SE) was calculated and results were shown in figure and tables.

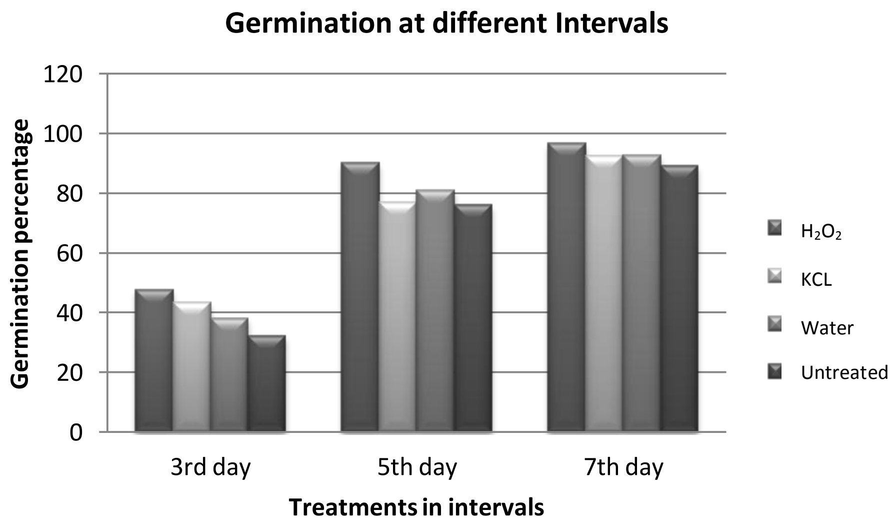

Figure 1. Effect of treatments on germination at different intervals.

Table 1. Effect of treatment on seedling growth traits under controlled condition means followed by same letters are not significantly different.

Treatment	Shoot length (cm)	Root length (cm)	Fresh weight (gm)	Dry weight (gm)
H_2O_2	7.4[a]	14.43[a]	1.445[a]	0.265[a]
KCl	7.05[ab]	12.41[b]	1.415[ab]	0.255[a]
Water	6.99[b]	10.94[c]	1.365[b]	0.245[a]
Control	6.07[c]	10.18[c]	1.295[c]	0.205[b]

Comparison of treatment means with critical difference (0.05).

RESULTS

Total seed germination, seedling lengths (shoot and root length) as well as seedling dry weight was investigated after seed treatments under normal (laboratory and pots) as well as moisture stress condition.

Effect on germination (Laboratory condition)

Data pertaining to the rate of germination observed on 3[rd], 5[th] and 7[th] day under laboratory condition are provided in Figure 1. The time required to reach 50% germination tended to be lower for H_2O_2 treated seeds observed as 3[rd] day count. The germination uniformity was also found higher for H_2O_2 treated seeds (data now shown). The superiority of H_2O_2 treatment was evident in observations on 5[th] and 7[th] days too with significantly highest germination percentage over others.

Effect on seedling growth (Laboratory condition)

The significant effect of treatments on seedling growth was evidenced by observations on seedling shoot, root length, fresh and dry weights (Table 1). The root length increased to 14 cm after H_2O_2 treatment and 12 cm after KCl treatment from 10 cm in untreated control. Though significant difference was observed among the treatments for shoot length, the treatments varied minimally for their effect.

Paralleling with the improvement in shoot and root lengths, the seedling fresh and dry weight also was higher in the treated seeds especially, H_2O_2 treated compared to control. The trend followed a similar pattern with H_2O_2 treatment giving maximum values followed by KCl and water. The untreated control had least values for both parameters.

Germination/emergence under normal and moisture stress condition (Pot study)

The seedling emergence studied in pots under normal moisture (80% FC) and under moisture stress condition (40% FC) also showed the enhanced effect of treatment over untreated control Figure 2). Notably, the effect on final emergence was clear under moisture stress

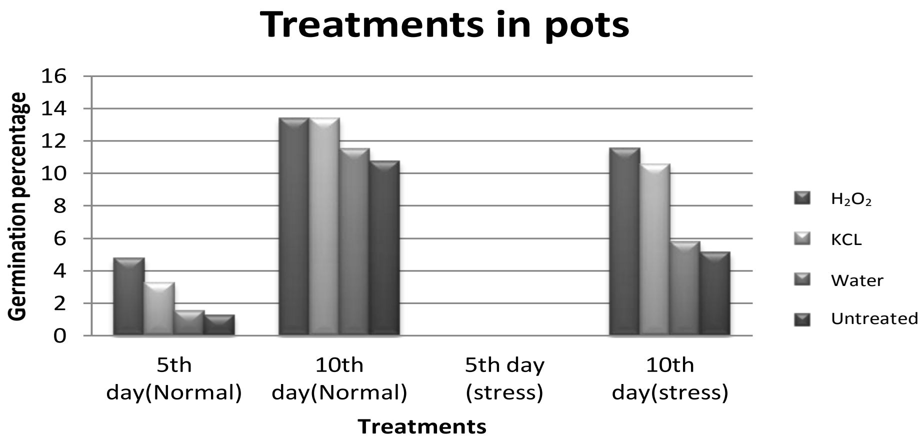

Figure 2. Effect of treatments on germination under normal and moisture stress condition.

Table 2. Effect of treatment on seedling growth traits under normal and moisture stress.

Treatment	Shoot length (Normal) (cm)	Shoot length (Stress) (cm)	Fresh weight (Normal) (gm)	Fresh weight (Stress) (gm)	Dry weight (Normal) (gm)	Dry weight (Stress) (gm)
H_2O_2	10.966[a]	8.533[a]	4.200[a]	3.066[a]	0.916[a]	0.416[a]
KCl	10.700[a]	8.33[a]	3.863[a]	2.866[a]	0.900[a]	0.413[a]
Water	9.166[b]	6.20[b]	3.000[b]	1.666[b]	0.470[b]	0.310[b]
Control	8.300[c]	4.966[b]	2.933[b]	1.666[b]	0.453[b]	0.260[c]

Means followed by same letters are not significantly different Comparison of Treatment means with Critical Difference (0.05).

condition where the H_2O_2 treated seeds had significantly high emergence.

The values for shoot and root length showed a similar pattern under both the soil conditions with H_2O_2 treated seeds giving the highest values followed by KCl and water (Table 2). To address whether these enhanced effects of treatment on germination and seedling growth is due to improvement in cellular membrane stability and antioxidant enzyme system, further study on electrical conductivity of seed leachates and malonaldehyde levels were determined.

Electrical conductivity

The membrane stability observed through electrical conductivity of seed leachates was maximum in H_2O_2 treated seeds which had lowest values for electrical conductivity (Figure 3). The untreated control had the minimum membrane stability shown by the highest values for conductivity of seed leachates.

Malonaldehyde content

It was observed that treated seeds released fewer amounts of volatile aldehydes as compared to untreated control seeds. The best results were obtained in H_2O_2 treated seeds which gave the lowest result where as the highest volatile aldehyde content was observed in control (Figure 4).

Activities of major anti-oxidant enzymes

Data showed that the activity of catalase, one of the major antioxidant enzyme as significantly high in treated seeds as compared to control (Figure 5a, b, c). The highest enzyme activity was observed in H_2O_2 treatment followed by KCl and water. The lowest activity was observed in untreated control. Similarly peroxidase enzyme activity was highest for H_2O_2 and KCl treated seeds compared to others.

DISCUSSION

Improved seed invigoration techniques play significant role in reducing the germination time, obtaining synchronized germination, improving germination rate and seedling stand in all major crops including cotton (Bradford et al., 1990; Rathinavel and Dharmalingam,

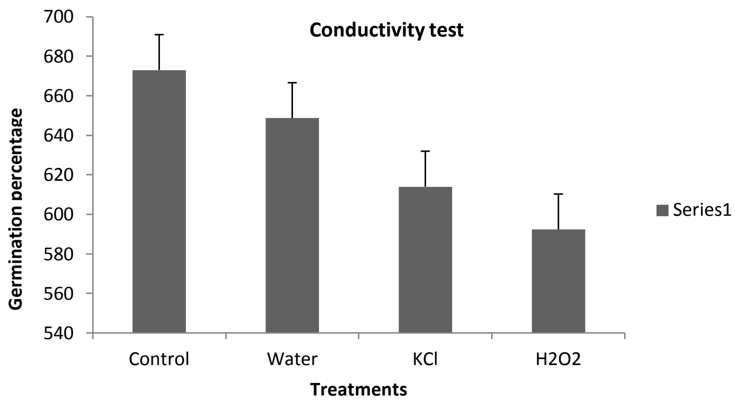

Figure 3. Effect of seed treatment on electrical conductivity of seed leachates.

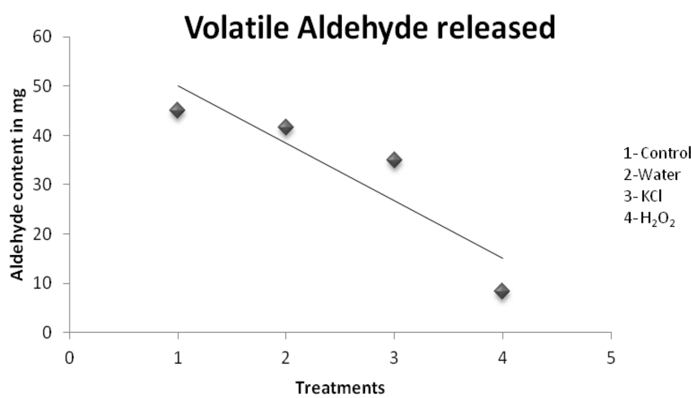

Figure 4. Effect of seed treatment on volatile aldehydes released from cell membrane.

2000; Amjed et al., 2002) and field crops like wheat, maize and rice (Basra et al., 2006; Janmohammadi et al., 2008; Farooq et al., 2004). These invigoration techniques include seed soaking/seed priming/pelleting treatments. Spraying of a water mist over the seeds is considered a simple hydro priming technique which allows the moisture to equilibrate (Van Pijlen et al., 1996) and enhance early germination. Various organic seed treatment preparations (biodynamic and herbal) have been recommended to be applied as spray on seeds followed by quick drying to encourage germination and seedling establishment (Courtney, 1994).

Similar method was applied in the present study also where required concentration of H_2O_2 and KCl as well as water was sprayed over the seeds followed by drying. The process allows limited entry of moisture just enough to initiate the germination process unlike soaking treatment where there is no limitation of water availability. Moreover, the technique is farmer friendly with no loss of imidachloprid insecticide coating provided on cotton seeds.

The results on seed germination, seedling growth and root length showed the positive effect of treatments, H_2O_2 and KCl in enhancing the cotton seed performance under moisture stress, compared to water treated and untreated control. The influence of seed priming in improving the germination rate, germination uniformity and total seed germination has been well documented in rice and wheat (Basra et al., 2002, 2004). In cotton, seed priming with KCl enhanced the speed of germination and activities of antioxidant enzyme (Aghani et al., 2012). KCl has been shown as an effective osmotic agent for enhancing seed germination of wheat (Leila et al., 2010; Mehrdad and Hosseini, 2012) and rice (Mohammed et al., 2006). Greater efficiency of seed priming with KCl is possibly related to the osmotic advantage that K+ has in improving cell water saturation, and that they act as co-factors in the activities of numerous enzymes (Taiz and Zeiger, 2002).

The treatment with H_2O_2 proved the best among all the seed treatments with regard to germination and growth parameter studied in the experiment. This is in contrary

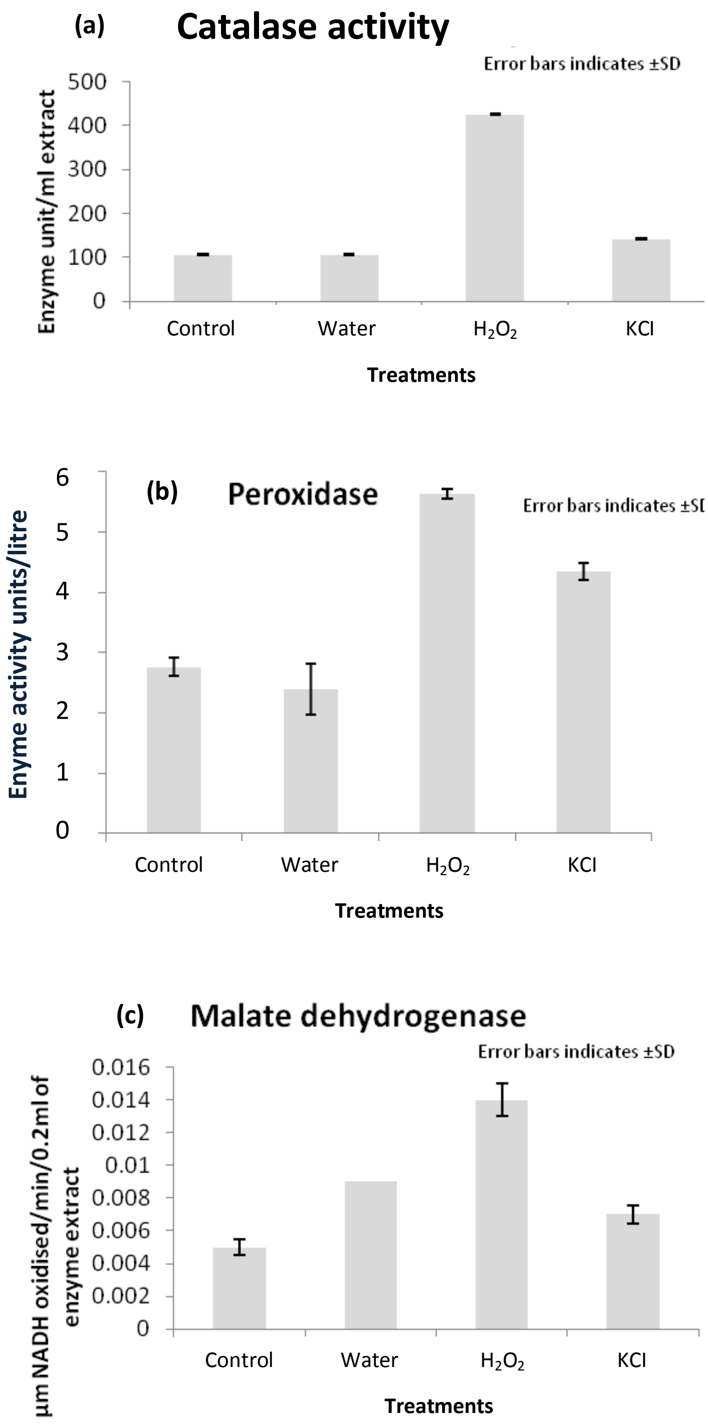

Figure 5. a, b, c, Comparison of enzyme activities in treated and untreated seeds.

with earlier finding in cotton by Saeed (1974) who observed decrease in germination % and seedling root length after H_2O_2 seed treatment. It was supported by the explanation that H_2O_2 suppressed meristematic activity of root cells. However, the study was performed under laboratory conditions in Petri dishes, unlike the present one. Acceleration of seedling growth and increased root growth after H_2O_2 seed treatment was shown in several other crops such as wheat (Hameed et al., 2004; Yushi et al., 2008), barley (Kürsat and Kabar, 2010; Kabar, 2010), maize (Azevedo et al., 2005) etc. The treated seeds revealed higher activity for antioxidant enzymes such as peroxidase and catalase with H_2O_2 pretreatment giving the highest values Increase in activities of these enzymes after seed priming with KCl 2% (Mohammed et al., 2012) and after seed treatment with Atonik (Djanaguiraman et al., 2005) were observed in earlier studies on cotton. These enzymes are known to scavenge the reactive oxygen species produced during imbibitions and decrease their adverse effects (Del Ryo et al., 2002). Similar effect of seed treatments on activity of scavenging enzymes such as catalase, peroxidase and superoxide dismutase resulting in enhanced germination has been reported in other crops too (Zaheer et al., 2012; Papassorn et al., 2012; Adnan et al., 2012; Mustafa et al., 2010).

Membrane repair could be ascribed to evoke activities of free-radical scavenging enzymes (Adnan et al., 2012). This was confirmed by the low values obtained for electrical conductivity of seed leachates from treated seeds especially those from H_2O_2 treated ones. Present results indicate the higher membrane stability of treated seeds. Correspondingly, there was decrease in malonaldehyde content in the treated seeds compared to untreated control as observed in Jatropha by Feng et al. (2011). Enhanced membrane stability due to reduced membrane damage rate and MDA content was observed in wheat after pretreatment of seeds with H_2O_2 (Liheng et al., 2009).

Conclusion

The results suggest that seed priming (uniform spraying on seeds) with H_2O_2 at 80 mM is a convenient method of seed priming to improve germination and better moisture stress tolerance in cotton. The improved germination and stress tolerance may be attributed to the enhanced activity of anti-oxidant enzymes and improved membrane stability.

Conflict of Interests

The authors have not declared any conflict of interests.

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Reduction of soil water content fluctuations and soil temperature variations under retrievable drip irrigation

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Wide soil water content and temperature variations affect crop yields for reasons ranging from rate of seed germination, seed development, to plant growth. This study aimed at evaluating the extent to which drip irrigation can reduce soil water content and temperature variations. An experiment was carried out in a 154 m^2 glasshouse with Tottori dune sand of Japan. Two irrigation levels of 60 and 100% of evapotranspiration, and two dune sand covers of 2 and 5 cm on the drip lines were used. Soil water content and temperature variations were significantly ($P < 0.001$) reduced under the 5 cm dune sand cover but insignificantly reduced under the 2 cm dune sand cover. Minimum soil temperature was increased, and maximum soil temperature was decreased under the 5 cm dune sand cover. Irrigation level of 100% of evapotranspiration under 5 cm dune sand cover resulted in 20% dry matter yield increase of sorghum. Irrigation level of 60% of evapotranspiration under 5 cm dune sand cover resulted in no significant dry matter yield increase of sorghum. From this study, we conclude that the practical minimum depth of dune sand cover on the drip lines can be 5 cm.

Key word: Irrigation level, sand dune soil, soil temperature, surface drip irrigation, water content.

INTRODUCTION

Water resources in the world are finite. The population in the world benefits from the efficient use of the water resources. Irrigation is the largest consumer of fresh water on earth (Shiklomanov, 1998), using 60% of all freshwater withdrawals. To reduce the severity of water scarcity, water management must be improved. Agriculture offers the greatest potential for solving the problem of global water scarcity (Longo and Spears, 2003) through efficient use of water.

Surface drip irrigation has been used for agricultural production for more than three decades, has higher water use efficiency than other irrigation methods and more is efficient in keeping stable soil water content and soil temperature variations than other irrigation methods (Camp, 1998). Surface drip irrigation can keep sufficient soil water content and high soil temperature for seed germination and seedling development (Wang et al., 2000).

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Under surface drip irrigation, soil evaporation is nonetheless inevitable. The solution to this was the introduction of subsurface drip irrigation which still came with its own disadvantages. Crop rotations became inherently inflexible since crop bed widths could not be varied (Burt and Barreras, 2001). Moving the drip lines closer to the surface has become a possible solution to problems associated with both surface and subsurface drip irrigation. The new system is called retrievable drip irrigation.

Wide soil water content fluctuations and soil temperature variations on the soil surface or near the soil surface are experienced not only under surface drip irrigation but also under other irrigation methods. Soil water content fluctuations and temperature variations under surface drip irrigation depend on soil type, environment and irrigation interval. Relative evapotranspiration decreases with decreasing soil water content as the soil water content in the profile is controlled by the atmospheric demand for evapotranspiration rate due to external environmental conditions (Singh and Singh, 2002). Wide soil temperature variation in the root zone results in poor root uptake of water at low temperature and also results in reduction of root uptake of nutrients at high temperature (Kuiper, 1964; House and Jarvis, 1968).

In an experiment in Canada, temperature on the soil surface increased from 26 to 42°C for surface drip lines (Parchomchuk, 1976) whereas on drip lines covered with 15 cm of soil, the maximum soil temperature on the soil surface reduced from 42 to 32°C (Parchomchuk, 1976). Drip lines covered by soil help to keep the soil surface dry thus reducing soil evaporation. The top 20 cm of soil had lower water content resulting in reduced soil evaporation when drip lines were buried at the depth of 45 cm (Phene et al., 1983). They also outlined the following problems as being associated with subsurface drip irrigation: inspection of a subsurface system is very difficult; emitters' clogging by roots and solids may cause poor system performance; and a subsurface system is difficult to be repaired and maintained.

Lamm and Trooien (2005) and Neelam and Rajput (2007) examined the effect of drip line depth on subsurface drip-irrigated field corn grown on deep silt loam soils of western Kansas. Results indicated that drip line depths ranging from 0.20 to 0.61 m are acceptable for field-corn production on silt loam soils in the region. They recommended that placement of drip lines might be practical at depths less than 10 cm under sandy loam soil.

Neelam and Rajput (2007) evaluated the effect of the depth of placement of drip lines on yield of potato at 0, 5, 10, 15 and 20 cm under sandy loam soil. When drip lines were buried at the depth of 5 cm, upward movement of water took place. When drip lines were buried at the depths of 20 to 61 cm under deep silt loam soil of western Kansas, soil temperature variation was greatly moderated (Lamm and Trooien, 2005).

The interactive effect of covering drip lines with dune sand on soil water content and soil temperature regimes should also have a profound effect on plant growth and, therefore, merits investigation. Dhavu et al. (2010) found out that Tottori dune sand has self-mulching properties. The effect on soil water content fluctuations and soil temperature variations by covering drip lines with the Tottori dune sand has however not been evaluated yet. The objectives of this study were to determine the minimum cover on drip lines with the Tottori dune sand and to study the effects of different levels of application of irrigation water on soil water content fluctuations and soil temperature variations. The dune sand cover effect on soil water content and soil temperature would be further related to sorghum crop growth (plant height and dry matter yield). ''Covering drip lines with dune sand has no effect on soil water content and soil temperature variation'' was our null hypothesis.

MATERIALS AND METHODS

Experimental layout

The experiment was carried out in a 154 m^2 area glasshouse at the Arid Land Research Center, Tottori University, Japan (35°32'N; 134°13'E; 23 m above sea level). It was unheated and naturally ventilated with a single continuous roof vent. Lateral windows were kept open during daytime. The soil type of the Tottori dune sand was Arenosol (silicious sand, typic Udipsamment) with 96% sand (Qui et al., 1999). The relationship between soil water pressure and volumetric water content of the dune sand is shown in Figure 1. The water content at field capacity and permanent wilting point of the dune sand were, respectively, 0.074 and 0.022 cm^3/cm^3 which corresponded to the matric potential of -0.006 MPa and -1.5 MPa, respectively (Qui et al., 1999). Porosity and saturated soil hydraulic conductivity of the dune sand were 0.4 m^3/m^3 and 2.7×10^{-4} m/s, respectively (Qui et al., 1999). Some of the physical properties of the dune sand are summarized in Table 1.

Two plots (Plots A and B) were used in this experiment as shown in Figure 2. Sorghum (*Sorghum bicolor*) was planted on each sub-plot on June 16, 2008 at 50 cm row and 30 cm in-row spacing making 267 000 plants per hectare. Fertilizer was applied at the rate of 180 kg/ha N, 45 kg/ha P and 80 kg/ha K just before sowing. After sowing the sorghum, the drip lines were covered with sand dune soil as shown in Figure 3. The sorghum was harvested on October 24, 2008.

Thickness of cover

Each of the two plots was further divided into three sub-plots. Three drip lines were arranged on each sub-plot. The drip lines were spaced at 50 cm. Emitters was spaced at 30 cm along the drip lines. This irrigation system was operated at a pressure head of 14 m. Three drip lines were not covered with the sand dune soil on the control sub-plots of Plots A and B and this is referred to as T0. On two sub-plots of Plots A and B, the drip lines were covered by 2 and 5 cm of the sand dune soil, and these are referred to as T2 and T5, respectively. The section view of the position of the drip lines, sensors and plants under T0, T2 and T5 is shown in Figure 3. Protrusion of drip lines was observed under T2 for both 0.6Ep and 1.0Ep during the growing period. This could have been caused by expansion and contraction of the drip lines due to temperature variations.

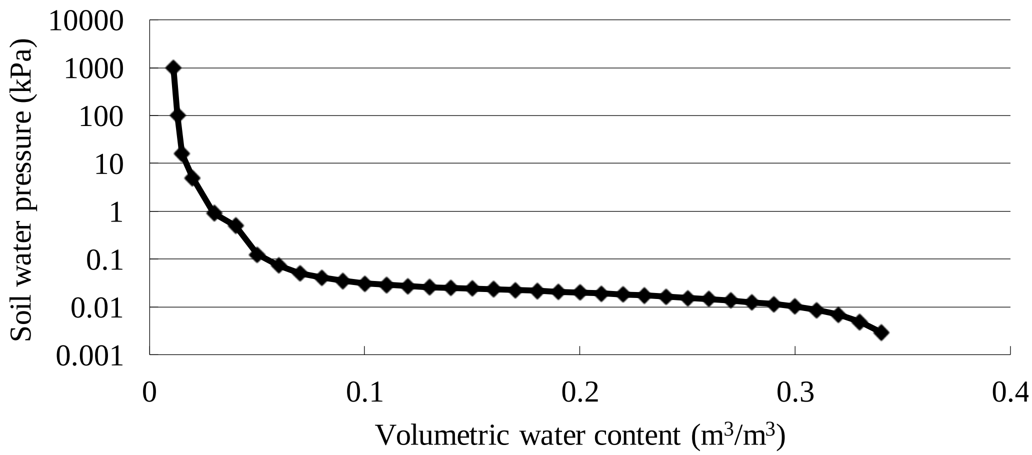

Figure 1. Soil water pressure and volumetric water content of the Tottori dune sand.

Table 1. Physical properties of Tottori dune sand.

Depth (cm)	Particle size composition (%)			Bulk density (Mg/m^3)
	Sand	Silt	Clay	
0 - 5	96.2	2.0	1.8	1.50
5 - 10	95.7	3.0	1.3	1.49
10 - 15	95.2	3.0	1.8	1.49
25 - 30	94.7	3.5	1.8	1.50

Irrigation level

Two small evaporation pans were placed in each sub-plot, and were weighed twice daily at 08:30 and at 20:30. Irrigation water was applied once in 2 days based on the small pan evaporation readings and scheduling.

Different irrigation levels were applied to Plots A and B. For Plot A, 100% of the estimated evapotranspiration of sorghum was applied and this is referred to as 1.0Ep. For Plot B, 60% of the estimated evapotranspiration of sorghum was applied and this is referred to as 0.6Ep.

Evapotranspiration

Evaporation from the small evaporation pan was converted to Class A pan evaporation using the Agodzo et al. (1997) equation:

$$E_A = a \times E_S^b \quad (1)$$

where, E_A is Class A pan evaporation (mm/2 days), a and b are fitting parameters, with a = 0.17, b = 1.92 and E_S is the evaporation from the small evaporation pan (mm/2 days). Measured E_S and E_A were correlated for 10 days at the Arid Land Research Center, Tottori University, Japan.

Class A pan evaporation was then converted to the potential evapotranspiration using the Doorenbos and Pruit (1977) equation:

$$ETo = Kp \times E_A \quad (2)$$

where, ETo is the potential evaporation (mm/2 days) and Kp is the pan coefficient (dimensionless). Kp = 0.8, and was obtained from Kp = 0.75 as given by Doorenbos and Pruit (1977) based on location, and adjusted by 7.5% to Kp = 0.80 for sorghum (Kp = 1.075 × 0.75 = 0.80). The Kp values relate to evaporation pans located in an open field with no crops taller than one meter (1 m), and depend on general wind and humidity conditions of an area. The Kp values were therefore adjusted because the small evaporation pans were placed in a glasshouse (a small enclosure) and surrounded by sorghum.

The ETo from Equation (2) was converted to evapotranspiration of sorghum (ETc) (mm/2 days) using the Doorenbos and Pruit (1977) equation:

$$ETc = Kc \times ETo \quad (3)$$

where, Kc is the crop coefficient (dimensionless). The Allen et al. (1998) Kc values of 0.7, 1.1 and 0.55 for early growth stage, middle growth stage and late growth stage, respectively were used in this experiment.

Irrigation time was calculated from the following equations:

$$T = \frac{A \times 0.6 \times ETc}{Q} \quad (4)$$

$$T = \frac{A \times 1.0 \times ETc}{Q} \quad (5)$$

where, T is the irrigation time (hours), ETc as previously defined (mm/2 days), A is the wetted area (assumed circular and of measured radius of 15 cm) (m^2) and Q is the emitter discharge (l/h).

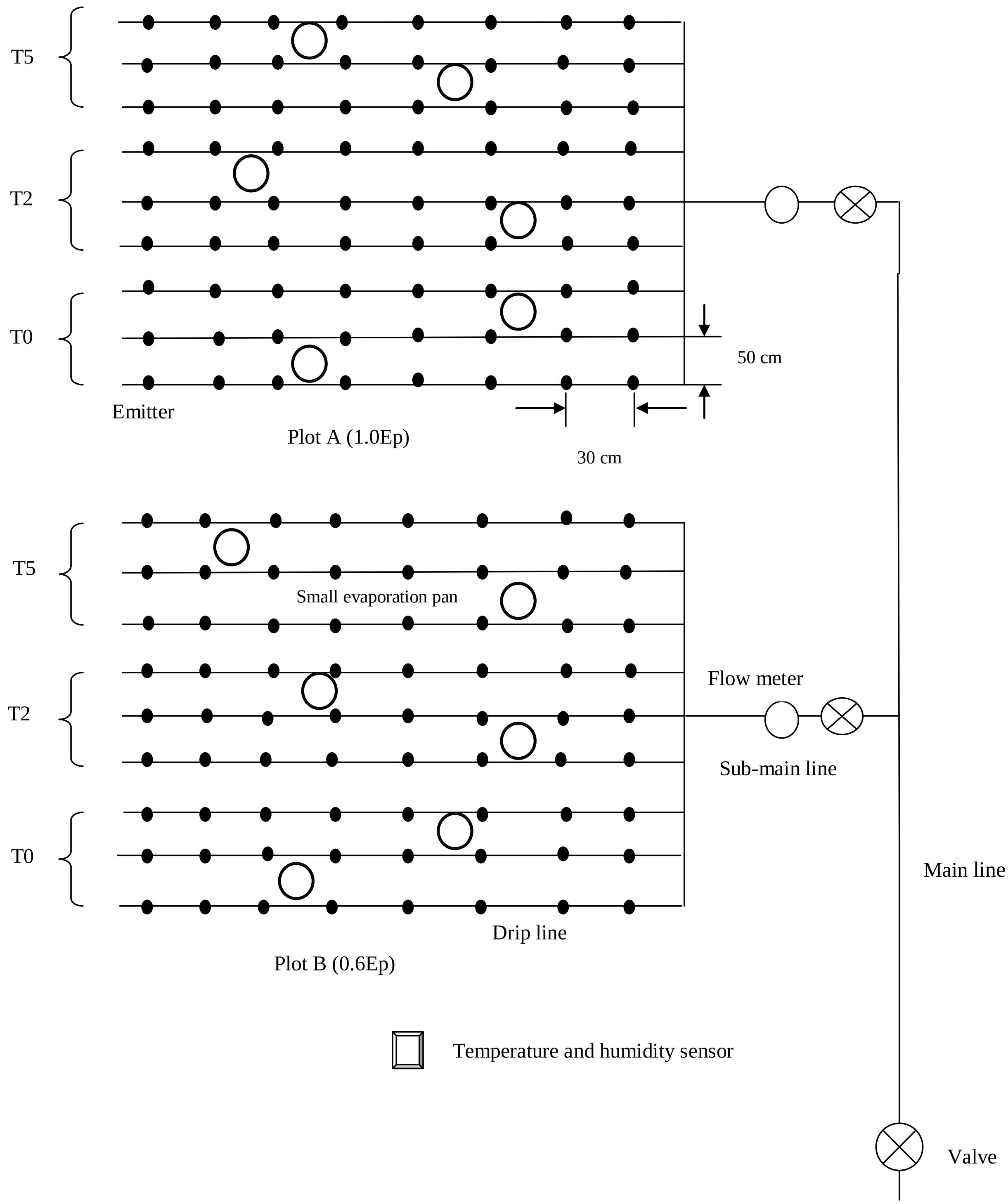

Figure 2. Experiment plots.

Soil water content and soil temperature

Soil water content was measured using ECH_2O capacitance probes (Decagon Devices Inc., Pullman, Washington, USA) installed at depths of 5 and 25 cm. The sensor installation depth of 25 cm was based on Yamamoto and Cho (1978) who reported that the most effective root-water uptake zone in the sand dune soil under surface drip irrigation was the top 25 cm. Water content was not measured at the surface because the sand dune soil dries quickly. Water content was recorded every hour by Em50 ECH_2O data loggers (Decagon Devices Inc., Pullman, Washington, USA). Soil temperature was measured by thermocouples (copper-constantan

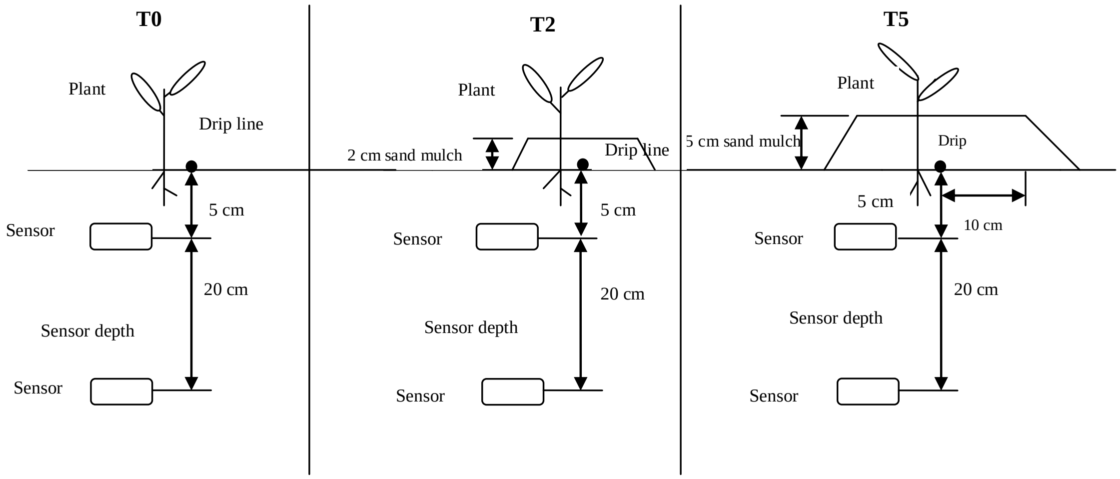

Figure 3. Section view of the position of drip lines and sensors under T0, T2 and T5.

Table 2. Climatic conditions in glasshouse.

Month	Air temperature (°C)		Average humidity (%)
	Maximum	Minimum	
June	31.1	12.4	83
July	35.9	16.7	80
August	39.5	18.1	81
September	33.8	13.7	80
October	28.5	9.4	76

thermocouples) installed at depths of 5 and 25 cm. Soil temperature was measured every 15 min and averaged over one hour intervals by 21X and CR10X data loggers.

Climate condition and plant growth

Air temperature and humidity in the glasshouse were measured at a height of 2 m by ESPEC temperature and humidity sensors (ESPEC MIC Corp., Aichi, Japan). These were installed at the center of the glasshouse. Air temperature and humidity were recorded ever hour by ESPEC data loggers (ESPEC MIC Corp., Aichi, Japan). The climate conditions in the glasshouse are summarized in Table 2. The maximum is the highest daily air temperature in each month and the minimum is the lowest daily air temperature in each month.

Three plants were randomly selected from each sub-plot of Plots A and B for measurement of plant height and dry matter weight. Plant height measured from dune sand surface to the latest leaf was measured at early stage, middle stage and late stage by a meter rule. At the late stage, plant height was also measured for each plant row to determine the plant height distribution. After harvesting, the dry matter weight was measured after drying the samples in an oven at 70°C for 48 h.

RESULTS AND DISCUSSION

The total amount of irrigation water applied to each dune mulch treatment during the cropping period was 344 mm for 0.6Ep and 521 mm for 1.0Ep.

Variation of soil water content

Variations of daily soil water content at the depth of 5 cm under T0, T2 and T5 for 0.6Ep are shown in Figure 4. The variations of daily water content at the depth of 5 cm are important since seed germination and emergence occur effectively up to this depth (Smith et al., 1999). Smith et al. (1999) found percentages of emergence close to 100% down to a depth of 5 cm with a drastic fall afterwards. Daily water content is the average of hourly water content per day.

Soil water content under T0 reached highest peaks immediately after application of irrigation water as compared to the water content peaks reached under T2 and T5. Soil water content under T5 reached lowest peaks as compared to the water content peaks reached under T0 and T2. The observed trend could have been because water losses through soil evaporation and/or seepages from the 5 cm depth were fastest under T0. This is evidenced by the sharp drop in soil water content under T0. Soil water content during the growing season

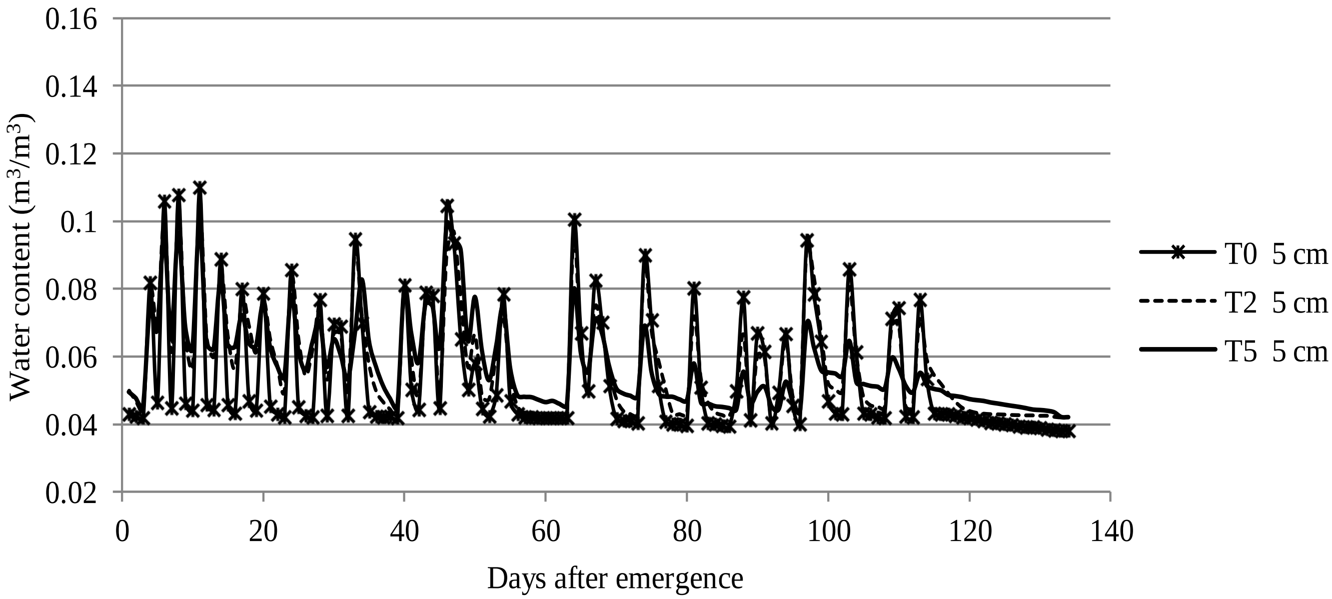

Figure 4. Soil water content at the depth of 5 cm (0.6Ep).

Table 3. Soil water content peaks and averages for the growth period.

Irrigation level	Depth (cm)	Sand cover	Maximum (m^3/m^3)	Minimum (m^3/m^3)	Range (m^3/m^3)	Average (m^3/m^3)	SD (m^3/m^3)
0.6Ep	5	T0	0.110	0.038	0.072	0.054[a]	0.019
		T2	0.104	0.041	0.062	0.058[a]	0.015
		T5	0.099	0.042	0.057	0.058[a]	0.013
	25	T0	0.105	0.049	0.056	0.064[b]	0.014
		T2	0.107	0.057	0.050	0.072[c]	0.013
		T5	0.095	0.065	0.030	0.075[c]	0.005
1.0Ep	5	T0	0.157	0.032	0.125	0.061[b]	0.026
		T2	0.101	0.035	0.065	0.065[d]	0.017
		T5	0.093	0.048	0.044	0.068[cd]	0.012
	25	T0	0.120	0.044	0.073	0.069[cd]	0.018
		T2	0.102	0.055	0.047	0.072[c]	0.009
		T5	0.102	0.057	0.045	0.074[c]	0.009

Values followed by different letters are significantly different at $P < 0.001$, SD is standard deviation.

of sorghum had a range of 0.072 m^3/m^3, 0.062 m^3/m^3 and 0.057 m^3/m^3 under T0, T2 and T5, respectively as shown in Table 3. This means soil water content under T0 experienced the widest fluctuations, while experiencing the narrowest fluctuations under T5. The average soil water content under T0, T2 and T5 at the depth of 5 cm were however not significantly different at $P < 0.001$.

Variations of soil water content at the depth of 25 cm under T0, T2 and T5 for 0.6Ep are shown in Figure 5 and summarized in Table 3. The variations of soil water content at the depth of 25 cm are important for plant root growth and nutrient uptake as reported by Yamamoto and Cho (1978). Similar trends as observed at the depth of 5 cm in soil water content variation under T0, T2 and T5 at the depth of 25 cm were observed. The maximum soil water content reached were, however not as high as experienced at the depth of 5 cm. Consistent with infiltration theory (Smith et al., 1969), soil water contents

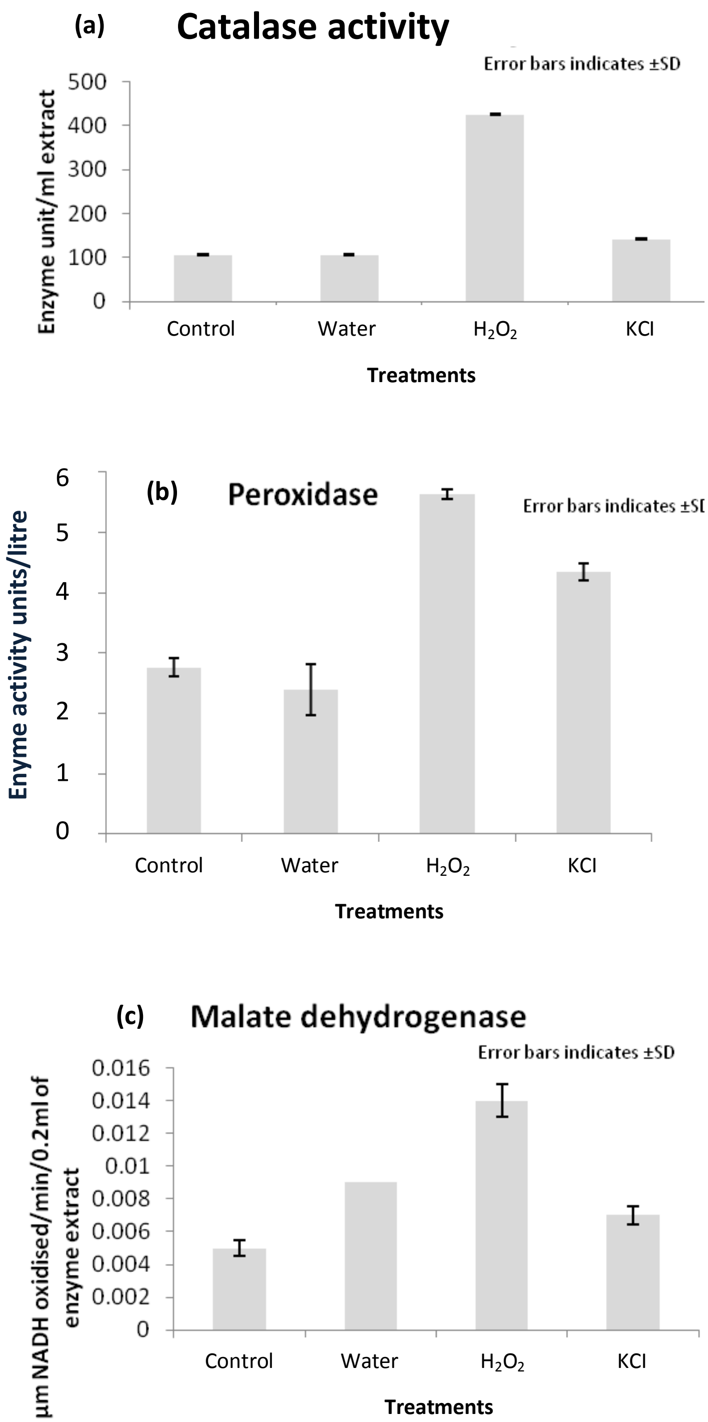

Figure 5. a, b, c, Comparison of enzyme activities in treated and untreated seeds.

reached maximum directly under the drip lines while the minimum soil water content was lowest under T0. Covering the drip lines with 2 and 5 cm sand dune soil reduced the maximum daily soil water content and raised the minimum daily soil water content at the depth of 25 cm probably through soil evaporation reduction. The average soil water content under T0, T2 and T5 at the depth of 25 cm was significantly different from those under T0, T2 and T5 at depth of 5 cm for 0.6Ep ($P < 0.001$). Variations of soil water content at the depth of 5 cm under T0, T2 and T5 for 1.0Ep are shown in Figure 6. The high peaks around 75 to 80 days after emergence

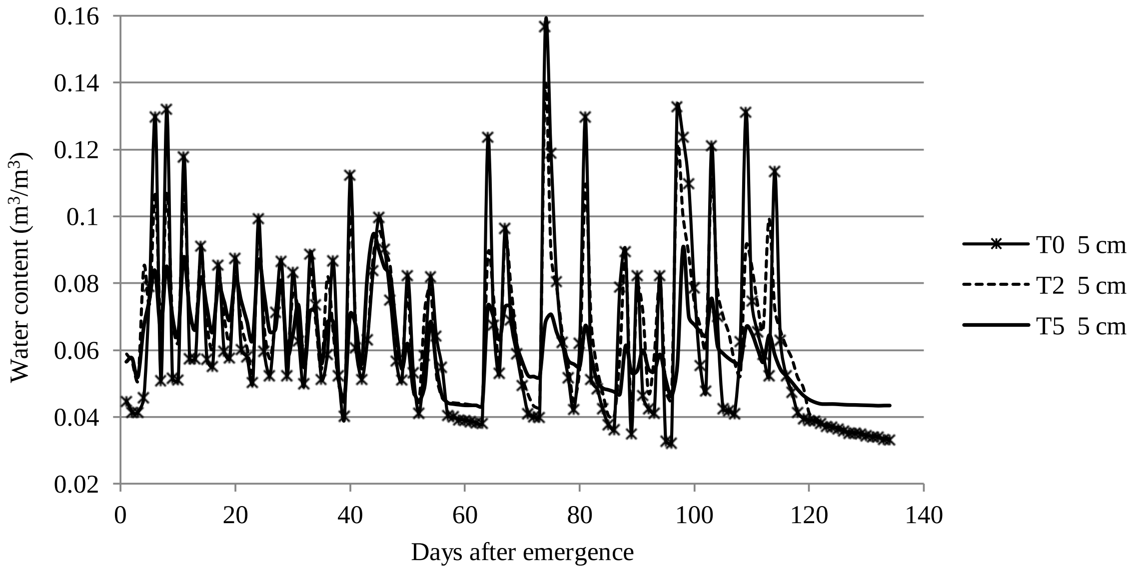

Figure 6. Soil water content at the depth of 5 cm (1.0Ep).

could have been because of high temperatures experienced in August. The soil water content variations under T0, T2 and T5 for 1.0Ep also follow the same trend as observed for 0.6Ep. The average soil water content under T0 at the depth of 5 cm for 1.0Ep was however significantly different from those under T2 and T5 ($P < 0.001$).

The variations as shown by the ranges in Table 3 are wider for 1.0Ep than for 0.6Ep at the same depth of 5 cm under the three different dune sand covers except for T5. The variations for 1.0Ep are wider probably due to more irrigation water applied as compared to those for 0.6Ep which applied only 60% of the water lost through evapotranspiration. Deficit irrigation together with dune sand cover of 2 and 5 cm help reduce soil water content variation under retrievable drip irrigation. Dry dune sand cover helps to reduce soil water content loss through soil evaporation. Deficit irrigation on the other hand, reduces the peak soil water content that could be reached when full irrigation is practiced. The trend in these results is similar to those found by Gunduz et al. (2011). They found that the fluctuations of soil water content was greater in treatments that received more water than in those that received less water. Variations of soil water content at the depth of 25 cm under T0, T2 and T5 for 1.0Ep are shown in Figure 7. The soil water content variations under T0, T2 and T5 also follow the same trend as observed at the depth of 5 cm and at the same depth of 25 cm but for 0.6Ep. The variations are however narrower at the depth of 25 cm than those at the depth of 5 cm while they are generally wider for 1.0Ep than 0.6Ep at the same depth of 25 cm under the three different dune sand covers. There were probably less soil evaporation and deep percolation losses from the depth of 25 cm than that from the depth of 5 cm. The effect of water vapor adsorption is lower at the depth of 25 cm than at the depth of 5 cm, hence lower soil water content peaks at the depth of 25 cm. These results are consistent with those found by Kosmas et al. (1998) who found that diurnal fluctuations of soil water content decreased with increasing soil depth, soil wetness and surface mulching due to water vapor adsorption. Soil water content variations are summarized in Table 3. Generally, there is higher soil water content under dune sand mulch than under unmulched dune sand. Ramakrishma et al. (2006) also observed higher soil water content in the 0 to 60 cm soil layer of the mulched plots compared to that of the unmulched plots. They also observed higher soil evaporation from unmulched plots than from the mulched plots. From Table 3, the variations of soil water content at the depths of 5 and 25 cm were wider under T0, T2 and T5 for 1.0Ep than under T0, T2 and T5 for 0.6Ep. Narrower variations of daily water content for 0.6Ep than for 1.0Ep were because insufficient irrigation water was applied for 0.6Ep. Therefore, the combination of T5 and 0.6Ep was the best in reducing the variations of daily water content. This response was important since the most effective root-water uptake zone in the Tottori dune sand is up to the depth of 25 cm (Yamamoto and Cho, 1978).

Variation of soil temperature

Variations of daily soil temperature at the depths of 5 cm under T0, T2 and T5 for 0.6Ep are shown in Figure 8. The variations of daily soil temperature at the depth of 5 cm are important since seed germination and emergence occur effectively up to this depth (Smith et al., 1999).

Daily soil temperature was the average of hourly soil

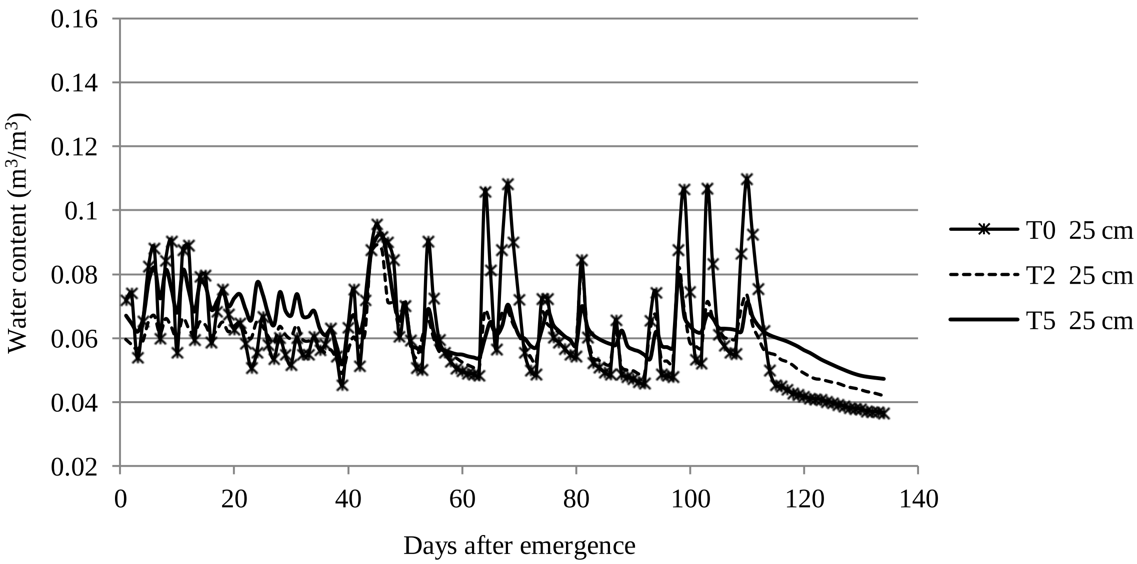

Figure 7. Soil water content at the depth of 25 cm (1.0Ep).

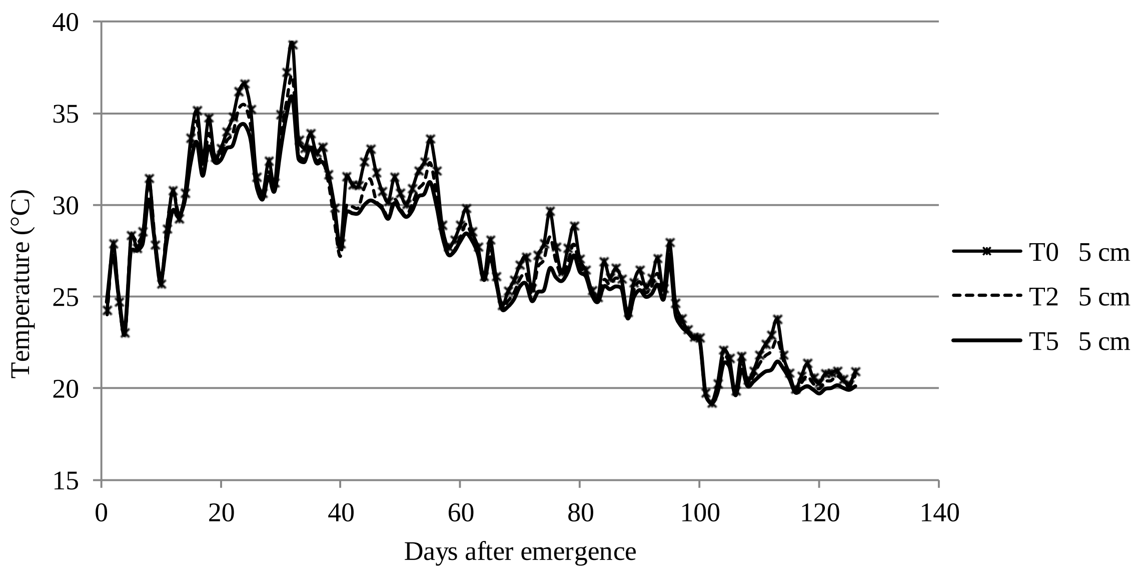

Figure 8. Daily soil temperature at the depth of 5 cm (0.6Ep).

temperature recorded per day. Daily soil temperature at the depth of 5 cm under T0 was significantly different ($P < 0.001$) from those of both T2 and T5 during the growing period with highest soil temperatures being reached under T0 and the lowest being reached under T5. Covering the drip lines by 2 and 5 cm dune sand reduced the soil temperature at the depth of 5 cm. These results are in agreement with findings by Varadan and Rao (1983) who found that soil temperature differences under mulched and unmulched conditions were significant within the first 10 cm of soil depth.

Variations of daily soil temperature at the depth of 25 cm under T0, T2 and T5 for 0.6Ep are shown in Figure 9. Similar trends in soil temperature variations were observed at the depth of 25 cm as those at the depth of 5 cm. Highest soil temperatures as also shown in Table 4 were observed under T0 while the lowest soil temperatures were observed under T5. Soil temperatures under T0, T2 and T5 at the depth of 25 cm were significantly different ($P < 0.001$) from each other and from those at the depth of 5 cm. Covering the drip lines by 5 cm sand soil narrowed the variations of daily soil

Table 4. Soil temperature peaks and averages for the growth period.

Irrigation level	Depth (cm)	Sand cover	Maximum (°C)	Minimum (°C)	Range (°C)	Average (°C)	SD (°C)
0.6Ep	5	T0	38.75	19.20	19.55	27.59[a]	4.672
		T2	36.95	19.15	17.80	27.06[b]	4.445
		T5	35.85	19.15	16.70	26.68[b]	4.370
	25	T0	36.40	18.95	17.45	26.15[c]	4.131
		T2	31.55	18.75	12.80	24.54[d]	3.352
		T5	30.13	17.65	12.48	23.64[e]	3.184
1.0Ep	5	T0	38.20	18.75	19.45	27.12[ab]	4.751
		T2	35.10	18.00	17.10	26.20[ce]	4.533
		T5	34.00	17.75	16.25	25.52[f]	4.532
	25	T0	34.85	17.50	17.35	24.96[d]	4.218
		T2	31.70	17.45	14.25	23.84[e]	3.683
		T5	29.90	17.35	12.55	23.01[g]	3.552

Values followed by different letters are significantly different at P < 0.001, SD is standard deviation.

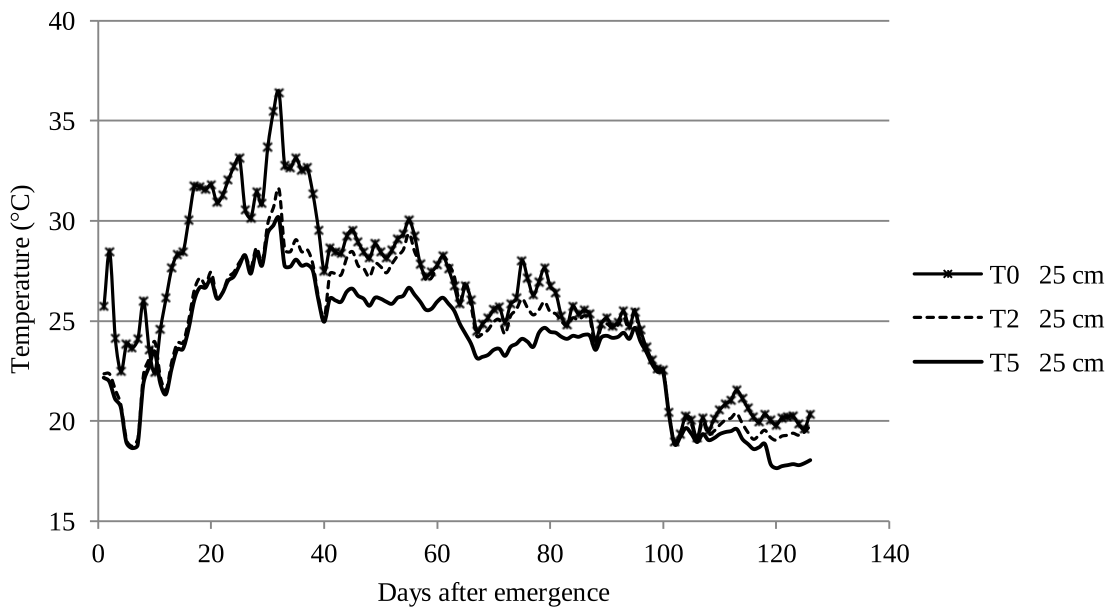

Figure 9. Daily soil temperature at the depth of 25 cm (0.6Ep).

temperature.

Variations of daily soil temperature at the depths of 5 cm under T0, T2 and T5 for 1.0Ep are shown in Figure 10 and summarized in Table 4. Again, we observed highest temperatures under T0 while the lowest temperatures were observed under T5. From this figure and table, it can be seen that covering the drip lines by 2 and 5 cm of sand dune soil results in significantly different (P < 0.001) soil temperature.

Variations of daily soil temperature at the depths of 25 cm under T0, T2 and T5 for 1.0Ep are shown in Figure 11. Again, we observed highest soil temperatures under T0 while the lowest temperatures were observed under T5. From this figure, it can also be seen that covering the

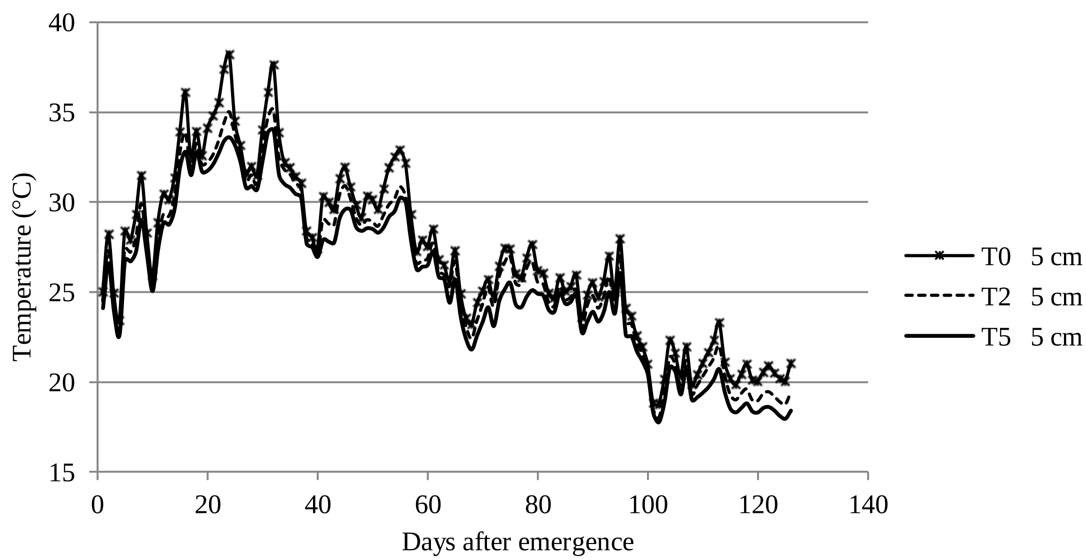

Figure 10. Daily soil temperature at the depth of 5 cm (1.0Ep).

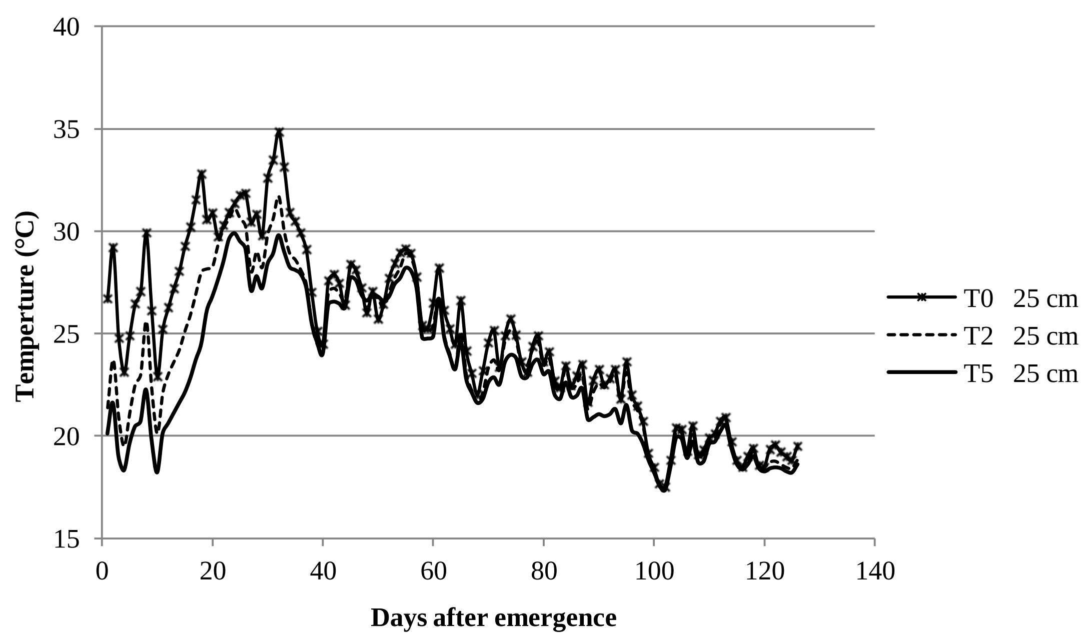

Figure 11. Daily soil temperature at the depth of 25 cm (1.0Ep).

drip lines by 2 and 5 cm of sand dune soil lowers soil temperature. Chiemeka (2010) also found out that soil temperature was highest at the depth of 5 cm. The 5 cm depth is closer to the earth's surface and the solar radiation reaches that depth before other layers (Chiemeka, 2010).

Soil temperature variations are summarized in Table 4. The maximum soil temperature is the highest soil temperature during the growing season. The minimum soil temperature is the lowest soil temperature during the growing season. Soil temperature variation is the difference between maximum and minimum soil temperatures observed during the growing season.

The average daily soil temperatures at the depths of 5 and 25 cm were higher under T0, T2 and T5 for 0.6Ep than under T0, T2 and T5 for 1.0Ep. Covering the drip lines by 5 cm and applying sufficient irrigation water resulted in the reduction of the daily soil temperature more than that of covering the drip lines by 5 cm and applying insufficient irrigation water.

Crop growth

Plant heights at three growth stages under T0, T2 and T5 for 0.6Ep and 1.0Ep are shown in Figure 12. For 0.6Ep, the plant heights at the three growth stages under T0, T2 and T5 were not significantly different at $P < 0.001$. These results show that covering the drip lines by 2 and 5 cm dune sand under deficit irrigation had no significant effect on the vegetative growth of sorghum. This could have been because insufficient irrigation water was applied.

For 1.0Ep, the plant heights at the early growth stage under T0, T2 and T5 were not significantly different at $P < 0.001$. At the middle growth stage, the plant heights under T0, T2 and T5 were significantly different at $P < 0.001$. At the late growth stage, the plant heights under T5 were significantly different from those under T0 and T2. Covering the drip lines by 5 cm sand dune soil significantly supported the vegetative growth of sorghum. This result could be because the 5 cm dune sand mulch help to maintain stable soil temperatures and soil water content.

At the early growth stage, the plant heights under T0, T2 and T5 were not significantly different ($P < 0.001$) for both 0.6Ep and 1.0Ep. During the early growth stage, the bulk of evapotranspiration could be through soil evaporation and at this stage the 0.6Ep and 1.0Ep were still almost equally exposed to factors of soil evaporation. At the late stage, the plant heights under T5 for 1.0Ep were significantly higher than T5 for 0.6Ep. Soil temperature variations caused expansion and contraction of drip lines under T2 for 0.6Ep and 1.0Ep. The expansion and contraction of the drip lines caused some sections of the drip lines to protrude to the soil surface. This caused poor growth distribution along the drip lines. Covering the drip lines by 5 cm dune sand and applying sufficient irrigation water supported the vegetative growth of sorghum. These results are consistent with findings by other researchers. Sammis et al. (1988) reported that plant height can change at different levels of deficit irrigation. Some researchers stressed that deficit irrigation shortened plant height (Stone et al. 2001; Pandey et al. 2000).

Dry matter yields under T0, T2 and T5 for 0.6Ep and 1.0Ep are shown in Table 5. For 0.6Ep, the dry matter yield under T5 was higher than that under T0 and T2. The average plant weight under T0 and T2 was significantly different ($P < 0.001$) from that under T5. Low dry matter yields of sorghum have been reported by other researchers (Oliver et al., 2005; Marsalis et al., 2010). Previous research has shown that yield levels are environment and variety specific (Casler et al., 2003).The increase in plant weight and yield with dune sand cover could be attributed to higher soil water content retained in the soil due to the dune sand mulch. Surya et al. (2000) concluded that the greater soil water content under mulch as important implications on the utilization of water by crop and soil reactions that control the availability of nutrients and biological nitrogen fixation. For 1.0Ep, the dry matter yield under T5 was higher than those of T0 and T2. Covering the drip lines by 5 cm significantly increased the dry matter yield of sorghum. The dry matter yield under T5 was higher than the recommended dry matter yield of sorghum.

There was insignificant increase in the dry matter yields under T2 for 0.6Ep and 1.0Ep. The dry matter yield was higher under T5 for 1.0Ep than under T5 for 0.6Ep. The dry matter yields under T0, T2 and T5 for 1.0Ep were higher than for 0.6Ep. This was because sufficient irrigation water was applied for 1.0Ep as compared to that for 0.6Ep thus improving soil water availability. Improved soil water availability can result in taller and more robust plants, a larger average leaf area increased vegetative dry matter and promote leaf tip emergence, flowering and grain filling (Abrecht and Carberry, 1993).

The dry matter yield of sorghum was highest under T5 for both 0.6Ep and 1.0Ep. This phenomenon could be attributed to the improvement in soil water content and soil temperature conditions relative to those under T0. The sand dune soil cover prevents evaporation of water from the soil surface. At the same time, water moves from deeper soil layers to the topsoil by capillarity and vapor transfer, thereby keeping the topsoil (ideally 25 cm for Tottori sand dune soil under drip irrigation) water content relatively stable (Wang et al., 1998; Li et al., 1999). This result is consistent with the results obtained by Li et al. (1999, 2004) for maize growth.

Covering the drip lines by 5 cm sand dune soil and applying sufficient irrigation water was the best combination that reduced the variations of daily water content and daily soil temperature. This combination resulted in the increase in the dry matter yield of sorghum of about 20%. Sand dune soil cover can significantly affect the soil microclimate (soil temperature and soil water content) (Ghosh et al., 2006), and hence plant growth components. Yi et al. (2011) also found that mulches improve topsoil water retention and decreased soil temperature when compared to non-mulched surfaces.

Conclusions

Observations from this glasshouse study indicate that soil water content and soil temperature variations in the soil, under retrievable drip irrigation can be different depending on the drip irrigation management system. Soil water content and soil temperature variations were reduced by 2 and 5 cm dune sand cover.

Covering the drip lines by 2 cm dune sand, however, had the problems of expansion and contraction of the drip lines. The drip lines protruded out of the soil because of this problem. The 2 cm dune sand cover is therefore not a practical cover for drip lines to reduce the variations of

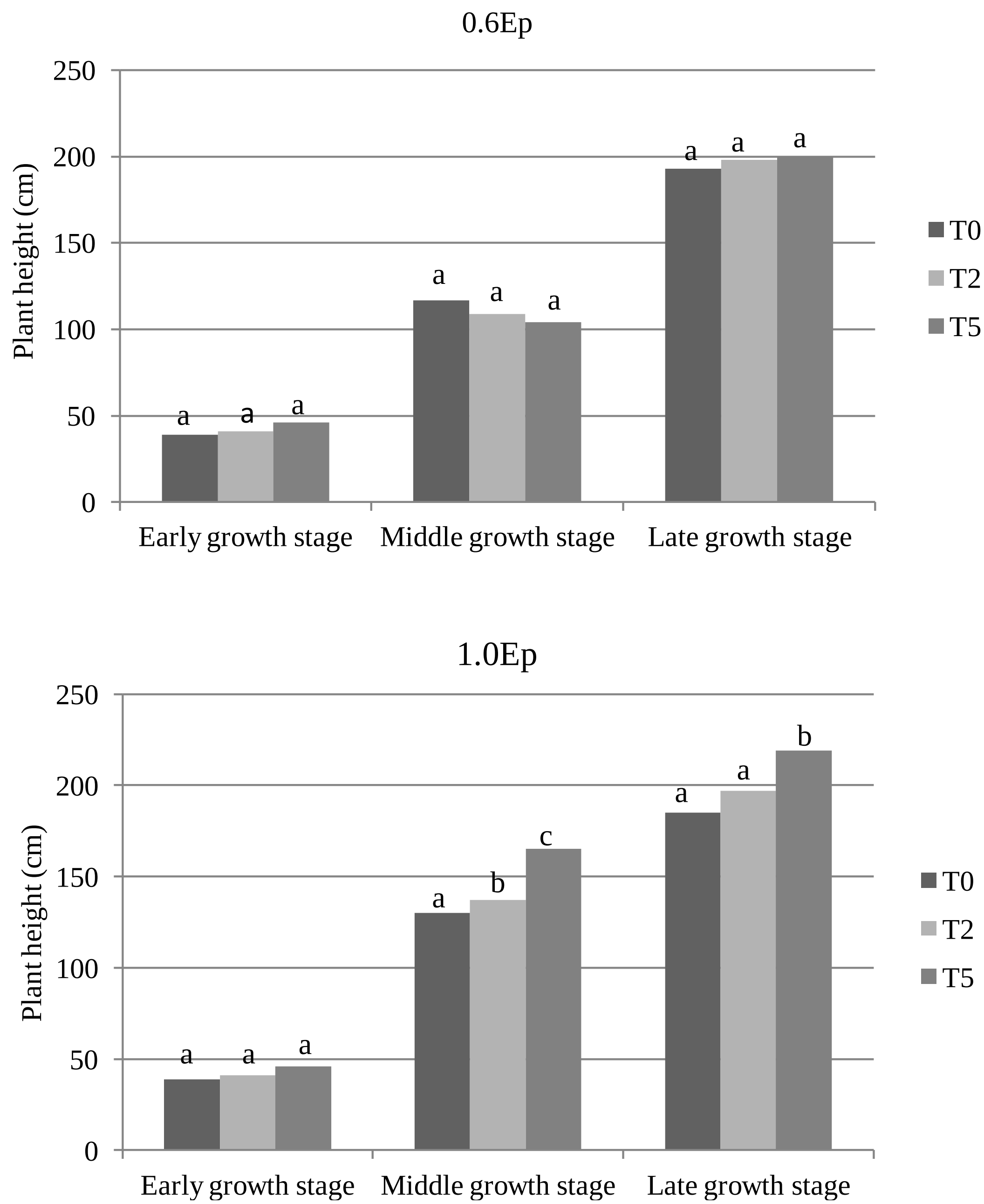

Figure 12. Plant height at three growth stages for 0.6Ep and 1.0Ep (Bars within the same growth stage for both 0.6Ep and 1.0Ep with different letters on top are significantly different at P < 0.001).

Table 5. Dry matter yield under T0, T2 and T5 for 0.6Ep and 1.0Ep.

Sand cover	0.6Ep			1.0Ep		
	Yield (kg/m^2)	Mean (kg)	SD (kg)	Yield (kg/m^2)	Mean (kg)	SD (kg)
T0	1.8	0.19a	0.02	2.5	0.19a	0.08
T2	1.9	0.22a	0.03	2.2	0.24b	0.07
T5	2.1	0.32b	0.07	3.0	0.34c	0.06

Values followed by different letters within a column are significantly different at P < 0.001, SD is standard deviation.

daily water content and daily soil temperature. Maximum soil temperature was reduced by covering the drip lines by 5 cm sand soil. The variations of daily water content and daily soil temperature were best reduced under 5 cm sand soil cover and sufficient irrigation water. The combinations of 5 cm sand dune soil cover and sufficient irrigation resulted in increased sorghum plant height and sorghum dry matter yield.

Conflict of Interests

The authors have not declared any conflict of interests.

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