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Full Length Research Paper

Local Perspectives on Benefits of an Integrated Conservation and Development Project: The Annapurna Conservation Area in Nepal

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Integrated conservation and development projects (ICDPs) have recently been criticized for their ignorance of community heterogeneity, mismatch between project output and expectations, and lack of connection between conservation and development initiatives. Using Nepal's Annapurna Conservation Area Project (ACAP) as an example this paper examined how perceived benefits from one ICDP varied between stakeholder groups and how local resources were allocated. Data collection for this research was conducted through 96 interviews with three groups, that is, ICDP staff, local management committee members, and marginalized peoples. Results showed that the programs introduced by ACAP and their resource allocations were not perceived as having a fair and equitable impact across all households, community, and regions within the protected area. Moreover, there was a perceived discrepancy between ACAP allocation of resources in certain sectors, local residents' expectations from ACAP and outcomes of the funding, that is, conservation vs. tourism. Future research is suggested for collecting more data from additional residents, communities and with other ICDPs.

Key words: Annapurna Conservation Area, conservation, development, integrated conservation and development project, marginal groups.

INTRODUCTION

Within the framework of community-based conservation, the integrated conservation and development project (ICDP) has been adopted by various national and international organizations to achieve more sustainable and equitable governance of protected areas. These projects combine the dual agenda of conservation and development and are based on the basic assumption that local people are more likely to develop favorable attitudes

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toward conservation if their own livelihood needs have been met. Due to the need to reduce the pressure on natural resources development, options such as tourism, roads, and infrastructure are frequently offered as compensation for benefits restricted to local residents in protected areas (Hughes and Flintan 2001; Wells et al., 2004; Zinda et al., 2014).

When first initiated, ICDPs were considered a win-win situation for all due to their ability to combine three important aspects of sustainable development: biodiversity conservation, public participation, and economic development of the rural poor (McShane and Newby, 2004). As the popularity of ICDPs soared in the 1980s and 1990s, these projects were highly criticized. Although considered a better option to manage and oversee protected areas, biologists today have accused ICDPs of giving more priority to people and their well-being over conservation (Oates, 1999; Terborgh, 1999; Wilshusen et al., 2002). In their review of ICDPs, Hughes and Flintan (2001), observed how the construction of roads as a development initiative has resulted in land clearing and fragmentation, increases in migration, and illegal trade which has posed additional demands on natural resources. Past literature has also been critical toward ICDP's simplification and presentation of communities as spatial units comprised of a small population with shared norms and identities (Agrawal and Gibson, 1999; Bryant and Bailey, 1997; Gupte, 2004; Robbins, 2012). The issue of a heterogeneous community becomes even stronger in developing countries due to well-defined differences based on wealth, gender, caste, ethnicity, age, etc., which have implications for how natural resources are appropriated, used, regulated and controlled by various entities.

Power and authority largely determine patterns of nature-society interactions and control over benefits (Nightingale and Ojha, 2013). In the case of ICDPs, many protected areas in developing countries use tourism as a development strategy to benefit local people. But socio-economic pressures have led bigger trekking agencies and tourism entrepreneurs living outside the protected area to reap all the economic benefits, leaving the local communities in poverty (Karanth and Nepal, 2012; Spiteri and Nepal, 2008). In such cases, ICDPs not only reinforced the already existing socio-economic differences within a protected area but also heightened differences between different groups. Unequal distribution of benefits has also resulted in decreased support for conservation activities (Mbaiwa and Stronza, 2011; Robbins, 2012; Wells et al., 1992; Young, 2003).

This paper will examine the consequences of integrated conservation and development efforts in the Annapurna Conservation Area Project (ACAP). Launched in 1985, the ACAP represents one of the earliest ICDPs in the developing world (Baral et al., 2007; Wells, 1994). Researchers have highlighted the need to understand the relationships between different groups of people in a community to better understand natural resource use and implications for conservation (Waylen et al., 2013).

Understanding the perceived fairness of distribution of the costs and benefits of community-based conservation initiatives are necessary to understand the role and effectiveness of ICDPs (Sommerville et al., 2010). Therefore, this paper has two main objectives: 1) to identify the perceived benefits of one ICDP, from the perspectives of project staff, management committee members, and marginal household members (women, lower caste Dalits and poor) in the Annapurna Conservation Area (ACA); 2) to evaluate the distribution of resources, e.g., funding, programs and services to determine if they are pro-conservation or pro-development.

METHODS

Study Site: Annapurna Conservation Area (ACA)

Nepal established its first national park in Chitwan in 1976 in the southern subtropical region. This and the other national parks that followed were controlled centrally by the State and with support from Nepal's Army. The presence of army personnel, restrictions to customary rights of indigenous groups, and relocation of settlements from park grounds subsequent to park designation resulted in antagonistic local attitudes toward wildlife and park management (Nepal and Weber 1993). Therefore, when it was determined that the Annapurna region could potentially be a national park, an alternative model of conservation was sought in which resident communities would have a role to play in ensuring its long-term viability. The National Trust for Nature Conservation (NTNC), formerly known as the King Mahendra Trust for Nature Conservation, was established in 1982 as an autonomous NGO. This Trust was legally mandated to manage the ACA, an arrangement that was new to the country at that time, where a local NGO and not a State agency, was given the authority to manage conservation and development projects in such a large contiguous area (see Hough and Sherpa 1989 for more on ACA's inception). A pilot project, the Annapurna Conservation Area Project (ACAP), was launched in one Village Development Committee (VDC) in 1986, which was expanded to 16 VDCs in 1990. A VDC is the lowest political unit; each VDC usually consists of nine wards or sub-villages under it. After a four-year review of the project by the Department of National Parks and Wildlife Conservation, the ACA was officially designated as a conservation area in 1992. Currently ACAP manages 57 VDCs under seven-unit conservation offices (UCOs).

Adopting a decentralized decision-making structure, all of ACAP's programs are carried out through management committees that consist of local residents. The Conservation Area Management Committee (CAMC) is the local institution under ACAP required by the 1996 Conservation Area Management Regulation and legally recognized under the Conservation Area Management Act. The Act stated that each VDC within ACA should have one CAMC to manage all the conservation and development programs. Under the CAMC there are many different management subcommittees such as tourism management, drinking water, kerosene depot, school, health post, etc.

The ACA is the largest protected area of Nepal, situated in the north-central part of the country. This 7,629 km2 protected area is rich in biodiversity and is home to 1,233 plant species, 23 species of amphibians, 40 species of reptiles, 488 species of birds, and 102

Table 1. Sampling frame, size, gender, and interview length for interviewed groups.

Group	Sample size	Sampling frame	Gender		Avg. length of interview)
			Male	Female	
ACAP staff	8	Entire ACAP staff	8	0	45 min
Management committee	44	Membership list obtained from ACAP	19	25	45 min
Marginal group	44	Household list obtained from the VDC office	15	29	30 min

species of mammals (NTNC 2009). It is home to roughly 120,000 people belonging to diverse ethnic, cultural, and linguistic groups (NTNC, 2009). Gurung is the dominant ethnic group followed by Thakali, Bhotia, Magar, Brahmin, Chhetri, Kami, Damai and Sarki; the latter three are collectively referred to as the untouchables or Dalits. ACA is a popular tourist destination, visited by more than 60% of the country's trekkers; therefore, tourism is an important source of income for residents living on popular trekking routes. Households away from the main trekking routes depend on subsistence agriculture, livestock herding and overseas remittances. Ghandruk's VDC was selected as a case study since ACAP has invested a lot of time and money in the region. Ghandruk is a popular tourism hotspot not only for international but national tourists as well. Ghandruk is situated at 2000 m above the Modi River on a south-facing slope, and offers magnificent views of mountains like Annapurna South, Machhapurchre, Hiuchuli, and Gangapurna. The VDC consists of 945 households with a population of 5080, out of which approximately half are men and half women; 48% of the residents are Gurungs, 30% Dalits, 13% Brahmins/Chhetris, and others.

Data collection

Data were collected during field work conducted between August and October 2010, using semi-structured interviews with ACAP staff, management committee members, and marginal peoples, hereinafter referred to as the management group and marginal group respectively. Using purposive sampling, 44 members of five different management committees were chosen for interviews. These committees were: conservation area management committee (CAMC), tourism management subcommittee (TMSC), electricity management subcommittee (EMSC), *Mul Ama Samuha* (Main Mothers Group; MAS) and *Ward Ama Samuha* (Ward Mothers Group; WAS). The 44 individuals were chosen to include members in leadership positions and any marginal individuals present in management committees. Although an effort was made to ensure an equal number of individuals from each ward and each committee, it was not possible due to either the group being inactive (in the case of WAS), or in the majority of cases, due to the unavailability of its members (e.g., left the group or the village for better opportunities and their replacement had not been appointed).

The second subgroup consisted of 44 household members representing the marginal group. Participants were purposively chosen to include women, lower caste, and landless residents. The sample consisted of 15 males and 29 females. The number of women in the sample was higher for two reasons: first, gender was a criterion for choosing the sample; and second, in many marginal households the men had been involved in international labor migration to Middle Eastern countries and only women were available for interviews.

The same questionnaire was used for the management and marginal groups. The questionnaire consisted of both close and open-ended questions. The close-ended questions were used to measure socio-economic information about the respondents, e.g., age, caste, gender, birthplace, education, and occupation. The open-ended questions focused on people's perspectives on the benefits of ACAP, distribution of benefits, relationships with ACAP staff, role of ACAP in their area, expectations from, and future prospects of ACAP.

Informal conversations with many residents aided in providing insight to the themes that emerged from the interviews. Secondary data were also obtained from study of ACAP's management plan, budget, CAMC operation plan, Ghandruk UCO's annual report, etc. With respect to interviews with ACAP staff, these included the entire eight field staff present in Ghandruk. The staff were the officer in charge (OIC), six program officers representing specific sectors (that is, tourism, alternative energy, agriculture, natural resource management, environmental education, community development), and the accountant responsible for financial matters. Semi-structured interviews were also conducted with ACAP's director in Pokhara and the program officer for the mountain region at NTNC's headquarters in Kathmandu. The interviews consisted of open-ended questions that focused on topics related to the duties of the staff, specific program details, ACAP's mandates and priorities, local benefits and its distribution, sources of funding, ACAP's efforts to include marginal groups, rapport between project staff and local residents, and future prospects. Table 1 show more specific information on interview length, sample size and gender breakdown for each group. As the primary researcher in this study was from Nepal, all interviews were conducted in Nepali without the use of an interpreter. The interviews were recorded (with the consent of the participants), translated and transcribed. The transcript was coded using inductive coding to identify themes, and data were categorized according to these themes. To ensure accuracy during translation, quotes and words in Nepali were used followed by their translation in parentheses. Most respondents' quotes provided in the paper were kept anonymous.

RESULTS

Perceived benefits of ACAP

The results reported here are based on all 96 semi-structured interviews. ACAP staff, and the management and marginal group members were asked to identify the benefits that ACAP has delivered in the region. The groups differed in several areas in how they perceived these benefits (Table 2). These benefits are based on the groups' perception which may differ from on the ground facts, e.g., actual funds distributed. However, how they view their relationship with the stakeholder groups within the ACA is critical in the future relationship they have with ACAP.

All ACAP staff identified community involvement as a key benefit. Eight of the staff identified conservation as a

Table 2. Percentages for groups' perceived benefits of ACAP.

Variable	Management (%) n=44*	Marginal (%) n=44	Residents (%) n=88	ACAP staff (%) n=8
Conservation	86	20	53	100
Women's empowerment	11	2	7	0
Cleanliness	18	9	14	0
Development	25	20	23	0
Education	5	7	6	0
Vegetable farming	7	7	7	0
Community involvement	0	0	0	100
Institutional – field staff, efficiency, etc.	0	0	0	75
International recognition	0	0	0	38
No benefit	0	39	19	0

* Multiple responses were recorded per respondent.

benefit whereas six of them discussed the presence of field officers in villages and the opportunities they provide as a benefit. Some other factors such as transparency, the ease of getting work done as compared to government offices, and the international recognition that Ghandruk received because of ACAP were also mentioned as benefits.

The majority (86%) from the management group identified conservation as the primary benefit whereas only 20% from the marginal groups identified this benefit. In contrast to this, development was identified as a benefit by almost similar proportion of respondents from both subgroups (25% management and 20% marginal). Roughly 39% of the marginal group perceived no benefits from ACAP whatsoever. Further probes revealed that the marginal group did not have any knowledge about who had provided them with electricity, water, education and other development services. Eighteen percent of the management committee perceived the promotion of cleanliness as a benefit through clean-up programs and sanitation initiatives, for example, construction of toilets. Reflecting back on how it was before ACAP, an older woman from the management group said: "Before ACAP roads were filled with trash and human waste. We did not have toilets in the homes… Today our roads and village are clean. ACAP has shown us how to live a clean and healthy life, and because of the cleanliness tourists like coming to our village".

The empowerment of women and the formation of '*Ama Samuhas*' or mothers' group was also identified as an important benefit by some. However, these participants also blamed the political instability in the country and the Maoist war as a cause for the women's groups being inactive today. The Maoist movement is "based on a sense of injustice due to the way in which a social group is treated" (Murshed and Gates, 2005: 122). Because of the 1996 civil war, class struggles between different castes has intensified, each wanting greater domination of political and economic advantages. The Maoist movement aims to collect all castes and gender together to create a wholesome new Nepal. Maoists (majority of whom is lower caste) are raising their voices for equality of Dalits and declaring discrimination against castes as illegal.

Distribution of resources

Roughly 84% from the management group and 100% of the marginal group stated that the benefits of ACAP have not been equally distributed. Although the ACAP staff admitted to unequal distribution of benefits among groups and regions, they also discussed how indirectly conservation, water, electricity, cleanliness, health post, schools, etc., benefits everyone. A few staff members also discussed how the people of Ghandruk do not consider all these facilities to be benefits, and perceive only direct economic benefits as tangible. The ACAP staff indicated some frustrations as to how Ghandruk residents expect large-scale economic projects from ACAP and view these as the only tangible benefit that could make a difference in their livelihood. Tourism was seen as one highly visible and significant benefit. The ACAP staff also expressed disappointment in regards to the villagers' low attendance in events organized to introduce programs directed to the poorest of the poor, or other micro enterprises and empowerment initiatives, "They only come for programs that have money in it, or they come for the *bhatta* [daily stipend] they receive for attending trainings", observed a program officer.

Location

The distance from one's household location (sub-village or ward) to Ghandruk village proper (Ghandruk is both a VDC and a village unit) was perceived to be relevant (23% management, 20% marginal) to where programs were launched and who stood to benefit from them. Communities that were not part of the main village were not pleased because ACAP had done nothing for their wards. A woman from Ward 1 (the ward located at the beginning of the VDC) complained that ACAP had not done anything for her ward. She explained how she had asked ACAP staff many times for their support in opening a day care center in her ward, but she was told ACAP did not have the funds for such activities. When asked if ACAP had helped them with funding, she skeptically replied:

"A long time ago they had given a few farming-related trainings, but that was given to keep us quiet; all the bigger developments and benefits are always given to the above wards [main village]". The staff also admitted to unequal distribution of funding across the region. Since ACAP started the pilot project, its resources were mostly allocated to Ghandruk VDC during the first ten years of its operations. They agreed that even within Ghandruk VDC not all villages have equally benefited from its programs. For example, the main walking path to and through Ghandruk and beyond are well-developed and maintained on a regular basis, while the rest of the paths in the village are not very well-maintained and are almost impassable during the rainy seasons.

Hotel ownership

Roughly 50% of the management group and 36% of the marginal group reported how ACAP's benefits have mostly been targeted toward hotel owners. They complained that the hotel owners were reaping many benefits, and it was the poor farmers that were bearing the cost of conservation. For example, most of the marginal group perceived that the increase in forest cover and wildlife was negatively affecting their livelihood, farmland, and crops.

Several members of the tourism management committee agreed that to some extent hotel owners in Ghandruk had received more benefits than others during ACAP's formative years. They stated how ACAP had provided various trainings for hotel management (cooking, baking, housekeeping, etc.), and in communicating in English so they could better interact with the guests. The hotel owners admitted that they benefit more than the farmers; however, they indicated many farmers fail to take advantage of opportunities available to them. For example, a member of several different management committees who was also the owner of one of Ghandruk's bigger hotels stated:

"There is an option for the farmers and hotels to work together. People from the city bring eggs and vegetables and sell it to us at more than double the regular price. We have no choice and have to buy it because we need it for our hotel. If the local people here could supply that to us, it would benefit us and them both. But the farmers here do not want to do it." ACAP staff acknowledged that in the beginning all of ACAP's trainings and incentives were targeted at hotel owners. Alternative energy options like solar, back boiler, and improved stoves were also provided to these hotel owners at a subsidized rate to reduce the demand on fuelwood. But the same incentive did not work with farmers and other lower-caste residents primarily because not many were willing to adopt alternative energy technologies due to its installation cost and lack of awareness of the benefits from such technologies.

Committee membership

One third of the marginal group perceived the management group to be much better off as the primary recipients of ACAP benefits. Although 84% of the management group admitted that the distribution of benefits was not equal, all of them denied that they were getting more benefits than those not on a committee. One person responded angrily: "We are the ones who are spending so much of our time for the village, are not getting paid, and our own businesses and family life are suffering because of the time conflicts from attending meetings."

Community members' activism

According to 48% of the management and 16% of the marginal group, local residents who were very active and vocal in making their opinions known in village level public events and gatherings, were more capable of persuading ACAP to provide benefits favoring them. A management committee member stressed that ACAP is there for technical support and it was up to the villagers to take the initiative. According to him and a few others, if some regions are less developed than others, a part of it has to do with the people's own skills and actions more than ACAP. Only four people in the management committee stressed the need to look at the bigger picture and how, on the social scale, everyone has benefitted from ACAP. A member of the electricity committee responded: "If we have electricity we can use TV, phone, etc. Due to the presence of schools [in the village, and opened with ACAP support] our children have been able to learn...So I think overall everyone has benefitted, although direct financial benefits might be aimed at hotels".

Conservation or tourism

A common refrain echoed by the respondents in Ghandruk was that ACAP was good in the beginning but in the last ten years they have not done anything for the residents. The staff admitted that the number of programs in Ghandruk had decreased in the last ten years, but stated that ACAP was still investing in Ghandruk. The staff provided two reasons for the decline in programs: a decrease in funding, and the need to distribute funding to other areas. “ACAP’s main source of funding is the Nepalese Rupee; 2000/person (equivalent to approximately US $ 20.00) is collected as a tourist entry fee.” The staff noted that due to political instability, the number of tourists coming to ACA plunged since 1999 and reached a record low of 36,224 visitors in 2005. In 2006, the ten-year long Maoist insurgency ended with the overthrow of the monarchy and Nepal was declared a People’s Republic. Since then there has been a steady increase in the number of tourists entering the ACA. In 2010, the number of tourists reached an all-time high of 88,000, and recently it stands at a little over 100,000 (MoCTCA, 2014).

The issue of tourist fees in Ghandruk was an important concern among the staff and management group. Twenty-three percent of the management group stated that they had no knowledge of how ACAP used tourist fees, and complained that ACAP was not investing any money in Ghandruk. A hotel owner, who also happened to be a member of the tourism management subcommittee, stated: “My friend works in the trekking agency; he said that last year, in one group he brought 54 Koreans; 54 times 2000 is 108,000 for just one group. So you can imagine how much they [ACAP] make in one year.” A staff familiar with the budget explained how the entry fees collected from tourists first goes to NTNC and the NGO distributes it to ACAP in the form of a yearly budget. On the other hand, reductions in funding from the tourist entry fees was an issue the staff identified as being problematic. Distribution of the revenue generated through tourist entry fees can be challenging. ACA is divided into seven Unit Conservation Offices (UCO) which consists of 57 VDCs, all of whom demand a fair share. “For example, in 2009 only 31% of the budget allocated for the Ghandruk was used for Ghandruk VDCs, and the rest was for the other five VDCs in this UCO.” “According to the annual report for UCO Ghandruk (2009/2010), Ghandruk VDC spent 18% of its budget on conservation, 50% on development, 22% on empowerment, 6% on administration, and 4% on education. However, the distribution of the budget and the programs it financed was unknown to the residents of Ghandruk. Moreover, many stated that the sectoral allocation was somewhat arbitrary and not prioritized well.

The staff complained that Ghandruk residents did not understand that funds had to be distributed to those areas that needed it more than Ghandruk, since it was already well developed. “They think all the money should be spent on them only,” added a younger field staff. The primary reasons for the differences in allocation of resources are mostly due to the sectoral focus that ACAP had been following until 2009; the main focus areas in Ghandruk were on conservation and tourism, and, therefore, the majority of Ghandruk’s funding was spent on programs related to those sectors. Hence no clear determination could be made if funds were distributed to more conservation or tourism-related activities, although it seemed that funds were more readily available for tourism. A staff member further elaborated: “There are agriculture programs in Ghandruk, but the main focus in Ghandruk is tourism. In Lwang [another VDC] there is more emphasis on agriculture; so we are focusing on tea plantation there. Similarly, our focus on ACA’s upper regions is on heritage tourism because of the area’s rich cultural heritage.”

DISCUSSION

This paper set out to accomplish two main objectives: 1) to identify the perceived benefits of the Annapurna Conservation Area (ACA) ICDP from the perspectives of project staff, management committee members, and marginal peoples (women, lower caste Dalits and poor); 2) to evaluate the distribution of resources, e.g., funding, programs and services to determine if they are pro-conservation or pro-development. This study is important because it reinforced some of the strengths/weaknesses that have been identified about ICDPs but also sheds some light on some of the challenges researchers face in trying to assess how social, governmental and cultural structures, e.g., caste systems, impact communities so they can be empowered to develop entrepreneurial activities that can be sustained.

Views on benefits

ICDPs such as ACAP were launched with the belief that by providing basic community infrastructure development, alternatives to fuelwood, and economic opportunities for livelihood securities demand for natural resources would decrease and people would develop favorable attitudes toward conservation. To an extent, this was true for ACAP (Baral et al., 2007; NTNC, 2009; Wells, 1994). Today Ghandruk has development facilities (e.g., health posts, schools, day care centers, electricity, solar panels, clean drinking water, cable TV, cell phone towers, etc.) that most villages in Nepal are lacking. At the same time, conservation efforts have also been very successful as indicated by its relatively high quality of biological diversity and protection of many endangered species within its boundaries. Therefore, unlike other ICDPs (Brown, 2003; McShane and Newby, 2004), ACAP should be considered successful in achieving objectives of conservation and development.

The community perceived benefits differently by the various groups that were interviewed particularly, management and marginal groups. Our results are consistent with findings of other studies from ACA (Spiteri and Nepal, 2008) who found that perceptions of benefits differed greatly between households in villages on the main trail (more positive) than those off the main trail (less positive). Perhaps ACAP's staff in Ghandruk view benefits mostly through the institutional lens; the staff are ground-based functionaries whose job is to implement activities endorsed and mandated by the larger institution (that is, NTNC) for whom they work. That may be one reason why they recognize conservation, community involvement, international recognition, and institutional efficiency as the primary benefits. Members of the management group, on the other hand, recognize more visible and tangible local level benefits such as women's empowerment, cleanliness, and (infrastructure) development.

Only one-fifth of the marginal group members perceived conservation and development benefits, while 40% did not perceive benefits of any kind. There could be several explanations for such results. They indicate to deeply entrenched asymmetric power relations between ACAP staff, management and marginal groups (Dahal et al., 2014). The marginal groups belong to the lowest social hierarchies in Ghandruk and thus have not been able to have their voices heard in the public discourse. It also implies that ACAP needs to gain the trust of marginal groups and take extra efforts in communicating outreach activities targeted to those individuals. This finding is consistent with past research that has examined how development goals for indigenous communities to alleviate poverty, increase incomes, and empower local residents can be implemented if residents are able to adapt their livelihoods (Coria and Calfucura, 2012).

The portrayal of communities as homogeneous entities and lack of understanding of entrenched feudal socio-cultural and political norms in developing countries led many proponents of ICDP to assume that the benefits of ICDP programs and services would be equally distributed to those living in and around the protected area (Neumann, 1997; Wells et al., 2004). This historical situation makes it difficult to study complex communities because of existing attitudes and the time it will take for political and economic conditions to change. "But in reality, past projects have shown that the ICDPs are more beneficial for selected groups and there are many who do not benefit at all (Bajracharya et al. 2006; Robbins 2012; Spiteri and Nepal 2006; Wells et al. 2004)." In this study, the primary beneficiaries were those involved in tourism businesses (e.g., hotel owners and operators). While it made sense for ACAP to reach out to this group to encourage environmental stewardship, and usage of renewable energy and energy saving devices, it disenfranchised the poor, the landless, the women and others who expected equitable distribution of resources from ACAP. Other communities have experienced similar challenges with conservation strategies but biological and social data are expensive to obtain and monitor outcomes (Brooks et al., 2006).

ICDPs play a role in making some groups more powerful and marginalizing others, e.g., women, poor and landless, whether it is intentional or not. We further stress the fact that people's perceptions of a lack of economic benefit from natural resources can lead to negative attitude towards conservation and stifle any progress toward conservation; this has been shown to be the case in many protected areas around the world (Sommerville et al., 2010), and this study is no exception. If ICDPs are to engage local residents and help communities in the long term, stakeholders of every type will need to be more educated about day-to-day operations and local decision-making so current residents and the next generation will be more likely to have the skills to effectively manage its own future (Borman, 2008).

Resource allocations

A major source of conflict between the staff and Ghandruk residents was due to ACAP's financial uncertainty. The literature has many examples of ICDPs that have failed due to lack of adequate funding over time (Wells et al., 1992). ACAP's long term commitment in the region and adequate funding until now had been one of the reasons for its success (Baral et al., 2007; McShane and Newby, 2004; Wells et al., 1992). However, given the current political uncertainty, ACAP has experienced a drastic reduction in its funding and thus in its number of programs. Reductions in ACAP funds have created a situation where ACAP finds it difficult to meet local expectations. This has encouraged local residents to raise questions about ACAP's use of entry fees, its financial transparency, and even its legitimacy to operate in the region. Local residents are disappointed because they had become dependent on ACAP for trainings, development and other financial benefits. Expectations turn into disappointments if programs cannot be delivered. ACAP currently has empowered the CAMC to collect hotel taxes, money from tree permits and fines. However, the revenue generated from these funds is much less compared to the amount Ghandruk's residents are accustomed to through tourist entry fees. Therefore, project managers and NGOs need to be aware that in such cases many ICDPs, especially those that started out on a large scale, do not have the capacity to generate sufficient revenue to sustain their program costs as well as generate benefits for the community (Wells et al., 2004). It can be argued that 25 years is a long time for a project like ACAP to fulfill its goals. But if one considers the large geographic coverage of ACA, and sparsely populated villages distributed across long distances posing logistical challenges in delivering program support, it is perhaps appropriate to conclude that ACAP is spread too thin. Allocating resources equitably to all 57

VDCs is challenging and the situation can get worse if constituents feel ignored and demand attention. During the late 80s and early 90s, ACAP had focused the majority of its funding in Ghandruk, and as a result much progress was made winning accolades from around the world. For ICDPs, this view of resource allocation is nothing new. Similar issues of financial distribution of resources were seen in the Lupande project in Zambia where chiefs of different groups argued that their area should get more money because their area had more wildlife (Child and Dalal-Clayton, 2004). The literature illustrates that conservation and development projects have a political facet to them and are influenced by the power and interests that different actors have in these projects (Berkes, 2004; Bryant and Bailey, 1997). It appears ACAP has so far successfully taken a balanced approach to implementing conservation and development programs, but there is pressure locally for ACAP to deliver more tangible monetary benefits either through increased opportunities to participate directly in tourism or other programs that are likely to have more visible impacts in improving local livelihoods. The findings of this study and others suggest the apparent limitations of ICDPs and their involvement in tourism. While they are crucial in generating initial enthusiasm and local support, ICDPs have not been necessarily successful in offering a lasting solution to deep-rooted problems of poverty and unequal access to resources and economic opportunities. Past research has shown that nature tourism can have a positive effect on the poor and marginalized if significant money can be made and outside entities do not usurp the locals (Coria and Calfucura, 2012). These problems are complex and intertwined in the social, economic, ecological and political arenas in developing countries like Nepal. The study raises questions about what should development practitioners and local communities expect from an ICDP, and how these expectations should be managed.

ACAP's focus on tourism and the economic benefits villagers received from tourists affected the way people perceived benefits in Ghandruk. This view bolstered peoples' expectations to go beyond the project's capability, a trend common with many conservation and development projects (Ferguson, 1990; McShane and Newby, 2004). Although education infrastructure and health benefits such as schools, electricity, water, and sanitation were things in which everyone had equal access, these development initiatives were rarely perceived as a benefit by the majority of residents. Residents only viewed benefits positively if they produced individual monetary gains. If tourism and development activities can build capacity for local residents versus outside businesses, this outcome will contribute more to the economic and ecological aspects of the area and its people (Coria and Calfucura, 2012). ACAP's dependence on tourist entry fees may pose a problem in the future. Results showed that after 2006, the number of tourists in the ACA has steadily increased, and the tourist arrival numbers reached a record high in 2013. However, tourist arrivals are dependent on many factors including, but not limited to politics, economics, spread of diseases, terror attacks, natural disasters, etc. Thus, management and policy makers need to diversify the source of income and develop partnerships with government and other organizations to ensure future sustainability of the project and balancing this with protecting natural resources. As with other ICDPs who strive to be successful, the need to conserve resources and support local livelihoods is critical but the scientific rigor in making this assessment is missing in the literature (Bauch et al., 2014).

ACAP's programs depend solely on the number of tourists visiting the conservation area, which can also be problematic when issues of sustainability are key to attracting tourists to an area rich in biodiversity. ACAP needs to develop ways to understand how to integrate funding into internal sources through increasing agricultural productivity and promoting more small scale enterprises. An effective ICDP also needs partnerships between different organizations, NGOs, donors, and government as a way to pass on benefits local residents (McShane and Newby, 2004; Wells et al., 1992). Current research suggests more innovative ways to generate revenue for ICDPs by working with local governments through creative tax incentives and subsidies (Winkler, 2011). Previous research on sustainable development has shown that there is a need for a community to value the benefits of a managing agency in order for them to generate future support for conservation, tourism or other projects (Mbaiwa and Stronza, 2011; Songorwa, 1999; Thapa, 2013). Within Nepal, additional research should focus on comparing Ghandruk to other VDCs (all 57 if possible) that are less developed and those that ACAP is slowly investing in. It would also be beneficial to understand if differences in community members' attitudes towards ACAP and conservation differ within other VDCs now and in the future. For other ICDPs, future research should more thoroughly investigate the conservation-development dilemma using different methods beyond the simple win-win, win-lose situation that is often the case. As Miller et al. (2011) point out, there is a need to explore the conservation-development relationship as a system of trade-offs using multiple criteria and through various disciplines to provide a more in-depth analysis of approaches to understanding costs and benefits.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

In vitro conservation of exotic potato genotypes through different incubated temperatures, aerophilic and micro-aerophilic conditions

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The present study was carried out to study the *in vitro* conservation of potato genotypes at different temperatures and aerophilic and micro aerophilic conditions. A total of 31 genotypes were conserved at different incubated temperature ranging from 10 to 25°C. At lower temperature (10°C) plant growth was slowest as compared to plants incubated at high temperature (25°C). The results revealed that aerophilic condition was optimum for the growth of all potato genotypes. Data were collected on plant height, number of roots and number of nodes. Maximum plant height, highest number of roots and number of nodes were observed in all genotypes grown at 25°C. *In vitro* microareophillic condition of the plant growth was very slow but conservation was maximum. It was concluded from the present investigation that low temperature and micro-aerophilic condition is best for in vitro conservation of International Potato Center (CIP) germplasm which can increase the period between sub culturing.

Key words: *In vitro* conservation, genotype, sub-culturing, aerophilic.

INTRODUCTION

Potato (*Solanumtuberosum* L.) is the most important food crop throughout the world. In financial terms its ranked 4th in the world after wheat, rice and maize. In the world Pakistan is the 7th largest potato producing country (Afrasiab and Iqbal, 2010). Potato is exceedingly heterogenic plant and their germplasm cultivars are therefore needed to be kept up through vegetative propagation as clones, to monitor their hereditary trustworthiness. There are numerous reports on potato micro-propagation and protection that could be possible through in vitro and in situ process (Yousef et al., 2001; Badoni and Chauhan, 2009; Rahman et al., 2010). On-field conservation of potato germplasm through clonal propagation required a lot of time, space and labor. This additionally opens the plants to infections and bugs, and dangers of misfortune because ofabiotic anxieties and

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characteristic cataclysms. Along these lines, all through the world potato gene banks like to preserve parentalclones as in vitro producing micro-plants under ailment free tissue society conditions (Roca et al., 1989).Conservation of plant genetic resources is essential for food security and agro-biodiversity. Genetic diversity provides options to develop through selection and breeding of new and more productive crops, resistant to biological and environmental stresses (Nisar et al., 2011; Rao, 2004). For more food, it will be necessary to make better use of a broader range of genetic diversity across the globe. Many plant species are now in danger of becoming extinct (Panis and Lambardi, 2005). More than fifteen million hectares of tropical forests are vanished each year (Rao, 2004). Their preservation is essential for plant breeding programs. Biodiversity provides a source of compounds to the medical, food and crop protection industries (Panis and Lambardi, 2005). Genetically uniform modern varieties are being replaced with highly diverse local cultivars and landraces of traditional agro-ecosystems. Deforestation, urbanization, pollution, habitat destruction, fragmentation and degradation, spread of invasive alien species, climate change, changing life styles, globalization, market economies, over-grazing and changes in land-use pattern are contributing indirectly to the loss of diversity (Pitman and Jorgensen, 2002). These reductions are a threat for food security in the long term. Gene banks were established in many countries for conservation of plants (Rao, 2004). Advances in biotechnology, especially in the area of in vitro culture techniques and molecular biology provide some important tools for improved conservation and management of plant genetic resources (RamanathaRao and Riley, 1994; Withers, 1995). Conservation of plant genetic resources can be carried out either in the natural habitats (*in situ*) or outside (*ex situ*). *Ex situ* conservation is generally used to safeguard populations, in danger of destruction, replacement or deterioration. An approach to ex situ conservation includes methods like seed storage in seed banks, field gene banks, botanical gardens, DNA and pollen storage (Rao, 2004). Among these, seed storage is the most convenient method of long-term conservation for plant genetic resources.

In vitro conservation of genetic resources has got importance in recent years. Since, last 40 years, CIP has been contributed to developing tissue culture techniques for conserving potato germplasm (Withers et al., 1997).It is the most prominent and efficient way for distributing clonal materials. It ensures the availability of planting material any time and made possible the eradication of virus through meristem culture. Furthermore, in vitro conservation is less expensive as compared to preservation process (Maltaris et al., 2007).

Potato needsub-culturing after every 4 to 6 weeks, to extend the time of sub-culturing, growth retardants in blend with a less energy source, low temperatures and minimum light intensity may be utilized. Hence this part of biodiversity protection must be guaranteed through germplasm accumulations in gene banks where the local hereditary material must be secured and kept up for further utilize. Apropertechnique of potato germplasm storage is the material conservation in slow growth conditions (Sarkar and Naik, 1999). The principle of slow growth storage allows a safe use of in vitro culture without the disadvantages of frequent sub cultivation. The cultures can be observed while they grow and can be returned to normal multiplication subculture (Withers, 1991) and particularly useful for local varieties of potato (Kotkas, 2004; Ciobanuet al.,2011).

Present investigation was therefore, carried out to study the influence of temperature on in vitro conservation of 31 exotic genotypes and to find out the best temperature ranges for multiplication and conservation of potato germplasm. It is aimed that establishing the proper conditions for slow growth in potato will aid in preserving their germplasm for the purpose of later reintroduction and sustainable use.

MATERIALS AND METHODS

Plant materials

A total of 31CIP potato (*Solanum tuberosum L*.) variety was used for in vitro conservation through different incubating temperature 10, 16 and 25°C. For that, explants (1 to 2cm) were inoculated in MS media and incubated at different temperature 25, 16 and 10°C. Enhanced growth rate was observed in plants incubated at 25°C whereas, the slow growth rates were observed in plants incubated at 10°C.

In vitro conservation

To induce a shoot from explants and to cultivate cell in suspension various kind of media have been designed. For the sake of convenience, macro and micro nutrients necessary for plants growth were formerly combined in a definite proportion to form Murashige &Skoog MS (1962) media. One of the commonly used media for tissue culture was that developed by Murashige &Skoog for tobacco tissue culture. Both the over concentrated and poor concentrated media never show satisfactory result. For in vitro conservation,simple media was used without supplement of any plant growth regulators (PGRs) and agar is also added to solidified the media which provide support into the new explant. The previously multiplied explants were used as plant materials.

*In vitro*multiplication was carried out by culturing nodal segment of 31 CIP different genotypes. All the equipments (Forceps, Scalpels, Petri plates) were surface sterilized in an autoclave at 121°C temperature and 15 PSI Pressure for 1h. Under aseptic condition plantlets of the CIP genotypes were taken out in a sterile plate, with the help of sterile forceps. With the help of sterile scalpel, the rootsand leaves of these plantlets were removed and finally shoot part was cut into smallsegment, each segment having at least one node. Maintaining the proper polarity of the cut segment, and inoculated in the culture medium in test tubes (size 25×190 mm, containing 10ml of solidified media). After inoculation, explants cultures were incubated at three different temperatures 10, 16 and 25°C under the light of white fluorescent tubes for 3 weeks. And for the study of aerophilic (tubes covered with plugs) and micro aerophilic (tubes covered with tight Caps) study the explants culture were incubated at the same temperature, that is, 25˚C.

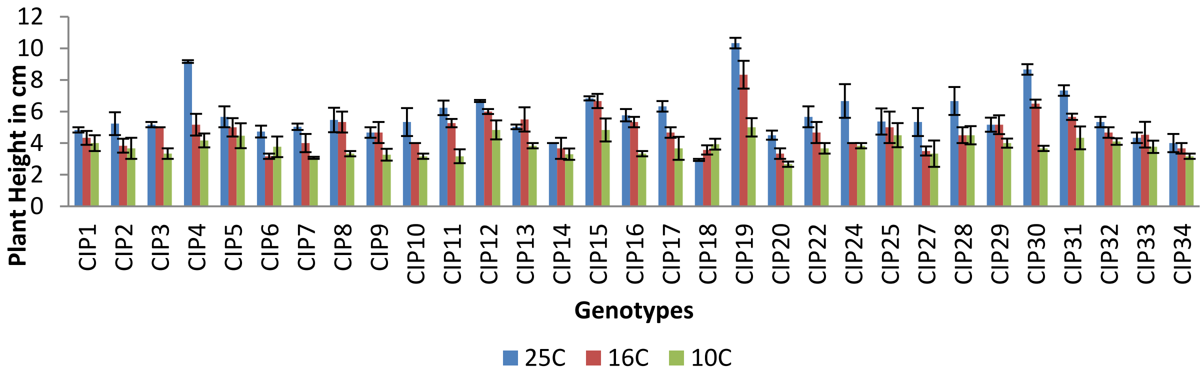
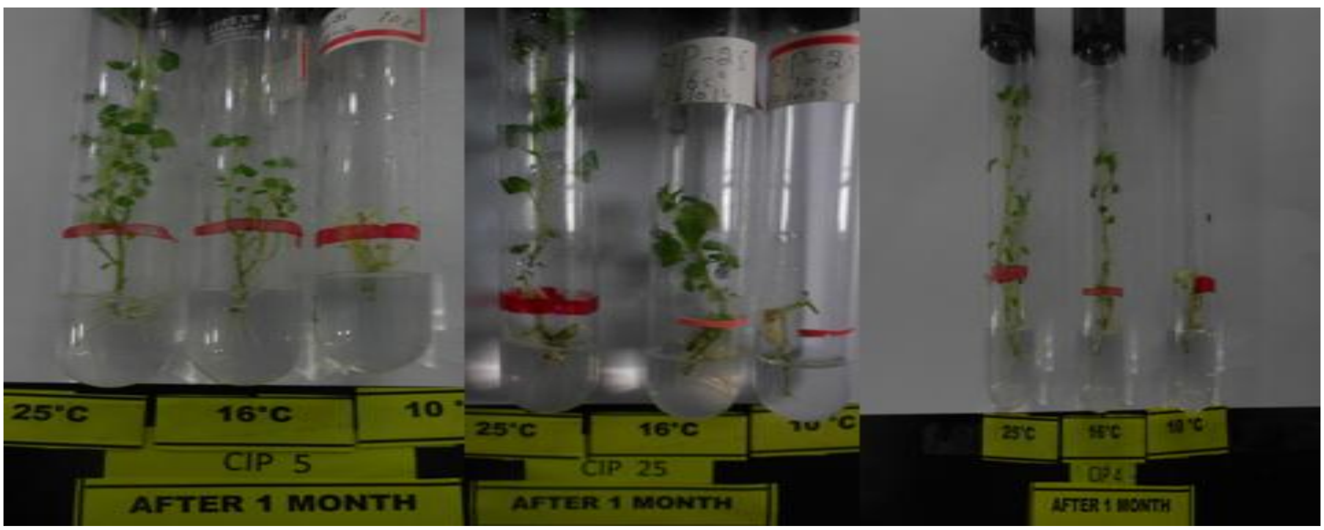


Figure 1. Plant height of 34-CIP potato germplasms grown at different temperature levels.



Picture 1. Plant height and number of nodes of 34-CIP potato germplasms at different temperature ranges.

Statistical analysis

All experiments were established in a completely randomized design. Experiments showing responsive treatments were repeated once. The data were recorded the length of plants and the number of nodes and root per plants with help of ruler and then plotted on the Excel sheet for measuring the mean value andstandard error value. The data were analyzed by descriptive statistics and both the mean andstandard values were used for graphs designing.

RESULTS AND DISCUSSION

In the present study influence of temperature on in vitro conservation of 31 exotic genotypes were examined and monitored for one month. Overall plant height and health were examined during experimentation period.

Plant height

The plant height was recorded visually with the aid of feet meter scale after four weeks. The results revealed that maximum plant height occurred in plants grown at 25°C. Maximum plant height was recorded in CIP 04 and CIP 19 genotypes. In contrast at 10°C, lowest plant height and growth was examined (Figure1andPicture1). Ourresult was also confirmed by Arrigoni-Blank et al. (2014) who reported that other than genotype, temperature effects on shoot height and shoot viability of sweet potato. Similar observation was reported by Boese and Huner (1990) that chlorophyll and carotenoid contents were twofold higher in 16°C than in 5°C leaves on a dry weight basis. It was also shown that the plant grown in lower temperature produced more thick leaves as compared to higher temperature, and is due to 1-4 fold increase in the mean length of palisade and spongy mesophll cell. Gopal et al. (2003) reported that slow-growth *in vitro* conservation of potato germplasm occur by decreasing propagated temperature. Similar report by Ranjbar and Khan (2012) showed that difference in plant

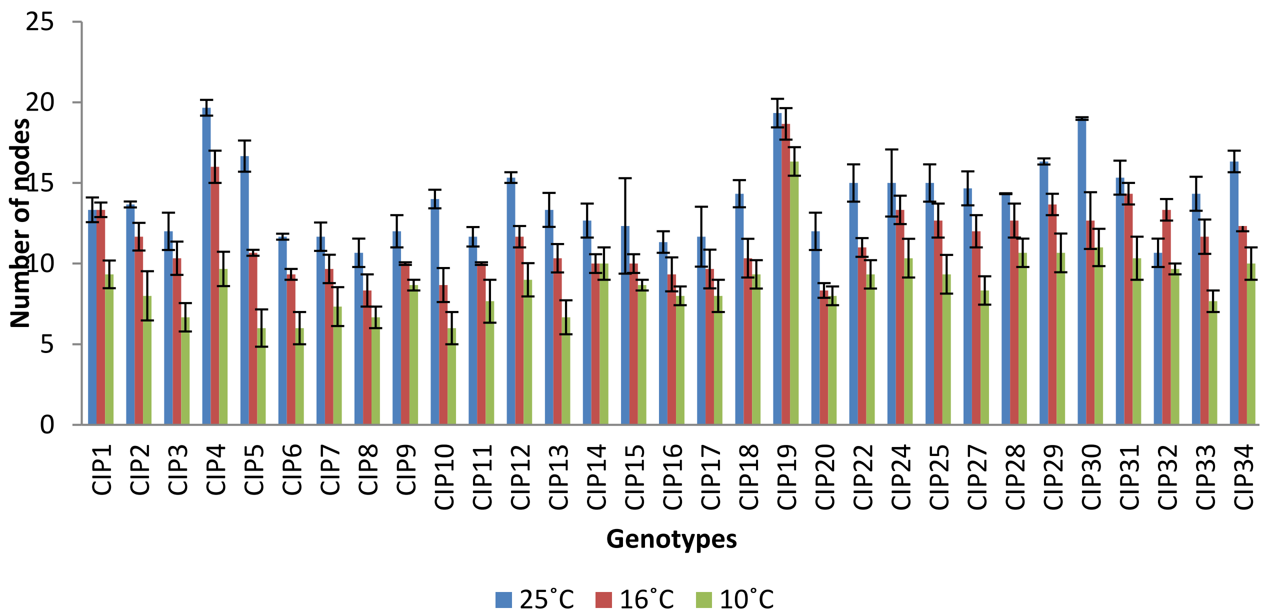


Figure 2. Effects of incubated temperatures on number of nodes of 34-CIP potato germplasms grown at different temperature ranges.

heights in term of length and number of internodes may be attributed to genetic difference in varieties.

Number of roots

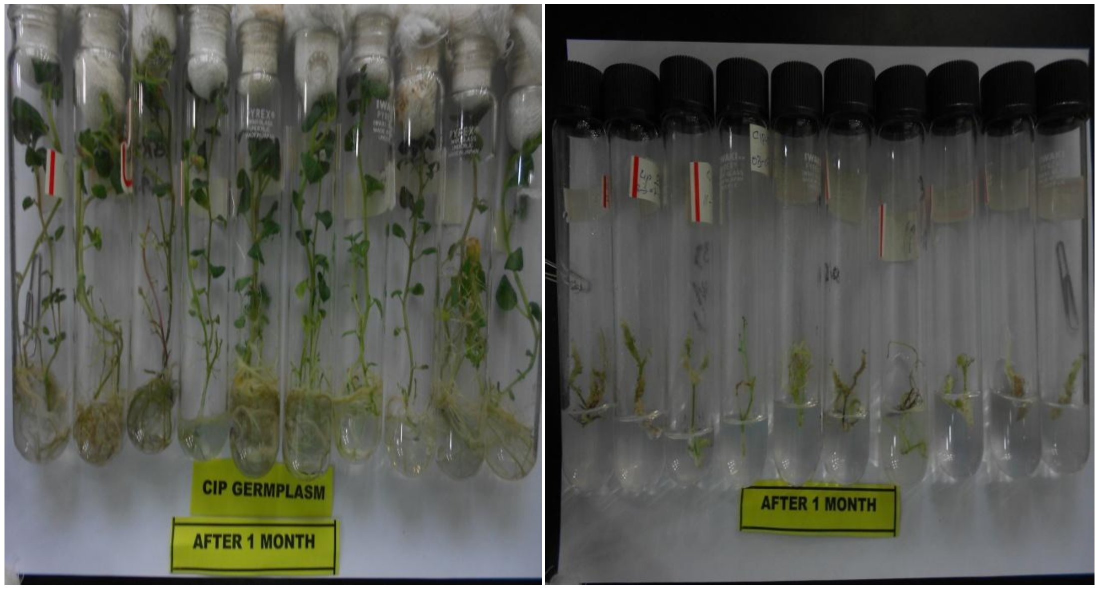
The number of roots per plant was counted by visual observation. The results revealed that the plants produced maximum number of roots that were incubated at 25°C as compared to plants incubated at 10 and 16°C. It was concluded that lower temperature can suppress the plant growth to some extent without causing harmful effects.Badoni and Chauhan (2009) reported that highestnumber of roots was produced in plants cultivated at 25°Ctemperature.

Number of nodes

Results showed that the highest number of nodes wasproduced in genotypes incubated at 25ºC. While the lowest numbers of nodes were revealed in genotypes cultivated at 10ºC. It was also revealed that increase in temperature cause increase in plant height as well as in the number of nodes (Figure 2). Similarly, Ciobanu and Constantinovici (2012) also suggested that forconserva-tion of potato, low temperature (6-12°C) wasfavorable as it reduced the ascertained number of nodes.

Effect of aerophilic and micro-aerophilic conditions on growth

The results showed that ventilation was the basic need for growth and development of plant in vitro incubated (condition) environment (Figure3 andPicture2). The CIP genotypes were cultivated in tube covered with plug (aerophilic condition), showed best growth rate and the plants were very healthy as compared to plants grown in caped test tubes (microaerophilic condition). The plug covered plant showed maximum (43%) plant height as compared to cap plant. It was also observed that plant grown in tube covered with plug produced large number of roots then cap covered growing plants. Similar report by Mohamed and Alsadon (2009) showed that using ventilated vessels with low sucrose concentration under ambient CO_2 concentration of the growth room could successfully induce photomixotrophic culture resulting in healthy plantlets. Higher leaf dry weight and anatomically well-developed leaves of plantlets were produced in ventilated vessels which facilitate ex vitro acclimation of plantlets. The plant grown in high oxygen availability was very healthy; respiration and photosynthesis rate were very high with direct effect on plant growth. Similar report by many researchers revealed that rising O_2 supply is apparently balanced by increasing O_2 consumption, that is, mitochondrial respiration (Rolletschek et al., 2005a). In the absence of oxygen, the mitochondrial ATP supply will be inhibited because oxygen is the terminal electron acceptor in the respiratory chain. Hence, it is not surprising that the imposition of hypoxia leads to a rapid decrease in both the availability of ATP and biosynthetic fluxes Geigenberger (2003); Greenway and Gibbs (2003); Rolletscheket al. (2003), it was also reported bymany authors (Chang et al., 2000; Klok et al., 2002; Liu et al., 2005) that oxygen affects gene



Picture 2. Effect of aerophilic and micro-aerophilic conditions on growth.

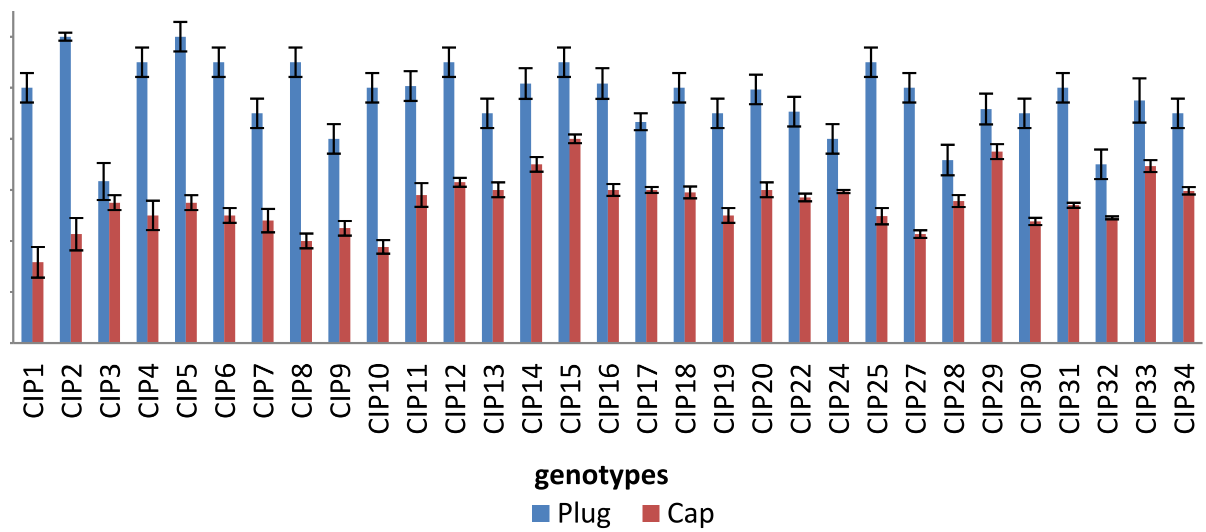


Figure 3. Effect of aerophilic and micro-aerophilic conditions on plant height of 34-CIP potato genotypes.

expression more generally and thus affect the plant growth. It was observed in the present study that plugcovered plant produced large number of root than the plug grown plants which can directly affect the plant growth. Similar observation was obtained by many other researchers. Cherif et al. (1997), Bhattarai et al*.* (2006), and Acuña et al*.* (2008) reported that aeration is one of the important factors that influence root and plant growth. Plant cells require oxygen for division and function. If rooting medium has oxygen deficiency, plants will be severely injured or dead in limited time.

Respiration requires oxygen to produce energy for shoot and root growth and also helps in ion absorption. Metabolic processes like cell division, water movement into roots and mineral uptake can be prohibited by root oxygen scarcity creating changes in root system morphology; also, roots will die after disturbance of absorbing water and ions resulting from lack of satisfactory oxygen reported by Morard and Silvestre (1996) and Caron and Nkongolo (2004). Mobiniet al.(2009) also reported that increasing the level of aeration led to remarkable increase in growing period and delay in physiologic maturity of plant but induced tuber initiation. Ritter et al*.* (2001) and Factor et al*.* (2007) reported thatsufficient amount of O_2 concentration was needed to increase tuber yield, dry matter and most of the growth parameters such as green leaf area index (LAI), grain harvest index (HI) and significantly ratio of root and shoot.

Conclusion

The study thus revealed that temperature of 25°C is the most favorable for multiplication of potato germplasm because at this temperature the growth rate is very fast, irrespective of the variety and time interval but for conservation of in vitro germplasm, 10°C was found optimal. Establishing the proper conditions for slow growth in potato will aid in preserving their germplasm for the purpose of later reintroduction and sustainable use. In micro-areophillic condition, the growth rate was very slow as compared to areophillic which shows its suitability for the conservation of plantlets.

Conflict of Interests

The authors have not declared any conflict of interest.

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Phenotypic variation in cowpea (*Vigna unguiculata* [L.] Walp.) germplasm collection from Botswana

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Characterization of cowpea (*Vigna unguiculata* [L.] Walp.) accessions is an important exercise in improvement of the crop. A total of 432 cowpea germplasm accessions collected from five agricultural districts of Botswana during 1972 to 1987 were evaluated under field conditions at the Department of Agricultural Research Station, Gaborone. The germplasm were assessed using 37 agro-morphological characters to determine the diversity of Botswana cowpea germplasm. DIVA-GIS were used to conduct a gap analysis to estimate the degree of coverage of the germplasm accessions across the country. Areas not yet explored and those that need additional sampling were identified. The study demonstrated a significant amount of diversity among the germplasm based on the analysis of variance (ANOVA) and Shannon Weaver Diversity Index (H'). The majority of accessions had their first flowering more than 50 days after sowing and 100 days for 95% of maturity which shows that they are more inclined towards late maturing cowpeas. Early maturing accessions with less than 110 days to maturity are found in Ngamiland, Southeast and unknown origin. The accessions from Central districts had the largest variation for most characters (11) followed by Southeast with 10 among the 22 quantitative characters evaluated. Principal components analysis (PCA), revealed characters which discriminated more efficiently between accessions than others such as peduncle length, 10 seeds weight, seed width, seed thickness, pods per peduncle, and 100 seed weight. Cluster analysis delineates germplasm into three clusters, based on the origin of the germplasm according to different agro-ecological zones. Germplasm accessions originating from Ngamiland formed a separate cluster from the rest and had several peculiar materials, which could be a potential source for new germplasm for cowpea improvement. Further molecular studies are required to complement and validate the current agro-morphological variation observed in the Botswana cowpea germplasm.

Key words: Accessions, agro-morphology, cowpea, diversity, germplasm.

INTRODUCTION

Cowpea (*Vigna unguiculata* [L.] Walp.) is an important indigenous African grain legume grown in places with severe weather conditions in the tropics and sub-tropics in Africa, Asia and South America (Singh et al., 1997; Ba et al., 2004). It is a major source of dietary protein in sub-Saharan Africa where most production and consumption is taking place (Nielsen et al., 1993). Most of the world's cowpea production is in Nigeria, Burkina Faso, United Republic of Tanzania, Cameroon, Niger, Mali and Kenya (FAO, 2013). Cowpea is multipurpose it is used at all stages of the crop for both human and animal consumption (Gómez, 2004; Sprent et al., 2009). It is valued for its ability to tolerate drought, and fix atmospheric nitrogen (rhizobium bacteria) which allows it to grow and improve poor soils (Mahalakshmi et al., 2006), and these makes it an important component in many cropping system (Fall et al., 2003). Therefore the crop is suitable for poor soils like those of Botswana (Moroke et al., 2005).

Cowpeas originate from Africa, but the exact area of domestication, and the center of diversity is still speculations (Zeven and De Wet, 1982; Ba et al., 2004). Studies suggests that Southern most region of Africa could be the center of origin for *V. unguiculata*, while domestication might have occurred in West Africa (Padulosi and Ng, 1997). In Southern Africa, Botswana is one country with higher genetic diversity of wild species of cowpea, such as *V*. *unguiculata* subsp. *dekindtiana, V. unguiculata* subsp. *tenuis* and *stenophylla* (Mathodi, 1992; Padulosi and Ng, 1997). Botswana is also an important cowpea growing country in Africa (Singh et al., 1997).

Cowpea is the main grain legume grown in Botswana it is the third economic crop of importance after maize and sorghum (DAR, 1997). The crop is produced in all the ten districts (CSO, 2013), but most production is concentrated in the Central, Kweneng and Southern districts (CSO, 2006; CSO, 2007/08; CSO, 2011). However, average production is at 139 kg/ha at national level (CSO, 2012). Several factors are attributed to this low level of production such as poor agronomic practices, and poor choice of well adapted and high yielding varieties (Manthe, 1987).

The National Plant Genetic Resource Centre (NPGRC) was established in 1986 after recognizing the importance of genetic resources and formal conservation (Mathodi, 1992). However, the initial attempt to collect and conserve crop germplasm was in the early 1970s by individual scientists from Department of Agricultural Research (DAR) (DeMooy, 1984). Botswana is in possession of a significant amount of cowpea germplasm collections of more than 1500 maintained by the DAR, (NPGRC), in the Ministry of Agriculture (www.moa.bw). The accession consists of wild and local landraces and improved varieties from International Institute of Tropical Agriculture (IITA) (Botswana Cowpea Project, 1982/1983).

It is important to conserve cowpea genetic variability for future use, but equally important is the actual utilization of the accessions (Nass and Paterniani, 2000).

Understanding the level of genetic diversity in a germplasm is helpful to plant breeders as it support their decision on the selection of parental genotypes and important in widening the genetic base of the crop (Prasanthi et al., 2012). Assessment of diversity also allows efficient sampling especially when core samples are developed, which allows proper management of the germplasm (Van Hintum et al., 2000). Hitherto the accessions in Botswana are primarily assessed based on morphological characters which depends on few genes and may not necessarily reflect the real variation for the agronomic characters present in the crop (Mayes et al., 2009).

The cowpea breeding programme has identified some germplasm useful in improvement of the crop. These includes discovering populations of wild Vigna in the Kalahari Desert which is resistant to bruchid beetle a serious storage cowpeas (Mathodi, 1992), and high levels of aphids (*Aphis craccivora*) (DAR, 1985/86). Some local cultivars which mature extra early, dual purpose and triple purpose were identified (Botswana Cowpea Project, 1982/83; DAR, 1985/86). Sources of resistance to *Alectra vogelli* have been found among local germplasm (Fite, 2010), other local materials such as B301 and B359 have been explored in other international institutions (Singh and Emechebe, 1990; Lane et al., 1996; Riches et al., 1992).

In this study we report on the characterization of more than 400 germplasm in the catalogues assembled for a period of fifteen years. The objective of this study is to analyze the morphological and agronomic traits of Botswana cowpea germplasm collected from different agro-ecological zones of the country to assess their genetic diversity. The study also aims to estimate the degree of coverage of already sampled areas, to identify areas that need additional sampling and those where no collections have been conducted yet.

MATERIALS AND METHODS

Germplasm collection and conservation

Over 100 cowpea germplasm were collected from various locations of Botswana by DAR research officers between 1972 and 1981. To augment this initiative a national cowpea collection germplasm programme was set up in 1982, through the assistance of Colorado State University and Cowpea Collaborative Research Support Program (CRSP). A number of surveys were conducted to obtain seed samples from many farming communities with different

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representation of soils, climatic environment found in Botswana. The accessions were collected from field crops, agricultural fairs and research stations. The cowpea samples collected were separated according to seed type and assigned an accession number. The accessions were put into cold storage and later removed and used for field experimentation. Based on the collections between 1972 and 1987, four hundred and thirty two germplasm accessions were evaluated for various morphological, physiological and agronomic characteristics of interest to plant breeders and growers (Paterson and Mathodi, 1987). The germplasm accessions were collected from five districts of Botswana.

Experimental site

The evaluation was conducted at the Department of Agricultural Research Station, located in Sebele, approximately 12 km north of the capital city, Gaborone. The station location is at latitude 24° 34' south and longitudes 25° 57' east at an altitude of 994 m. The soils at the station are underlain by Gaborone granite and the accessions were planted on chromic cambisol having coarse sandy texture. The soils are well drained with a depth of 90 cm or greater, and vary from acid pH 5.1 to 6.0 in the top soil to mild alkaline pH 6.6 to 7.8 in the subsoil. The field experiments were conducted during the rainy season of 1982, 1983, 1985 and 1987. Rainfall is mostly within the months of October through to April and is highly variable. The mean average rainfall, mean monthly minimum and maximum air temperatures for Sebele over the four cropping seasons were 350 mm, 20.3 and 35.4°C, respectively.

Experimental layout, design and planting

A total of 432 cowpea accessions were evaluated, each treatment consisted of one single row, five metre plot for each accession. The rows were spaced at 1.5 m with 20 cm plant spacing within a row. Super phosphate (P_2O_5 = 10.5%) was applied pre-plant at the rate of 250 $kgha^{-1}$. Data were recorded on 54 descriptors based on International Plant Genetic Resource Centre (IPGRC, 1983) for cowpeas (DeMooy, 1984). All the accessions evaluated were of cultivated origin and none were wild or weedy type.

Data tabulation

Data were collected from accessions that survived to maturity and harvest. The scoring was on an individual plant basis using five randomly selected plants per plot (DeMooy, 1984; Paterson and Mathodi, 1987). A total of 37 qualitative and quantitative characters were used for analysis. Fifteen qualitative characters analyzed were, growth habit, twining habit, attachment of pods to peduncle, raceme position, determinancy, flower pigmentation, plant pigmentation, pod pigmentation, pod shape, terminal leaflet shape, pod shattering, seed crowding, testa texture, eye pattern and eye colour.

Twenty two quantitative characters such as number of branches, number of nodes per main stem, peduncle length, days to 50% flowering, days to 95% ripe pods, pod forming period, vigor height, index width, pod length, pod width, leaflet length, leaflet width, 10 seed weight, seed length, seed width, seed thickness, pods per peduncle, locules per pod, seeds per pod, pods per plant, 100 seed weight, yield per plant (DeMooy, 1984; DeMooy, 1987; Paterson and Mathodi, 1987), were used.

Statistical analysis

Data analysis for the quantitative characters were subjected to analysis of variance (ANOVA) using the SAS version 9.2 (2010) to determine the statistical differences on the traits for the given accessions. The range, mean and standard error of means were calculated on the 22 agronomic data. The means values of measurements for each trait were standardized by subtracting the mean from respective traits and dividing by the standard deviation in order to reduce the influence of the scale differences. The standardized data was used in multivariate polymorphism in cluster analysis and principal component analysis. The accessions diversity was compared based on the five agricultural districts with different agro-ecological zones and some from an unknown origin. Some techniques for diversity analysis were employed such as Shannon weaver diversity index (H'), and the use of geographical distribution based on DIVA-GIS analysis.

Analysis of variance (ANOVA)

The material was divided according to agro-ecological zones of the country, and data from multiple years were averaged for each accession. Distribution pattern was used as the dominant factor in the analysis of variance to determine the range, mean and variances of the different traits in cowpeas germplasm accessions (Table 1).

Shannon weaver diversity

The diversity index was tested using Shannon-weaver index of Genstat version 13.0 to measure the diversity for the different characters. The calculations are based on phenotypic frequencies of each trait, and this reveals traits which are more varied and useful to plant breeders when making selection (Table 2).

Geographical distribution based on Diva-GIS analysis.

Diva-GIS is useful for analyzing the distribution of germplasm to elucidate geographic and ecological patterns and is useful in identifying gaps in the collection (Hijmans et al., 2012). Data for DIVA-GIS was gathered from 300 accessions with passport information, such as collection number, district name, village name, latitudes, longitude, sample status (cultivated or wild), collection source and date of collection. DIVA-GIS software version 7.5 was used for mapping the collection sites from the five districts (Figure 2).

Cluster analysis and principal component analysis

The agronomic data were subjected to principal component analysis (PCA) to identify traits that revealed most variation. Eigenvalues greater ≥ 1 were selected and used based on Multivariate Statistical Analysis (MVSP) software (Kovach, 2006). For cluster analysis, the unweighted pair group method with arithmetic averages (UPGMA) was performed using MVSP on Euclidean distance and dendrograms were produced to show the relationship between the accessions from the five districts.

RESULTS

Distribution of cowpea diversity in Botswana

The study consists of 432 cowpea germplasm accessions

Table 1. Range, mean and variances of different traits in cowpea germplasm accessions from Botswana.

Traits	Range						Mean					
	Central	Kweneng	Ngamiland	SouthEast	Southren	Unknown	Central	Kweneng	Ngamiland	SouthEast	Southren	Unknown
No. of branches	1 - 9	2 - 7	3.7 - 6.0	1 - 8.7	2 - 6	1 - 8	4.152^{a}	3.64^{a}	4.74^{a}	3.51^{a}	4^{a}	3.84^{a}
Nodes per stem	2 - 9.7	3 - 9	3.7 - 9.6	2.0-10.3	3 - 8	2 - 10.3	4.964^{a}	5.172^{a}	5.52^{a}	4.771^{a}	5.513^{a}	5.263^{a}
Pedunel Length (mm)	3 - 42.3	3.67 - 36	7.5 - 17.0	4.6 - 48.7	6.7 - 25.3	4 - 48	14.64^{a}	17.33^{a}	11.998^{a}	18.418^{a}	14.453^{a}	20.793^{a}
DFF	39.0 - 168	47.0 -158	57.0 - 82.0	36 - 157	48 - 148	38 - 158	97.77^{a}	84.958^{ba}	69.2^{bc}	61.751^{c}	87.06^{ba}	59.878^{c}
Days to 95%PCT	47.0 - 188	87 - 185	102 - 110	66 - 189	79 - 189	65 - 189	143.85^{a}	145.65^{a}	104.8^{b}	108.42^{b}	161.4^{a}	103.196^{b}
Pod form period	12 - 132	25 - 127	28 - 50	13 - 147	26 - 132	13 - 141	48.32^{b}	60.6^{ba}	35.6^{b}	46.52^{b}	74.333^{a}	44.535^{b}
Vigor height (cm)	6.66 - 23.3	8.33 - 22.7	13 - 20.7	6.0 - 30	7.66 - 17.0	5 - 26.7	13.54^{a}	14.804^{a}	14.9^{a}	13.73^{a}	12.932^{a}	16.092^{a}
Index width (cm)	7.33 - 42.0	4.0 - 31.3	21.7 - 38.3	4.7 - 34.3	12.3 - 32.0	4 - 39.3	21.94^{ba}	22.14^{ba}	27.2^{a}	20.476^{b}	22.708^{ba}	23.33^{ba}
Pod length (mm)	37.5 - 208.7	89.66 - 194	121.7 - 163.3	65.0 - 206.7	81.7 - 199.7	57.3 - 220	139.56^{a}	139.412^{a}	150.83^{a}	127.63^{a}	131.08^{a}	129.536^{a}
Pod width (mm)	5.0 - 11.7	6 - 11.0	7.33 - 10.0	4 - 11.33	6 - 11.7	5 - 11	8.23^{a}	8.432^{a}	8.908^{a}	7.327^{b}	8.354^{a}	7.483^{ba}
Leaflet length (mm)	32 - 111.0	48.3 - 143.3	37.7 - 123.3	28 - 140	36.3 - 110	8 - 174	97.261^{ba}	97.613^{a}	60.464^{b}	81.036^{b}	86.71^{ba}	93.174^{a}
Leaflet width (mm)	22.3 - 100.0	35.0 - 83.33	27.7 - 86.7	19.3 - 90.0	23 - 80	24 - 103.3	53.44^{ba}	58.013^{a}	41.668^{b}	50.196^{b}	52.833^{ba}	57.156^{a}
Seed 10 weight (g)	0.5 - 3.3	0.67 - 3.5	1.37 - 2.4	0.38 - 3.3	1.0 - 3.4	0.5 - 2.7	1.693^{a}	1.674^{a}	2.014^{a}	1.38^{b}	1.84^{a}	1.38^{b}
Seed length (mm)	4.0 - 12.0	5.0 - 10.0	7.0 - 10.0	4.0 - 12	4.0 - 12	4 - 11	7.704^{a}	7.2^{ba}	8.6^{a}	7.286^{ba}	7.6^{ba}	7.246^{b}
Seed width (mm)	4.0 - 9.0	4.0 - 8.0	6.0 - 7.0	4 - 12	5 - 8	4 - 8	6.68^{a}	6.4^{a}	7^{a}	5.72^{b}	6.533^{a}	5.73^{b}
Seed thickness (mm)	3.0 - 7.0	3.0 - 6.0	5.0 - 6.0	3 - 6	4.0 - 7	3 - 7	4.6^{bc}	4.8^{bac}	5.6^{a}	4.511d^{c}	5^{ba}	4.376d
Pods per enduncle	1 - 3	1 - 3.0	2.0 - 3.0	1 - 4	1 - 2	1 - 4	1.705^{ba}	1.83^{a}	2.2^{ba}	2.054^{b}	1.466^{ba}	2.0866^{ba}
Locules per pods	5 - 21	8 - 17	12 - 14	7 - 20	10 - 16	9 - 21	14.06^{a}	14.2^{a}	13.5^{a}	13.49^{a}	13.666^{a}	14.016^{a}
Seeds per pod	2 - 16	6 - 16	12 - 14	3 - 47	5 - 14	2 - 21	10.51^{a}	11.68^{a}	13.25^{a}	10.929^{a}	10.133^{a}	10.296^{a}
Pods per plant	0.03 - 96.66	0 - 16.3	1.8 - 35.7	0 - 87.8	0.5 - 40.6	0.03 - 53.5	10.315^{ba}	4.0196^{b}	10.68^{ba}	11.356^{a}	7.534^{ba}	11.107^{ba}
Seed 100 weight (g)	3.3 - 30.10	6.75 - 33.0	12.9 - 21.8	5.4 - 36.4	9.1 - 31.0	4.6 - 24.23	16.53^{ba}	16.462^{ba}	17.404^{ba}	13.476^{b}	17.598^{a}	13.619^{b}
Yield per plant (g)	0.34 - 98.60	0.5 - 23.4	N/A	1 - 65.7	0.92 - 41.2	0.65 - 36.41	15.7^{a}	8.004^{a}	N/^{A}	17.108^{a}	16.91^{a}	11.522^{a}

collected from 40 villages and five agricultural districts of Botswana. The majority of the accessions do not have known record of origin (132) followed by those from Southeast (129) while the least (5) are from Ngamiland. The districts that have not yet been explored are Kgatleng, Chobe, Ghanzi, Kgalagadi and Northeast (Figure 1). Central district provided majority of accessions that were collected from villages (121), while Southeast contributed most of the samples from research station (95) and 22 were collected at the fields.

Quantitative and qualitative analysis of cowpea germplasm

Data for each character was subjected to analysis of variance to estimate the genetic variability among the germplasm. Highly significant ($P<0.001$) differences were detected among the germplasm in most of the characters (14), with the exception of vigor height, index width, leaflet length, locules per pods, seeds per pods, pods per plant and yield per plant. The Shannon-Weaver diversity index (H') was calculated on the qualitative and quantitative characters to compare diversity between the different characters and among various districts. Higher diversity was observed among the qualitative characters at an

Table 1. Contd.

Standard errors of LS mean						
Central	**Kweneng**	**Ngamiland**	**SouthEast**	**Southren**	**Unknown**	**F- value**
1.864	1.451	0.856	1.663	1.309	1.555	0.0667
1.577	1.243	2.344	1.575	1.467	1.814	0.503
6.98	8.451	4.026	8.366	6.209	8.884	0.0017
39.44	33.83	8.927	26.61	33.024	21.948	0.0001
41.5	32.08	3.563	40.795	38.104	38.749	0.0001
30.45	27.949	8.443	32.957	38.214	32.656	0.0156
3.629	3.641	3.281	4.072	2.825	4.348	0.21
6.51	5.442	6.609	6.507	5.485	7.965	0.1724
33.077	25.13	19.55	30.749	33.135	34.364	0.0436
1.503	1.375	1.132	1.418	1.702	1.308	0.0001
93.91	19.58	35.833	25.26	21.984	24.461	0.2592
13.956	13.626	25.378	15.241	15.591	15.53	0.0102
0.541	0.592	0.426	0.464	0.605	0.452	0.0001
1.508	1.29	1.1401	1.506	1.804	1.42	0.0194
1.175	1.08	0	0.974	0.99	0.992	0.0001
1.015	0.866	0.5477	0.791	0.925	0.819	0.0025
0.655	0.701	0.4472	0.7214	0.516	0.827	0.0012
2.402	2.254	1	2.371	1.951	2.103	0.3554
3.106	2.882	0.957	4.415	3.044	3.015	0.3057
15.278	4.264	14.15	13.983	10.367	10.335	0.2317
5.089	5.483	3.386	4.331	6.134	4.073	0.0001
20.138	5.872	N/A	14.741	17.309	8.454	0.3781

Table 2. Shannon-weaver diversity index of collected cowpea germplasm accessions in Botswana.

Traits	Central	Kweneng	Ngamiland	Southeast	Southren	Unknown	Average
Qualitative							
Growth Habit	0.88	0.84	0.72	0.81	0.98	0.87	0.85
Twinning habit	0.39	0.48	*	0.49	0.35	0.49	0.44
PodPeduncleatta	0.80	0.72	0.72	0.84	0.88	0.84	0.80
Racemeposition	0.82	0.77	0.97	0.97	1.00	0.95	0.91
Determinancy	0.94	0.97	0.97	0.98	0.84	1.00	0.95
Flower Pigmentation	0.78	0.78	*	0.92	0.84	0.87	0.84
Plant pigmentation	0.53	0.63	*	0.72	*	0.56	0.61
Pod pigmentation	0.43	0.65	0.72	0.54	*	0.43	0.55
Pod shape	0.67	0.92	0.72	0.83	0.87	0.58	0.76
Leaflet shape	0.66	0.69	0.72	0.68	0.57	0.76	0.68
Pod shattering	0.46	0.24	0.72	0.99	0.72	0.72	0.64
Seed crowding	0.93	0.85	0.97	0.81	0.95	0.70	0.87
Testa texture	0.67	0.63	*	0.55	0.57	0.72	0.63
Eye pattern	0.71	0.82	0.97	0.94	0.87	0.80	0.85
Eye colour	0.89	0.88	0.96	0.82	0.87	0.77	0.87
Average	**0.70**	**0.72**	**0.83**	**0.79**	**0.79**	**0.74**	0.75
Quantitative							
No. branches	0.77	0.87	1.00	0.80	0.93	0.77	0.86
Node per stem	0.76	0.76	0.96	0.82	0.91	0.76	0.83
Peduncle Length (cm)	0.96	0.89	1.00	1.00	0.99	0.97	0.97

Table 2. Contd.

DFF	0.96	0.94	0.96	0.92	0.98	0.93	0.95
Days to 95% maturity	0.93	0.96	0.96	0.95	0.98	0.95	0.96
Pod form period	0.97	0.98	1.00	0.94	1.00	0.93	0.97
Vigor height (cm)	0.95	0.96	1.00	0.95	0.96	0.95	0.96
Index Width (cm)	0.97	0.98	1.00	0.96	0.99	0.97	0.98
Pod Length (mm)	0.99	1.00	1.00	0.98	1.00	0.99	0.99
Pod Width (mm)	0.92	0.90	1.00	0.90	0.96	0.85	0.92
Leaflet Length (mm)	0.80	0.87	0.96	0.82	0.86	0.84	0.86
Leaflet Width (mm)	0.86	0.90	*	0.84	0.95	0.86	0.88
Seed10Weight (g)	0.91	0.94	0.96	0.87	0.99	0.89	0.93
Seed Length (mm)	0.80	0.89	0.96	0.82	0.89	0.84	0.87
Seed Width (mm)	0.86	0.89	*	0.84	0.89	0.86	0.87
Seed Thickness (mm)	0.85	0.87	0.97	0.84	0.89	0.73	0.86
Pods per peduncle	0.87	0.92	0.72	0.77	1.00	0.86	0.86
Locules per pod	0.82	0.95	0.81	0.87	0.95	0.85	0.87
Seeds per pods	0.93	0.92	0.95	0.89	0.95	0.87	0.91
Pod per plant	0.98	1.00	1.00	0.99	1.00	0.99	0.99
100 seed weight (g)	0.99	1.00	0.99	0.98	1.00	0.99	0.99
Average	**0.90**	**0.92**	**0.96**	**0.89**	**0.96**	**0.89**	0.92

*Too few samples for analysis.

average of 0.75. The most diverse variation (H') was observed on determinancy at 0.95 with the least diverse trait of twinning habit at 0.44. The most diverse morphological characters were observed from Ngamiland at 0.83 (Table 2). Shannon-weaver diversity (H') was higher among the quantitative characters at an average of 0.92, with more variation in characters observed in the Southern district and the least are in Southeast district at 0.89. The characters which revealed higher diversity H' above 0.95 were, peduncle length, days to first flowering, days to 50% flowering, pod forming period, vigor height, index width, pod length, pod per plant and 100 seed weight.

Diversity analysis based on growth habit

Based on the IPGRC (1983) there are seven classes of cowpea growth habit**,** all the seven types of plant growth habit were observed with the majority 121 of those with erect habit followed by 109 with semi-erect most of them come from unknown origin and Southeast districts respectively. A significant number of semi-prostrate growth habit (78) were recorded, and these could be useful as forage and good for leafy vegetables, the majority of them 34 accessions were collected from the central district. The accessions from Central district showed the maximum range among 11 traits followed by those from Southeast with 10 traits. Accessions from unknown origin had maximum range in pod length from 57.33 to 220 mm (Table 1).

Diversity based on plant physiology

Days to 50% flowering less than 50 days was observed in all the districts, with the exception of Ngamiland, where flowering occurred at 57 days after sowing. However, the crops in Ngamiland reach 95% maturity earlier than from all the regions at approximately 110 days. The vigor index which includes the plant length and width showed no significant difference between the plant heights among the five districts. Differences in plant width were observed only between accessions from Ngamiland and those from Southeast (Table 1).

Diversity in leaf and pod characteristics

There was no significant difference in pod length among all the districts but on average all the pod length was lower than 150 mm with the exception of those from Ngamiland. For pod width measurements, the Southeast district and unknown origin had smaller pod width of 7.32 and 7.48 mm respectively while the rest of the districts had more than 8 mm pod width (Table 1). Broader leaves in leaflet length (97.6 mm) and leaflet width (58.1 mm) were observed in accessions from Kweneng district but

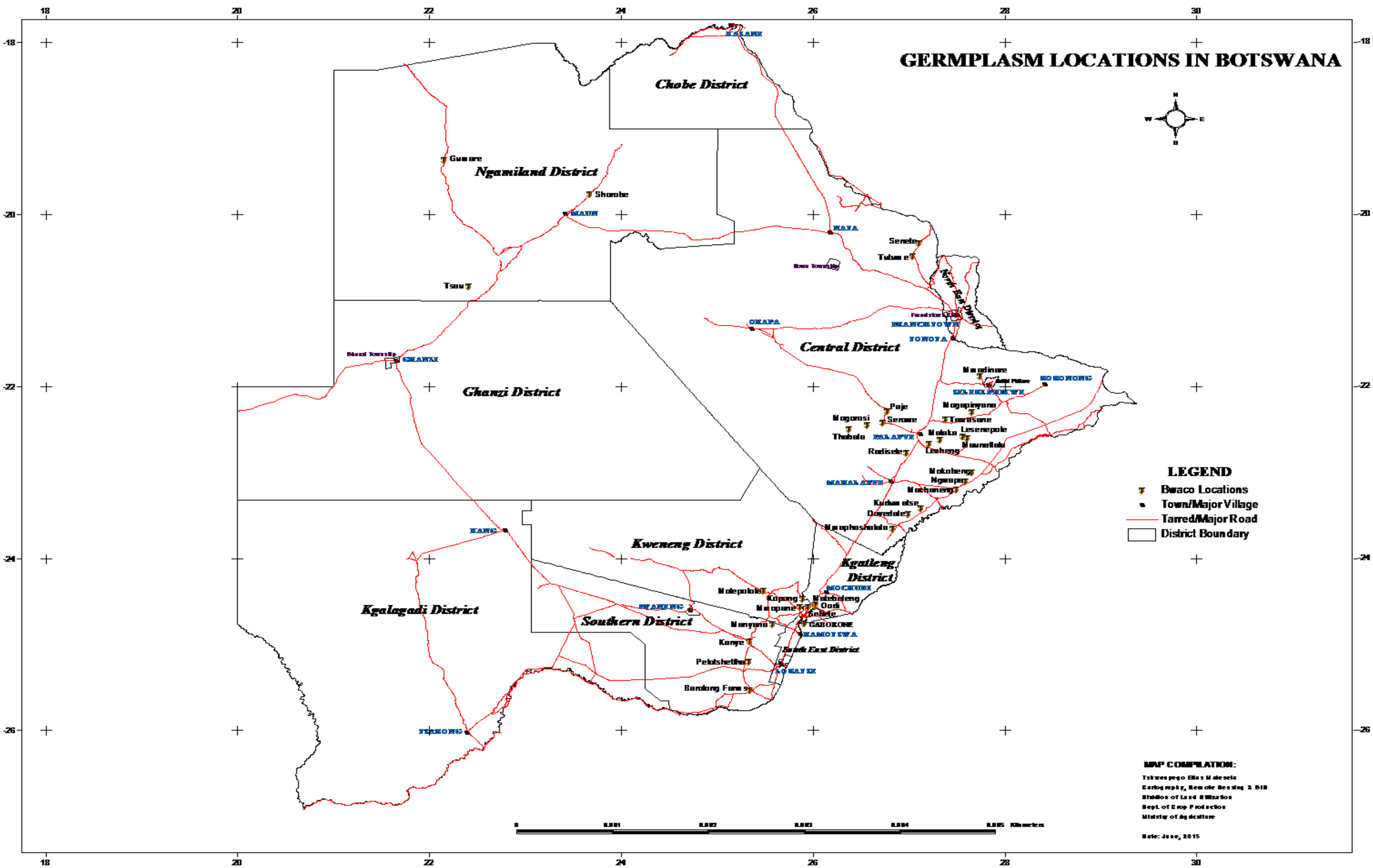

Figure 1. Distribution of cowpea accession in the National Plant Genetic Resource Centre using DIVA-GIS. The ten agricultural districts are inserted.

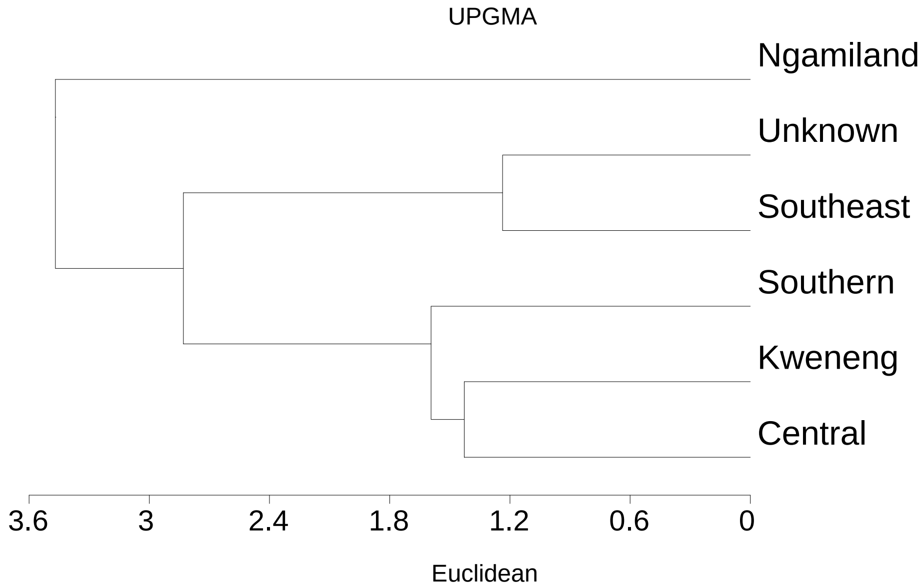

Figure 2. Dendrogram based on the principal components analysis capturing 86% of variation in the 432 Botswana cowpea germplasm collected for a period of 15 years.

were only significantly different from those from Ngamiland and Southeast which had narrow leaves (Table 1).

Diversity in seed characteristics

The accessions produced seeds width less than 1.7 mm and seed length smaller than 7 mm; it was only the Ngamiland accessions that had bigger seeded cowpeas at an average of 8.6 mm seed length and 2.01 mm seed width. The small seeded accessions were observed in Southeast and from unknown origin (Table 1). The seed thickness from Ngamiland is similar to those from Kweneng and Southren district but significantly different from the other districts. The 10 seed weights from all the districts are similar with the exception of those from Southeast and Ngamiland which are similar with 1.38 g. The Shannon-weaver diversity index (H') was relatively higher for eye pattern and eye colour at an average of 0.85 and 0.87, respectively. The more diverse accessions for eye pattern and colour are in Ngamiland and Southeast district (Table 2).

Diversity in yield components

Average weight for most accessions from Central, Kweneng, Southeast and unknown origin was more than 13 g for 100 seed weight, but the Ngamiland and Southern districts performed slightly better with over 17 g. Pods per plants from Southeast and unknown origin produced a slightly higher numbers with an average of more 11 pods per plant, which are light in weight while those from Kweneng were fewer in numbers but relatively heavier. The accession from Southeast also revealed relatively higher yield per plant because of the higher numbers per plant, though smaller in sizes (Table 1).

Accessions clustering and principal component analysis

Cluster analysis carried out using the Euclidean distance revealed greater diversity among Botswana cowpea germplasm, with a genetic distance ranging from 1.2 from unknown origin to 3.54 at Ngamiland district (Figure 2). The accessions from the five agricultural district and some from unknown origin were separated into three clusters, based on the origin of the germplasm. Accessions from Ngamiland formed cluster 1, while those with unknown origin together with those from Southeast formed cluster 2. The third cluster comprises accessions from Southern, Kweneng and Central these districts show some marginal difference (Figure 2). The principal component analysis for the 22 quantitative characters was conducted among the 432 accessions. The first two principal components with eigenvalues over one, which accounted for 86.28% of the total variation, were selected to analyze the germplasm (Table 3). The principal component analysis identified traits contributing more diversity among the accessions such as days to 50% flowering, pods forming period, seed width,10 seed weight, seed thickness, peduncle length, pods per

Table 3. Principal component, matrix of eigenvalues for 22 quantitative characters of 432 cowpea germplasm collection in Botswana.

Variables	PC 1	PC 2
Eigenvalues	1.898	1.490
Total contribution	48.331	37.950
% Accumulated	48.331	86.281
No. branches	0.168	-0.124
Node per stem	0.079	-0.022
Peduncle length (mm)	-0.308	0.044
Days to 50 % first flower	0.237	0.331
Days to 95%	0.248	0.574
Pod form period	0.052	0.343
Vigor height (cm)	-0.083	-0.143
index Width (cm)	0.155	-0.194
Pod length (mm)	0.169	-0.106
Pod width (mm)	0.300	-0.021
Leaflet length (mm)	-0.115	0.249
Leaflet width (mm)	-0.137	0.209
Seed10weight (g)	0.351	-0.040
Seed length (mm)	0.204	-0.177
Seed width (mm)	0.425	-0.022
Seed thickness (mm)	0.336	-0.183
Pods per peduncle	-0.093	-0.322
Locules per pod	-0.018	0.065
Seeds per pod	0.153	-0.233
Pod per plant	-0.055	-0.123
100 seed weight (g)	0.272	0.070
Yield per plant (g)	0.034	-0.022

peduncle and 100 seed weight (Table 3).

DISCUSSION

In this study, we describe for the first time a collective analysis of cowpea germplasm from the different regions of Botswana. Significant variability was discovered among the 432 cowpea germplasm, since more than 60% of the selected characters were highly significant (P > 0.01). However, Ehlers and Hall (1997) stated that even when vast variation is observed in the morphological variation in cultivated cowpeas, there is limited genetic variation among the cultivated gene pool. Bozokalfa et al. (2009), observed that vast variation in the quantitative characters can be useful in the development of variety description and identification. The availability of this diversity is an important resource useful to initiate a breeding program so as to select the best genotypes (Govindaraj et al., 2014). The cowpea breeding programme has taken advantage of this resource, cultivars with great potential have been selected among the local germplasm such *Maeatshilwana* (DAR, 1947-1959), *Morogonawa* (Botswana Cowpea Project, 1986-87), *Mogweokgotsheng* and *Nakedi* (DeMooy, 1984).

Principal component analysis was used to identify variables describing the phenotypic diversity of the genotypes; similar observations were made by Doumbia et al. (2013), when analyzing 94 genotypes from Mali and Ghana. Both studies identified days to 50% flowering , seed weight, seed length, seed width and seed thickness as important traits in diversity analysis which could indicate similarities between the west African and southern Africa germplasm. However, Botswana germplasm indicated more characters based on PCA analysis such as peduncle length, pod forming period, pods per peduncle possibly because more traits and germplasm were analyzed.

The cluster analysis revealed that the Botswana cowpea germplasm were clearly separated on their area of origin, which is an indication that the geographical origin contributes to the genetic variability among the genotype. Possibly the breeding program can be planned based on the known geographical patterns of the country as planned by the Ministry of Agriculture (Sims, 1981). However, our results are generally not in accordance with those of Cobbinah et al. (2011) who did not find clustering according to regional bases among the eight geographical regions of Ghana when characterizing 134 genotypes. According to their explanation this might be due to repeated collections within regions without proper documentation and extensive exchange of cowpea accessions that occurred in the past between regions.

The germplasm from Ngamiland with short duration to reach maturity and big seeded could be crossbred with those with higher yielding but with long maturity from Central, Kweneng and Southern. The results may prove to be particularly important for breeders and farmers to develop varieties with high potential for specific regions. In this study we observed close similarity between accessions from SOUTHEAST and unknown origin and between Kweneng, Southern and Central district. A similarity in clusters observed between regions could mean exchange of seeds between close regions (Uguru, 1998; Cobbinah et al., 2011). In this instance the similarities of collections from unknown origin and those from southeast is collections of about 70 lines were collected in about 60 km radius of the SEBELE research, which is in the SOUTHEAST district and an additional of approximately 100 collected from agricultural trade fairs and research stations (Botswana Cowpea Project, 1982 - 83).

The use of DIVA-GIS is essential for identification of potential areas of diversity and collection gaps especially when planning future collection explorations (Mujaju and Faith, 2011). The results demonstrated that most collections are from southeast /eastern part of the country where probably most of the cultivation of cowpeas is taking place (DeMooy, 1984; CSO, 1979), such as in Central, Kweneng and Southren districts. Shannon weaver (H') revealed more genetic diversity in Ngamiland and Southern districts but these areas are underrepresented in the collections (Figure 1). Regions that have not yet been explored such as Kgatleng, Ghanzi, Northeast, Kgalagadi and Chobe have recently shown some records of cowpea production (CSO, 2010; CSO, 2012), though relatively low. According to (CSO, 1972), lack of explorations in Chobe, Ghanzi and Kgalagadi districts could be attributed to fewer subsistence farmers in the districts except for livestock, and inaccessibility of the roads in the region. Following a GIS-based gap analysis of the cultivated cowpea collection held at IITA, Botswana was among a few countries that were identified as priority for new germplasm acquisition (Rysavy, 2009). However, analyses of more than 1000 germplasm have not yet been conducted (unpublished data), to give further details on the genetic diversity of Botswana germplasm. Due to frequent drought in Botswana, cowpea has a great potential to contribute in increasing and stabilizing food production (Botswana Cowpea Project, 1983/84). In addition farmers are most likely to favor the production of cowpeas as compared to cereal because it is less labour intensive especially with regard to bird scaring and weeding (Luzani, 1992).

Conclusion

There is a broad genetic diversity of cowpea in Botswana. Most variation were attributed to growth habit, days to 50% flowering, seed weight, seed width, peduncle length, pod forming period, pods per peduncle. These characters are useful in characterizing and in cowpea improvement. Characters with more variation were observed in the Central and Southren district due to the wider ranges observed. The Shannon Weaver diversity identified Ngamiland and Southren districts to consist more diversity.

The germplasm clustered into three major groups according to geographic area of origin, accession from Southeast grouped with those with unknown area of origin, while those from Southern, Kweneng and Central formed one group which shows marginal difference among the groups. Ngamiland accessions formed a separate cluster from the rest and had several peculiar materials, which could be a potential source for new germplasm for cowpea improvement. Some areas have not yet been explored such as Kgatleng, Chobe, Ghanzi and Northeast which are also a potential source of new materials.

Conflict of Interests

The authors have not declared any conflict of interests.

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