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Full Length Research Paper

Assessment of farmers' perception and adaptation mechanism to soil erosion problem in Shomba Kichib, Gimbo District, Kaffa Zone, South West Ethiopia

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Soil erosion is one of the major problems challenging farmers in Ethiopia. Though a number of soil and water conservation methods were introduced and practiced, sustaining the application of these measures is far below expectations and soil degradation is still a persistent problem. This research was conducted with the aim of finding out the type of indigenous and introduced soil and water conservation measures, determining the farmer's adaptation mechanism to erosion and biophysical factors that influence the use of these measures in the area. For this study, a total of 35 households were interviewed and farm fields were visited. The results showed that farmers in the area were mainly annual crop producers on slope farmland with traditional as well as newly introduced conservation structures. Contour farming for maize and furrow making, *gulgualo* and *gilalo* methods for millet and pepper production are the common ones. Continuous farming, tillage on slope land with no conservation structures, deforestation and frequent tillage up to 5 times for some crops are important factors aggravating soil erosion. As a recommendation, the very sloppy nature of the study area has to be given due emphasis and priority for an appropriate designed soil and water conservation practice.

Key words: Soil erosion, soil and water conservation, farmers' perception, conservation measures.

INTRODUCTION

Agriculture is a back bone of the economy of Ethiopia and a way of life for which agricultural land is an indispensable resource on which the welfare of the society is built on. The livelihood of the vast majority of the population depends directly or indirectly on this sector. Needless to mention, such dependence obviously leads to increased vulnerability of the economy to problems related to land degradation (Wegayehu, 2003). Though agricultural land in Ethiopia has provided a means of livelihoods for the majority of the population, land resources are facing increasing degradation mainly due to soil erosion by surface runoff water in the form of sheet and rill erosion. The problem is particularly severe on cultivated marginal and sloping land because such areas are generally susceptible to soil erosion (Tadesse and Belay, 2004; Greenland et al., 1994). Soil erosion is greatest on cultivated land where average annual soil loss was 42 t/ha/yr (Hurni, 1990).

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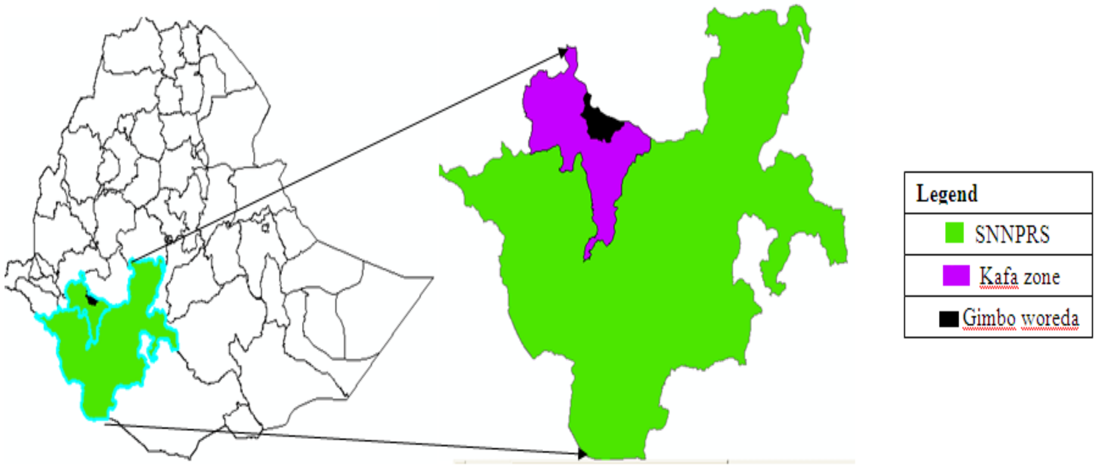

Figure 1. Map of study area.

The Soil Conservation Research Project (SCRP) has estimated an annual soil loss of about 1.5 billion tons from the highland. According to the Ethiopian Highlands Reclamation Study (EHRS, 1984) soil erosion is estimated to cost the country 1.9 billion US$ between 1985 and 2010. Soil erosion and nutrient depletion presents a threat to food security and sustainability of agricultural production in many developing countries. Betru (2003) reported that, Ethiopia losses around 2 billion tons of fertile soil and subsequently losses 2% of the annual grain production, which is roughly equivalent to 120, 000 tons of cereal per annum (Mesfin, 2004). According to Mesfin (2004), the annual loss in grain production due to erosion in 2000 was 170,000 tones. This shows the loss of income in terms of lost agricultural production of US $150 million. The Ethiopian highlands have been experiencing declining soil fertility and severe soil erosion due to intensive farming on steep and fragile land (Abegaz, 1995).

To increase agricultural production and to conserve land resources in sustainable farming, different strategies have to be introduced targeting conservation agriculture (CA). Conservation agriculture is an interdisciplinary and synergetic set of principles to combat soil fertility loss, soil structure degradation, reduced water use efficiency and rapidly declining production levels (Kaumbutho and Josef, 2007). Conservation agriculture is not an actual technology; rather, it refers to a wide array of specific technologies that are based on applying one or more of the three main conservation agriculture principles (IRRR and ACT, 2005 cited in Kaumbutho and Josef, 2007). The application of the three principles include: minimal soil disturbance (reduce the intensity of soil tillage), cover the soil surface permanently and diversify crop rotation (Ibid).

Among conservation agriculture technologies, soil and water conservation measures (better soil erosion control, better soil water infiltration capacity), agronomic soil fertility management technologies/practices (mulching, organic matter incorporation, crop rotation, integrated soil fertility management), integrated weed management, integrated pest and disease management, post harvest techniques and mechanization (specialized) implements are the major ones. The rate of soil loss in Ethiopia was put in severity levels as, very high (>100 t/ha/yr); high (50-100 t/ha/yr); moderate (10-50 t/ha/yr); low (1-10 t/ha/yr) and no erosion (<1 t/ha/yr) (Hurni, 1983). Farmers in the area practice crop production on slope land due to different causes like shortage of land. In addition, the crops being cultivated were those requiring frequent tillage to fine the soil that could aggravate soil erosion and therefore, the importance of this research was roughly to assess and discuss how soil erosion was highly occurring especially on slop farmland and what type of conservation methods were practiced by farmers and thereby to identify farmers' adaptation mechanisms to mitigate soil erosion in the area.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Gimbo district, Kaffa zone, southern Ethiopia. It is found within the southwestern plateau of Ethiopia. The area lies within 07°00'- 7°25'N Latitude and 35°55'-36°37'E Longitude. Its altitude ranges from 1600 to 1800 m.a.s.l. The topography is characterized by slopping and rugged areas with very little plain land (Matheos, 2001). Climatically, the area experiences one long rainy season, lasting from March /April to October. The mean annual rainfall ranges from 1710 to 1892 mm. Over 85% of the total annual rainfall, with mean monthly values in the range of 125 to 250 mm occurs in the 8 months long rainy season. The mean temperature ranges from 18 to 19.4°C (Matheos, 2001). The area is known by its dense natural forest with diverse tree and wild life species (Figure 1).

The soils of the area are deep, clay red soils with an agric B-

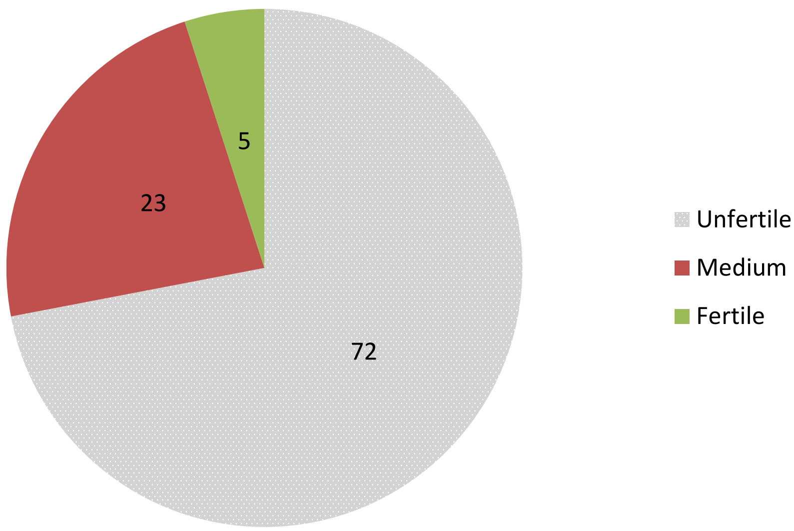

Chart 1. Land fertility level in percent.

horizon dystric nitosols. The soils have good agricultural potentialities, good physical properties and uniform profile. They are porous, clay-to-clay loam in texture and have low base saturation with less than 5.5 pH values and well drained (BoARD, 2010). Regarding the farming system of the area, it is mixed type of which crop production is dominant. It is estimated that over 62% of the total area is, or has been, under agricultural cultivation. Like in other areas, activities related to coffee production provide the largest income and employment opportunities for the local communities. Apiculture and non timber products like spices also play an important role in the household's economy of the study area.

Sampling technique

Gimbo is one of the districts, in which various cereal productions takes place. Shomba Kichib administration, (hereafter KA), was selected based on the severity of soil erosion in farmlands. Four villages namely Gojamsefer, Melligawa, Keja, and Matana were selected. To collect information on farmers' perception on soil and water conservation, a total of 35 households out of 619 were selected using systematic random probability sampling. From three villages 9 households (HHs) each while from one village 8 HHs totally contributing more than 5% of HHs were selected and interviewed.

Data collection

Both formal and informal methods of data collection were employed. Data on soil erosion problems, conservation practices (indigenous and/or introduced) and the extent to which farmers continuously use it, adaptation mechanism of erosion risks, cropping systems, responsibility of farmers and governments on soil and water conservation, farmers practice on tree and fruit plantation and their awareness on importance of land certification were collected by interviewing sample respondents with an instrument of structured questionnaire. Transect walk across the village were conducted in order to obtain all the necessary biophysical information of the area. Moreover, key informants interview (KII) was done with for detail understanding on the issues. The data was analyzed using simple descriptive statistics using SPSS software.

Table 1. Causes of soil fertility losses.

Main causes	Percent
Soil erosion	35
Continuous farming	51
Not using fertilizer	9
No decrease in soil fertility	5
Total	100

Source: own survey, 2012.

RESULTS AND DISCUSSION

Fertility status of soil in the area

The fertility level of farmland in the area was assessed physically as well as using interview. Most of the farmers, 72% of the cases, responded their soil fertility status being under medium (Chart 1). Respondents explained that the main causes of the soil degradation are dominantly continuous farming and soil erosion respectively. However, 74% of farmers do not consider soil degradation as priority problem because of different economic (input cost) as well as social (land rent and share cropping) reasons (Table 1).

Farmers' perception on soil erosion occurrence, its cause and risk

As it was indicated in Table 2, farmers have different understanding and explanation about the soil erosion occurrence. However, it is clear from the data that a farmer could observe whether soil erosion exists when,

Table 2. Farmers perception on defining soil erosion occurrence on farmland.

Explanation from the respondents	Frequency	Percent
Top soil color change to red	6	17
Crop yield reduce annually	3	9
Black soil collected on furrow in farm	6	17
Sandy soil occur on top of farmland	4	11
Fertile soil seen down slop in furrow	5	14
Rills observed on farmland after rain	2	6
Deposited soil seen on tree root	4	11
Red soil upslope and black soil down slop in furrow	1	3
Deposited soil on level land after rainfall	3	9
Indifference	1	3
Total	35	100.0

Source: Own survey, 2012.

Table 3. Response for causes for soil erosion on farm land.

Causes raised by farmers	Count	Percent
frequent cultivation	8	23
High tillage frequency or (ploughing 4 to 5 times before sowing)	7	20
Heavy rainfall during sowing time	8	23
Absence of SWC on slope land	8	23
Deforestation on the top catchment	3	8
Unreliable and erratic rainfall due to climate change	1	3
Total	35	100

Source: own survey, 2012

how, and why it occurs on his land and its preventive measures. All the ideas raised by farmers about soil erosion occurrence are true definitions unless it varies from farmer to farmer depending on real event on his farm land. Almost all of the farmers justified that soil erosion was very high during millet and chili pepper production. Since the topography of the farmlands were mostly sloppy and also farmers were very interested to produce these crops on their limited sloppy land it was not uncommon to see erosion occurring there The reasons raised were; they plough the land for these two crops 4 to 5 times during land preparation which can pulverize soil particles making it simple for transport by runoff; they cultivate slope farm land for these crops with no advanced conservation structure except traditional furrows which fills soon after first rain allowing the soil to be eroded thereafter; the crops were planted with wide spacing which expose the land to rain drops. In addition to this, time of cultivation for these crops is during high rainfall period. Some of them explained their reason in relation to deforestation because the forest on top slope of their land was cleared resulting to higher runoff to damage the land at down slope. According to the response, due to climate change problem, erratic or unpredictable rainfall occurs resulting to unexpected erosion on the farmland (Table 3).

Soil and water conservation practices

Various soil and water conservation practices (indigenous and improved) have been identified in the study area. The area has practice of both introduced and traditional soil and water conservation activities. 74% of respondents practice either of the above methods however, 26% did not have any conservation practice because of less awareness of farmers on the risk of soil erosion on yield of crops (Chart 2).

Indigenous soil and water conservation practices

Farmers in Shomba Kichib used different types of indigenous soil and water conservation measures to conserve and maintain their farm land. From the study it was observed that farmers were resistant to construct physical structures and give priority for indigenous ones because, the introduced one compete for land, it requires

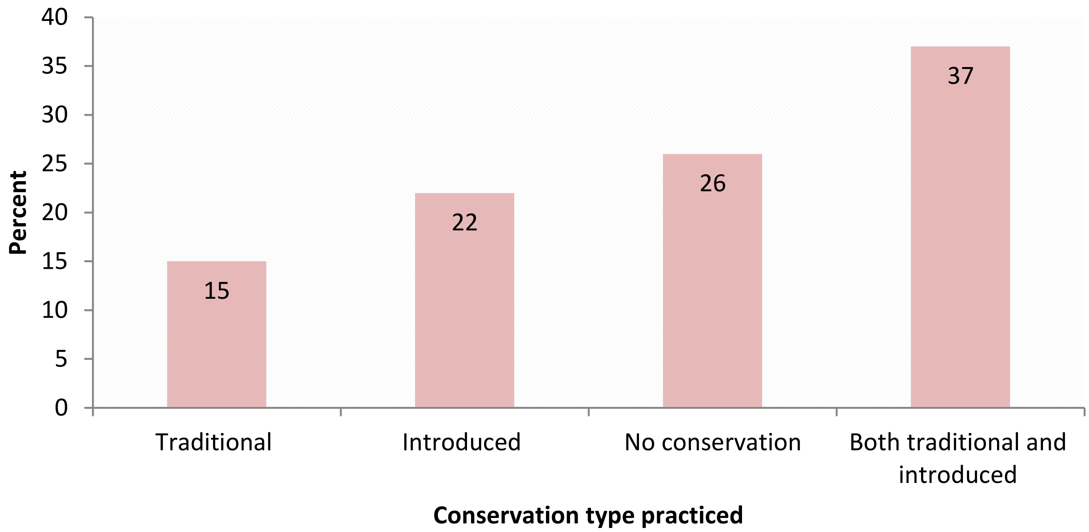

Chart 2. Conservation methods practiced by farmers.

labor, difficulty to plough by oxen and intensive machinery farming between constructed bunds. Due to this, farmers apply traditional soil conservation practices assuming that it does not have significant difference in terms of controlling soil loss from farmland. Less interest to adopt introduced soil and water conservation practice was also related to less awareness on sustainable and long term importance of the farmland. However, there were appreciable indigenous methods of soil erosion control. These include contour farming, making furrow (locally called *boie*), making trash line across slope on contour, *gulgualo*, *gilalo* and leaving crop residue on farmland. The drawback of traditional methods is; its application did not follow the watershed management approach/ soil and water conservation design requirement which highly depends on land survey result/. Traditional method has temporary advantage like for a given season. This indicates that tradition conservation method is not sustainable way to solve soil erosion problem. The common traditional methods practiced in the area include:

Contour farming: Farming the field across the slope following hypothetical contour line.

Furrow making (locally called *boie*): Farmers make furrow (channel) with undefined interval after last tillage and during sowing time. They assume that the furrow will collect soil eroded from above furrow interval (catchment). It was observed that the furrow was full of soil deposit.

Laying trash line: Trash is residue of crop or rubbish in the farmland. The name *trash line* stands for laying trash on contour line. It is applied with given interval on contour line. The trash decomposes for the coming season and its decomposition is used as good fertile soil for the coming season.

Gulgualo: Farmers put undisturbed clot of soil mass across slope in the field during sowing. These soil mass was thought to obstruct germination of seed if they are left in the field as they are. Thus they pick them from field and put on contour line to use it for soil erosion control.

***Gilalo*:** It is a farmers practice during weeding period of crops specially millet and pepper. It was the method by which the uprooted weeds are laid across slope following contour to control soil erosion.

Residue management: Leaving crop residue on the farmland when any crop is harvested without consideration of contour line (opposite to putting residue as trash lines on contour).

Strip cropping: Cultivating the strip of a similar crop at least with 10 meter wide space but not limited length of strip. A farmer can have a strip of two or more crops planted at the same time in a given farmland area. One strip having short duration and the other long; one with short height and the other long height. The difference in strip can help to reduce erosion like strip of millet with maize.

Generally, most of the farmers use *contour farming*, *furrow making*, residue laving on farmland, and strip cropping methods for maize sowing while *furrow making*, *gulgualo*, *trash line, gilalo* and contour farming methods for millet and chili pepper sowing.

Integrating the traditional and introduced conservation practices

It was suggested by farmers that one of the main factors for resisting construction of terrace was top down approach which strictly follow only the principle of technical design prepared on the manual than the participatory approach. The introduced soil and water

Table 4. Ranking of Farmers' adaptation mechanism for soil erosion control.

Rank	Adaptation mechanism+	Respondent's										TRS**
		Number					Relative score*					
		1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th	
1	Furrow making with given interval	29	6	-	-	-	21.56	1.03	-	-	-	22.59
2	Crop residue leaving	10	22	3	-	-	2.56	13.82	0.17	-	-	16.56
3	laying trash line on contour	-	5	25	5	-	0	0.71	11.17	0.11	-	11.99
4	Putting *gulgualo* across slope	-	-	5	22	18	-	-	0.48	4.3	5.85	10.6
5	Introduced Soil conservation structure	-	-	6	10	17	-	-	0.38	1.49	7.23	9.1
6	Putting *gilalo* across slope	-	-	8	25	2	-	-	1.23	7.18	0.1	8.51
7	Strip cropping	-	2	5	25	3	-	-	0.67	7.18	0.23	8.08
		39	35	52	87	40						

Source: own survey, 2012. *Relative score was calculated by multiplying the number of respondents in each rank by its proportion (e.g. (29*29/39), **Total Relative Score, +Couture farming was commonly used by farmers who apply the above seven adaptation mechanism and this was the reason not to include it in the list in the above table.

conservation measure did not appreciate the traditional practice and resulted in failure of integrating both practices. Similar findings was reported by Mekonnen and Abiy (2014), that in southern Ethiopia, absence of integrating indigenous SWC with exotic one is one of the main constraints that exists in the country. Farmers try to follow indigenous practice than advanced because advanced ones need much labor, it also looses wide land for embankment due to its technical requirements, it needs more attention during ploughing not to be destructed by oxen and it need experts be available on field for planning and survey before construction. Some farmers apply both traditional and introduced practice at the same time. This include preparing furrows on the surveyed contour, planting grass strips on the contour with the help of survey points and preparing *gulgualo* and trash lines across the slope (along contour) during cultivation. These practices can be said as integration of indigenous and introduced practices. It can also motivate farmers to protect their land from erosion. According to Kessler (2006), the planners and implementing agencies of physical soil and water conservation interventions should not ignore local level biophysical and socio-economic profiles of the area under consideration.

Farmers' preference on soil erosion prevention measures

To evaluate farmers' preference on soil erosion prevention measures, respondents were asked to rank the five most preferable mechanisms for soil erosion controls and then total relative score (TRS) was calculated. As it is shown in the Table 4, furrow making with given interval, residue leaving, laying trash line on contour, putting *gulgualo* across slope and terracing were the five most preferred mechanisms.

Introduced soil and water conservation practices

The farmers who constructed the soil bund were highly eager on soil productivity increment and for new technology adoption. The introduced soil and water conservation practices in the area include soil bund, fanya- juu terrace, bund stabilized with biological measure and fanya-juu stabilized with biological measure. Fanya-juu terrace differ from soil bund by the principle of throwing dug soil material upslope (upward direction) opposite to soil bund which uses throwing dug soil material downward direction. 71.5% of the respondents in the area have practiced introduced physical soil and water conservation structures while 28.5% of the cases integrate physical and biological conservation measures to reduce soil erosion. Physical conservation measures in the area were constructed with help of Sustainable Land Management (SLM) Project. Crops planted on physical structures as biological conservation measures were multipurpose grasses such as vetiver grass *(Vetiverial zizanioides)*, used for stabilizing soil bund, thatching house, mulch material and forage; Desho grass ((*Pennisetum pedicelluatum*) used for stabilizing soil bund, and forage; and elephant grass (*Pennisetum purpureum)* used for stabilizing soil bund, mulch material and forage. The project provides fruits and coffee seedlings for farmers who construct physical soil and water conservation structures on their land to build up their farm income.

Responsibility of farmers and government for land management

As elsewhere in the country, farmers do have responsibility for the proper management of their land. 40% of the respondents explained that awareness

Table 5. The response of farmers on their expectation from the Government for land management.

Farmers' expectation from the government for land management	Percent
Monitoring and evaluation of land management	8.6
Surveying and layout preparation of SWC	31.4
Providing important materials for us	14.3
Awareness creation	40
Providing technology and experts,	5.7
Total	100

Table 6. Response of farmers on their awareness, their responsibility of land management.

Response on farmers' awareness on their responsibility of land management	Percent respondents
Properly managing land according to experts advice	14
Controlling soil erosion is my mandate	3
Contributing for labor for activities done on my land	40
Construction of soil bunds	43
Total	100

Source: Own survey, 2012.

Table 7. Farmers' awareness on the issue of land certificate and their knowledge about its content.

Farmers' awareness on the issue of land certificate	Percent
Did not read	37
Have no land certificate	9
Yes I read	54
Total	100

Source: Own survey, 2012.

creation and technical support is expected from the government. As it is indicated in Table 5, farmers' understanding on what is expected from the government differ from individual to individual farmer. Regarding soil erosion control, 31% responded that they need support from the government during surveying and layout preparation of soil and water conservation activity. Similarly, they explained that they are responsible in contributing of labor and implementation of the advice of technical agricultural experts (Table 6).

Extension service provision to farmers

90% of the respondents have access to agricultural extension services in terms of technical support, awareness creation and provision of agricultural inputs on time on credit and kind basis. Only 10% of the surveyed farmers were not benefitted from such services. This could be due to the problem of top-down approach which did not consider farmers priority interest. On the other hand, farmers in the area have been complaining on the increased cost of fertilizers which motivate them to economize their farming system.

Awareness on land certification

As it was responded by 77% of farmers, they have good awareness on land certification that has been given since 2006. It has an advantage of increasing sense of ownership on the land. When they were asked about their knowledge on the written sentences about the mandate of land owner to conserve or manage his land from degradation, only 54% respondents said that they know about it. However, 37% of the land certificate holders have never read the contents of the certificate (Table 7). This shows that 41% of the land certificate holders have

Table 8. Farmers' knowledge on the issue of soil erosion vs vs land certificate.

Knowledge about issue of soil erosion written in the certificate	Percent
Tells about my mandate on soil erosion control	23
It says about advantage of land ownership	77
Total	100

Source: own survey, 2012.

never read the contents of the certificate (Table 8).

Farm and home garden tree planting practice

Farmers in the study area have practice of protecting natural trees on their farm. In addition, according to this study 94% of respondents have at least four tree species on their farm as well as in their home garden. The tree species found were *Milletia ferrugina, Ficus vasta, Cordia Africana, Albizia schimperiana,Grevillea robusta, Eucalyptus camandulensis, Acacia spp.,Prunus Africana, Olea welwitschii, Ficus sur, Sapium ellipticum, Azadirachta indica and Sesbania sesban.* They also plant agro forestry fruits which include Banana (*Musa* spp.), Mango (*Mangifera indica*), Avocado (*Persia americana*), Orange (*Citrus sinesis*) and papaya at their home garden. The source of seedlings for trees and fruits species was from office of Agriculture and different Non-governmental organization.

CONCLUSION AND RECOMMENDATIONS

Soil erosion is a threat to the decline of agricultural productivity in Kafa zone Gimbo district as it affects the crop production significantly. The study area, Shomba Kichib, is characterized by steep and undulating terrain being cultivated for annual crop like maize, millet, chili pepper. The area also receives intense and heavy rain during rainy season concentrated in few months (June to September). The low fertility of the soil in the area was due to continuous cultivation and soil erosion from sloppy farmland. Farmers revealed that cultivating slope land is due to shortage of land for crop production. Their indigenous system to cope up with soil erosion was observed as the method with two advantages, that is, controlling erosion temporarily and increasing fertility for next season by decomposed trashes.

Besides, the heavy dependence of society on agricultural sector mainly on production of millet and pepper, cultivating millet and pepper aggravates soil erosion due to its requirement of very fine soil. Combined with heavy rainfall during the same period, fine soils are washed away, that demands soil and water conservation intervention. In this regard, the result of assessment in the study area showed a range of conservation measures were introduced with the objective of conserving, developing and rehabilitating degraded agricultural lands and increasing food security through increased food production and/or availability. These measures were categorized into indigenous and introduced types. Indigenous methods used were contour farming, furrow making, making trash line across slope on contour, *gulgualo*, *gilalo* and leaving crop residue on farmland. Similarly, introduced measures practiced in the area include soil bund, fanya- juu terrace, bund and fanya- juu stabilized with biological measure. The biological measures planted on physical structures were multipurpose grasses such as vetiver grass, desho grass and elephant grass. Farmers who have good awareness to sustainable land use have an interest to adopt introduced soil conservation structures to be more effective in preventing soil erosion and ensuring sustainability of yield.

Based on the assessment result of soil and water conservation activities in the area the following recommendation could be forwarded. Farmers whose land slope is more than 8% should get continuous awareness creation (get knowledge about the erosion risk and controlling methods through training at Farmers Training Centers (FTCs). Training at FTCs should focus on main factors aggravating soil erosion such as the slope of the farmland, type of crops exacerbating soil erosion and intense rainfall. The training should also focus on problems of using traditional soil erosion control methods, role of integrating physical and biological soil and water conservation practices.

Cultivation of crops which need fine textured soils should be treated with proper slope selection and supporting with proper physical as well as biological soil and water conservation measures. Since farmers are very sensitive with ownership principle of land, special attention should be given on filling the farmer's knowledge gap on the importance of land certificate as well as rules and regulations written about erosion control in land use certificate. The farmers, who complain about the fragmentation of farmlands during construction of soil and water conservation structures, should frequently learn using FTC with practical observations or occurrences at the field in a participatory approach. Farmers also need to be made aware of the economic losses due to soil erosion from the cultivated fields. Farmers who try new technologies by themselves on their own land should be targeted for technically supported. Those who did not understand about the impact of soil erosion should get field visit program for experience sharing from other nearby farmers.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

More than two decades of climate change alarm: Farmers' knowledge, attitudes and perceptions

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We conducted a questionnaire survey to assess farmers' knowledge, attitudes and perceived threats of climate change. The findings show that the farmers are generally aware of direct and observable causes of climate change and the main impacts of climate change on agriculture but are not clear about the interconnections between the natural environment and farm management activities that result in climate change. This observation maybe explained by the fact that farmers rarely obtain information from accurate sources. Analysis of results showed that knowledge and attitudes towards climate change are influenced by gender, age and education. The results suggest the need to shape farmers' attitudes/perceptions about climate change through participatory formulation and implementation of policies and the need to spread information through social networks. The roles and behaviors which individuals and organization can feasibly implement should be ascertained to increase adoption of actions that support formal and informal institutional arrangements.

Key words: knowledge, attitudes and behavior/ practices (KAP), survey, anthropogenic activities, livelihoods, climate change, agriculture.

INTRODUCTION

In the past two decades, there have been great variations and changes in global climate. Consequently, academicians, policy makers, activists, politicians and the general public have been engaged in debates about causes, impacts and solutions to the climate changes. Scientists are unequivocal that climate change is happening as a result of anthropogenic activities that have led to the increasing atmospheric greenhouse gas concentrations (IPCC, 2007a; UNEP, 2010). These atmospheric greenhouse gases trap the heat energy that would otherwise re-radiate to space, helping to rise the temperatures, a phenomenon popularly known as global warming. Climate change has been shown to have dramatic impacts on weather patterns, food production, ecosystem health, species distributions and phenology, and human health (IPCC, 2007b). It has been argued that climate change is proceeding faster, and with more unexpected manifestations, than predicted by climate

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scientists a decade ago (Rahmstorf et al., 2007; Steffensen, 2008). This has led scientists and policy makers to make a clarion call for adoption of measures that help to reduce the dangerous impacts of climate change because they will be severe and potentially irreversible (Schellnhuber et al., 2006).

On one side, agriculture is extremely vulnerable to climate variability with reductions in rainfall, extreme weather conditions, floods and drought causing significant impacts on productivity levels (Crimp et al., 2008). On the other side, agriculture is partly responsible for greenhouse gas emissions. Globally agriculture directly accounts for 14% of GHG emissions in CO_2 equivalents and additional 17% when land use and forest conversion for crops and pasture are included in the calculations (IPCC, 2007a; World Bank, 2009; Cole, 2010). Agricultural sector generates greenhouse gases through intensive use of chemical fertilizers and pesticides (Frolking et al., 1999), methane generated from flooded rice fields (Zhang et al., 2010), anaerobic animal waste processing and enteric fermentation in ruminants (Johnson and Johnson, 1995) and biomass burning (Zhang and Chen, 2010).

The threats posed by climate change to agricultural sectors need critical assessment especially in developing countries whose societies and economies are fundamentally dependent on agriculture (World Bank, 2009). This is more so because in addition to climate change, the arable land is dwindling (Roy et al., 2011) and rainfed agriculture is obviously becoming unsustainable. Using studies of agricultural water management from 1962 to 2011 (Valipour, 2014a) estimates that ratio of area equipped for irrigation to cultivated area will change from 16.5 to 83.2% from 2011 to 2060. Moreover agriculture is under more pressure to feed the world population that is expected to increase from the current 7 billion to 9 billion by 2050 (Ronald, 2011) and subsequently demanding agricultural productivity to increase by 70 to 110% by 2050 (Tester and Langridge, 2010; Tilman et al., 2011). Developing countries particularly those in South-east and west Asian countries are considered very vulnerable to climate change where farmers could suffer unstable food supply due to decline in yield, constrained income due to increased input for sustaining crop productivity and from other loss due to extreme event damage (IPCC, 2007b; FAO., 2013; Valipour 2013, 2014a, b; Valipour et al., 2014). Therefore, farmers in the developing countries are the key players in the global efforts to act against climate change.

Our current study is necessary for Chinese because agriculture in china is characterized by intensive application of chemical N fertilizers (Heffer, 2009; IFA, 2011; FAO, 2013) and mechanization both of which emit greenhouse gases. In addition, 23% of Chinese agricultural land is under rice production (Frolking et al., 2002), which has already been considered a major source of greenhouse gas (IPCC, 2007b). Furthermore, more than half of the populace live in the rural areas and depend on agriculture for their livelihood (National Bureau of Statistics of China, 2010). Thus, understanding farmers' knowledge and attitudes towards perceived impacts of climate change is critical for policy makers to design incentives for farmers to mitigate and adapt to climate change. This study explores the factors influence farmers' perceptions and knowledge about climate change and also the efficient media of conveying climate change information to the farmers.

Literature

Most studies on climate change seem to involve some aspects of knowledge, attitudes and behavior/ practices (KAP) model as described by World Health Organization (WHO, 2008). KAP surveys are conducted to get insights on what an individual or community knows, (Knowledge) how they feel (Attitude) and how they act (Practice) about certain topics or issues, in this case climate change. These surveys have been used extensively worldwide by the World Bank, United Nations agencies, and by both government and nongovernmental agencies in areas of family development, education, public health, and sanitation (Ekman et al., 2008). Recently the approach has gained popularity in the field of environment with majority focusing on one or two aspects of the KAP triad.

Knowledge/environmental awareness

Environmental awareness is the attention and concern of individuals to environmental problems. It results from understanding and appreciating the interrelatedness of humans, their culture and their biophysical surroundings (Sudarmadi et al., 2001). An environmentally aware person knows and is concerned that human behaviors that degrade environment are a threat to life and that the threat goes beyond those who pose it. In other words, people who are conscious that greenhouse gases are causing climate change are likely to support policies that are aimed at mitigating climate change. Knowledge about both the causes of climate change and means of reducing emissions is an important factor influencing pro-environmental intentions and behaviour (O'Connor et al., 2002; Maddison, 2007; Gram-Hanssen, 2009). Higher level of environmental concern has been shown to significantly and positively relate to the adoption of organic farming (Burton et al., 2003; Läpple, 2010) and water management (Wang et al., 2006; Tang et al., 2013). However, lack of awareness has been blamed for low rates of adoption of environmental innovations (Wang et al., 2010; Liu et al., 2013) and total failure to adopt tree planting in Greece (Kassioumis et al., 2004). Certainly, Climate change awareness is a major impediment for implementation of climate change mitigation plans.

Information about climate change

Opportunities to manage agricultural risk are dependent on climate information and are yet to be fully exploited partly because of gaps in existing climate information services. The gap is increasingly widening because climate changes and variations have rendered the traditional ways of weather prediction less relevant. This role has been left to researchers, government agencies and the mass media. This is because researchers' motivation is to publish their findings in scientific journals that limit their audience to fellow researchers and scientist who can understand scientific work. Simply stated, researchers' purpose for their work is not to communicate findings to anyone outside their area of expertise (Willems, 2003; Kyvik, 2005). This disconnect has given the media a leading role in regard to disseminating information about this salient subject. In fact many studies have underscored this media role (Stamm et al., 2000; Russill and Nyssa, 2009; Sampei and Aoyagi-Usui, 2009) in informing the public about climate change.

Risk perceptions

Perception of an environmental problem is the ability to perceive environmental issues in the real world, based on memory and influenced by prior experience (Sudarmadi et al., 2001). There is a vast body of literature suggesting that individual perceptions and attitudes towards environmental awareness are influenced by knowledge, past experiences, social networks and institutional trust (Blake, 2001; Doss and Morris, 2001; Kollmuss and Agyeman, 2002; Dessai et al., 2004; Marenya and Barrett, 2007; Mwirigi et al., 2009; Liu et al., 2013). Experience of an environmental problem plays a crucial role in the process of forming environmental perception (Diggs, 1991) because experience or prior knowledge is the basis of recognition (Sudarmadi et al., 2001). According to (Burton and Kates, 1963) individuals who have had personal encounter with an environmental disaster were more likely to have positive attitude towards environmental protection because the disaster is a reality to them. The finding is corroborated other studies that show that people who had encountered extreme weather events such as floods (Spence et al., 2011) hurricanes and droughts (Woudenberg et al., 2008; Borick and Rabe, 2010) were more cognitive and perceptive of climate changes.

Studies have also shown that women express more willingness to adopt pro-environmental behaviours than men (O'Connor et al., 1999; Kollmuss and Agyeman, 2002; Sundblad et al., 2007). Social scientists attribute this to the fact that a feminine identity stresses attachment, empathy, and care (Keller, 1985). In addition, majority of women are not economically empowered and are likely to be vulnerable to the effects of climate change (Davidson and Freudenburg, 1996; Brody et al., 2008; Hemmati and Röhr, 2009).

MATERIALS AND METHODS

Study area

The study was done in Qinxi Township, Jing County, southeastern Anhui Province, located between 30.7° N latitude, and 118.4° E longitude and belongs to the northern fringe of the middle subtropical zone. Its mean annual temperature is between 15.4 and 15.9°C; mean annual precipitation is between 1143.2 and 1503.4 mm. This area is characteristically dependent on agriculture with the main crops cultivated being wheat, rice, soy beans, rape and fruits and vegetables. The main landform is a valley basin. The nearest city where market for inputs and outputs can be located is 150 km away.

Field survey

The study used both qualitative and quantitative methods to build on their complementarities for cross-checking information received from the respondents (Bernard, 2006; Mayoux, 2006). We collected data using structured questionnaire based on the research objective. Some questions were presented as a statement and put on a five point Likert scale (Marshall, 2010; Marshall et al., 2013) and other questions were closed- and open-ended. In addition, focus group discussions were conducted to give more insight to issues that were not well captured in the questionnaires and highlight the differences between participants (Silverman, 2004). For this, a checklist was used to moderate the discussions (Lloyd-Evans, 2006). The questionnaire was formulated in English and translated into Chinese by a native bilingual English speaker who also back-translated it to ensure accuracy. The Chinese version of the survey tool was then pre-tested in a different site and necessary adjustments made before the actual survey. This allowed for restructuring of questions and solving all questionnaire-related problems before the actual data collection (Simon, 2006). The questionnaires were administered to a random sample (Marshall, 1996) of 293 households. Before the commencement of interviews, respondents were thoroughly briefed about the purpose of the study and asked if they were willing to participate. After giving consent, all interviews and discussions were recorded (Bordens and Abbott, 2008).

Data analysis

Data were coded and edited to remove missing values and outliers. The data were analyzed using Statistical Package for the Social Science (SPSS) version 16.0. Descriptive analysis was used to summarize data that were then presented as means and standard deviations. Index construction was undertaken by summing up the scores for all statements relating to knowledge and perceptions to obtain a single group of variables. T-tests were used for interval variables, whereas chi-square tests were used for categorical variables.

RESULTS

Out of the total 380 households sampled, 293 were

Table 1. Farmers general information (N=293).

Gender	Percent response	Age	Percent response	Education	Percent response	Other sources of income	Percent response
Male	47	<30	25	Not educated	13	Business	23
Females	53	30-40	29	Primary school	27	Employment	16
/	/	40-50	15	Middle school	52	None	61
/	/	50-60	14	High school	8	/	/
/	/	>60	17	College	/	/	/

Table 2. Farmers’ sources of information.

	Fellow farmers	Extension officers	Traditional sources	Mass media	Workshops and seminars	Internet	Friends and family	Professional publications
Never	/	13	/	/	57	81	/	93
Rarely	6	17	/	8	13	17	3	7
Sometimes	20	22	14	26	11	2	24	/
Often	31	21	12	42	11	/	33	/
Always	43	27	18	24	9	/	40	/

The frequency is presented in percentage (N=293).

interviewed. The gender composition was slightly more females than male (53:47). Majority of the farmers were less than 40 years. Barely 10% of the farmers went beyond middle school and the vast majority (61%) depended purely on agriculture for their livelihood (Table 1).

Responses to knowledge/awareness of climate change

Majority of the interviewed farmers (91%) had heard about climate change. The vast majority of farmers agreed or strongly agreed that climate change is human induced (76%), agriculture is a major cause of climate change (63%), transport sector emits greenhouse gases (65%), China is experiencing impacts of climate change (63%), fossil fuel is a major source of greenhouse gases (76%) and that greenhouse gas emissions are proportional to energy consumptions (53%). The summary of the questions on awareness and attitudes towards climate change (means and standard deviations) is shown in Figure 1.

However, the farmers appeared not to have a clear understanding of inter linkages between electricity generation and use and the potential of agriculture to mitigate climate change. The majority of the farmers (54%) and (52%) disagreed or was not sure that agriculture has potential to mitigate climate change and that electricity generation and use result in greenhouse gas emissions respectively. Statistical analysis showed significant difference between knowledge and education (t=0.218, P=0.00), age (t=0.267, P=0.00) and gender ($\chi 2$=3.89, p=0.05).

When asked to rate the frequency of obtaining information from the various sources, it was clear that most farmers obtained information through social networks. The results showed that farmers often or always sought information from fellow farmers (73%), friends and family (73%), mass media (66%), close to half (48%) sought information from extension officers and 30% relied on traditional knowledge. It is also clear from the results that all the farmers never or rarely sought information from professional publications, internet (98%), and workshops and seminars (70%) (Table 2).

In regards to attitudes, half of the farmers strongly disagreed or disagreed and only 19% agreed or strongly agreed that they have a responsibility to mitigate climate change while 31% were not sure. This was clearly confirmed when 72% of the farmers strongly agreed or agreed that it is the government duty to mitigate climate change and only 4% was not sure. However, the biggest proportion (40%) was not sure if the government policies can adequately address climate change. Forty two percent strongly disagreed or disagreed and 18% agreed or strongly agreed that the policies can address climate change. As regards insurance cover against climate change, 45% of the farmers agreed or strongly agreed, 27% were not sure and 28% strongly disagreed or disagreed that it is necessary to take insurance covers (Figure 1). There was significant difference between attitudes and education (t=2.66, p=0.00), age (t=-2.09,

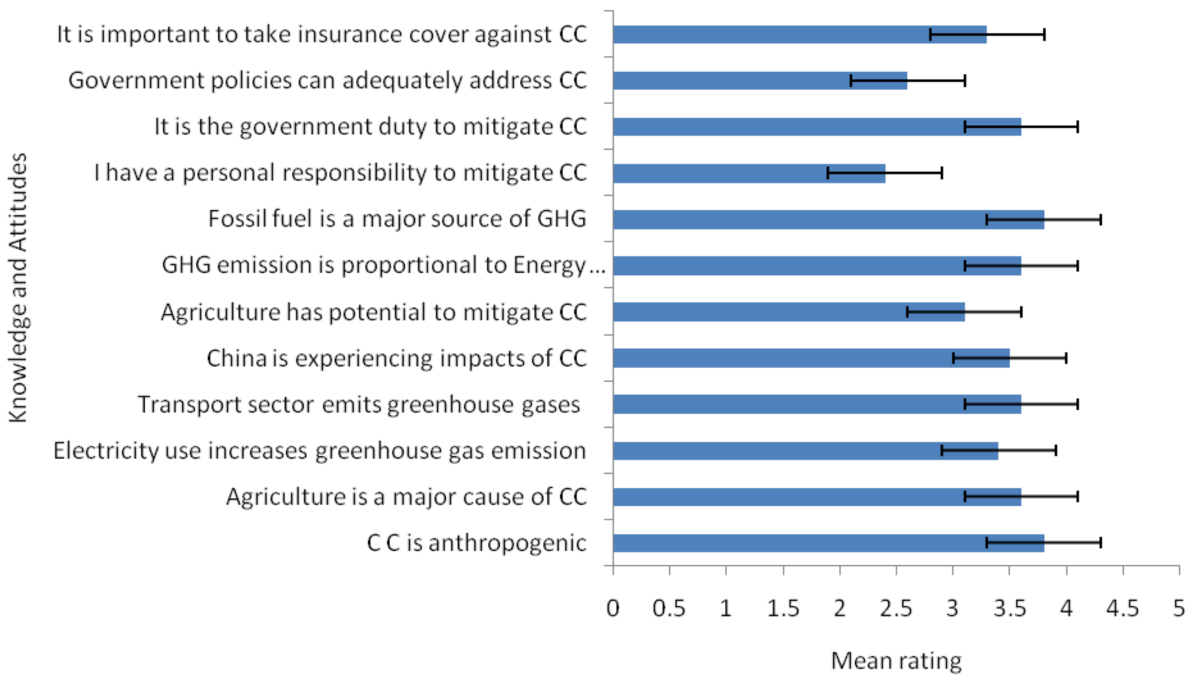

Figure 1. Knowledge and attitudes towards climate change. Statements are presented by mean level of agreement, error bars show standard deviation. Rating scale from 1 = 'strongly disagree' to 5= 'strongly agree' (N=293).

p=0.00), gender (χ^2=3.97, p=0.04).

Perceived threats of climate change

The results show that farmers are perceptive of threats posed by climate change. According to the farmers' responses, more than half of the farmers agreed or strongly agreed that adverse effects on agriculture (66%), severe hunger and malnutrition (58%), severe droughts and floods (55%), decrease in water quantity and quality (59%), change in vegetation composition (60%), increased incidences of human diseases (73%) and conflicts among communities (54%) will result from climate change. Many farmers (48%) agreed that land degradation will occur due to climate change, (37%) were not sure if climate change will result in livestock and crop diseases and only 38% of the farmers agreed that climate change will cause rise in poverty levels. The summary of the perceived threats due to climate change (means and standard deviations) is shown in Figure 2.

DISCUSSION

Literature indicates that, understanding of climate-change issues depends largely on individual characteristics such as educational level, age, gender and social networks. Our study shows that older farmers were more perceptive of climate change and had positive attitudes towards mitigating climate change. This observation is corroborated by other studies (Maddison, 2007; Nhemachena and Hassan, 2007; Lee and Zhang, 2008; Deressa et al., 2009) that age, which builds the farming experience, has positive influence on farmers' awareness, attitudes and practices towards climate change. In agreement with other studies (O'Connor et al., 1999; Kollmuss and Agyeman, 2002; Sundblad et al., 2007) our study shows that women are more aware about climate change and have positive attitudes than men. This observation has been attributed by Brody et al. (2008) to women's vulnerability to environmental hazards and that they value social relationship (Miller, 1976; Kanter, 1977) which enhance information sharing. This observation can be construed to mean that although both men and women have share sources of information; women may have a greater intrinsic value for environment. Our study also shows that higher level of education is a major tool for shaping people's attitudes and awareness about climate change. The results of this study are in agreement with other work (Schuck et al., 2002; Gregory and Leo, 2003; Sidibé, 2005; Liu et al., 2013) that the awareness created though education has influence on adoption of environmental interventions. Generally, the farmers have a relatively high level of understanding of climate change and reasons for its occurrence. Though not necessarily using scientific terminology, farmers described climate change as resultant of human activities. These findings agree with other work (IPCC, 2007a; Hofmann et al., 2009; Stern,

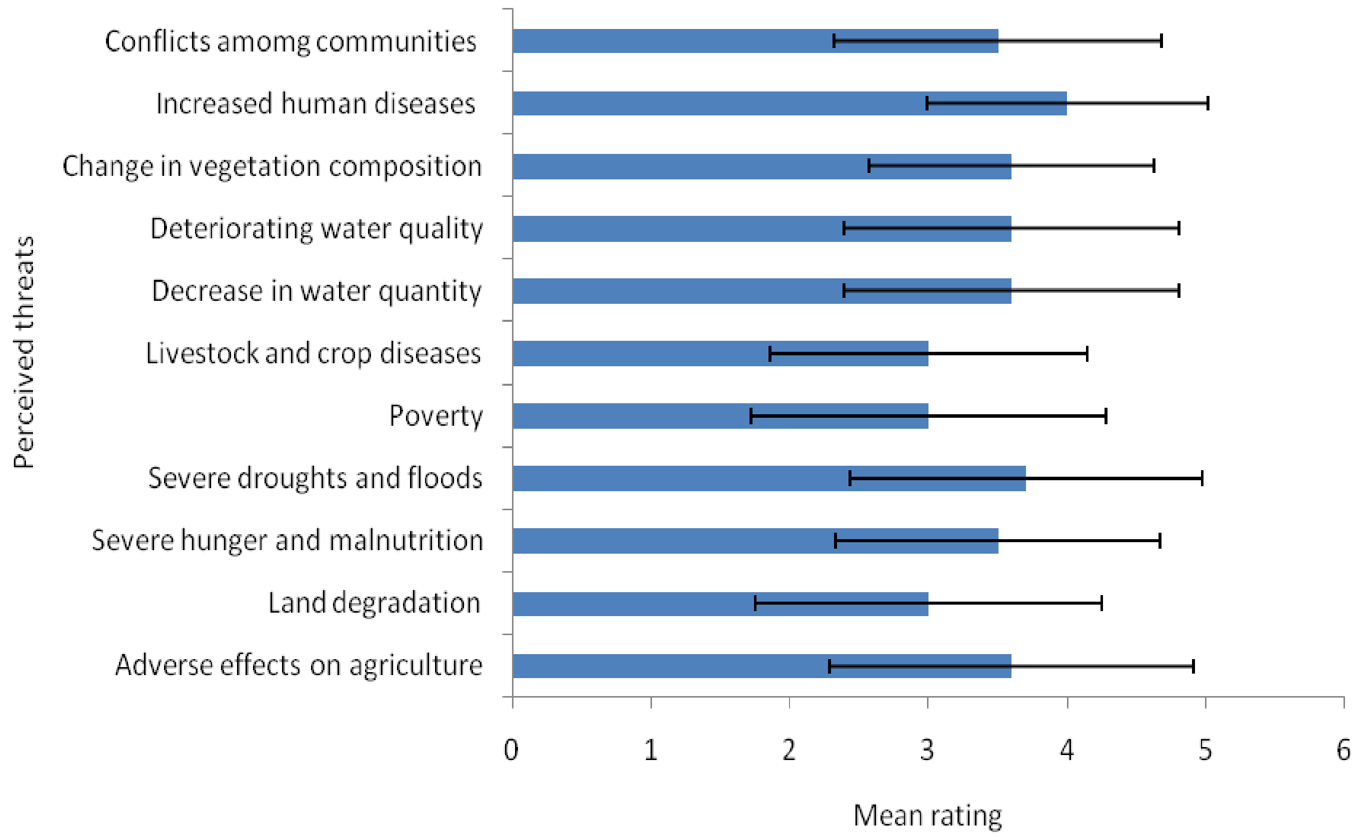

Figure 2. Perceived threats of climate change. Statements presented by mean scores, error bars show standard deviation (N=293).

2009) that have shown that climate change is anthropogenic. Discussions with the farmers revealed awareness that agriculture contributes to climate change mainly through deforestation, livestock production, inputs (fertilizers, pesticides,) and machinery and land management practices with specific reference to burning crop straws. Crop straw burning has been shown to be a big source of greenhouse gas emissions (Cao et al., 2008). Farmers recognition of the farming practices' contribution to climate change is a positive step towards solving the problems because knowledge about both the causes of climate change and means of mitigating environmental problems is important in influencing pro-environmental actions (O'Connor et al., 2002; Gram-Hanssen, 2009).

However, farmers lack detailed knowledge about greenhouse gases and their sources. In addition, most farmers did not have clear understanding about the inter-linkages between environment and human activities such as generation of electricity and the potential of agriculture to mitigate climate change. This implies that although farmers are aware and perceptive about climate change, they may not fully understand the responses needed in order to ameliorate its impacts. Our finding supports other work (Etkin and Ho, 2007; Kellstedt et al., 2008) that show that though knowledge of causes and ways of adapting or mitigating the disastrous impacts of climate change exists, there is disconnect between the flow of information from the sources and the general public. Moreover, our results show that farmers rarely or never interact with the accurate sources of information. The information they get may therefore have misconceptions of facts and sometimes cause confusion. For instance, most information in the media is based on debates between groups supporting and opposing climate change. This may in some cases, portray climate change as unsettled topic yet many researchers concur that climate change is anthropogenic and will have adverse impact on societies (IPCC, 2007b). This means that the sense of salience of the subject, one of the most important factors in determining whether people engage in pro-environmental behavior (Kaplan, 2000; Kollmuss and Agyeman, 2002; Gilg et al., 2005). As a result, farmers may under estimate the threats even in situations where they are imminent because their sources of information may not portray the threats as sufficient for farmers to take drastic actions.

The farmers recognize that the threats are real and have been experienced in different parts of China. The impacts of climate change have had far reaching implications to people's livelihoods and heath. For instance, prolonged droughts (Qiu, 2010), floods (Zong and Chen, 2000), reduced yields and crop failure (Chen et al., 2013) and human health problems (Kan et al., 2012). However, the farmers tended to distance themselves from taking responsibility to mitigate climate change and also believed that government policies' capacity to address climate change were not adequate. This observation could hint to lack of policy implementation by relevant agencies or lack of impact where policies were implemented since the government has been enacting or amending laws to address environmental issues (Lin and Swanson, 2010). Farmers felt the need for insurance covers against climate change related damage. This is clearly because of their dependency on agriculture for livelihood and it has become reality that climate change related damages will have adverse impacts on their livelihoods. Maddison (2007) and Gbetibouo (2009) have shown that people respond to natural occurrences when they pose challenges to their lives and that people show high risk perceptions when they have encountered disasters (Woudenberg et al., 2008).

Conclusion

Farmers are aware of climate change and its impacts. However, there is clear lack of understanding of some linkages between natural environments and climate change and mitigation. This observation presents a gap that calls for concerted efforts of multiple stakeholders, including first and foremost, farmers, but also policymakers, extension agents, nongovernmental organizations, researchers, communities and the private sector. To achieve this, the government should promote climate change awareness through social networks and extension services and offering incentives for adoption of climate change mitigation practices. Studies have underscored the importance of contact with extension services and demonstration trials attendance in knowledge transfer and adoption of environmental practices (Schuck et al., 2002; Rahman, 2003; Mariano et al., 2012; Reimer et al., 2012). Moreover, the way a climate change message is designed and transmitted is important in determining people's attitudes and responses to environmental issues (Pooley and O'Connor, 2000; Nicholson-Cole, 2005). While the government can play a leading role in response to climate change, individuals and organizations must be convinced that they also have a role to play. The government should consider funding pro climate change policies, education and demonstration programmes that can provide a framework that encourages farmers to develop and/or adopt practices that ensure agricultural productivity can be maintained and GHG emissions can be reduced. The key to successful implementation is involvement in farmers not only in implementation of programs but in innovation within their farming systems.

Conflict of Interest

The authors have not declared any conflict of interest.

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Influence of drip fertigation and sowing season on plant growth, physiological characters and yield of pigeonpea (*Cajanus cajan* L.)

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Field experiments were carried out during two seasons *Kharif,* 2010 (March to June) and *Summer,* 2011 (January - May) at Agricultural College and Research Institute, Madurai, Tamil Nadu, India to study the influence of drip fertigation and sowing season on growth, physiological attributes and seed yield of pigeonpea (*Cajanus cajan* L.) cv. VBN3. The treatments included four fertigation levels (F_1- 50% of SRDF through drip, F_2- 75% of SRDF through drip, F_3- 100% of SRDF through drip and F_4- 150% SRDF through drip) and three foliar spays (S_1- foliar spray of 0.5% $ZnSO_4$, S_2 -foliar spray of 100 ppm succinic acid and S_3- foliar spray of 100 ppm humic acid) and control (surface irrigation with conventional method of fertilizer application). The experiment was laid out in split plot design with three replications. Drip fertigation was given once in six days as per the treatment schedule and drip irrigation was given once in three days. The results revealed that drip fertigation with 100% SRDF through water soluble fertilizers + foliar feeding with 0.5% $ZnSO_4$ (F_3FS_1) and lowest with 50% SRDF as WSF through drip registered higher crop growth, physiological characters and seed yield in both season. Between the seasons, *Kharif* crop recorded 15.2% higher seed yield over *Summer as* compared to normal soil application of fertilizers. The increased in seed yield with 100% SRDF as WSF + foliar feeding with 0.5% $ZnSO_4$ was mainly due to greater and consistent availability of nutrients, growth hormones and soil moisture which leads to better crop growth, physiological characters and seed yield components and eventually reflected on the seed yield.

Key words: Pigeonpea, drip fertigation, season, growth characters, seed yield.

INTRODUCTION

Pigeon pea (*Cajanus cajan* (L.) Millsp. is a multipurpose legume with a long tradition of cultivation in India. With 22% protein, which is almost three times that of cereals, pigeonpea supplies a major share of protein requirement of the predominantly vegetarian population in the country. The biological value improves greatly, when wheat or rice

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is combined with pigeonpea because of the complementary relationship of the essential amino acids. It is particularly rich in lysine, riboflavin, thiamine, niacin and iron.

Pigeonpea is cultivated in more than 25 tropical and sub-tropical countries, either as a sole crop or intermixed with cereals or with legumes. Being a legume, pigeonpea enriches soil through symbiotic nitrogen fixation. The crop is cultivated on marginal land by resource-poor farmers, who commonly grow traditional medium and long duration varieties. Pigeonpea seed crop requires well irrigated schedule to provide quality seeds and any method to save water will help in mitigating the harm caused by reduced water and formation of hard seeds. Water requirement is though low during the first 60 to 70 days, increases during flowering and pod formation. One of the possible ways to bridge the gap between demand and supply of water is to increase the pigeonpea seed yield and water saved per unit area by adopting appropriate production and management technologies.

Fertigation is a relatively new but revolutionary concept in applying fertilizer through irrigation as it helps to achieve both fertilizer-use efficiency and water-use efficiency. When fertilizer is applied through drip, it is observed that 30% of the fertilizer could be saved (Sivanappan and Ranghaswami, 2005). The main cause for low seed multiplication rate is that pigeonpea is mainly grown under agro-ecological constraints compounded by paucity of nutrients and hormones. The environment interaction plays a very important role in desired seed production.

At present, the knowledge regarding the effect of environmental factors on seed production is meagre. The rise in atmospheric temperature causes detrimental effects on growth, yield, and quality of the pigeonpea crop by affecting its phenology, physiology, and yield components (Sheehy et al., 2005). A growing season is a period during which a crop experiences favourable weather condition for its optimum growth, development and yield.

As information on suitable season of seed production will be highly useful to the seed growers of pigeonpea under drip fertigation system. Hence, the objective of present study was conducted to evaluate the performance of the crop in two seasons *viz.,* Kharif, 2010 and Summer, 2011 to fix the optimum dose of drip fertigation and foliar spray treatments for realizing higher growth, physiological characters and seed yield of pigeonpea cv. VBN 3.

MATERIALS AND METHODS

The present investigation on the influence of drip fertigation and season on the growth and seed yield of pigeonpea cv.VBN3 was carried out during two seasons *Kharif,* 2010 (March to June) and *Summer,* 2011 (January - May) at Agricultural College and Research Institute, Madurai located at 9º 54' N Latitude 78° 54' E Longitude and at Altitude of 147 MSL. The soil of the study area was clayey with a pH of 7.4, available N, P, K status of 180, 10 and 312 N P K kg ha^{-1} respectively. The organic carbon content was 0.48% and electric conductivity 0.42 dSm^{-1}. Seeds were treated and were sown in raised bed at the spacing of 45 × 30 cm as direct spot seeding on raised beds of 90 cm width and furrows of 10 cm. Adopting the drip fertigation as per the first crop fertigation schedule in the same area and all other agronomic and plant protection measures were carried out as and when required as per the crop production guide. The experiment was laid out in split plot design with three replications.

Lay out of drip system

Laterals (12 mm) from sub main were fixed at a spacing of 120 cm and inline lateral emitters in fixed at 20 cm with a 16 mm tap at the head of each lateral. First irrigation was given immediately after sowing and subsequent irrigations were scheduled once in three days based on the daily pan evaporation. The drip irrigation system was well maintained by flushing and cleaning the filters. The quantity of water was calculated as follows: Volume (L ha^{-1}) = PE × Kp × area (m^2), PE = pan evaporation, Kp = pan factor (0.80).
Time of operation of drip system to deliver the required volume of water per plot was computed based on the formula:

$$\text{Time of application} = \frac{\text{Volume of water required (l)}}{\text{Emitter discharge (lit ha}^{-1}\text{) x No. of emitters/ plot}}$$

Field experiments were conducted with twelve treatment combinations are furnished in Table 1.

Fertigation

The SRDF dose was used as base for calculating the fertigation schedule. Accordingly F_1 treatment involved 50% of SRDF as soil and the balance as WSF. Similarly for F_2 25% as soil and 75% as drip. In 100% fertigation, the SRDF was applied as WSF. The fertilizer sources for supplying NPK through drip irrigation were urea, MAP (12:61:0 kg NPK), MOP (0:0:60 kg K). Each plot consisted of one lateral for irrigating two rows of crops. The required quantity of N, P and K fertilizers as Urea, MAP and MOP as per the treatment were dissolved separately in water. Fertigation was done through fertigation tank once in six days starting from 15 to 90 DAS, which was regulated by taps, provided near the take off points of the sub main. Fertigation was carried out in three consecutive steps *viz.,* wetting the root zone before fertigation, fertigating the field and flushing the nutrients with water.

Observations

The assessment of growth characteristics was done in each experimental plot; ten plants were selected at random and tagged for recording biometric observations were recorded at 90 DAS.

Biometric observations

In each experimental plot, ten plants were selected at random and tagged for recording biometric observations were recorded at 90 DAS. The assessment of growth characteristics such as plant height (cm), number of branches plant^{-1} and the physiological parameters *viz.*, LAI (Williams, 1946), LAD and CGR (Watson, 1958) were again observed in ten plants randomly selected per plot.

Table 1. Treatment details.

T_1 (F_1FS_1)	50% of SRDF through drip + Foliar spray of 0.5% $ZnSO_4$
T_2 (F_1FS_2)	50% of SRDF through drip + Foliar spray of 100 ppm succinic acid
T_3 (F_1FS_3)	50% of SRDF through drip + Foliar spray of 100 ppm humic acid
T_4 (F_2FS_1)	75% of SRDF through drip + Foliar spray of 0.5% $ZnSO_4$
T_5 (F_2FS_2)	75% of SRDF through drip + Foliar spray of 100 ppm succinic acid
T_6 (F_2FS_3)	75% of SRDF through drip + Foliar spray of 100 ppm humic acid
T_7 (F_3FS_1)	100% of SRDF through drip + Foliar spray of 0.5% $ZnSO_4$
T_8 (F_3FS_2)	100% of SRDF through drip + Foliar spray of 100 ppm succinic acid
T_9 (F_3FS_3)	100% of SRDF through drip + Foliar spray of 100 ppm humic acid
T_{10} (F_4FS_1)	150% of SRDF through drip + Foliar spray of 0.5% $ZnSO_4$
T_{11} (F_4FS_2)	150% of SRDF through drip + Foliar spray of 100 ppm succinic acid
T_{12} (F_4FS_3)	150% of SRDF through drip + Foliar spray of 100 ppm humic acid
Control	Surface irrigation with SRDF of 25:50:25 NPK kg ha^{-1} by two splits.

SRDF, Seed recommended dose of fertilizers; F, fertigation; FS, foliar spray.

Statistical analysis

The data pertaining to the experiment were subjected to statistical analysis by analysis of variance method as suggested by Gomez and Gomez (1984). Pooled analyses of the seasonal mean values were done for precise interpretation of the data. Wherever the treatment differences were found significant (F test), critical difference was worked out at five per cent probability level and the values furnished. The treatment differences that were not significant are denoted as NS.

RESULTS AND DISCUSSION

Drip fertigation, foliar spray treatments and season significantly influenced the morphological characters and seed yield of pigeonpea in both seasons.

Growth characters

Drip fertigation and foliar spray treatments significantly influenced the morphological characters such as plant height and number of branches was significantly influenced by surface drip fertigation. The interaction effect of drip fertigation and foliar spray treatments in both seasons were highly significant. The plant height at 90 DAS which was higher observed with fertigation using 100% SRDF as WSF (F_3) and foliar feeding with 0.5% of $ZnSO_4$ that resulted in higher values of 157.4 and 140.7 cm at 90 DAS in *Kharif* and *summer*, respectively (Table 2).

Plant height was increased by 25.4 and 28.7% in Kharif and summer, respectively with similar treatment combinations. Whereas in plant height in Kharif 2010 was higher 12.7% over Summer 2011at 90 DAS. The number of branches produced and their survival reflects on the total number of flowers initiated, pods at harvest which ultimately determine crop fecundity and seed yield. The results clearly indicated that the combination of 100% SRDF as WSF (F_3) + foliar feeding with 0.5% of $ZnSO_4$ recorded maximum number of branches 18.3 in kharif and 14.3 in summer at 90 DAS with 50.0 AND 81.0%, respectively higher compared to 50% of SRDF as WSF in kharif and summer respectively (Figure 1).

The results also clearly indicated that the water soluble fertilizers played a significant role in increasing the plant height and number of branches. Similarly, WSF provided based on crop stage wise nutrient requirement resulted in increased plant height compared to surface irrigation with 100% of SRDF and foliar spay as also reported by Kumar and Haripriya (2010) who revealed that monthly spray of Ferrus sulphate at 0.75% + Zinc Sulphate at 0.50% are significantly maximum values on all the growth attributes like plant height, number of secondary branches, no. of leaves per plant, plant spread and leaf area in Nerium.

Physiological parameters

Leaf area index being an important tool to quantify photosynthates accumulation in sink, resulted in increased growth of pigeonpea. The same best treatment combination at 90 DAS values were higher with LAI 20.4 and 27.8%, LAD 32.4 and 43.6%, CGR 52.4 and 93.3% was higher compared to 50% SRDF as WSF + 100 ppm humic acid which was recorded during *Kharif* and *Summer*, respectively (Tables 3 to 5).

Between the season kharif season recorded all physiological parameters were higher over summer. Similar results were expressed by Veeraputhiran (2000) attributing enhanced physiological parameters such as LAI, CGR and CGR using drip fertigation over the furrow band application of cotton. The enhanced dry weight of reproductive parts by growth regulators, organics and nutrients may be due to increased translocation of

Table 2. Influence of fertigation and foliar spray on Plant height (cm) at 90 DAS in pigeonpea cv. VBN 3. (in Kharif and Summer).

F- fertigation treatments	Plant height (cm) at 90 Days after sowing FS - Foliar spraying treatments											
	Kharif 2010 (S)				Summer 2011 (S)				Pooled mean (S)			
	FS_1	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**
F_1	140.6	129.5	125.5	131.9	119.4	115.2	109.3	114.6	130.0	122.4	117.4	123.3
F_2	143.4	136.4	131.6	137.1	128.8	121.3	116.6	122.2	136.1	128.9	124.1	129.7
F_3	157.4	153.5	146.4	152.4	140.7	136.5	132.5	136.6	149.1	145.0	139.5	144.5
F_4	151.7	145.6	141.6	146.3	135.5	129.8	125.7	130.3	143.6	137.7	133.7	138.3
Mean	148.2	141.4	136.3	141.9	131.1	125.7	121.0	125.9	139.7	133.5	128.7	133.9
	F	**FS**	**F X FS**	**FS X F**	**F**	**FS**	**F X FS**	**I**		**SEd**		**CD(P=0.05)**
SEd	0.742	0.649	1.294	1.299	0.844	0.387	1.054	0.774	S	0.388		0.854**
CD(P=0.05)	1.815**	1.376**	2.882*	2.753*	2.065**	0.820**	2.456*	1.640*	F	0.562		1.224**
									FS	0.378		0.770**
									F X FS	0.834		1.700**
Absolute control		125.5				112.3			S X F	0.973		NS
									S X FS	0.534		NS
									S X F X FS	1.069		2.177**

*DAS, Days after sowing.

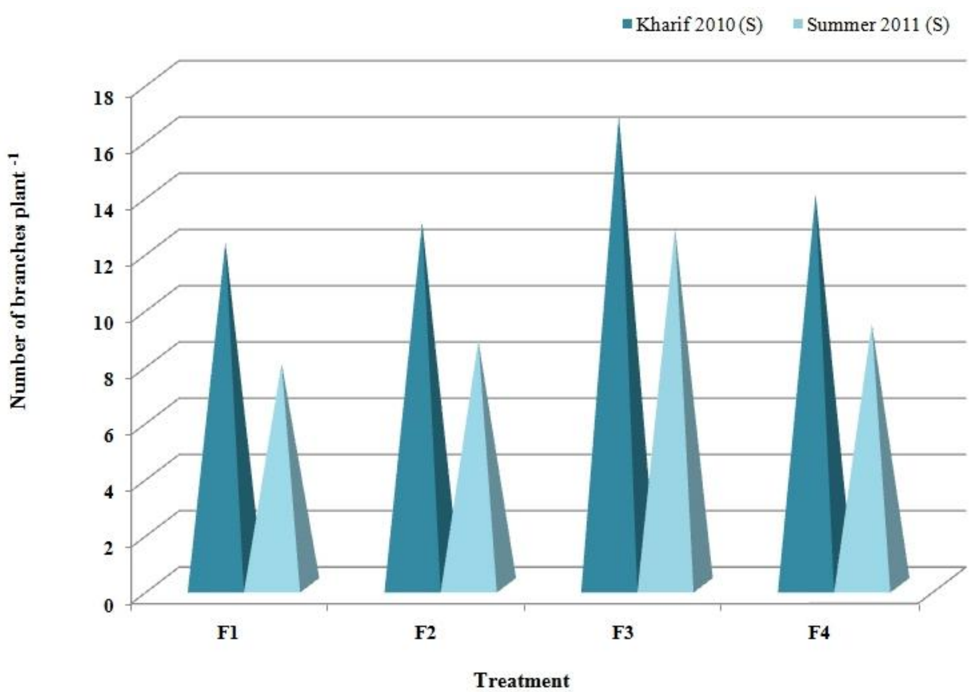

Figure 1. Influence of drip fertigation and sowing season on number of branches $plant^{-1}$ in pigeon pea.

assimilates from leaf and stem to the reproductive parts as also reported in pigeonpea due to application of zinc sulphate, succinic acid and humic acid.

Zinc plays a vital role as activator of carbohydrate and protein synthesis as well as their transport to the site of seed formation as also visulalized by Dell (2004) while comparing efficiency of plant use of foliar-fed nutrients versus soil-applied nutrients near roots and found foliar feeding provided about 95% use efficiency compared to about 10% efficiency use from soil applications thus

Table 3. Influence of fertigation and foliar spray on leaf area index at 90 DAS in pigeonpea cv. VBN 3. (in Kharif and Summer).

F- Fertigation treatments	LAI at 90 DAS											
	FS - Foliar spraying treatments											
	Kharif 2010 (S)				Summer 2011 (S)				Pooled mean (S)			
	FS_1	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**
F_1	5.63	5.46	5.35	5.48	4.72	4.44	4.24	4.47	5.18	4.95	4.80	4.97
F_2	5.81	5.66	5.65	5.71	4.93	4.75	4.62	4.77	5.37	5.20	5.14	5.24
F_3	6.44	6.35	6.25	6.35	5.42	5.30	5.17	5.30	5.93	5.83	5.71	5.82
F_4	6.22	5.89	5.81	5.98	5.24	5.02	4.78	5.01	5.73	5.46	5.30	5.49
Mean	6.03	5.84	5.76	5.88	5.08	4.88	4.70	4.89	5.55	5.36	5.23	5.38
	F	**FS**	**F X FS**	**FS X F**	**F**	**FS**	**F X FS**	**FS**		**SEd**		**CD(P=0.05)**
SEd	0.017	0.018	0.033	0.035	0.023	0.017	0.036	0.033	S	0.016		0.036**
CD(P=0.05)	0.042**	0.037**	0.074**	0.075**	0.057**	0.035**	0.081**	0.071**	F	0.014		0.031**
									FS	0.012		0.025**
									F X FS	0.024		0.050**
Absolute control		5.12				4.33			S X F	0.025		0.054**
									S X FS	0.017		0.035**
									S X F X FS	0.034		NS

*DAS, Days after sowing.

Table 4. Influence of fertigation and foliar spray on Leaf Area Duration in pigeonpea cv. VBN 3. (in Kharif and Summer).

F- Fertigation treatments	LAD – leaf area duration											
	FS - Foliar spraying treatments											
	Kharif 2010 (S)				Summer 2011 (S)				Pooled mean (S)			
	FS_1	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**
F_1	110.4	105.0	101.6	105.7	92.7	85.1	80.1	86.0	101.52	95.04	90.86	95.81
F_2	117.6	112.6	109.5	113.2	99.3	94.8	91.3	95.1	108.44	103.69	100.39	104.17
F_3	134.5	130.8	128.5	131.2	115.0	110.2	105.2	110.1	124.76	120.48	116.85	120.69
F_4	128.8	120.6	116.5	121.9	108.8	101.4	96.5	102.3	118.80	111.02	106.50	112.11
Mean	122.8	117.2	114.0	118.0	104.0	97.9	93.3	98.4	113.38	107.56	103.65	108.19
	F	**FS**	**F X FS**	**FS X F**	**F**	**FS**	**F X FS**	**FS**		**SEd**		**CD(P=0.05)**
SEd	0.356	0.365	0.693	0.729	0.318	0.415	0.749	0.830	S	0.333		0.734**
CD(P=0.05)	0.870**	0.773**	1.530**	1.546**	0.779**	0.880**	1.631*	1.759*	F	0.239		0.520**
									FS	0.276		0.563**
									F X FS	0.510		1.039**
Absolute control		101.2				83.3			S X F	0.413		0.901**
									S X FS	0.391		0.796**
									S X F X FS	0.781		NS

*DAS- Days after sowing.

providing a major benefit of foliar feeding where a specific plant nutrient deficiency may exist, be it a major or minor nutrient.

Yield and yield attributes

Seed yield (kg.ha^{-1}) was positively influenced by drip fertigation treatments and foliar spray treatments. Among the treatment combinations, Seed yield (kg.ha^{-1}) was higher with 100% SRDF as WSF + 0.5 % of $ZnSO_4$ recorded maximum in *Kharif* (1416 kg.ha^{-1}) and in *Summer* (1251 kg.ha^{-1}) by 40.2% and 48.0% higher seed yield compared to 50% SRDF as WSF + 100 ppm humic acid and 41.6%, 47.2% higher over the control plot during *Kharif* and *Summer*, respectively (Table 6). However,

Table 5. Influence of fertigation and foliar spray on crop growth rate g m^{-2} d^{-1} in pigeonpea cv. VBN 3 (in Kharif and Summer).

F- Fertigation treatments	Crop growth rate - CGR g m^{-2} d^{-1}											
	FS - Foliar spraying treatments											
	Kharif 2010 (S)				Summer 2011 (S)				Pooled mean (S)			
	FS_1	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**
F_1	16.5	16.3	15.3	16.0	13.2	11.5	10.4	11.7	14.83	13.91	12.88	13.87
F_2	20.2	16.8	15.9	17.6	13.6	12.3	10.6	12.2	16.90	14.54	13.28	14.91
F_3	23.6	23.0	22.6	23.1	20.1	17.4	16.6	18.0	21.84	20.20	19.61	20.55
F_4	18.6	17.6	16.5	17.6	15.5	13.9	12.1	13.8	17.05	15.77	14.27	15.70
Mean	19.7	18.4	17.6	18.6	15.6	13.8	12.4	13.9	17.65	16.11	15.01	16.26
	F	**FS**	**F X FS**	**FS X F**	**F**	**FS**	**F X FS**	**FS**		**SEd**		**CD(P=0.05)**
SEd	0.182	0.395	0.671	0.790	0.202	0.139	0.303	0.277	S	0.227		0.499**
CD(P=0.05)	0.447**	0.838**	1.438*	1.675*	0.494**	0.294**	0.687*	0.588*	F	0.136		0.297**
									FS	0.209		0.426**
									F X FS	0.368		NS
Absolute control		14.5				10.2			S X F	0.236		0.514**
									S X FS	0.296		NS
									S X F X FS	0.592		1.206**

*DAS- Days after sowing.

Table 6. Influence of fertigation and foliar spray on seed yield (kg. ha^1) in pigeonpea cv. VBN 3 (in Kharif and Summer).

F- Fertigation treatments	Seed yield per ha (kg)											
	FS - Foliar spraying treatments											
	Kharif 2010 (S)				Summer 2011 (S)				Pooled mean (S)			
	FS_1	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**
F_1	1056	1035	1010	1034	892	873	845	870	974	954	928	952
F_2	1143	1101	1075	1106	979	941	913	944	1061	1021	994	1025
F_3	1416	1367	1344	1376	1251	1213	1180	1215	1333	1290	1262	1295
F_4	1276	1244	1215	1245	1147	1113	1052	1104	1212	1179	1133	1175
Mean	1223	1187	1161	1190	1067	1035	998	1033	1145	1111	1079	1112
	F	**FS**	**F X FS**	**FS X F**	**F**	**FS**	**F X FS**	**FS X F**		**SEd**		**CD(P=0.05)**
SEd	3.237	2.225	4.865	4.449	5.149	3.114	7.236	6.227	S	2.639		5.809**
CD(P=0.05)	7.920**	4.716**	11.019**	9.432**	12.599**	6.601**	16.539**	13.201**	F	3.041		6.626**
									FS	1.913		3.897**
									F X FS	4.360		8.881**
Absolute control		1000				850			S X F	5.267		NS
									S X FS	2.706		5.512**
									S X F X FS	5.412		11.023**

*DAS, Days after sowing.

seed yield (kg.ha^{-1}) occurred more in *Kharif* with 13.2% higher yield over *Summer* with same treatment combination. Higher number of pods $plant^{-1}$ (415 in *Kharif* and 368 in Summer) with 12.8% higher number in *Kharif* over Summer (Figure 2). Fertigation with 100% WSF increased the seed yield significantly over furrow irrigation and drip irrigation as reported by Tayo (1990) and Somu (1995) in pigeonpea. This might be due to enhancement in growth and yield parameters as well as uptake of nutrients by this crop. Obviously, the cumulative effects of these parameters contributed to increased yield foliar application of $ZnSO_4$ (0.5%) could increase the grain yield significantly over control in rice (Manoharan et al., 2001). Foliar application of KCl, DAP, urea and KNO_3 increased the seed cotton yield due to more number of bolls per plant (Brar and Brar, 2002). Fertigation with 100% WSF increased the seed yield of tomato significantly over furrow irrigation and drip

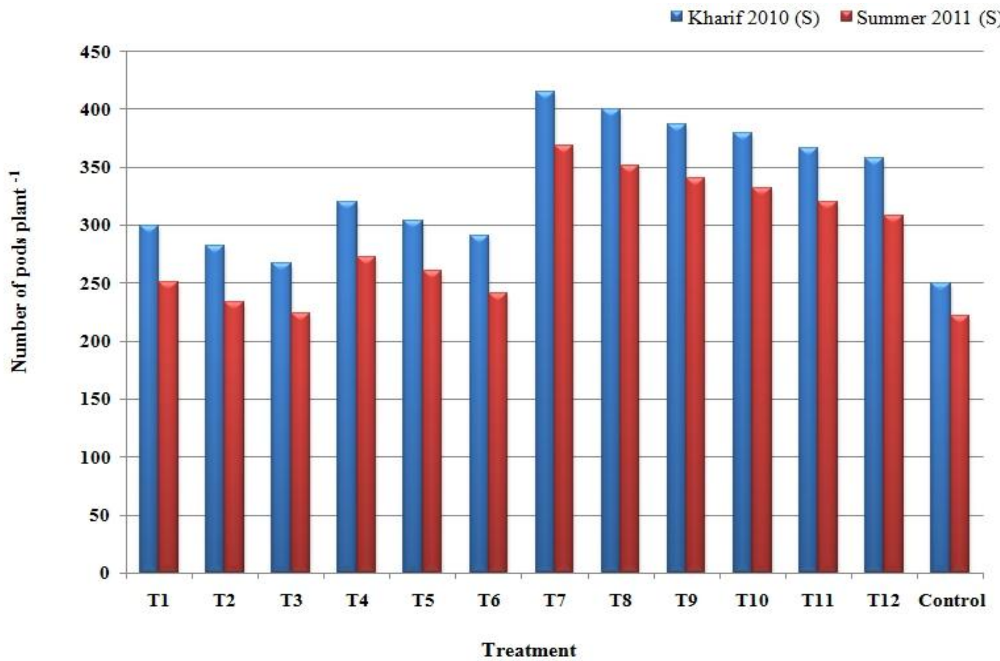

Figure 2. Influence of drip fertigation and sowing season on number of pods plant^{-1} in pigeonpea.

irrigation as reported by Hebbar et al. (2004). The higher seed yield correlating with higher level of water soluble fertilizers could be attributed to translocation of more carbohydrates due to high nitrogen levels.

Potassium plays an important role in this translocation of metabolites for the development of seed. Moreover, higher production of seed yield under surface drip irrigation and fertigation might have paved the way for increased production of photosynthates, which ultimately resulted in increased production of seeds at harvest as also found by Shashidhara (2006) in chillies.

Conclusion

Seed production is better for the *Kharif* season and the treatment combination of 100% SRDF as WSF + foliar spraying of 0.5% of $ZnSO_4$ and maximized the seed yield, better crop growth, higher yield attributes and substantial quantity of water saving. Thus, it clearly indicated the feasibility of introducing drip fertigation in pigeonpea seed production for higher water productivity; higher fertilizer use efficiency and sustainability in future pigeonpea seed production.

Conflict of Interest

The authors have not declared any conflict of interest.

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Effect of low N- stress to N, P, K contents and quantitative trait locus (QTL) analysis in maize kernels and stalks

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For elucidating the genetic basis of N, P and K contents in kernels and stalks in maize under different nitrogen supply condition, a set of 203 $F_{2:4}$ / $F_{2:5}$ family lines, derived from an elite maize hybrid Nongda108, were tested under nitrogen plus (N+) and no nitrogen plus (N-) treatments in the field over two years, and a genetic linkage map was constructed with 199 SSR molecular markers, covered 2100.9 cm for 10 chromosomes with an average interval length of 10.82 cm. The results showed that low N stress not only affected N content in maize kernels and stalks, but also affected the absorption and transportation of P and K contents in some degree. A total of 34 quantitative trait locus (QTL) including 15 QTLs in kernels and 19 QTLs in stalks for N, P, K content were identified by means of the composite interval mapping method (CIM), of which, 13, 9 and 12 QTLs detected for N, P, K content, respectively. Each QTL could explain the variance of phenotype ranged in turn from 7.30 to 31.09%, 7.57 to 14.3% and 8.11 to 32.82% for three main mineral elements content. The QTL *qNC4c*, *qPC9b*, *qKC10b* as well as *qNC4b*, *qPC5b*, *qKC6a* were main contributing QTL for N, P, K contents in kernels and stalks. Out of these QTLs detected for N, P, K contents in kernels and stalks, the results also implied that the loci derived from Huang C played important roles in N, P, K absorption, while the loci from Xu178 played marked roles in N, P, K transportation from stalks to grains.

Key words: Maize, low nitrogen stress, N, P, K content, quantitative trait locus (QTL), analysis.

INTRODUCTION

Nitrogen (N) fertilizer plays important roles in increasing yield and improving quality in maize production. The previous studies have demonstrated that the biomass, grain yield as well as nutrient quality for foodstuff in maize are higher under high N condition than low N condition (Agrama et al., 1999; Zhu and Chen, 2002; Aildson et al., 2005; Martín et al., 2008). Presterl et al. (2003) reported that about 37% grain yield was lost under N- condition compared with N+ condition, and the agricultural and yield related traits among $F_{2:3}$ families had significant genetic difference under high N (280 kg.ha^{-1}) and low N (30 kg.ha^{-1}) conditions (Agrama et al., 1999). For getting a high grain yield in maize production, the amount of nitrogen fertilizer input has increased gradually in recent

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years, especially in some countries or areas, the amount of nitrogen fertilizer input has far excess the real need of maize development, leading to the nitrogen using efficiency (NUE) decrease, induced the underground water pollution because of nitrate prediction, and increased the cost of agricultural production (Machado et al., 1992; Zhang et al., 1995), such as in China, the NUE is only 30 to 40% in some season, so grain yield in maize would be increased with adding nitrogen application within a certain range (Pan et al., 1995; Raja 2001). For getting a high grain yield, the commercial hybrids with NUE are required in maize production, so in maize breeding, it is urgent affairs of how to increase NUE in maize, and it is also the necessity requirement in the development of zoological agriculture (Zhang et al., 1995; Gallais and Hirel, 2004).

Many reports have showed significant differences existing in nitrogen absorption, transportation and utilization in some genotypes of maize, and some greater progress have gained by predecessors on the basis of physiology, biochemistry, phenotypes, germplasm collection and improvement (Machado et al., 1992; Zhang et al., 1997; Hirel et al., 2001; Presterl et al., 2003). For disserting the genetic bases of nitrogen usage, Bertin and Gallias (2001) had detected the QTLs for grain yield, nutrient components in maize kernels under N+ and N- conditions using a set of recombinant inbred lines (RIL) and its test population, they found that more QTLs were detected under N+ condition than N- condition. Gallais and Hirel (2004) reported that genotype × nitrogen interaction was significant for grain yield and explained by variation in kernel number. Also, in N- condition, N-uptake, the nitrogen nutrition index, and glutamine synthetase activity in the vegetative stage were positively correlated with grain yield, whereas leaf senescence was negatively correlated. The gene of glutamine synthetase locus on chromosome 5 in maize appears to be a good candidate, which can, at least partially, explain the variation in NUE (Gallais and Hirel, 2004). While in maize, more trials indicated that the NUE varied significantly with genotypes (Hirel et al., 2001; Presterl et al., 2003; Monneveux et al., 2005).

Oikeh et al. (1998) even trailed with five maize cultivars under four N levels (0, 30, 60, and 120 kg ha^{-1}) and showed that increasing N levels increased grain yield, kernel weight, and grain protein greatly for all the cultivars. While N is a component of protein, so it inferred that lack of nitrogen might reduce grain N content greatly. The similar results also reported by Liu et al. (2008) in maize, they showed that the grain yield, grain protein and oil contents in $F_{2:3}$/$F_{2:4}$ populations were significantly reduced, but the starch a little increased under N- conditions compared with N+ conditions at two locations.

Nitrogen is one of the three essential elements in nutrition for maize, low N stress not only affects corn growth, also leads to lose balance among nutrient elements. Teng et al. (2005) has made a trial on the effect of soybean yield under different ratios of N, P and K, their results showed that when the P and K fertilizer were enough, the soybean yield was even less under over nitrogen supplied than no N supply, while more yield could be gained with a suitable N supply. It implied that a proper ratio of N, P and K application was needed to get a reasonable high yield. Aildson et al. (2005) reported that N nutrient application could increase grain yield and grain N concentration in maize, while improved the kernel quality such as reducing breakage susceptibility. Although the nitrogen supply can affect the P, K absorption as well as the distribution in maize kernels and stalks; however there have few reports on the effect of low nitrogen stress to the contents of nitrogen (N), phosphorous (P) and potassium (K) as well as the corresponding QTL analysis in maize kernels and stalks.

The aims of this study were to (i) investigate the variance of N, P, K content in maize kernels and stalks by using a set of $F_{2:4}$ and $F_{2:5}$ family lines under two nitrogen conditions, (ii) identify the QTL for N, P, K contents in maize kernels and stalks under N+ and N- conditions, and (iii) finally expect to fulfill the theory foundation for further carrying out the research on high using efficiency of essential nutrients in maize.

MATERIALS AND METHODS

Materials supply and soil conditions

A set of 203 $F_{2:3}$ / $F_{2:4}$ population derived from an elite maize hybrid, Nongda 108 (Huang C x Xu178), was used as a basic material in the study. The hybrid has extended widely in China, for its two parents, the inbred line Xu178 has high NUE, and Huang C was sensitive to nitrogen element (Chen et al., 2003; Tang et al., 2005a). The leaf DNA of F_2 individuals was extracted by modified SDS method (Saghai et al., 1984). Because the kernels in the ears of $F_{2:3}$/$F_{2:4}$ families were $F_{2:4}$/ $F_{2:5}$ progeny respectively, therefore, the content of N, P, K in kernels of the $F_{2:3}$/$F_{2:4}$ ears was described in this paper as the $F_{2:4}$/ $F_{2:5}$ population which was one more generation than stalks in turn.

The soil nutrient composition in 0-20 cm top layer was tested according to the method by Bao (2000), the contents of N, P, K in the soil were tested by the method of Kjedahl's for N test, colorimetry for P and blaze luminosity for K, respectively. The soil condition was 8.52 g.kg^{-1} organic materials, 0.78 g.kg^{-1} total nitrogen, 8.6 mg.kg^{-1} available phosphorous, 69.2 mg.kg^{-1} available potassium. The soil was lack of nitrogen based on the plentiful or lack index in North China.

Field evaluation and data analysis

The $F_{2:3}$ / $F_{2:4}$ populations were planted in Xinzheng Agricultural Institute (Xinzheng, China) in 2004 and 2005, which located at the main maize belt in China. The experimental design in the field was under a split block design with two replications, each material was planted in one plot, with the length of 4 m and 0.67 m apart between two rows, each row with 15 plants and the total density was 56250 plants per hectare. Nitrogen was the main treatment including nitrogen supply (N+) and no nitrogen supply (N-), and the segregation family was subsidiary treatments. At seedling stage, 67.5 kg.hm^{-2} P_2O_5 (calcium superphosphate) and 101.3 kg.hm^{-2} k_2O

Table 1. The N, P, K concentrations in maize kernels and stalks under two nitrogen conditions.

Trait	Year	N	Element	F_1	Parent		$F_{2:4}/F_{2:5}$ populations			
					Xu178	Huang C	Variance range	Mean±σ	Skewness	Kurtosis
Kernel	2004	N+	N	1.21	1.45	1.60	1.01-1.62	1.33±0.14	-0.11	-0.69
			P	0.27	0.40	0.42	0.18-0.59	0.36±0.08	0.36	0.19
			K	0.41	0.51	0.56	0.30-0.75	0.51±0.08	0.37	0.09
		N-	N	1.11	1.52	1.31	0.95-1.61	1.27±0.15	0.39	-0.3
			P	0.26	0.41	0.31	0.21-0.69	0.38±0.09	0.72	0.38
			K	0.39	0.34	0.69	0.34-0.82	0.56±0.09	0.31	-0.15
	2005	N+	N	1.51	1.39	1.95	1.18-1.97	1.58±0.15	0.11	-0.22
			P	0.32	0.37	0.34	0.18-0.55	0.37±0.07	-0.17	0.47
			K	0.39	0.30	0.68	0.25-0.80	0.51±0.10	0.56	0.28
		N-	N	1.41	1.51	1.64	1.14-1.83	1.49±0.13	0.02	0.01
			P	0.41	0.33	0.45	0.22-0.55	0.37±0.06	0.16	-0.06
			K	0.39	0.44	0.54	0.32-0.73	0.49±0.09	0.39	-0.5
Stalk	2004	N+	N	1.09	0.95	1.38	0.90-1.61	1.21±0.13	0.19	0.01
			P	0.28	0.04	0.18	0.10-0.47	0.24±0.07	0.52	0.75
			K	1.59	0.92	1.43	1.06-2.04	1.52±0.19	0.33	-0.1
		N-	N	0.8	1.00	1.06	0.77-1.28	1.00±0.10	0.16	-0.14
			P	0.33	0.23	0.47	0.17-0.50	0.32±0.07	0.26	-0.52
			K	1.49	1.37	1.58	1.08-1.74	1.38±0.15	0.17	-0.53
	2005	N+	N	1.2	1.41	1.88	1.13-1.86	1.44±0.16	-0.04	-0.42
			P	0.24	0.27	0.32	0.16-0.46	0.31±0.06	0.10	-0.33
			K	1.31	1.04	1.05	0.74-1.55	1.12±0.15	0.24	-0.32
		N-	N	0.92	1.16	1.51	0.94-1.62	1.24±0.13	0.24	-0.24
			P	0.36	0.22	0.32	0.18-0.48	0.31±0.06	0.18	-0.16
			K	1.24	1.18	1.03	0.81-1.42	1.12±0.13	-0.14	-0.46

(potassium nitrate) were fertilized to all N+ and N- treatments, and 175kg.hm^{-2} pure N was supplied only to N+ treatment, other managements and irrigation just the same as common field cultivation.

The ear of five consecutive plants for each material was bagged before silking, and self-pollinated twice by hand in the field after the all silk was out. After mature, plants were harvested including ears and stalks, and air-dried respectively, then the stalks from one plot were mix smashed by miller with 60 eyes screen. The contents of N, P, K in kernels and stalks of each 3 samples from each plot were also tested according to the method by Bao (2000). The basic data of the three nutrients content in the population over two years were analyzed by SPSS software, respectively, and the broad-sense heritability of measured trait was computed according to Knapp et al. (1985) method.

Genetic linkage map construction and QTL mapping

In total, 635 pairs of simple sequence repeat (SSR) markers were selected from the maize genome database (http://www.maizegdb.org) to screen for polymorphism between the two parents, Huang-C and Xu178. Of these, 235 SSR markers displayed distinct polymorphism and were used to amplify the DNA of the individuals in the F_2 population. Molecular linkage maps were constructed with MAPMAKER 3.0 (Lander et al., 1987) at a logarithm of odds (LOD) threshold = 3.0.

The composite interval mapping method (Zeng, 1994) and Model 6 of the Zmapqtl module of QTL Cartographer 2.5 (North Carolina, USA) were used to identify QTL (Wang et al., 2004). The threshold of a LOD was calculated using 1000 times permutation at a significance level of P = 0.05, with scanning intervals of 2 cm between markers and putative QTL and with a 10 cm window (Churchill and Doerge, 1994; Doerge and Churchill, 1996). The number of marker cofactors for background control was set by forward–backward stepwise regression with five controlling markers. Two putative QTL, detected in different nitrogen treatments or locations within 10 cm, were considered as the same QTL (Stuber et al., 1987).

RESULTS

The N, P, K contents in maize kernels under two nitrogen conditions

The mean content of N, P, K in the kernels of F_1, parents and the $F_{2:4}$ / $F_{2:5}$ populations showed some differences between the two N levels in 2004 and 2005 (Table 1). The N content in the kernels of $F_{2:4}$ family lines was significantly increase under N+ condition comparing with N- condition (t= 3.36; $t_{0.05}$= 1.96; $t_{0.01}$= 2.58), while P and K content decreased obviously (t= -3.17 and t= -4.95). The N content in the kernels of $F_{2:5}$ family lines was also significantly increased (t= 5.74), but no significant differences were found in P and K content (t=-1.39 and t= 0.73). It inferred that adding N input was benefit to increase the N but P and K in maize grain. The increasing range of N content of hybrid Nongda108 was lower than that of the parent Huang C yet. The N content in the kernels of Huang C was decreased by 18.13 and 15.90% under N- condition compared with N+ condition in 2004 and 2005, respectively; 8.26 and 6.62% decreased in F_1 while 4.83 and 8.63% increased in parent Xu178. The broad sense heritability (H_B^2) of N, P, K contents in maize kernels was 25.8, 30.6 and 13.3% respectively. The low values of H_B^2 implied that the concerning traits were easy to be effected by environments, especially for P content. Correlation analysis results of N, P, K contents in kernels on average of $F_{2:4}$ / $F_{2:5}$ populations showed that a notable positive relationship existed between N and P with r=0.229 and r=0.132 ($r_{0.05}$=0.138, $r_{0.01}$=0.181) under N- and N+ condition respectively, while no significant correlation had been found between N and K either under N- or N+ condition. It inferred that the lack of nitrogen had more affect on P than on K content in the kernels.

The N, P, K contents in maize stalks under two nitrogen conditions

The N and K contents in the stalk of $F_{2:3}$ family lines were highly significant increased under N+ condition compared with N- condition (t= 14.73 and 3.47; $t_{0.05}$=1.96, $t_{0.01}$= 2.58), while P content obviously decreased (t=-8.98, Table 1). Also, the N content in the stalk of $F_{2:4}$ family lines was highly significant increased (t=12.73), P content decreased with the same trend as in $F_{2:3}$ family lines even though the difference was not significant statistically (t=-0.67), while no significant differences were found in the content of K (t=-0.01). The results showed that soil N level not only affect the maize absorption to N, but also affect the transportation of other elements such as P and K from stalk to grain in some degree. The heritability in broad sense of N, P and K contents in stalks was also low with 20.7, -9.8 and 15.4% respectively.

The correlation analysis results of N, P, K contents in stalks averagely of $F_{2:4}$ / $F_{2:5}$ populations showed that significant relationship existed between N and P under N+ condition (r=0.14), and between N and K under N- condition (r=-0.14) respectively. The results showed that nitrogen supply level in soil also affect the P and /or K contents in stalks in maize.

QTL detected for N, P, K contents in maize kernels

Out of the 235 SSR markers with polymorphism between both parents, 199 SSR markers were used to construct the genetic linkage map for the F_2 population by means of Mapmaker 3.0. The genetic linkage map included 10 linkage groups, spanning a total of 2100.9 cm with an average interval of 10.82 cm (Figure 1).

In total, fifteen QTL for N, P, K contents in maize kernels were detected using the composite interval mapping method under two N levels in 2004 and 2005. Of which, seven QTL were detected under N- condition, while eight were identified under N+ condition, the QTL located on all chromosomes except for Chro.5 (Table 2 and Figure 1). Among the 6 QTL for N content in maize kernels, 4 and 2 QTL were detected under N+ and N- treatments, respectively, and of which, one and one QTL were detected in 2004 and three as well as one QTL in 2005 under N+ and N- conditions respectively, located on chromosome 1, 4, 6 and 7. Single QTL could explain the phenotypic variation from 7.80 to 14.91%, the QTL *qNC1b*, *qNC4c* and *qNC6b* appeared increasing action from the loci of parent Xu178 and the other QTL from the loci of parent Huang C.

Out of the four QTL for P content in maize kernels, only one QTL was detected under two nitrogen conditions in two years respectively, with a contribution to phenotypic variance of 8.12 to 13.03%, all appeared increasing action from the loci of parent Xu178. Obviously, view from the point of nutrient compositions of maize grain, the parent Xu178 played main roles in P absorption and accumulation.

In the total of five QTL for K content in maize kernels, two and three QTL were detected under N+ and N- treatments, respectively, and of which, one and two were detected in 2004 and 2005 under two nitrogen conditions respectively, with a contribution to phenotypic variation from 8.85 to 12.36%. The QTL, *qK10b*, which detected under N+ condition in 2005, has a 12.36% contribution to K content in maize kernels. In these QTL detected for K content, the QTL *qKC3a, qKC3 c* and *qKC10b* was derived from the loci of parent Xu178, while *qKC6b* and *qKC10d* from Huang C performed increasing action to K content in maize kernels. Out of the fifteen QTL detected for N, P, K content under two nitrogen condition in two years (Table 2), two QTL appeared additive, five QTL exhibited partial dominance and eight QTL expressed over dominance.

QTL detected for N, P, K contents in maize stalks under two nitrogen conditions

There were nineteen QTL detected for stalk N, P, K contents under two N levels in 2004 and 2005. Of which, ten QTL detected under N+ condition, while nine under N- condition, located on all chromosomes except chromosome 8 (Table 3 and Figure 1). Among the seven QTL for N content in maize stalks, four and three QTL were detected under N+ and N- treatments, respectively, of which, two and one was detected in 2004 as well as

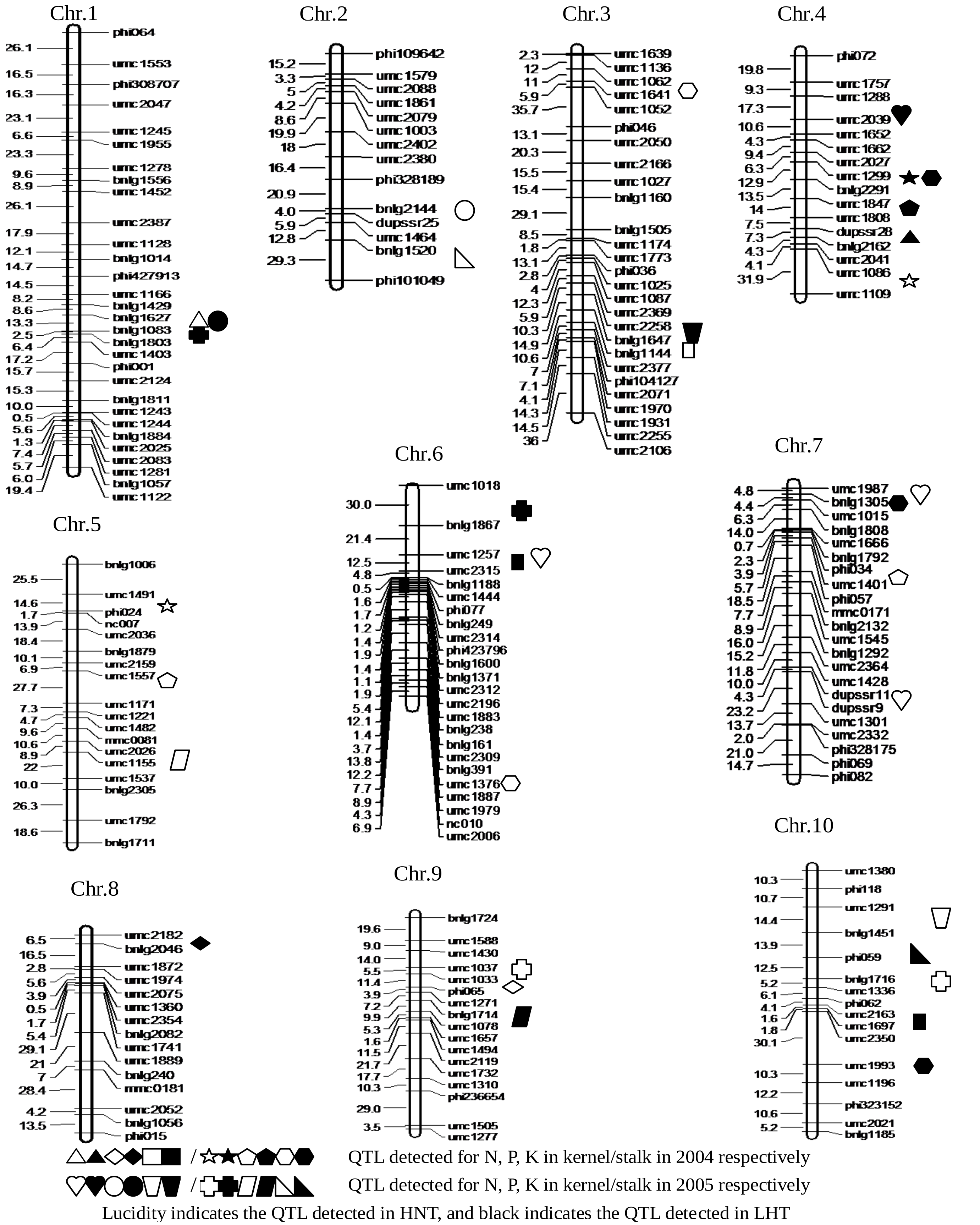

Figure 1. The QTL detected for N, P, K contents in maize kernel and stalk under two nitrogen conditions.

Table 2. The QTL detected for N, P, K contents in maize kernels under two nitrogen conditions

Year	N	Trait	QTL	Flanking markers	LOD	A	D	D/A	Effect	R^2%
2004	N+	N	*qNC1b*	bnlg1627~bnlg1083	3.85	-0.10	0.01	-0.10	A	10.39
		P	*qPC9b*	phi065~umc1271	4.57	-0.03	-0.02	0.59	PD	13.03
		K	*qKC3c*	bnlg1647~bnlg1144	3.75	-0.04	0.06	-1.56	OD	11.92
	N-	N	*qNC4c*	dupssr28~bnlg2162	5.58	-0.04	0.12	-3.33	OD	14.91
		P	*qPC8*	umc2182~bnlg2046	3.3	-0.01	-0.03	2.16	OD	8.12
		K	*qKC6b*	umc1257~umc2315	3.4	0.01	0.04	4.00	OD	8.85
			qKC10d	phi062~umc2163	3.89	0.04	0.12	0.34	PD	10.45
2005	N+	N	*qNC6b*	umc1257~umc2315	3.41	-0.05	-0.02	0.32	PD	7.80
			qNC7a	umc1987~bnlg1305	4.15	0.04	-0.09	-2.44	OD	10.22
			qNC7b	dupssr11~dupssr9	3.75	0.26	-0.09	-0.35	PD	9.55
		P	*qPC2*	dupssr25~mc1464	3.20	-0.003	0.03	-13.36	OD	8.66
		K	*qKC10b*	umc1291~bnlg1451	3.71	-0.01	-0.06	6.84	OD	12.36
	N-	N	*qNC4a*	umc1288~umc2039	3.20	0.08	-0.04	-0.51	PD	8.83
		P	*qPC1*	bnlg1627~bnlg1083	3.40	-0.02	0.04	-2.00	OD	10.87
		K	*qKC3a*	umc2258~bnlg1647	3.50	-0.04	0.003	-0.06	A	9.43

Positive/negative additive effect was from Huang C/Xu178 locus acting increasing effect (same as below).

Table 3. The QTL detected for N, P, K contents in maize stalks under two nitrogen conditions

Year	N	Trait	QTL	Flanking markers	LOD	A	D	D/A	Effect	R^2 %
2004	N+	N	*qNC4b*	umc1086 ~umc1109	4.58	0.08	-0.11	-1.48	OD	31.09
			qNC5	umc1491~phi024	3.82	0.03	-0.10	-3.02	OD	13.59
		P	*qPC5b*	umc1557~umc1171	3.74	-0.02	-0.03	1.67	OD	14.30
			qPC7a	phi034~umc1401	3.40	0.20	-0.04	-1.50	OD	7.57
		K	*qKC3b*	umc1062~umc1641	3.83	-0.10	0.05	-0.50	PD	10.70
			qKC6a	umc2309~umc1887	4.28	0.19	-0.20	-1.03	D	32.82
	N-	N	*qNC4c*	umc1299~bnlg2291	3.20	0.04	0.03	0.72	PD	9.59
		P	*qPC4*	umc1847~umc1808	4.58	0.04	0.03	0.74	PD	16.65
		K	*qKC4*	umc1299~bnlg2291	4.39	0.10	0.002	0.02	A	13.81
			qKC7a	bnlg1305~umc1015	3.92	0.08	-0.07	-0.89	D	8.95
			qKC10c	umc2350~umc1993	3.92	-0.04	0.12	-2.72	OD	16.76
2005	N+	N	*qNC9a*	umc1037~umc1033	3.60	-0.07	0.05	-0.65	PD	7.30
			qNC10a	bnlg1716~umc1336	3.61	-0.04	-0.04	1.04	D	8.36
		P	*qPC5a*	umc2026~umc1155	3.88	0.01	0.02	2.37	OD	10.24
		K	*qKC2*	bnlg1520~phi101049	3.72	-0.02	0.08	-4.36	OD	8.11
	N-	N	*qNC1a*	bnlg1083~bnlg1803	3.20	0.04	0.04	1.03	D	7.38
			qNC6a	umc1018~bnlg1867	3.20	-0.07	0.05	-0.68	PD	9.08
		P	*qPC9a*	bnlg1714~umc1078	3.10	-0.01	-0.02	1.83	OD	9.16
		K	*qKC10a*	phi059~bnlg1716	4.08	-0.07	0.08	-1.07	D	11.41

each two in 2005 under N+ and N- conditions, lied on chromosome 1, 4, 5, 6, 9 and 10. Single QTL could explain the variance of phenotype ranged from 7.30 to 31.09%, and the QTL *qNC4b* has a 31.09% contribution to phenotypic variation of N content in stalks under N+ condition in 2004.

Out of the five QTL for P content in stalks, three and two QTL were detected under N+ and N- treatments, located on chromosome 4, 5, 7 and 9, with a contribution for phenotypic variation ranged from 8.12 to 13.03%. The QTL, *qPC4* was an important QTL, with 16.65% contribution to the P content in stalks under N- condition in 2004.

In the total of seven QTL for K content in stalks, three and four QTL were detected under N+ and N- treatments respectively, and of which, two and three QTL were detected in 2004, while one and one was identified in 2005 under N+ and N- conditions, occupied on chromosome 2, 3, 4, 6, 7 and 10, with a contribution rate ranged from 8.85 to 32.82%. The *qKC6a* was a main QTL controlling the K content in stalks explaining the variance of phenotype by 32.82% under nitrogen condition in 2004.

Of the nineteen QTL detected for N, P, K content in maize stalks, one QTL appeared additive, five QTL expressed partial dominance, five and eight QTL exhibited dominance and over dominance. Obviously, over dominance was the main action of the loci controlling the N, P, K contents in maize stalks, followed by the QTL partial dominant and dominant effect. All from above, nine (about 1/2) were derived from parent Xu178 with only 38.55% increasing the action of total phenotypic variation (Table 3), while ten QTL derived from Huang C (about the rest 1/2) with 61.45% increasing the action of total phenotypic variation. The results demonstrated that the loci from the parent Huang C played important roles in N, P, K absorption while the loci from Xu178 played important roles in N, P, K transportation from stalk to grain.

DISCUSSION

Effect of low N stress to N, P, K nutrition balance

Although N, P and K are three important required mineral elements for crops, and play important roles on nutrient metabolism, growth and development. However, plant requires a certain ratio for different nutrient elements during its developing period normally. Lack of any nutrient element may induce plant disease symptom and affect the normal metabolism based on the equivalent important and irreplaceable principle (Liu, 2006). Besides, lack of any one nutrient element may break the balance between nutrient elements and lead to poor effect to plant in nutrient absorption and utilization. In fact, the N content in the soil in many areas of world is very absent, so low N stress not only reduces the concentration of N in grain and stalk, and affect grain yield, it also leads to increase or decrease the contents of P, K, that is, low N stress also affects the balance absorption and distribution of N, P, K in the stalks and kernels. But the variance ranges of nutrient contents tend to be narrower under N- condition based on the variance ranges of the three elements especially in kernels for $F_{2:5}$ population and in the stalks for the $F_{2:4}$ population (Table 1). Liu et al. (2006) have suggested that the average N: P: K ratio in the plant dry matter is about 6.0: 1: 5.4 for maize, in this study, the average ratio of N: P: K content in kernels and stalks of populations is about 5.1:1:1.9 and 3.6:1:4.0 under N- condition, as well as 4.0:1:1.5 and 4.8:1:4.8 under N+ condition, respectively. Observably, more N and K contents in stalks under N+ than N- condition, while inversion, more N and K contents in kernels under N- than N+ condition. The result showed that more N and K element are transferred from stalk to kernel in low nitrogen stress. Huang et al. (2004) have reported that the corn grain yields of combined application of N P K were significantly higher compared to P K, N K, and N P treatments, respectively. The grain yield in maize production which applied N, P and K could increase by 15.9, 6.9 and 12.1% for high-oil corn, as well as by 20.3, 8.6 and 12.7% for high-starch corn, respectively. Obviously, a proper ratio of N, P, K was essential for maize plant to get a higher yield, land the lack of N nutrient would reduce grain yield and affect the quality (Oikeh et al., 1998).

The genetic basis of nitrogen usage

People consider that conventional fertilizer recommendations result in higher than necessary costs to farmers and increased environment pollution (Zhang et al., 1995; Wu, 1997; Liu et al., 2006). Cai et al.（2002）thought that ammonia loss was an important pathway of N loss from fertilizer applied to maize (11 to 48%) in North Chinese Plain. So, the farmers must optimize the use of nitrogen (N) fertilizer in order to preserve their net income and to decrease pollution. To reach the objectives, specific farming techniques and varieties with a better NUE should be used synthetically for raising the economic in maize production (Bertin and Gallias, 2001). And as a whole, genetic variability was expressed differently in N+ and N- such as QTL for N-uptake were mainly detected in N+, whereas QTL for nitrogen utilization efficiency was mainly detected in N- (Bertin and Gallias, 2001; Gallais and Hirel, 2004), this suggests that the limiting steps in N- assimilation may be different when plants are grown under high or low levels of nitrogen fertilization. Based on the principle of nutrient elements equally important in plant nutrition metabolism, a proper ratio of N, P, K supply will maintain crops growing normally and lack of any one, such as under low N-stress, will affect the other nutrients uptake and transportation for the balance broken (Huang et al., 2004).

Gene expression and interaction with environment

Gene expression relies on given environments, the interaction between QTL and environment is one of the most important factors effecting quantitative traits, and so the QTL mapping results were different with conditions (Veldboom and Lee, 1996; Lübberstedt et al., 1997; Agrama et al., 1999; Bertin and Gallias, 2001; Tang et al., 2005b). Asíns (2002) reported that the variance of some quantitative traits was induced by the action of many genes together with environment. The QTL detected in this research for N, P, K contents were all only appeared in single condition, and showed variances distribution and genetic effect, which inferred that the inheritance of quality traits in maize was influenced by QTL and environments, similar results obtained in other researches on other traits in maize (Zhuang et al., 1997; Lan et al., 2005). So, digging QTL effecting in different environments will be more significance for associate breeding by molecule marker in maize.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Determinants of meat consumption pattern among university students in the Eastern Cape Province of South Africa

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There is a dearth of information on factors influencing the feeding habits and daily consumption of meat among university students in the Eastern Cape Province (ECP) of South Africa. As a result, this study was conducted by administering questionnaires to a total of 150 respondents from the black dominated and the white dominated Universities in the ECP. The results revealed that students from black dominated University (35%) showed more inclinations towards self-catering. Most of the males (80%) between 18 and 38 years, consumed above the recommended daily meat intake. On the contrary, female students from the white dominated university indicated higher preference for fast food due to availability of more disposable income and personal ethics. Probit regression model (χ^2:(9) 64.07(0.0000). Log likelihood: -52.860879 Pseudo R^2:37.73) showed that age (0.0506), monthly allowances (0.0002), amount spent on food (-0.0004), campus location (0.6587) and consumption of close substitutes such as fish (-3.3067) and vegetables (-86.4090) were significant determinants of meat consumption among university students.

Key words: Eating habits, recommended meat intake, monthly allowance, campus location, university students.

INTRODUCTION

In her post-apartheid era, South Africa has undergone enormous economic development and general improvement in food consumption patterns. As a consequence, common class citizens within the human society has been accorded the right to defend their interest in and advocate diverse food orientations as meat consumers, vegetarians and vegans (Hume, 2010; Fayemi and Muchenje, 2012; Ruby, 2012). Similar to what is obtainable in industrialised countries (Jensen and Smed, 2007; Sánchez et al., 2010; Grumert et al., 2011), the economic growth and transition towards market economy has significantly transformed South Africans' consumption patterns and feeding habits. With improved market accessibility, increased income and availability of

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financial aids (NSFAS, 2009), students in tertiary institutions are progressively shifting their food choice from unrefined grains to meat and other fast food products. This phenomenon has consequently impacted on the dietary preferences in line with the psychological variables, functional and cognitive peculiarities of the age-bracket in the tertiary institutions.

At the apex of food hierarchy in African context however, meat is a focal point in the meals of many homes where it provides the cherished quintessential status (Lokuruka, 2006; Fayemi and Muchenje, 2012). This food preference has thus motivated studies on meat species and meat products (Vandenriessche, 2008; Fayemi et al., 2011) and also, responsible for the growing concerns on food choices and consumption patterns in different societies (Holsten et al., 2012). The impact of these concerns has shown that students living away from home tend to develop peculiar eating habits contrary with those living with their families (Barquera et al., 2003; Papadaki et al., 2007). With due consideration for gender, age groups, educational and income status (McArthur et al., 2006; Temple et al., 2006; Adams and Rini, 2007), the nutritional status, consumption patterns and feeding habits of infants, adolescents and the elderly have been promoted (Susanna et al., 1995; Kant, 2003; Russell and Cox, 2004). So far, there is a paucity of information on studies that specifically address the consumption patterns and feeding habits of university students. This study therefore considered it imperative to examine the feeding habit and meat consumption pattern among the black and white dominated university students in the ECP where inequalities had been previously experienced.

METHODOLOGY

A cross-sectional study was carried out among students (n=150) within 16 and 45 age bracket, from two universities in the Eastern Cape Province, South Africa. Socio-demographic variables, of the respondents including gender, age-group, monthly disposable amount spent on feeding were captured in the questionnaire. Other responses that elicited their food habits, source of income or finance, amount spent on food items and the quantity of food items consumed and weight of individual students also featured.

Statistical analysis

Descriptive statistics were performed to compare respondents' socio-demographic characteristics, meat intake and consumption patterns. Close substitutes were tested with respect to the standard on recommended protein intake of the respondents (Joint FAO/WHO/UNU Expert Consultation report, 1992). Factors influencing the recommended daily meat intake among the respondents were analysed by probit regression model analysis. Probit regression model was fitted for both universities with a dummy variable for location of the universities and to identify the variables that significantly influenced per capita meat consumption among the University students. The theoretical relationship (Table 1) among the variables is as shown below:

Pcmc= *f* (age, +gender, + mntdisalow + weight + amtsof + fha+ location + fish intake + vegetable consumption)

Where:
Pcmc = per capita meat consumption of the University student
Age = mid age of the groups
Mntdisalow = monthly disposable allowance of the student
Weight = average weight of the student
Amtsof = amount spent on food
fh = food habit

The model used is explicitly stated as

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 .... + \beta_9 X_9 + \varepsilon_i$$

Where Y_i is the dichotomous dependent variable represented by dummy variable 1 for attainment of recommended meat consumption (those who consumed below or equal to the baseline) per day, and 0, is for otherwise (those who consume above the baseline).

Y= per capita meat consumption of the student. When attained the required level 1, otherwise 0,
β_0 = constant term
$\beta_{1,} \ldots \beta_9$ = the regression coefficients
X_1 = Age of the student (in years)
X2 = Genders
X3 = Monthly disposable allowance (in Rand)
X4 = Amount spent on food (in Rand)
X5 =weight of the student
X6 = Food habit (self-catering or otherwise)
X7 = Fish intake
X8 = vegetable consumption
X9 = Location of the Universities

The basic model of probit estimation involves defining a variable Z that is a linear function of the variables that determine the probability:

$$Z = \beta_0 + \beta_1 X_1 + ... + \beta_n X_n \quad (1)$$

Where *f* (Z) = the cumulative standardized normal distribution, give the probability of the event occurring for any value Z

$$p_1 = F(Z) \quad (2)$$

The maximum likelihood analysis is used to obtain estimates of the parameters. The marginal effect of X is

$$\frac{\partial p}{\partial X_i} = \frac{dp}{dZ}\frac{\partial Z}{\partial X_i} = f(Z)\,\beta_i \quad (3)$$

Since *F (Z)* is the cumulative standardized normal distribution, *f*(Z) its derivative, it is therefore the standardized normal distribution itself:

$$f(Z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}} Z^2 \quad (4)$$

The binary function (above) was used because its output is confined to values between 0 and 1, and also takes value from negative infinity to positive infinity. The basic assumption was that the students who had meat intake less than or equal to the baseline (0.212 kg) was scored 1 (that is, attained) and those who

Table 1. Specification for probit regression model.

Variables	Notations	Expected significance
Recommended meat intake per day	Dependent variable (dichotomous) : 1 for attainment, and 0 for otherwise (not attained)	Attained or not
Age group: Represented by mid-age of the group	Independent variable X_1	Positive
Gender: 0=male, 1=female	Independent variable X_2	Males expected to consume more than female.
Weight (average weight)	Independent variable X_3	Inverse relationship with Meat consumption.
Monthly Disposable Allowance (represented by mean monthly allowance)	Independent variable X_4	Higher disposable allowance is expected enhance higher probability of attainment
Amount spent on food	Independent variable X_5	More percentage spent on feeding, the higher the probability of attainment.
Eating Habits: 1 for self prepared food, 0, otherwise	Independent variables X_6	Self-prepared meal is expected to have higher influence on probability of attainment.
Per capita fish intake	Independent variable X_7	This is a close substitute. It has inverse relationship with per capita meat intake.
Per capital vegetable intake	Independent variable X_8	This could have both negative/positive influence depending on eating habit
Location: 1=rural, 0= urban	Independent variable X_9	

Table 2. Baseline daily recommended protein intake (Adapted from the Joint FAO/WHO/UNU Expert Consultation report, 1992).

Age groups	Grams (per capita) of protein needed per day
Girls ages 14-18	46
Boys ages 14-18	52
Women ages 19-40+	46
Men ages 19-40+	56

Source: The Joint FAO/WHO/UNU Expert Consultation report, 1992.

consumed more than the required per capital intake was scored 0, or otherwise. It was further assumed that those who consumed less than the recommended intake could make it up through other sources (close substitutes). The variable Z represents the exposure to some set of independent variables, while f (Z) represents the probability of a particular outcome, given a set of explanatory variables. The variable Z is a measure of the total contribution of all the independent variables used in the model. Probit regression model was preferred for this analysis because whether a coefficient has a positive or negative influence; it does not increase or decrease the probability (Schroeter et al., 2007). In addition, it strengthens the explanatory power of variables and produces relevant interpretation about the eating habits and meat consumption pattern of the respondents. The relationship between dependent variable, Y and X's, the independent variable are expressed in Table 1 below. Each of the regression coefficients describes the size of the contribution of the specified independent variable. A positive regression coefficient means that the independent variable increases the probability of the outcome, while a negative regression coefficient means that the variable decreases the probability of that outcome; a large regression coefficient means that the independent variable strongly influences the probability of that outcome, while a near-zero regression coefficient means that the variable (independent) had little influence on the probability of that outcome.

RESULTS AND DISCUSSION

This study empirically identified the socio-economic factors influencing eating habits and meat consumption patterns among the university students in black and white dominated Universities. The specifications on the probit regression model and standard on the daily recommended protein intake are presented in Tables 1 and 2 respectively. It was observed (Table 3) that 35% of the students in the University of Fort Hare (Black Dominated University (BDU) prepare their meals (through self-catering) as compared to 31% recorded in Rhodes University (White Dominated University (WDU). Students (17.5%) from the BDU prefer eating in the university dining hall but patronising fast food outlets was observed as the major eating habits in the WDU. The need for privacy could be attributed to the motivating factor influencing university students to exhibit such feeding

Table 3. Demographic and socioeconomic characteristics of the respondents.

Characteristics	University of Fort Hare		Rhodes University	
	Count	Frequency (%)	Count	Frequency (%)
Age group (Years)				
15-20	7	8.8	12	16.9
21-25	49	61.3	29	40.8
26-30	11	13.8	12	16.9
31-35	10	12.5	10	14.1
36-40	2	2.5	5	7.0
Above 40+	1	1.3	3	4.2
Gender				
Male	53	66.3	40	56.3
Female	27	36.7	31	43.7
Monthly disposable allowances				
Below R2000	61	76.3	23	32.4
R2100-4000	10	12.5	35	49.3
R4100-6000	6	7.5	8	11.3
R6100-8000	3	3.8	5	7.0
Amount spent on feeding				
Below 20%	17	21.3	5	7.0
21-40%	22	27.5	18	25.4
41-60%	25	31.3	26	36.6
61-80%	11	13.8	21	29.6
81-100%	5	6.3	1	1.4
Eating habit				
Prepare own meal	28	35.0	22	31.0
Patronise University dining hall	14	17.5	11	15.5
Patronise fast food outlets	17	21.3	25	35.2
Others	21	26.3	13	18.3
Study level				
Undergraduate	57	71.3	27	38.0
Postgraduate	13	28.8	43	62.0

habit (Miller, 2001; Blunt and Dowling, 2006). Intuitively, it could be cheaper to prepare meals than to buy cooked or processed foods because of the cost of added value for eating the fast food and the probability of improving per capita intake of meat by students by a unit. These results are consistent with previous research which found consumers feeding habit to be dependent on what they considered appropriate (Sosa et al., 2005). Elsewhere, those who even discriminated against milk and vegetables still indicated heavy dependence on fast-food consumption (Schroeter et al., 2007). The concept of 'ethical everyday' should be borne in mind in this scenario as the moral guidelines that informed the conduct of the respondents to either adopt self-catering approach or the habit of eating in the dining hall (Borgmann, 2000; Smith, 2000). In agreement with Hall (2011), basic ethical principles of right versus wrong; good versus bad, render consumer behaviour as an outlet for the expression of personal ethics. Forming the habit of eating fast food can thus be based on the availability of higher disposable incomes (Csikszentmihalyi, 2000; Abela, 2006; Hume, 2010) which is peculiar with the Y-generation consumers that purchase more, demand more and live on higher debt to equity ratio than their parents.

Although students seek other means of feeding themselves due to the peculiarity of their campus locations yet, a total of 80% of male students (under the age of 18 and 38 years) in BDU consumed above the recommended meat intake (52g and 56 g) per day (Table 4). Granted that gender class in both universities, reflects the peculiarities of consuming the required quantity of meat per day, the female students however eat less meat (46 g) per day than their male counterpart. Variation in

Table 4. Meat intake of students from the black dominated University (University of Fort Hare).

Characteristics	Count	Frequency	Valid percent	Cumulative
Above recommended intake	55	67.9	67.9	67.9
Recommended intake	26	32.1	32.1	100

Gender	Recommended meat intake per day	Mid Age (%)						Total
		18.0	23.0	28.0	33.0	38.0	43.0	
Male	Above recommended	4 (80.0)	19 (61.3)	4 (57.1)	0	4 (80.0)	0	31 (62.0)
	Less than/ equal to recommended	1 (10.0)	12 (38.7)	3 (42.19)	2 (100)	1 (20.0)	0	19 (38)
	Total	5	31	7	2	5	0	50
Female	Above recommended	2 (66.7)	15 (83.3)	3 (75)	1 (100)	1 (33.3)	2 (100)	24 (77.4)
	Less than/ equal to recommended	1 (33.3)	3 (16.7)	1 (15.0)	0	2 (66.7)	0	7 (22.6)
	Total	3	18	4	1	3	2	31

Table 5. Meat intake of students from the white dominated University (Rhodes University).

Characteristics	Frequency	Percent	Valid percent	Cumulative
Above recommended intake	57	81.4	81.4	81.4
Recommended intake	13	18.6	18.6	100

Gender	Recommended meat intake per day	Mid Age (%)						Total
		18.0	23.0	28.0	33.0	38.0	43.0	
Male	Above recommended	5 (100)	13 (86.7)	8 (80.0)	2 (66.7)	3 (75.0)	0	31 (81.6)
	Less than/ equal to recommended	0	2 (13.3)	2 (20.0)	1 (33.3)	1 (25)	1 (100)	7 (18.4)
	Total	5	15	10	3	4	1	38
Female	Above recommended	6 (75)	13 (100)	2 (100)	4 (80.0)	1 (50.0)	0	26 (81.3)
	Less than/ equal to recommended	2 (25.0)	0	0	1 (20.0)	1 (50.0)	2 (100)	6 (18.7)
	Total	8	13	2	5	2	2	32

age and gender groups seems somewhat perceptive here as it reflects what is obtainable in food security research (Morrison et al., 2011). Earlier studies found similar associations where age, race or ethnicity and income were associated with food group intake by boys and adolescent boys and girls eating equal proportion of fast food (Bezerra et. al., 2014). As a result, Sosa et al. (2005) did attribute consumers' food choice and intake to their age, gender, education, health and also to the appearance, texture, flavour, price, urbanisation and family type. Thus meat-eating and the negative feelings associated with meat are strongest among females (Gregory, 1997).

Moreover, the consumption pattern of female students in the University of Fort Hare (BDU) getting an average monthly allowance of R3000 is higher (in both "above the recommended" and "less/equal recommended level") than their male counterparts (Table 4). Female students that are getting monthly allowance in the range of R1000 to R7000 consume above the recommended intake per day as observed among the respondents from Rhodes University (Table 5). Similarly, as the monthly allowance increases, male students in both Universities tend to consume above the recommended meat intake (Figure 1a, b and c; Figure 2a, b, c and d). The coefficients and the marginal effect of the variables influencing meat consumption pattern in both Universities are presented in Table 6. Age of the student was significant ($p < 0.05$) and have positive effect (X_1, +0.0506) on meat consumption per day. Hence, the probability of consuming the required quantity of meat per day increases with the age of the students in both Universities.

The current study revealed that the weight gained by sampled students in both Universities is negatively related to meat consumption. The coefficient (X_3, -0.0132) which is not significant is in line with literature and past works. It also shows that there is the probability that the students have some enlightenment about weight gain and meat consumption with its resultant chronic conditions. From the study, we can infer that the

Table 6. Determinants of required meat consumption at the University of Fort Hare and Rhodes University.

Recommended Meat intake per day	Coefficient	Standard Error	Z	P>|Z|	∂F/∂x	x-bar	[95% Conf. Interval]	
Age	0.0506	0.0219	2.30	0.021**	0.0107293	25.8867	0.0075	0.0936772
Gender	-0.4232	0.3086	-1.37	0.170	-0.086273	0.413333	-1.0281	0.1816097
Weight	-0.0133	0.0088	-1.50	0.135	-0.002818	58.5867	-0.0307	0.0041306
Monthly allowance	0.0002	0.0001	1.75	0.080*	0.0000499	2293.33	-0.0000	0.0004994
Amount spent on food	-0.0004	0.0003	-1.77	0.077*	-0.000104	1061.33	-0.0010	0.0000539
Eating habits	0.8717925	0.5778	1.51	0.131	0.1848379	0.333333	-0.2608	2.004419
Fish consumption	-3.306786	1.9551	-1.69	0.091*	-0.701107	0.058655	-7.1388	0.5252446
Vegetable consumption	-86.40988	18.8206	-4.59	0.000***	-18.3207	0.02204	-123.297	-49.52207
Location	0.6587101	0.3195	2.06	0.039**	0.1396601	0.533333	0.0324	1.285011
Constant	-0.0432056	0.8354	-0.05	0.959	-0.009161	1	-1.6805	1.594163

n=150, LR χ^2 (9) 64.07(0.0000). Log likelihood= -52.860879 Pseudo R^2=37.73. ***,**,* Significant at 1, 5 and 10%; n= number of observations.

probability of consuming the required meat intake by the students declines as their weight increases. Development of a 'meat less' orientation especially among the young females women have been reported in the United Kingdom and Australia because of fat in meat (Kubberud et al., 2001). Compared to the more restricted females, the males in our study seemed to have a more pragmatic view on their own diet and displayed no such disgust with or concern for fat in meat. Our findings here is therefore consistent with Guzman et al. (2000) where females associated health, beauty and attractiveness with low meat-intake, good looks, slim bodies and good body image (Vandendriessche et al., 2005; Wang et al., 2009). The belief in thin, or slim bodies regarded as "diaphanous body image" could be deduced in our study to be upheld by the female respondents in both Universities (Adams and Rini, 2007; Wang et al., 2009).

Students' monthly allowance (X_4) has a positive relationship ($p < 0.10$) on attainment of the required meat intake per day. Although X_4 is small in magnitude (+0.00023) is very small there is the probability of eating required meat per day as the allowances of student's increases. The amount spent on feeding was negatively related (X_5= -0.0004911) to the recommended meat intake and thus, many students prefer to spend money on other food items or close substitutes rather than meat. Probit analysis showed that the fish consumption among the students in both Universities is significant ($p < 0.10$) but inversely related (coefficient = -3.306786) to the recommended daily meat intake. Even though the consumption of fish was the highest, a unit change (positive) in per capita meat consumption by the respondents resulted in 70% reduction in the consumption of both fish and vegetable. Table 6 also shows a positive relationship between eating habits of the students (X_6=0.8717) and the daily recommended meat intake. The study found that the probability of consuming the required meat per day being high when they prepare their meals through self-catering. The regression reveals that the probability of consuming the required meat per day was greatly influenced by students who prepare their own meals. The result in this context might be influenced by preference for close substitute and also, what the consumers consider appropriate (Sosa et al., 2005). Other factor like gender is inversely related to required meat consumption, although it is not significant. Regression analysis shows that the probability of male students consuming the required meat intake is higher than their female counterpart in both Universities. Table 6 also shows marginal effect of the independent variables on per capita meat intake among University students in Eastern Cape Province of South Africa. However, our study reveals that 5% change in the age of the students will cause a unit change in per capita meat consumption of the students.

Conclusion

The feeding habits and consumption patterns among the respondents in this study were greatly influenced by their monthly income, gender class and personal ethics in this study. Students from black dominated University showed more inclinations towards self-catering but those from the white dominated University, had higher preference for fast food due to availability of more disposable income.

Conflict of Interest

The authors have not declared any conflict of interest.

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Review

Rural development policies and programmes under colonialism and during the five year development plans in Lesotho

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Poverty has been said to be very high in developing countries, and many people live below the poverty line. There are different causes of poverty, but the most common one is food insecurity. Therefore, the contribution of agriculture to ensuring food security in the poor countries cannot be ignored. Although many farmers in some developing countries practise subsistence farming, agriculture accounts for a large share to the means of livelihood in the rural areas of developing countries. This is because about 80% of people in developing countries live in rural areas and depend on agriculture for livelihood. Despite the large contribution of agriculture to rural development in developing countries, the sector (agriculture) is confronted with many different challenges. There is low agricultural productivity (especially in peasant farming) because of the use of traditional technologies, and other factors. And this results in food insecurity in many households. However, countries implement different programmes and policies to increase productivity in agriculture. It is in this respect, this paper looks at the different policies, methods and programmes implemented by the Lesotho government to increase agricultural productivity/production since the period of colonialism.

Key words: Agriculture, rural development, crop production, food security, poverty, green revolution.

INTRODUCTION

Rural development as a development process in developing countries gained momentum after the Second World War, and intensified during the period of colonialism (Berry, 1993). The idea behind rural development was to improve the living standards of the rural poor by reducing poverty, unemployment and food insecurity (Lea and Chaudhri, 1983; Dixon, 1990). The above economic and social problems were solved through different rural development strategies, and the major rural development strategy was to increase productivity in agriculture (IFAD, 1991). In this respect, the initial period of rural development in Africa focused on soil erosion control and conservation measures (Makoa, 1999), as well as increasing agricultural productivity by introducing rural development projects, such as the Improved Farmers' Systems in countries such as Tanganyika (Berry, 1993). Raising the productivity of African peasant agriculture was a key concern for

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colonial governments, based on the assumption that traditional agriculture was backward and unproductive. Some colonial governments in Africa blamed the state of environmental degradation, especially soil erosion on the Africans' poor methods of cultivation and overuse of the natural resources. Therefore, anti-erosion campaigns for use of resources were introduced (McCann, 1999; Benjaminsen, 2000). And the measures used to control soil erosion included among others, compulsory tie-ridging, terracing, and compulsory reduction of livestock numbers (Östberg, 2000). Other conservation measures used by some colonial governments included demarcating forest reserves in which Africans were prohibited from farming or grazing livestock, and restricting access to natural resources. For instance, Benjaminsen (2000) points out that the colonial government in Senegal passed the law on the use of forests and forest products. The natives were prohibited from collecting nuts, wood, hunting and use the forest areas as pastures. While such measures were supposed to serve both the interests of Europeans and Africans, in practice, they often discriminate against the Africans.

Some colonial governments also introduced policies that aimed at transferring income and surplus from the rural areas in Africa to finance the urban development. For instance, in some countries such as Kenya and many others, the colonial governments introduced the hut tax to generate revenues. This income transfer left the peasants trapped in a vicious circle of poverty, as some of the farmers had to sell their livestock in order to pay the hut tax (Ensminger, 1996). Many African countries inherited some of the colonial governments' rural development policies and programmes at independence. In this case, the post-colonial states received most of their revenues from the peasants as the predominant producers in the economy. This was done by for example, using state marketing boards which engaged in unfair exchange with the peasants. Marketing boards bought peasants' produce at lower than market prices, the balance going to the state. The use of marketing boards to extract surplus from peasants has been observed elsewhere in Africa, for example in Zimbabwe (Cliff, 1988). The use of marketing boards has, in the majority of cases, tended to be a way of state extraction of surplus and income from the peasantry to finance mainly industrial development (Pugh, 1996).

Some colonial and post-colonial rural development policies and programmes in Africa and elsewhere contributed to poverty and food insecurity. As a result, the use of improved methods of production in agriculture was adopted during the modernisation period starting from the 1950s and onwards (Ellis and Biggs, 2001). This is because poverty, food insecurity and a lack of development in many developing countries were related to the use of outdated methods of production, especially in agriculture (Norton et al., 2006). In this regard, a lack of development in developing countries is illustrated by different theories / models of development that emerged in the Post-World War II, mainly in the 1950s and 1960s. First, Lewis (1954) associated a lack of development (poverty and food insecurity) in the rural communities of developing countries with low agricultural production and population pressure on marginal lands that forced people to migrate to urban industries in search of employment opportunities (Thirlwall, 1995). Second, Nurkse (1953) linked the underdevelopment in developing countries to vicious poverty. Nurkse (1953) argued that low incomes in developing countries result in little savings. In this regard, lack of savings results in low capital that can be used for investment/production. Third, Rostow (1960) also associated poverty, food insecurity and a lack of development in the rural communities of developing countries to low agricultural productivity because of the use of poor methods of production. Fourth, scholars such as Furtado, Myrdal and Frank ascribed underdevelopment in developing countries to unequal power relations between the North and South countries. The power relations are such that the South countries occupy the subservient position in the international division of labour. The international division of labour is organized such that, the poor countries specialise in the production of agricultural raw materials that are bought at low prices by the rich countries on the international market (Kay, 2005), and the North countries specialise in finished goods in the international market, and they are expensive for many poor countries. Evidence further shows that, the terms of trade for agricultural raw materials have declined in the world market with the introduction some synthetic products.

It is argued in this paper that, rural development in Lesotho, especially agricultural production was state driven. In this regard, government introduced different programmes to increase agricultural productivity to ensure food security. It is also argued that, although agriculture does not contribute to food self-sufficiency in Lesotho, poverty and persistent food insecurity were witnessed during the collapse of donor funded rural development projects and introduction of the Structural Adjustment Programmes (SAPs) in the late 1980s and early 1990s that emphasized a cut on government spending in agriculture (especially by helping small-scale farmers). This paper further argues that, there are some other factors that contribute to low agricultural productivity in Lesotho besides reducing government expenditure on agricultural subsidies.

Methods

This research is based on secondary data collected from different sources. The main sources of data for this study were books and journals. The internet also provided useful information on the rural development policies and programmes adopted by some developing countries to increase food production. Data on rural development programmes in Lesotho was collected mainly from the Five Year Development Plans. This research report is not simply about review of the literature, but analyses the agricultural rural development programmes and policies adopted by some developing countries to increase productivity.

The green revolution and modernisation of agriculture

Rural development strategies in the 1950s and 1960s focused on improving the lives of the rural poor by increasing national income and productivity in agriculture (Ruger, 2005). This was achieved through the introduction of the Green Revolution (Holdcroft, 1984; Machethe, 1995) that was concerned with improving agriculture through the adoption or the diffusion of modern agricultural technologies, especially the high yielding varieties (Davies, 2003). The adoption of the Green Revolution technologies came after realisation that the use of traditional technologies in agriculture is a stumbling block for development (Pavlich, 1988).

The theme around the transformation of traditional agriculture is well illustrated by Rostow in his model of “Stages of Economic Growth” (Rostow, 1960). The first stage of the model is about “the traditional society”. This stage states that societies adhere to traditional norms, where traditional agriculture is the main activity. Rostow (1960) argues that in traditional societies production is very limited and follows pre-capitalist methods. According to Rostow’s argument, societies which wanted to develop (modernise) had to transform their agricultural system and practice to allow them to prepare for implementation.

The so-called ‘backwardness’ of countries is also illustrated by Sir Arthur Lewis (1954) in the model of dual economies. This model stipulates that many developing countries have two sectors of the economy: the traditional (rural) and modern (urban) sectors. The former is traditional and has a reserve of unskilled labour, while the latter is considered modern and depends on the former for labour and agricultural products (Lewis, 1954). The model states that surplus labour in the traditional sector causes declining agricultural productivity. Therefore, the solution to the problem of diminishing returns is to increase productivity by modernising agriculture. The diffusion of modern technologies in agriculture was expected to increase productivity and reduce the number of people working on small pieces of land. Modernisation of traditional agriculture in the late 1960s and 1970s was done by the use of the Green Revolution technologies.

According to Paddock (1970) and Sonnenfeld (1992) the Green Revolution was initiated in Mexican agriculture in the early 1940s by the Rockefeller Foundation. The Green Revolution was also a common practice in some Latin American and Asian countries in the 1950s and 1960s (Evenson and Gollin, 2003). Sonnenfeld (1992) opines that the Rockfeller Foundation developed fertilisers and hybrid seed in laboratories in the United States and Mexico that would be used on large-scale irrigated landholdings. In the initial years the term Green Revolution was associated with the improvements in the high yielding varieties of rice and wheat only, whereas the high yielding varieties have nowadays been developed for other food-stuffs, such as maize and sorghum (International Food Policy Institute, 2002). The Green Revolution technologies achieved three important outcomes in developing countries:

First, there was a considerable increase in agricultural productivity/production. According to Bernstein (1992) the Green Revolution technologies increased yields and incomes for many farmers in Asia and other developing countries. In the processes, the yielding time of selected agricultural varieties was increased. For instance, the new rice varieties were preferred to the traditional ones which took 150 to 180 days to mature, while the new varieties took only 100 days (Davies, 2003). Therefore, the Green Revolution was a shift from the traditional use of agricultural methods to modern technologies where farmers could increase their productivity (Sen, 1970).

The mechanisation of agriculture during the Green Revolution replaced labour-intensive methods of production (Randhawa, 1977). This is because the new technologies enabled the specialisation of operations and changing practices to ensure high productivity. It is further stated that in order to increase productivity/production, the economies of scale were greatly enhanced by increased farm size and with the use of hybrid seedlings, the best yields were generated (Schuh et al., 1970). The potential of plants to be more productive was increased by breeding a variety of seed which had the characteristics of high yield, resistance to stem and leaf rust, drought resistant and a high adaptability to different conditions (Goldman and Smith, 1995; Davies, 2003). The Green Revolution also focused on the improvement of animal husbandry (Sonnenfeld, 1992; Leaf, 1980). As has been pointed out by Goldman and Smith (1995), the number of animals that provided people with meat, milk and other products increased dramatically.

Second, the Green Revolution ensured food security (Leaf, 1980). Therefore, as a result of increased production from the Green Revolution technologies, some countries in Asia (for example, Pakistan), Latin America and a few from Africa reduced their food insecurity and dependence on wheat imports from the United States (Shepherd, 1998). For instance, in India, food production per capita increased by about 30%, and from being a net importer of grains from 1951 to 1975, there were 30 million tons of grains in government reserves in 1984 to 1985 (Bernstein, 1992). The above-mentioned scholars argue that this increase in productivity was important so as to achieve national food sufficiency and a reduction of malnutrition, hunger and starvation in the country. Bernstein (1992) further points out that High Yielding Varieties packages enabled at least three harvests per year. There was a decline in real food prices affected by the cost-reducing technologies. The Green Revolution packages benefited mainly the poor because they had the means of producing their own food and this reduced their dependence and spending on food sourced elsewhere (Bernstein, 1992). Even though many scholars discuss the potential benefits of the Green Revolution, they argue that the Green Revolution often failed to solve the problems related to high levels of poverty, inequality and inequity. A number of crucial points should be explored in this respect.

First, the Green Revolution technologies did not ensure sustainable food production. The growth rates that were highlighted were simply a feature of the 1970s (Shiva, 1991) and were not sustained in the decades that followed; thus what resulted was food insecurity.

Second, the Green Revolution technologies failed to solve the problems related to poverty among the peasant communities. Citing Saith (1990), Bernstein (1992) points out that there was high government spending to reduce rural poverty during the Green Revolution in India. Because there were so many people below the poverty line, any government intervention through the provision of funds, improved their lives in the short term, rather than increasing the high yielding varieties packages (Deva, 1984). Strauss (2000) argues that there is an increasing number of people suffering from diseases that are related to insufficient caloric intake, despite the advent of these new agricultural technologies.

Third, access to the Green Revolution technologies was a matter of affordability. According to Ghatak (1995), Shepherd (1998), Strauss (2000) and the International Food Policy Research Institute (2002), access to agricultural inputs is determined by the amount of money one has. This was seen in practice when the Green Revolution technologies were monopolised by the large commercial farmers (Sen, 1970; Havens and Flinn, 1975; Hayami, 1984) because they had economic power and they could afford these technologies for their own use. Thus, the Green Revolution was blamed for causing and perpetuating social differentiation among the peasantry (Goldman and Smith, 1995).

Fourth, the Green Revolution did not assist in rural employment creation as these technologies were expected to be labour intensive (Jacoby, 1972). At the same time, in order to increase productivity, farm machinery was used. This caused an increase in unemployment in labour surplus economies, and the negative impact of the Green Revolution technologies was experienced by the labour tenants who depended on wages from agriculture for survival. This was evident when most of them lost their means of livelihood due to the advent of new farm machineries (Barrow, 1995; Ghatak, 1995).

It can be observed from the above discussion that the Green Revolution technologies were introduced to improve agricultural productivity in some developing, especially in Asia (India and Pakistan) and Latin America. However, the methods used to enhance agricultural productivity were not restricted to the adoption of the Green Revolution packages, there were other methods used. The following section studies the methods and programmes used by the Lesotho government (formerly known as Basutoland) to increase crop production during the colonial period.

RURAL DEVELOPMENT PROGRAMMES AND POLICIES IN LESOTHO

Rural development as a process took place in Lesotho during the colonial period. The colonial government was more concerned with controlling soil erosion, destocking and other programmes intended to increase productitivity in agriculture. The post colonial government included rural development programmes and policies in the Five Year Development Plans. The idea was also to increase production in agriculture through the adoption of new methods of production. This section studies rural development programmes and policies in Lesotho during colonial period and after independence, mainly during the Five Year Development Plans.

Colonial rural development strategies (1930s- 1965)

A number of measures were taken in an attempt to improve agriculture during colonial period in Lesotho. First, a range of measures was introduced to control soil erosion. The country had an exceptionally eroded landscape which had called for mitigation and prevention measures since 1936 (Showers, 1989; Showers, 1996). The control of soil erosion was tasked to the Department of Agriculture whose responsibilities included such activities as building anti-erosion control measures to prevent the run-off of surface water and to trap eroded soil. The most common control measures were building terraces, contour banks, meadow strips, and making furrows (McCann, 1999). In addition to establishing these measures, the ministry included other anti-erosion controls, such as planting trees and building dams and silt traps (Wallman, 1969). Among the anti-erosion projects implemented was, for instance, the Taung Reclamation Scheme established between 1956 and 1961 (Wallman, 1969). Wallman (1969) also notes that in some places, the colonial government prohibited farmers from cultivating their land for a certain period in the name of conservation.

Second, the government introduced open and closed seasons on rangelands for livestock in response to the overgrazing which was a major factor in the erosion of the rangeland (Ferguson, 1985). Thus, the blame was placed on the practices of livestock farmers for contributing to environmental degradation (Quinlan, 1995). As a result, pastures in the mountain areas were closed for certain periods and farmers instructed to move their livestock to places opened for grazing (Driver, 1999).

Third, measures to increase agricultural productivity were introduced by implementing area- based-development projects which were mainly concerned with increasing productivity in agriculture and adopting the Green Revolution principles of using improved agricultural inputs. Wallman (1969) avers that the main objective of these projects was to increase production in agriculture by introducing improved methods of production, the use of improved agricultural inputs and the control of soil erosion, while implementing it in the name of Community Development. Some of these area-based development projects included, among others, the Tebetebeng pilot project, which ran from 1960 to 1970 and the Maphutseng Valley Rural Development Project, established in 1947 (Cadribo, 1987; Makoa, 1999). These projects were concerned with the control of soil erosion, range management and improving productivity in agriculture. Makoa (1999) further states that the Maphutseng project mobilised farmers to form a block that would allow farming to be done jointly. Another important area-based development project was the Mafeteng Farm Mechanisation project which was established in 1960 and was concerned with the production of wheat (Wallman, 1969). The government provided farmers with agricultural inputs, including seeds and tractors but the costs of production were deducted from farmers after harvest (Makoa, 1999).

In general, these attempts during colonial rule were mainly focused on addressing soil erosion and improving agricultural productivity in order to ensure food security for the nation. It is observed that, unlike during the colonial period where anti-erosion control was the major task in rural development, in the 1970s many countries were concerned with rural development through modernising agriculture and other sectors of the economy by means of methods, policies and programmes in the Five Year Development Plans. The Lesotho government was not an exception. Thus, the next section scrutinises agriculture as the main rural development strategy in Lesotho. The section studies how agriculture was supported and promoted during the Five Year Development Plans.

Rural development during the five year development plans (1970-1999)

According to Mashinini (2000), the rural development sector in Lesotho comprised two distinct elements from 1970 to 1999; namely, agriculture and community development activities. The agriculture sub-sector involved crop production, livestock production and range management (Mashinini, 2000).

The Government of Lesotho introduced its First Five Year Development Plan in 1970, covering the five-year period of 1970/1971 to 1974/1975. The objective of this was to “lay the foundations for economic development and economic independence” (Kingdom of Lesotho, 1970:23). This was the result of the concern by the government about declining agricultural productivity. The target of the Government of Lesotho during the First Five Year Development Plan was to “to achieve a marked increase in productivity in the agricultural sector” in both crop and animal husbandry as “crop yields are generally poor and output of maize averaged 2-3 bags an acre, compared to 30-35 bags per acre on irrigated experimental cultivations” (Kingdom of Lesotho, 1970:9). The plan further states that there were differing reasons behind the decline in agricultural productivity, including: adverse climatic conditions; sandy soils with low fertility; a lack of irrigation; a shortage of labour because of the migrant labour system; the use of primitive farming practices due to insufficient agricultural equipment; and inadequate credit facilities (Kingdom of Lesotho, 1970).

The traditional land tenure system, soil erosion and use of primitive farming practices, such as monoculture were cited as the major obstacles to the modernisation of agriculture in the 1970s (Wallman, 1972). Traditional land tenure makes farmers reluctant to improve their land holdings, and also impedes their obtaining access to agricultural credit (Kingdom of Lesotho, 1970). The plan also argued that the country was importing food stuffs unnecessarily because of the low productivity in agriculture. Hence rural development with an agricultural focus, linked to processing was the most immediate, necessary, and sensible means to increase nationally produced wealth (Kingdom of Lesotho, 1970).

It is discussed in the introduction that agriculture in developing countries was characterised by low productivity in the 1960s and 1970s because farmers used primitive methods of production. Therefore the modernisation of agriculture, by increasing productivity, was emphasised and encouraged in the 1970s through the adoption of Green Revolution technologies, both in crop and animal production. Thus, the Lesotho Government’s objective was to increase productivity in agriculture by adopting some of the principles of the Green Revolution. According to the First Five Year Development Plan “the long term development objective for crop production is to transform crop farming from its present subsistence basis to the production of cash crops, such as wheat, peas and beans for import substitution and export” (Kingdom of Lesotho, 1970:56).

The transformation of subsistence farming was implemented through different programmes. First, the government introduced improved farming practices, including the use of fertilisers (Kingdom of Lesotho, 1970). The First Five Year Development Plan stated that the consumption level of fertilizers in the 1970s was too low at less than 100 000 packets and accordingly, increased consumption to 700 000 pockets over a period of five years (Kingdom of Lesotho, 1970). Second, the government introduced the mechanisation of agriculture via a tractor hire service. The Plan stated that draft animals were disappearing in the country and that in order to compensate for this, the government would introduce tractor hire to facilitate a more rapid process for the ploughing of fields. In addition, the objective of tractor hire was to ensure that there were no fallow lands in the country. Third, the government introduced irrigation projects on the basis that, according to the Plan, Lesotho would have enough water available for irrigation purposes. Fourth, the government introduced agricultural information services and farmer training centres, including among other things, the Lesotho Agricultural College for the training of agricultural personnel, such as extension workers.

It is stated in the First Five Year Development Plan that increasing productivity in agriculture, especially in crop production needs immediate attention through the use of some of the Green Revolution technologies, such as tractors and the application of fertilisers. It is during the Second Five Year Development Plan when the Government of Lesotho introduced agricultural programmes aimed at increasing productivity in agriculture to increase food security in the country. According to the Second Five Year Development Plan,"Lesotho is a rural, agricultural nation; and rural development with an agricultural focus is the most immediate, necessary and sensible means to increase nationally produced wealth" (Kingdom of Lesotho, 1976:71). As a result, the Ministry of Rural Development was formed in 1976 from the Department of Community Development (Walton, 1978) to implement rural development initiatives.

As a way of improving the living standards of the rural poor, the objectives of the Lesotho government during the second plan involving crop production included among other things; "to foster general yield and production increases but specifically to achieve net self-sufficiency in basic grain and vegetation production; to increase crop-derived income with greater cash crop area especially of wheat and beans; greater forage crop area in support of commercial livestock production; and significant introduction of high value cash crops including potatoes and asparagus" (Kingdom of Lesotho, 1976:78). In this respect, area development projects were established to meet the above objectives. However, the major shortfalls in the quality of farming were observed in some area development projects (especially in Thaba Bosiu). As a result, the Lesotho government proposed an attempt to improve the provision of basic services to farmers by stabling the Basic Agricultural Services Programme in 1978 (van de Geer and Wallis, 1982).

The objectives of the Basic Agricultural Services Programme were to improve traditional agriculture by encouraging the use of new innovations (agricultural inputs), such as seeds, fertilisers, insecticides and marketing outlets to farmers, the improvement of animal husbandry and the establishment of physical infrastructure (Walton, 1978; van de Geer and Wallis, 1982). The projects that benefited from the Basic Agricultural Services Programme and had a combination of crop and livestock production included: Thaba-Tseka; Khomokhoana, Phuthiatsana; Matelile and Thaba-Bosiu Integrated Rural Development Projects (Kingdom of Lesotho, 1976). However, for the purposes of this paper, the discussion will analyse the Thaba Bosiu and Thaba Tseka Integrated Rural Development Projects.

Thaba-Bosiu integrated rural development

According to the Second Five Year Development Plan (1975/1976 to 1979/1980) the objectives of the Thaba-Bosiu Integrated Rural Development Project were:

(i) To control erosion and increase crop production within the existing social system.
(ii) To transform land use that integrated farming, that is, combining appropriate crop rotation with livestock production can be achieved.
(iii) To provide a more assured subsistence and to increase considerably the income derived from crops and livestock.
(iv) To provide data for the preparation of similar rural development projects in other areas.

The Second Plan indicates that these broad objectives were implemented through dry-land crop production, soil conservation, livestock production and asparagus production and canning. Asparagus cultivation at the Thaba-Bosiu Integrated Rural Development Project was linked with the establishment of a processing cannery in the project area in the year 1975 (Kingdom of Lesotho, 1976). However, a bigger cannery (agribusiness), Basotho Fruits and Vegetable Canners, was established in Masianokeng in 1976 through the assistance of Del Monile Cooperation from Germany, the United Nations Development Programme and Food and Agriculture Organisation (Khati, 1984). The processed asparagus was exported to the European Union, especially to West Germany. Once again, there is some evidence that agricultural production was associated with rural development.

Thaba-Tseka integrated rural development project

According to the Second Five Year Development Plan (1975/1976 to 1979/1980), even though Thaba-Tseka Project was established as a decentralisation process in

Lesotho, the project improved the lives of the rural people in the mountains. As a result, there was an improvement in animal husbandry and crop production. As stated by Wallman (1976), the mountain areas are mostly suitable for livestock production. Therefore, some development of low-cost techniques for producing and improving forage was very important for improved livestock. An improvement in animal husbandry was seen especially in dairy farming and in wool and mohair marketing (Kingdom of Lesotho, 1976). There was also the establishment of some non-farm rural industries, such as handicraft centres for processing raw materials from wool and mohair production (Kingdom of Lesotho, 1976). As a way of ensuring communication between the project area and the market area for the supply of raw materials and other businesses, a road was constructed linking the project area with the lowlands, especially with Maseru.

Agricultural credit institutions

During the Second Five Year Development Plan, the Lesotho government established credit schemes to encourage improvement in input use in mechanisation; contribute to the adoption of new higher-yielding crops; higher quality breeds of animals; and more efficient methods of farm management and marketing (Kingdom of Lesotho, 1976). The plan highlights the involvement of credit institutions including: forty-eight credit unions; twenty-seven thrift societies; three banks; three area-based projects; and four other institutions (Kingdom of Lesotho, 1976). However, the discussion will be limited to the credit schemes. First, the Agricultural Development Fund provided short-term loans (3-5 years) to farmers; furthermore, channelling credit to some farmers through the Government Extension Service. In addition to providing loans to farmers, the Agricultural Development Fund also supervised farmers using their credit. Second, Co-op Lesotho was established in 1974 to market crops produced in Lesotho (Moody, 1976). Co-op Lesotho provided agricultural credit to members (farmers and cooperatives saving with it), in the form of farm inputs and marketing (Kingdom of Lesotho, 1976). Other credit institutions included Credit Union Cooperatives and Project Credit Revolving Funds which were established to provide credit to farmers in the area-based, integrated rural development projects.

Although different programmes and institutions were established to facilitate rural development process during the Second Five Year Development Plan, there were many challenges in implementing such programmes. Most of the integrated rural development projects in the country received funding from external sources. The main funding agencies were the World Bank, the Food and Agriculture Organisation and other bilateral institutions. However, most of the donor funded rural development projects lacked sustainability and as a result collapsed, due to a number of reasons.

First, as stated by Walton (1978), a lack of community participation in development projects is considered the major hindrance to meaningful development. As pointed out by the author, rural development projects in Lesotho lacked consultation. This is because delegates from donor institutions met with government officials to decide on what could be done to improve the lives of the rural poor, but the affected people were not included. Therefore, many of these projects lacked popular support at local level. For example, according to the FAO (1977) many farmers in the Mohale's Hoek District where the Senqu River Valley project was established and implemented did not know about it. However, the FAO (1977) argued that some farmers acknowledged the benefits brought by the Senqu River Valley Project, such as the introduction of fertilisers and consolidated block farming. Another integrated rural development project that demonstrated the lack of farmers' participation in the decision- making process was the Thaba-Tseka agricultural project concerned with cash cropping. As stated by Ferguson (1994) the local farmers did not need cash crops, such as wheat and peas; instead, they needed the provision of social services, such as water, health and other services.

Second, according to the FAO (1977) most of the rural development projects introduced by the foreign lending agencies advocated consolidated block farming. The report by the Food and Agriculture Organisation states that this practice worked effectively in some rural development projects, but it introduced problems to others. This is because some activities, such as harvesting and weeding needed communal labour, especially in block farming. Moreover, some people were reluctant to work because they did not like farm work (FAO, 1977) and this created a burden or too much work for those who liked farming. This shows that some farmers were free riders, taking advantage of the situation.

Although there were some challenges facing rural development initiatives during the Second Five Year Development Plan, the Third Five Year Development Plan emphasized a move towards self-sufficiency in basic foodstuffs for food security and processing by agro-industries (Kingdom of Lesotho, 1981). In order to achieve the objective of ensuring food self-sufficiency and the supply of raw materials to agro-industries, the government introduced an agricultural project called Food-grain Self-Sufficiency Programme. The project received funding from China and specialised in the production of wheat and maize (Morakeng, 1984).

In order to enable the processing of wheat and maize produced under the auspices of the Food-grain Self-Sufficiency Programme, the Lesotho government established the Lesotho Flour Mill in 1979, with a silo complex for storage purposes (Kingdom of Lesotho, 1981). The Third Plan addresses the purpose of the flour mill which was to make Lesotho "self-reliant in wheat flour and bran processing, create local value added, and a link to the programmes of accelerating domestic wheat production" (Kingdom of Lesotho, 1981:170).

An idea of establishing, upgrading and extending activities of the existing agro-industries was considered during the Fourth Five Year Development Plans (Kingdom of Lesotho, 1987). This was in particular reference to the National Abattoir and Feedlot Complex. As stated by the Fourth Plan, the objectives of agro-industries resemble those of the industrial sector as a whole; the generation of growth and employment. The plan further states that the activities of the existing agro-industry (Basotho Fruits and Vegetable Canners) were to be extended to some other places. In addition, the National Abattoir and Feedlot Complex was to encompass other activities, such as a meat deboning factory, a meat packing and processing plant and a pig slaughter facility (Kingdom of Lesotho, 1987). However, these developments did not take place because of a number of financial constraints.

The financial constraints that hindered implementation of some rural development strategies during the Fourth Five Year Development Plan could be linked to the macroeconomic frameworks that the Lesotho government introduced, mainly stricter fiscal policy. The Fifth plan states that "fiscal policy has the aim of increasing the flow of resources to the government sector for financing development expenditures and providing infrastructure that in turn should generate more growth" (Kingdom of Lesotho, 1992:43). Fiscal policy in Lesotho considered some of the macro-economic problems, such as the budget deficit that hampered development. In order to solve the macro-economic problems, the Lesotho government adopted the Structural Adjustment Programmes in 1988, while enhanced Structural Adjustment Programmes were adopted in 1989/1990 and 1990/1991 (Matlosa, 1991).

The plan states that during the reforms, the government was able to reduce the fiscal deficits from 17.4% of the Gross Domestic Product in the fiscal year 1988/1989 to a projected 2.2% of the Gross Domestic Product in 1990/1991 (Kingdom of Lesotho, 1992). The major reforms were undertaken especially in agriculture, health, education and other sectors of the economy. According to Matlosa (1991), the privatisation of state institutions was implemented in the early 1990s. This resulted in the privatisation of some state institutions, such as Co-op Lesotho (Kingdom of Lesotho, 1992). The plan states that Co-op Lesotho was performing under its capacity; therefore, it had to be sold out. It is also stated that these credit and financial institutions were inefficient (Kingdom of Lesotho, 1992).

The impact of macro-economic reforms on rural development

The impact of the macro-economic reforms in Lesotho was still felt in the decades that followed the 1980s, and the main sector affected was agriculture. The Lesotho government stopped providing agricultural programmes and institutions with subsidies. The agricultural development programme that was affected most was the Food Self-Sufficiency Programme that government stopped supporting, as well as its Technical Operations Unit (Makenete et al., 1997). As a result, the programme collapsed. Another example is that of Co-op Lesotho that experienced the state's withdrawal of agricultural subsidies (Makenete et al., 1997), leading to its closure in the early 1990s. The implication of this is low agricultural productivity leading to food insecurity. In this regard, one can argue that reduction/withdrawal of government expenditure on agriculture resulted in food shortage. As a result, the country is too dependent on food donations/aid sourced from other countries.

Although the impact of macro-economic reforms, especially reduction of agricultural subsidies to small-holder farmers can be cited as the major contributing factor to food insecurity, agriculture in Lesotho is confronted with different impediments.

Factors affecting agricultural productivity/production in recent years

It should be noted from the previous discussion that rural development in Lesotho has centred on improving agricultural production through the use of modern agricultral inputs. However, research on the country reveals that the total land area of the country is 30 355 square kilometres, of which 75% is mountainous, while only 9% is suitable for cultivation (Sebotsa and Lues, 2010; Morojele, 2012). Even though about 85% of Basotho households are in the rural areas, and 70% of them make a living from agriculture (Central Bank of Lesotho, 2003), productivity in agriculture has been in decline for the past few decades because of different factors. First, soil erosion is cited as the major factor that results in low agricultural production. It is argued by Wellings (1986) and Mbata (2001) that the arable land is situated in the lowlands, but the soils are thin, infertile and prone to erosion. As a result, the contribution of agriculture to the Gross Domestic Product has been in decline for a number of years. For example, in the 1980s the contribution of agriculture to the Gross Domestic Product fluctuated between 20 and 26%, and in 1991 it declined to 13.9% (Selinyane, 1997; Johnston, 1996; McCann, 1999; Central Bank of Lesotho, 2003). Evidence further shows that from 1991 even the small manufacturing sector contributed more to the Gross Domestic Product than agriculture which is the sector employing the largest proportion of the labour force, according to official statistics (Central Bank of Lesotho, 1997). Furthermore, self-sufficiency in the major staples, such as maize and wheat fluctuated between the 1980s and 1990s. For example, maize production declined from 50 to 40%, while wheat declined from 50 to 15% (Ministry of Economic Planning, 1997).

The downturn in food production resulted in food insecurity in the country, affecting mostly the poor, women and other vulnerable groups. In this regard, vulnerability estimates a nation-wide food deficit ranging from 10 to 47% of the total access to food (Sebotsa and Lues, 2010). Thus, food aid from countries, such as the United States of America and Japan and food imports from South Africa are used to ensure food availability in the country (Makenete et al., 1998; Mbata, 2001).

Second, the traditional land tenure system is cited as another factor resulting in the decline in agricultural productivity. As argued by Wellings (1986) and Makoa (1999), the communal land tenure system is often associated with the mismanagement of land, especially through soil erosion and the destruction of vegetation. It is further indicated that the communal land tenure system in Lesotho discourages long-term investment in the land, especially for soil conservation (Mbata, 2001). It is also observed that farmers in the traditional land tenure system are not granted loans by commercial banks because of the risks involved. As a result, there is poor access to credit, inputs, extension services and marketing structures to farmers (Wellings, 1986).

Third, high population growth increases the demand for settlements on agricultural land. It is stated by Omole (2003) that the population growth in Lesotho is estimated at 2.6% per annum. Therefore, population pressure has resulted in landlessness estimated at about 60% in the year 2000 compared to 22% in 1980 (Omole, 2003). In addition, the increasing fragmentation of landholdings and the rising level of landlessness are associated with high population pressure (Wellings, 1986).

The research on Lesotho further associates existing non-development in the rural areas to labour migration (Wallman, 1972). This is because the migration of the active labour force from the rural areas of Lesotho to South African mines causes a decline in agricultural production (Cadribo, 1987; Ulicki and Crush, 2007), as well as the failure of some rural development projects (Wallman, 1972). This situation occurs because agriculture is left in the hands of old and young people (Wallman, 1972; Cadribo, 1987). However, more recent studies show that South African Gold mines have been shedding more jobs (Central Bank of Lesotho and Bureau of Statistics, 1995; Marais, 2013) starting from the 1990s, and this has coincided with downsizing in the public sector due to the adoption of Structural Adjustment Programmes by the Lesotho government in 1991 (Matlosa, 1991). Therefore, the challenge that faces Lesotho is to absorb a high number of retrenchees from the South African Gold mines, together with people who were retrenched from the public sector because of downsizing. At the same time, food security to food insecure households has to be ensured (Mbata, 2001; Sebotsa and Lues, 2010).

CONCLUSION

Lesotho is faced with many development challenges, mainly poverty and food insecurity. It is expected that the introduction of the Green Revolution technologies by the Lesotho government after independence would have increased food production. The Lesotho government worked together with some international organizations to ensure food security. The development aid played an imperative role in this regard. For instance, the Lesotho government benefitted greatly from donor agencies such as FAO, the World Bank and some bilateral institutions to increase food production. Many of these donor rural development programmes are discussed in this research paper. However, many of them collapsed after the project's life circle, while others were less supported by the local communities. Many of these agricultural development programmes were initiated by the government and donors for the local people. They lacked participation on the part of the beneficiaries during the planning stage. As a result, many of them collapsed. The clear example is that of the Senqu River Valley agricultural project that faced resentment from the young people because many of them were not interested in farming but working in the South African mines. Some other factors that affected agricultural production in Lesotho include severe droughts, soil erosion and encroachment of arable land by settlements.

The decline in agricultural productivity/production in Lesotho has forced many Basotho men to migrate into South Africa in search of employment in the mines, plantations and industries to supplement meagre agricultural incomes. The migrant labourer remittances are also used to purchase the agricultural inputs to improve subsistence farming. However, recent studies show that the number of Basotho men working as migrant labourers in the South African goldmines has declined drastically over the years. And this has affected subsistence farming severely. The decline in migrant labourer incomes also suggests that, the incidence of poverty has increased among the households that depended on such incomes for making a living. The prevailing food insecurity has forced the Prime Minister to declare the state of emergency on food insecurity in 2012 and pleaded with the outside world to assist with food donations/hand-outs.

In the light of the above, this research paper recommends the implementation of the programmes and policies that can increase food production. First, that the land tenure system in Lesotho should be revisited. Land ownership in Lesotho is based on inheritance, and many farmers who lack resources engage in subsistence farming. Lack of resources by many farmers resulted in many fields or land remaining fallow for many years. In this respect, land should be redistributed to capable farmers who have resources and capital. The traditional land tenure system should be replaced with private leasehold tenure with the hope to promote small-scale commercial farming. Second, farmers should be encouraged to diversify their crops, they should cultivate both subsistence and cash crops. In this regard, asparagus production should be revived, and other cash crops that are suitable for the agro-climatic conditions of Lesotho should be introduced. Third, irrigation projects should be resuscitated and irrigation farming be promoted throughout whole country. Most of the government and donor funded agricultural rural development projects used irrigation facilities. However, with the collapse of such projects, farming in Lesotho depends on unreliable rainfall, and during the dry seasons food production declines drastically.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Physiological maturity of pumpkin seeds

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The objective of this study was to evaluate the physiological changes of pumpkin seeds during the maturation process. Thereby, the study was conducted in the municipality of Juazeiro, at the experimental area of the State University of Bahia. Seeds of the cultivar 'Maranhão' were harvested from fruits at regular intervals, every 10 days, from 15 to 60 days after anthesis (DAA). The experimental design was completely randomized with six treatments (15, 25, 30, 40, 50 and 60 DAA) and four repetitions. For each period, the fruits were assessed visually and average weights were determined, and the seeds extracted from fruits were evaluated for the following tests: moisture content, dry matter of the seeds, germination, electrical conductivity, field emergence, emergence speed index. The seeds reached physiological maturity at 50 days after anthesis, although the best time to begin harvesting fruit of this cultivar is between 50 to 60 DAA. At this time the seeds moisture content is low enough to allow the harvest.

Key words: Germination, harvest, seed quality.

INTRODUCTION

In vegetable seeds production must ensure maximum quality and it should be as or more intense than other crop seeds, specially, because of the unit cost of the some of these species is high and there is a provided economic return.

In the latter case, it is important to remember that, in recent years, the cost and productive advantages, qualitative and quantitative of the hybrids have played an important role in development of the agricultural sector. Therefore, hybrid seeds are usually more expensive than other types of seeds because hybrid seeds production involves more advanced technology and as well as more laborious work and thus, it requires the best physical, physiological and sanitary quality as well as maximizing its use. Thereby, it is of great importance to determine the best time to harvest seeds, but also the best storage conditions which will make them last longer.

Considering that, when harvested, the seeds are detached from the mother plant, which until that time was their natural environment. After harvesting, men are responsible for the tasks of conserving the seeds in the best conditions throughout time. However, seed storage starts before the harvesting operation when the seeds have reached their point of physiological maturity (Costa et al., 2006). Harvesting fruit for the purpose of seed extraction in cucurbits is normally done when the fruits

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Table 1. Meteorological data of the area during the experiment.

Year	Month	RH average (%)	Temperature (°C)	Precipitation (mm)
2012	December	62.4	26.5	187.2
2013	January	58.1	28.3	55.4
2013	February	56.4	29.1	51.3
2013	March	71.5	27.8	153.0

are ripe, however, it can be performed even before complete maturation, and followed by post-harvest storage (Bisognin et al., 1999). Therefore, it is of fundamental importance to determine the best time to harvest the fruits combined with the post-harvest storage for obtaining seeds of high physiological quality. The post-harvest fruit storage is related to the fact that the seeds continue to ripe if they have not completed their maturity in the field, reaching maximum levels of germination and vigor (Morocco et al., 2011).

Research findings with other cucurbits indicated different behaviors regarding optimal harvest time and post-harvest storage. The most positive on germination and vigor were obtained when the fruits harvests were done early for pumpkin cv. 'Menina Brasileira' (Morocco et al., 2011), and for Italian squash (Alvarenga et al., 1991).

For cucurbits, which have fleshy fruits, the difficulty is to know the time when their seeds reach the point of maximum physiological quality. For this family the process of seed maturation continues after harvest, reaching maximum levels of germination and vigor after undergoing a rest period, which varies among different species (Vidigal et al., 2006; Dias et al., 2006). Therefore, the objective of this work was to determine the physiological maturity of seeds of pumpkin.

MATERIALS AND METHODS

The experiment was conducted in the experimental field of vegetables at the Department of Technology and Science of the University of the State of Bahia/ UNEB, situated in Juazeiro-BA during the period December 2012 to March 2013. Seeds of pumpkin cv. Maranhão were used. The soil of the experimental area soil classified as Vertisol and soil samples were collected and sent for chemical analysis to the Laboratory of Soils Analysis of the UNEB and the results obtained were as follows: pH in water = 6.5; P = 69.64 mg.dm^{-3}; K = 0.34 cmolc.dm^{-3}; Ca = 6.4 cmolc.dm^{-3}, Na = 0.06 cmolc.dm^{-3} and Mg = 1.1 cmolc.dm^{-3}. The municipality of Juazeiro is located at 09°24' latitude and 40°30' longitude WGR, and an altitude of 368 m. The climate is semi arid according to Koppen classification. The meteorological data of the area, collected during conduction of the experiments are shown in Table 1.

In tillage practices were performed plowing and disking followed by farrowing and plant fertilization was performed according to the recommendations of the results of soil analysis (Cavalcanti, 1998). Irrigation water was applied once daily, using drip emitters with 1.8 L.h^{-1}. Pumpkin seeds sowing was carried out with the cultivar 'Maranhão' using polystyrene trays containing 128 cells filled with Plantmax© commercial substrate. At 12 days after sowing, the transplanting of seedlings was performed (when the plants have two true leaves). The seedlings were planted at a spacing of 2.0 m x 1.0 m. Other agronomical practices were performed based on the crop needs for optimal production (Filgueira, 2008). The crop cycle was checked daily for monitoring plant growth. The flowers were tagged with colored ribbons on the day of anthesis and their fruits were harvested in accordance with pre-established ages.

Immediately after harvest, the fruits were sent to the Laboratory Storage of Agricultural Products, and kept for 10, 20 and 30 days at room temperature around 28°C. After this period, the seeds were removed and then placed to determine the moisture content and dry mass. The seeds were washed and subjected to disinfection with sodium hypochlorite solution of 1% for three minutes to eliminate contaminants, and placed to dry at room temperature (27 to 30°C) for 12 h in the laboratory (Kikut, 2005). Seed quality was evaluated by the following tests:

Moisture content: Was performed with four subsamples (and four replicates) of 0.5 g of seeds per treatment at 105 ± 3°C oven method for 24 h, according to the Rules for Seed Analysis - RAS (Brasil, 2009) and the results expressed in percentage.
Dry weight of seeds: Was determined in two subsamples of 30 seeds (and four replicates) based on the final outcome of the seeds after drying at 105 ± 3°C for 24 h (Brasil, 2009) and results were expressed in g.30^{-1} seeds.
Germination: Was performed using four subsamples of 50 seeds (and four replicates) that were sown in germitest paper towel rolls, moistened with an amount of water equivalent to 2.5 times the weight of dry paper and packed in transparent plastic bags and kept in a germination chamber at a temperature of 25°C. The evaluations were performed daily until the eighth day after sowing, determining the percentage of normal seedlings (Brasil, 2009).
Emergence speed index (ESI): Were performed using four subsamples of 50 seeds (and four replicates). The seeds were sown following the same procedure used for the germination test and the number of seedlings until the eighth day of sowing was counted daily.
Electrical conductivity: Was performed using four subsamples of 25 seeds (and four replicates). The seeds were weighed and placed in plastic cups to soak containing 75 ml of distilled water and kept in a BOD incubator for 4 h at 30°C (Torres et al., 1998). Readings were taken and the results expressed as μS.cm^{-1}.g^{-1} seed.
Field emergence of seedlings (EC): Four subsamples of 50 seeds (four replicates) were sown 0.5 cm deep in plastic trays containing washed and sterilized sand, moistened to 60% capacity retention. Trays were kept in a green house by a 70% of lighting and at an average temperature of 28°C. The number of emerged seedlings was counted daily until the eighth day (Maguire, 1962).
The experimental design was completely randomized with six treatments (15, 25, 30, 40, 50 and 60 DAA) and four replications. Statistical analysis was performed using the Sisvar software (2000). All variables were subjected to regression analysis and curve fitting based on the age of the fruits.

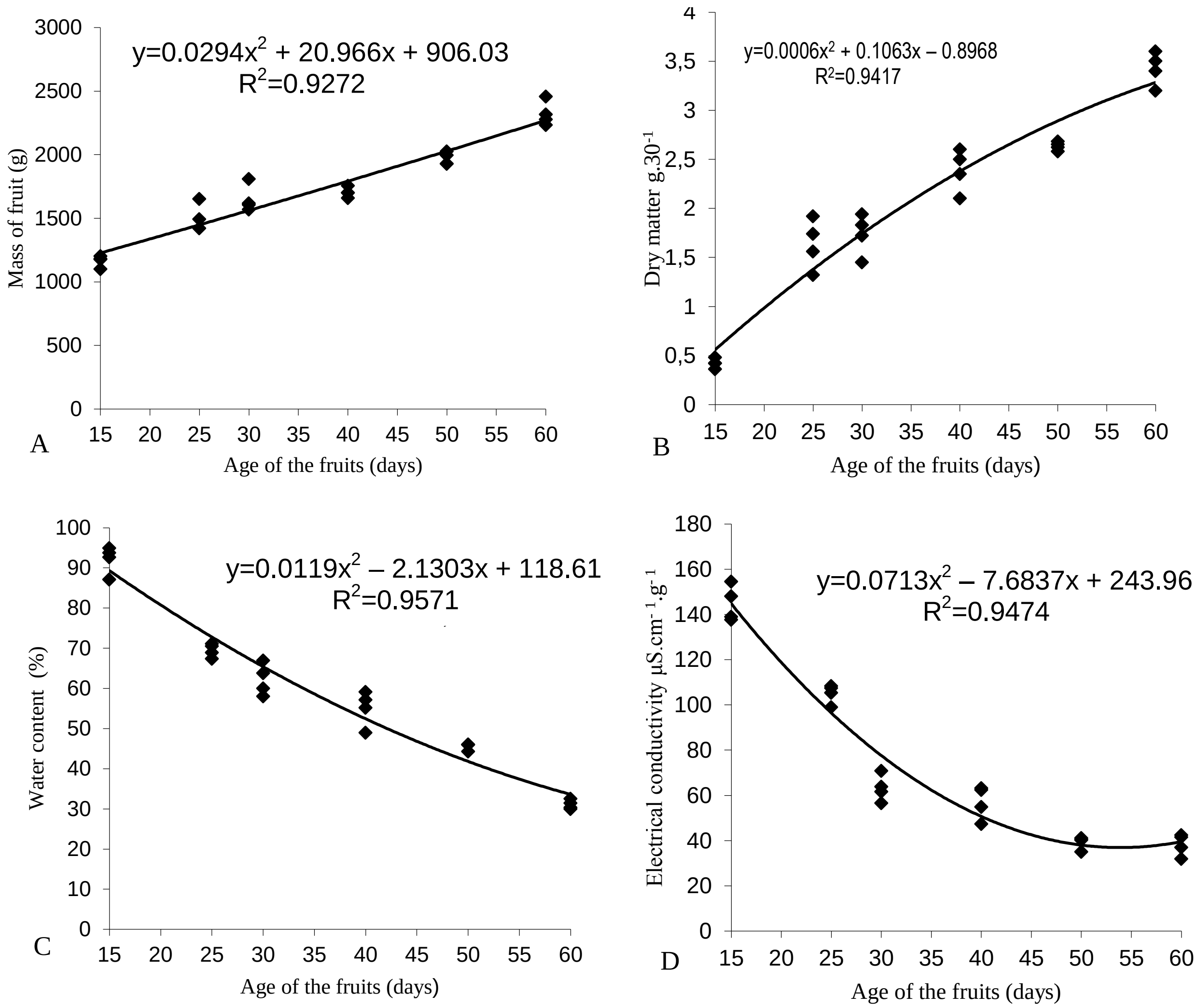

Figure 1. Mass of fruit. (A), Dry matter g.30^{-1} (B), % water content (C) and electrical conductivity µS.cm^{-1}.g^{-1}(D) of pumpkin seeds, cv. Maranhão, depending on the age of the fruit.

RESULTS AND DISCUSSION

The average fruit weight ranged from 1163.81 g at 15 days after anthesis (DAA) to 2319.65 g at 60 DAA, that is, increased gradually during the period of fruit development (Figure 1A). In early stages of fruit growth, the dry mass was small, having intensified from 30 DAA, during which an average increase of 18%. It was opposed to the final period, when the fruits showed a higher accumulation of dry weight, with an average increase of 57%.

According to Medeiros et al. (2010), the accelerated growth phase corresponds to the stage of predominant cell expansion and the stage of ripening. Similar behavior was observed in other cucurbits such as squash (Medeiros, 2006; Vidigal et al., 2007) watermelon (Grangeiro et al., 2005), and cantaloupe (Villanueva et al., 2000; Giehl et al., 2008) (Figure 1).

There was significant increase in dry weight of the pumpkin seeds, cv. Maranhão, from 15 to 60 days, which corresponded to the last harvesting of fruits (Figure 1B). The dry mass of the seeds is considered by many authors, one of the surest measures of seed maturity. The seed reaches physiological maturity when it reaches its maximum dry weight (Costa et al., 2006).

The early seed development is characterized by relatively slow dry mass accumulation (Figure 1B) as it is at this stage that dominated the division and cell expansion, responsible for setting up the appropriate structure for receiving the substances transferred from the mother plant. The next phase is characterized by the accumulation of dry mass that intensifies until it reaches its maximum, which occurs when the seeds still have relatively high water contents (Marcos Filho, 2005).

Accordingly, Costa et al. (2006) found in hybrid squash fruits that the seeds gain mass until 50 DAA, occurring

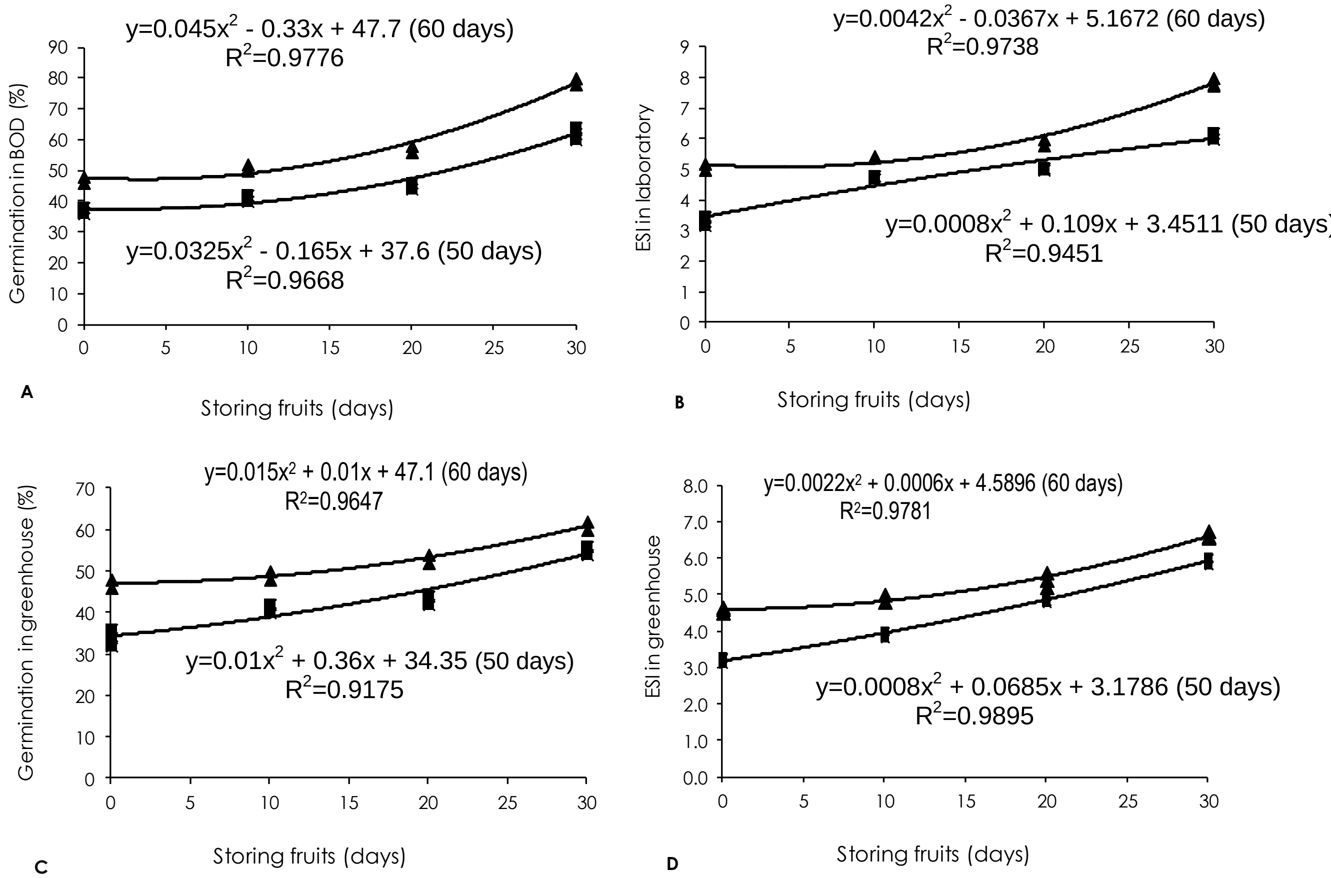

Figure 2. Germination (A and C) and Emergence Speed Index (ESI) (B and D) of pumpkin seeds, cv. 'Maranhão', depending on the storage of fruits after harvest at 50 (■) and 60 (▲) DAA, evaluated in BOD and greenhouse.

stabilization from this point.

The water content of seeds extracted from freshly harvested fruits decreased as age of the fruit increased. At 15 DAA the seeds showed average water content of 93.44% and at 60 DAA this number decreased to 30.54%. There was increased dehydration from 30 DAA, although the seeds have reached at the end of the observation period even with high water content. This may have occurred because they are fleshy fruits with high water content, which was also observed by other authors in Italian squash fruit (Alvarenga et al., 1991), pepper (Vidigal et al., 2009a,b) and tomato (Vidigal et al., 2006).

The seeds from fleshy fruits reach physiological maturity with high water content, tending to the stability, close to physiological maturity (Marcos Filho, 2005). In this kind of fruit, the seeds do not normally pass through the phase of fast dehydration, or suffer large fluctuations in its water content as a function of relative humidity (Dias, 2001). It occurs because of the constitution of fleshy fruit with thick flesh, maintaining high water content inside the fruit, as well as reducing the interference of increased relative humidity. According to Welbaum and Bradford (1988), although the water content of the seeds is used as an adequate indicator of physiological maturity, it is not a proper indicator of physiological maturity because of genetic and environmental influences. However, similar results were verified by Alvarenga et al. (1991), working with Italian pumpkin. Similarly, in squash cultivar 'menina brasileira', the water content observed at the end of the study period (at 60 DAA) was 50% and it was considered high (Morocco et al., 2011), confirming the results obtained to the fruits of pumpkin cv. Maranhão (Figure 2C).

According to Nakada et al. (2011) seeds were harvested at 30 days after anthesis had a water content around 70% and dry matter accumulation was still quite low (30%). Data corroborate those found for pumpkin cv Maranhão. The obtained values for electrical conductivity (Figure 1D) indicated that there was initially a large amount of leachate, but it decreases as increases days to harvest the fruit.

Electrical conductivity ranged from 144.72 $\mu S.cm^{-1}.g^{-1}$ at 15 DAA seeds to 38.12 $\mu S.cm^{-1}.g^{-1}$ at 60 DAA and remained decreasing, although with less intensity from 30 DAA, indicating that there is an organization and greater integrity of cell membranes during the fruit harvest. In tomato, the values of electrical conductivity (EC) observed for the seeds extracted from fruits harvested 60 DAA indicated that the seeds were already fully formed (Vidigal et al., 2006).

In cucumber, Nakada et al. (2008) obtained similar results in seeds harvested at 30 DAA, observing values of 71 $\mu S.cm^{-1}.g^{-1}$ at 30 and 16 DAA $\mu S.cm^{-1}.g^{-1}$ at 55 DAA. According to Medeiros et al. (2010), the values of electrical conductivity for gherkin fruits were high. The values ranged from 2321.57 $\mu S.cm^{-1}.g^{-1}$ at 15 DAA seeds to 1556.19 $\mu S.cm^{-1}.g^{-1}$ at 40 DAA. These results indicate that the seeds initially had lower physiological quality, releasing great amounts of leachate as a result of the low structure and selectivity of the membranes. Later, there was a reduction in the leaching of solutes due to the proper structuring of cell membranes with the approach of physiological maturation. These values can vary in larger or smaller intervals depending on the length of the vegetative cycle and cucurbit species studied.

Based on these results, it is recommended to harvest the pumpkin fruits cv. Maranhão, from 60 DAA, if they are not stored. However, when these data with those obtained in the germination rate and speed of seedling emergence in BOD and a greenhouse tests are compared, it appears that a period of 30 days is required for the fruits harvested from 60 DAA to have seeds with considerable germination.

In the present study it is possible that, after reaching the maximum dry weight, pumpkin seeds still needed an additional period of thirty days, to structuring and differentiation of their tissues and then to express their maximum germination potential, unlike what established by Popinigis (1985) stating that maximum germination is reached just before the seeds reach maximum dry matter.

In Figure 2 it can be seen that the storage of the fruits harvested at 60 DAA have similar trends with respect to results obtained in the BOD and greenhouse. Seed germination was increasing as the storage time was increased, but without damages in the fruits. This result is similar to that found by Costa et al. (2006) when stored fruits of squash hybrid. It is observed that the seeds stored in the fruits during 30 days and at 60 days after anthesis will get an increase of 25% germination in BOD conditions, in relation to 50 days.

Another point to be highlighted is the minimum difference of germination curves of Figure 2, increasing the difference between the result of the ESI in the BOD and greenhouse. Therefore, in BOD seed germinates faster and its percentage of germination is higher compared to the seeds placed in greenhouse.

Conclusions

Pumpkin fruits can be harvested at 60 DAA for obtaining seeds with maximum physiological quality. Pumpkin seeds reach physiological maturity in the period between 50 and 60 DAA, when they have the lowest water content and electrical conductivity practically stable. After harvest, the storage of fruits is essential to ensure seed quality and a period of 30 days is recommended.

Conflict of Interest

The authors have not declared any conflict of interest.

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