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Leaders' underestimation, overestimation or alignment: Perspectives in program implementation

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Leadership is critical to shaping and supporting individual teachers' endeavors to integrate new programs into their teaching. To determine the necessary support, leaders must be aware of the needs of the school and its individuals. In understanding their needs, leaders can then support teachers through appropriate professional development and the discussion of identified issues to sustain improvements in teaching and learning throughout the school. Optimally, school leaders' perception of need will match that of the teachers with whom they work. However, when perceptions do not match, there may be possible repercussions.

Key words: Program implementation, perspectives, professional development, school improvement, cultural impact.

INTRODUCTION

This article seeks to heighten educational leaders' awareness of the importance in understanding different perceptions of difficulty between them and teachers in relation to various aspects of program implementation. While the study focused on the implementation of the International Baccalaureate's (IB) Primary Years Program (PYP), the objective is to share the results of six Case Study Schools in Spain to promote similar analysis and reflection by leaders in relation to their own contexts. The research determined: What aspects in program implementation were perceived as easy or difficult? The statistical hypothesis stated teachers and leaders perceived differently the ease of program implementation in schools. This article goes on to discuss the cultural dimensions of leadership's possible impact on program implementation.

During the time of this study, the PYP grew 154% worldwide. In the last year of the study, it grew 14% and its 1000th PYP school was authorized (IBO, 2013). The PYP is for students aged 3 to 11 where 11 may be the students' age at the end or beginning of the academic year; the final year of the PYP is often dependent on legislation of the host country. Spanish education is compulsory from 6 years of age. Primary Education comprises three two-year stages: 1st Cycle (ages 6-8), 2nd Cycle (ages 8-10) and 3rd Cycle (ages 10-12). Pre-primary Education comprises two three-year stages: 1st Cycle (ages 0-3) and 2nd Cycle (ages 3-5). The school year comprises at least 175 days with schools operating an average of 25 (55-min) periods over five days. Compulsory content areas at the time of the study included: Natural, social and cultural environment; art;

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physical education; Spanish language and literature; foreign language; mathematics; religion (compulsorily offered, voluntarily taken); and citizenship or human rights education (in 5th or 6th grade). The implementation of the Ley Orgánica de Educación (MEC, 2006) took place during this study from 2006/07 to 2009/10. The main curricular aspects addressed were the development of the core for the second cycle of Pre-primary and Primary Education culminating in the development of core curricula for the third cycle of Primary. In October 2013, the Spanish Ministry of Education and Culture signed an agreement with the IB to improve recognition, pilot programs and research impact to improve the quality of education (Kearney, 2013).

The first IB school in Spain was authorized to impart the Diploma Program in 1977. At the start of the study, 2 schools were PYP authorized in Spain, both international schools catering to employees of multinationals and embassies. The six Case Study Schools comprised the subsequently authorized schools in Spain. These schools belong to a family-owned group of schools. The President oversees its running, assisted by the Vice President and Director General. At the time of the study, the Secretary General was responsible to the Director General and oversaw corporate and educational management. The school directors were responsible to the secretary general but worked closely with the corporate and educational management sectors. In educational management, the Director of the International Programs (DPPII) with the Coordinator of International Programs, specialized in the PYP, developed the institutional PYP implementation plan. The Coordinator of International Programs oversaw the implementation process in the schools, communicating directly with PYP Coordinators in the schools and coordinating work as necessary with the Directors, Primary and Infant Coordinators. The Department of Innovation and Pedagogy supported the DPPII in areas related to Spanish Ministry legislation and institutional memory. The Case Study Schools are overseen by a Director who works with Coordinators in Primary and Infants. Along with the PYP Coordinator, they comprise a minimal pedagogical leadership team. Over the years, this structure changed in some schools to include Subject Coordinators and in 2010-11, the position of Sub director of Learning and Development was added. The PYP Coordinators were scheduled to work with teams of teachers at each grade level and specialist teachers as necessary and, when possible early in the process, to develop the Program of Inquiry and the unit planners. School Directors, Primary and Infant Coordinators were responsible for scheduling these meetings on the timetable.

Support and resources are organized by schools. As noted previously, by law, the development of methodology and choice of textbooks and teaching materials is the responsibility of the school. At the start of the implementation process, the DPPII suggested books to order. This was a two-year process, turned over to the schools. These orders, placed institutionally, were approved by the Finance Department then passed to the Purchasing Department. Improvements in ICT were already in motion, fully supporting the PYP initiative. The Systems Department ensured the professional development and availability of technological resources throughout the process. Changes in staff were planned to increase the number of bilingual teachers. This meant the Administration of Personnel Department needed to support advertising and hiring aligned to this initiative as requested by School Directors. Along with the Human Resources Department, professional development in the PYP would be in their interest.

The Case Study Schools, belonging to four different Spanish Autonomous Communities – Madrid, Catalunya, Andalucia and Galicia, are generally located in suburban areas, removed from the metropolitan hub; however, the Primary only school is in the heart of Madrid. The Case Study Schools are private national schools catering to the local community where students are primarily Spanish nationals; there are very few other nationalities represented in the student populous. The number of students in the PYP program in these schools ranges from 265 to 955 and serve ages 1-12. Five of the schools have or have had the IB Diploma program in place for many years when they began the PYP implementation process. Equally four of the schools have authorization for the implementation of the Middle Years Program of the IB. The decision for the implementation of the PYP was to give continuity to the other two programs. Keeping this in mind, the schools were organized into two phases of implementation with three schools in each phase and one year difference in the process between the two phases. The implementation of each phase followed the quality assurance process of the IB with consideration given to the needs in changing paradigms within the cultural context of each school. Implementation of the PYP began in 2006. The study concluded in 2013 with the authorization of the sixth school.

DuFour et al. (2010) identifies school leadership as key to successful program implementation. The level of trust and value alignment between school leaders and teachers as well as program expectations influences implementation (Culross and Tarver, 2011; Hartman, 2008; Gigliotti-Labay, 2010). Leaders are responsible for building this trust and communicating with teachers to ensure a positive school culture (Chance, 2009). Perceptions affect receptivity and implementation. Principals and coordinators must believe in, support and actively promote new programs to ensure buy-in, thereby reducing uncertainty and avoidance by teachers. Gu (2010) advocates for a culturally relative approach to innovation, emphasizing the importance of considering culturally bound values and conventions in the

implementation process. Hofstede (2008) conceptualized four dimensions of independent preference across national cultures to show how values in the workplace are influenced. These comprised the following indexes: Power Distance (PDI), Individualism vs Collectivism (IDV), Masculinity vs Femininity (MAS), and Uncertainty Avoidance (UAI). The two indices addressed in this article, Power Distances (PDI) and Uncertainty Avoidance (UAI), have been given more global objectives than used by Hofstede. In teaching and learning, these may broadly define some of the interferences that can affect the implementation of educational initiatives in different cultural contexts. That is, Uncertainty Avoidance levels may influence expected communication and Power Distance may lead to differences in contextual perceptions. Hofstede and Minkov (2013) defined these dimensions as follows:

1. *Power Distance* (PDI) "…the extent to which less powerful members… within a society expect and accept that power is distributed unequally (page 7)."
2. *Uncertainty Avoidance* (UAI) "…the extent to which a member… feels threatened by uncertain, unknown, ambiguous, or unstructured situations (page 8)."

There is a 100-point range in the indices between countries that have very small/strong and very large/weak power distance and uncertainty avoidance tendencies.

Along with administrative support, Pinto (2005) identified instructional freedom as influencing program implementation. The breadth or specificity of policy and law define the profession as well as the adaptability and compatibility of adopted curricula. Educational responsibilities in Spain are defined and regulated by sectors under the Spanish Ministry of Education. The central government sets general organization, minimum curriculum requirements and regulates academic and professional qualifications. Becoming a school leader in Spain is largely dependent on the High Inspectorate's analysis of teachers who express interest in public school administrative roles. In private schools, leaders usually move up from teaching positions without training. Autonomous communities are responsible within territories for the next level of curriculum development and staff management. Education inspections at this level address diagnostic evaluations. Local administration is responsible for sites, extra-curricular activities and monitoring compulsory schooling. Spanish curriculum is 65% prescriptive (55% in Autonomous Communities with a regional language) giving freedom to schools to organize the other 35% of the curriculum. Schools are autonomous in organizational, educational and financial matters. Educational institutions may be owned by the education administration or a private party (person or legal entity). Private schools may be financially independent or government dependent (CIDE, 2008).

By Spanish law, pre-primary and primary teachers are required to hold teaching degrees. The Maestro degree is obtained in a three (now four) year program of study at the end of which those who complete the program are considered generalist teachers. Music, physical education and foreign language teachers are specialist subjects. In public-funded schools, teachers are selected by examination and positions are usually permanent. Private school teachers sign a contract with the management of the teaching center (MEC, 2007). Teachers in this national context are often torn between balancing "meaningful, applied learning situation in integrated contexts … [and the] focus on traditional, conceptual learning of subject-based knowledge" (Venville et al., 2009). Deng and Carless (2009) found that teachers experimented and demonstrated communicative-teaching orientation more when not subjected to heavy exam-oriented mandates but rather the opportunity to diversify curricula when less pressured. Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) exams heightened the pressure to achieve good test results around the world, putting teachers under the spotlight. The Spanish Inspectorate may oversee exams and use student results in evaluating school success. These are still published nationally in league-type tables. This stress often impacts teacher beliefs and practices by diminishing their motivation to experiment with pedagogical practices, which are long-term and holistically oriented.

Hattie (2015) found critical the role of teachers as well as the leaders in maximizing student achievement. Beane (1996) envisioned four challenges teachers may encounter when implementing a new program: Resource availability, school infrastructure, their perception, and student variation. When clear, practical connections are made to what is familiar and need is established individually and collectively, buy-in is more successful. This comes to the fore especially when innovation is a top-down decision from leaders rather than one agreed upon by teachers.

Teachers' prior experience, knowledge and perceived value of the program as well as their self-efficacy also influence achieving implementation goals (Tschannen-Moran and McMaster, 2009; Pinto, 2005; Powell and Anderson, 2002). Value and perceived need are equally influenced by their beliefs and assumptions about the program, learners' characteristics, and knowledge about teaching and learning (Nishino, 2012). These, in turn, are subject to the influence of cultural beliefs and norms. Cultural dissonance is found to pose potential challenges to the integration of the International Baccalaureate (IB) programs into teaching (Drake, 2004; Lee et al., 2011). The philosophical underpinnings of the IB are abstract and elusive philosophical concepts (Halicioglu, 2008). Its non-specificity has been perceived as an obstacle for teachers (Gigliotti-Labay, 2010). The IB curriculum relies

heavily on teachers' creative professionalism, their understanding of IB philosophy and grasp of implementation skills (McGhee, 2003). Success of implementation can be related to teachers' qualities. Teachers who lacked exposure during teacher training to the fundamental aspects of the IB have shown greater concern (Twigg, 2010).

The International Baccalaureate® (IB) is a non-profit educational foundation designed to develop intellectual, personal, emotional and social skills needed to live in today's changing world (IBO, 2013). A strong leadership team is critical to shaping and supporting individual teachers' endeavors to integrate IB program philosophy and practice into their teaching (Hall et al., 2009; Riesbeck, 2008). IB´s Primary Years Program (PYP) is one of their four programs. Aspects fundamental to all IB programs include: International mindedness, inquiry-based teaching, constructivism, conceptual MEC, 2006). In either mode, content is meant to be taught in both languages in accordance with a proportional distribution, so that pupils can express themselves correctly in both at the end of compulsory education. It is not intended that all content be taught in both languages. Established textbooks are not meant to be used for the teaching of the additional language understanding, approaches to learning and reflection, among others.

In the Definition and Selection of Competences, the OECD (2005) recognized that an internationally minded person is characterized by more than knowledge, concepts and skills. Today's society calls more on personal attributes as well as characteristic attitudes towards various aspects of life which ensure the well-being of the individual to support that of a group. The IB mission statement promotes an understanding of other people, with their differences and an acceptance and tolerance towards these (IBO, 2013). It translates into a set of attributes, the IB Learners' Profile (IB, 2009), embodying what it means to be internationally-minded. These serve as learning outcomes for IB program graduates as well as a map for one's life-long journey.

Inherent in the IB learner profile is educating the whole person for a life of active responsible citizenship. The concept of action is a thread that runs through IB programs. Dewey (1938) saw experience as a transaction between the individual (internal) and the environment. Kolb (1984) recognizes that knowledge is continuously gained through personal and environmental experience. Like Kolb, Moon (2009:126) maintains that experience alone does not guarantee learning but rather requires self-initiative, "intention to learn" and an "active phase of learning".

Contact with other languages affords students the opportunity to know and value different cultures, understanding other points of view. The IB, therefore, requires schools to place importance on mother tongue, host country and other languages by holding all teachers responsible for student language development (IBO, 2010). Content and Language Integrated Learning (CLIL) was the pragmatic, pro-active approach to language learning which emerged across Europe and rapidly grew through the 1990's in mainstream education. Marsh (2002) believed it to be the socio-pedagogical adaptation to Europe's border-free context. The transdisciplinary nature of the PYP aligned to the proposals of CLIL. Though Alfaya et al. (2009) did not see a commonly used term for it in Spain, legislation specified areas to be taught in particular languages within its context. The modes comprised of teaching in Spanish jointly with a co-official language (that is, Catalonian, Galician) or jointly in one. The first mode meant integrated, simultaneous or bilingual teaching of two foreign languages. The second mode consisted of learning integrated curricular content in the specific languages of the Autonomous Communities specified under the Linguistic Standardisation Acts 1982/1983 (as they are not adapted to students' real knowledge. Rather, teachers should create and use their own materials, noting that these are needed for all subjects taught in the additional language.

Coyle et al. (2010) acknowledges the uncertainty many teachers feel about CLIL, because language, subject knowledge and assessment should address attainment of the additional language as well as subject content learned. To overcome this uncertainty, in-service teacher training is promoted by education authorities for all teachers of foreign language, irrespective of their specialization. In 2004/05 the Department of Education launched a pilot bilingual Spanish/English CLIL project to reach 110 publicly funded pre-primary and primary schools dispersed throughout the Autonomous Community of Madrid. This project specified participation in international projects and exchanges, not unlike evidence looked for in the promotion of international mindedness in the IB.

Murtagh (2012) identified key themes in successful program implementation that included the need for focused pre-service training and continuing professional development. Schools must comply with IB professional development requirements by guaranteeing teachers and leaders receive IB-recognized training, which address both levels, at authorization and evaluation (IBO 2010). IB-recognized professional development is defined as "Activities listed on the IB events calendar on the IB public website (http://www.ibo.org) or in-school professional development activities organized by the relevant IB office." The requirement is meant to ensure compliance with the program's objectives. Professional learning communities (PLCs) can also provide opportunities for professional growth. These are characterized by an environment that fosters cooperation, emotional support, personal growth, and a synergy of efforts (Dufour and Eaker, 1998). Glickman (2002) believes that teachers cannot improve their craft in

isolation from others. Fixsen et al. (2005) found peer coaching and consulting, another form of collaboration, as the most effective vehicles to prompt change in teaching practice.

Danielson (2007) and Marzano (2007) support the systematization of professional development where observation is part of the process. Hattie's (2009) "microteaching" focuses on reflection with teachers as a professional development strategy to drive change. This reflection on observed practice in videos proved to have a great effect on teaching behaviors that did not diminish over time. A similar practice is currently used by Coyle with teachers in the Bilingual Schools project in Spain (Coyle et al., 2010).

The Spanish Ministry considers in-service training a right and obligation of all teachers. In-service training falls under the auspice of the Education Administrations and schools. In-service training programs adapt knowledge and teaching methods to trends in education including specific methodologies, aspects of coordination, guidance, tutoring, attention to diversity and organization in order to enhance the quality of education and the functioning of schools.

Inquiry is the leading pedagogical approach of the IB. The descriptor of this attribute in the IB Learner Profile mentions natural curiosity, acquisition of skills, independence, enjoyment and love of learning (IBO, 2009). Banchi and Bell (2008) address four levels of scientific thinking to guide teachers in an understanding of student progress in a developmental continuum of inquiry. These are supported by Bell et al. (2005) where the amount of teacher guidance and information provided to students varies per the level of inquiry needed. Inquiries can be done individually, with a partner, or in small or large groups. They go beyond the units of inquiry to touch subject areas (IBO, 2009:4).

Discussion promotes critical thinking inherent to inquiry. Bangert-Drowns and Bankert (1990) showed that open, unguided inquiry fostered critical thinking most powerfully in those cultures where student thinking was not previously valued. Schwab (1960) identifies two main components of inquiry: Materials and discussion. Discussion allows the learner to clarify or further question thinking. Lindfors' (1999) "inquiry acts" support this. Contrasting the inquiry approach, Hattie (2009) suggests that the most direct and active methods of teaching appear to be optimal for achieving the construction of conceptual knowledge.

The antecedents of inquiry based learning are found in the constructivist learning theories and works of Piaget, Dewey, Vygotsky and Freire which in the 1960's became known as the discovery learning movement. Bruner, often credited with originating the movement, notes that "Practice in discovering for one self teaches one to acquire information in a way that makes that information more readily viable in problem solving" (Bruner, 1961:26) A continuous cycle of building, testing, confirmation or modification of personal models of how the world works is undergone in the search for meaning. Vygotsky defined learning as "the creation of meaning that occurs when an individual links new knowledge with [...] existing knowledge" (Mann, 2012). Two of Coll´s (1990) fundamental ideas surrounding the development of constructivism align to the IB:

1. The student is ultimately responsible for their learning.
2. The role of the teacher is to guide and counsel students in their process of constructing knowledge.

In planning, existing knowledge must be verified and students provided with experiences to check and revise their models, establish relationships and create their own meaning. Olson (2003) in Hattie (2009:241) states, "it is the students themselves, in the end, not teachers, who decide what students will learn". Boix-Mancilla and Gardner (1997) argues that constructivism should change the way curriculum is taught allowing teachers to relate knowledge students already have with their individual learning styles in the context of new experiences.

Schwab (1960) noted the need for scientists to move away from their love of facts and pushed for them to try new conceptual patterns. The essence of teaching science was coverage and his worry about knowledge obsolescence drove him to promote the use of simple guiding concepts. He felt materials for student inquiry should provide varying perspectives to look at a problem through the eyes of the different disciplines. Erickson's (2008) work on conceptual lenses amplifies this. She coins the term to explain how a macro concept forces thinking to a more concrete level of integration allowing patterns and connections to surface across broader frames of study. Without this, she claims, study reverts to memorization of facts and superficial understandings. Erickson (2012:6) notes the importance of attending "to both the key concepts and more disciplinary-specific related concepts to ensure that students develop breadth and depth of conceptual understanding".

Approaches to learning (ATL), originally the PYP transdisciplinary skills, were recently adopted across all IB programs (IBO, 2014). These skills; social, communication, thinking, research and self-management skills are relevant to all learning. They not only transcend the boundaries of subject areas but also life, in and outside of school. The European Union and the Ministry of Education have identified eight basic competences which align explicitly or implicitly to the former PYP transdisciplinary skills (that is, linguistic competence, social competence, autonomy, knowledge acquisition, and learning to learn). Others are incorporated under disciplines (that is, mathematical and artistic competence). Variable student groupings support not only inquiry in the classroom but the opportunity to develop and use these transdisciplinary skills. When

students work with a partner, in small or large groups, they engage in situations requiring communication, social and self-management skills. Ford (2005) notes that no one grouping pattern is bad but the exclusive use of one may lead to problems in the classroom. Valentino (2000) notes flexible grouping can make a teacher's job easier and students more productive. Grouping should not only consider those led by teachers but those led by students, giving them greater voice in metacognitive processes. The frequency of these opportunities ensures more independence when activating and transferring the use of these skills.

Kompf and Bond (2001) quote Dewey in Barer-Stein and Kompf (2001) "successive portions of reflective thought grow out of one another and support one another", creating a scaffold for further learning, in support of constructivism, to allow further experiences and reflection. Kolb (1984) cites Freire's (1973) work on praxis or the reflection and action upon the world to transform it. Freire states, "Men are not built in silence but in word, in work, in action-reflection (pp. 75-76)." He explains the concept of word as work or praxis and notes that it has two dimensions beyond dialogue, one of action and one of reflection. He notes that when a word is not authentic it contorts one of these dimensions, sacrificing the other. If action is compromised, reflection is just chatter. If reflection is compromised, action leads to activism, negating dialogue. It arises explicitly in the IB action cycles but is seen in the IB learner profile attribute of reflective. The descriptor addresses metacognition and assessment, "They (students) give thoughtful consideration (to) their own learning and experience. They can assess and understand their strengths and limitations to support their learning and personal development" (IBO, 2009b). Reflection is a tool not only to move students toward taking responsibility for their learning but also as an assessment method.

Evaluation is an essential part of all teaching and learning processes. Schools are expected to develop evaluation procedures and practices that reflect the philosophy and objectives of the PYP which are then documented in an Assessment Policy. Hattie (2009: 28) cites studies by Biggs and Collis (1982) and Brown (2002) where a student's measure of success is surface knowledge acquisition and a teacher's goal is usually deep learning outcomes. Boyer (1995) notes this difference in the curiosity of young children versus the query of older children as to whether the information being addressed "will be on the test". It is therefore imperative that teachers guide students carefully and effectively through different forms of appraisal, formative as well as summative; process as well as product. To know where students are in the process, records of pre-assessment are important to assess the extent to which the depth of understanding and knowledge have increased. Teacher feedback should become a tool to provide incentive to improve. Although the approach legislated for classroom assessment in Spain is global and continuous, there are compulsory end of first and third cycle national exams. The exams address curricular areas of mathematics, natural, social and cultural environment, and Spanish language. Results of these exams are made public, ranking schools in tables from highest to lowest overall average scores. These are also used in school inspections (CIDE, 2008).

Specific to the PYP are its transdisciplinary framework, corresponding components and the attitudes. The concept of a transdisciplinary inquiry-based curriculum was first raised in progressive education. Nicolescu (1996) notes going beyond multi and interdisciplinary teaching in the works of Piaget, Morin, and Jantsch. His manifesto on transdisciplinarity translated by Voss (2001) sees uniting knowledge to reduce fragmentation and dichotomous thinking; the goal being greater human consciousness about the present world. Nicolescu, however, was concerned that the term may be used to legitimatize decisions without really creating change. The PYP transdisciplinary framework (Program of Inquiry) arose from Boyer's (1981) suggestion to organize curriculum on core commonalities of human experience rather than subject disciplines.

The essential elements (concepts, knowledge, skills, attitudes and action) are components of transdisciplinarity. Boyer (1995) mentioned the need to gain understanding beyond subjects, implying a focus on concepts. The PYP is comprised of eight key concepts meant as a research tool to unlock knowledge. They shape the inquiry around a big (central) idea through lines of inquiry which suggest further questions to explore. The planner is used as a tool to organize each unit. Knowledge is balanced between these human commonalities and the disciplines. The transdisciplinary skills, now ATLs, and action are part of all IB programs. This leaves PYP attitudes. Together the IB Learner Profile attributes and PYP attitudes define a curriculum based on values. Although the OECD (2005) defines competency as more than knowledge and skills by drawing on attitudes, the transfer into the Spanish national curriculum defined the contexts in terms of subject disciplines, leading to repetition. As a stand-alone entity, attitudes are seen transversely in the PYP creating a more global view.

Comunidad Autónoma de Madrid (CAM) assessments are administered to 4th and 6th grade students, with a trial for 2nd grade students currently in place. The results of these exams are published in national press (MEC, 2013). While the PYP is not against standardized testing, its main objective for assessment is to provide information on progress in the learning process. "The PYP assessment approach recognizes the importance of evaluating both the process and the results of the inquiry, and seeks to integrate and support both" (IBO 2009: 44).

As models, the attitudes support students' reflection on their own metacognitive set of values in a variety of contexts. The PYP considers these as "habits of mind" that inform curriculum decisions, impacting the learning environment and personal interactions within it (IBO 2009: 24).

Lauder (2007: 442) suggests the implementation of the PYP, including the socio-cultural factors impacting teaching and learning, is "still in its infancy". Given the significant role of leaders and teachers, the implementation of the PYP depends on positive working relationships between these two groups.

METHODS

As social inquiry is influenced by a variety of sources at many different levels to investigate a given problem, the mixed methods provided the tools to address these. Although prime importance was given to the research questions, the diverse approaches gave value to both objective and subjective knowledge. The strength of the qualitative analysis in this study for inductive or theory-development driven research lies in the systematic review of documents used in program implementation. As these emerged over a given timeframe, the data supported an understanding of the process and provided detailed information about the setting and context. This study involved intensive case studies at six schools in one group of schools and a single national context. Non-probability accidental sampling was used as schools were conveniently part of a group of schools' implementation project. The use of case studies as part of the qualitative approach emphasized the perspectives of the participants and provided greater depth in understanding the different aspects of the investigation.

The strength of the quantitative analysis in this study for deductive research lies in gathering descriptive and comparative information in order to measure variables and yield numeric data that provide statistically founded relationships. This data has the potential to establish probable cause and effect, generalizations across populations and provide insight into a variety of experiences. The quantitative analysis was applied to data collected from two interrelated questionnaires: one for the teachers' perceptions of difficulty on various aspects of the program and a second for the leaders' perception of how difficult they felt the aspects were for the teachers.

The non-experimental, mixed method research comprised of both a qualitative and a quantitative framework. The interpretive paradigm of the research offered an opportunity to understand and decipher the complexity of the schools' contexts. The combination of objective and subjective perspectives offered by the qualitative document analysis and the quantitative survey instrument served to describe the challenges of program implementation in the schools involved.

Documents for the qualitative analysis included: Feasibility studies, application forms, preliminary visit reports, school action plans, studies of parent satisfaction surveys, professional development plans, records of development (program of inquiry, units of inquiry, assessment tools), and authorization reports.

Definition of documents

1. Forms A and B: The January 2003 version of Form A and the
2. September 2006 revised version of Form B were submitted. The two application forms are comprised of ten areas to complete, all but the tenth area being the same. These ten areas include:

i. Contact details (school addresses)
ii. School information (year founded, legal status, type of school, academic structure, number of students, ages, school size, and other IB programs offered)
iii. PYP area information (number of classes, organization of classes, nationalities of students, languages offered, Mother Tongue provision)
iv. School planning and support (reasons for implementing the PYP, formal decision by governing body, consultation with other sectors, identification of responsibilities, PYP training received, collaborative meeting facilitation plans, time frame for all staff training)
v. School infrastructures (nature of school, special facilities including library and ICT)
vi. Teaching personnel information (number of full and part-time PYP teachers, support staff, subject coordinators, single subject teachers, nationalities, meeting times, PYP document availability, responsibilities for hiring)
vii. PYP Coordinator information (name, responsibilities, non-teaching time)
viii. Finance and planning (fee payment, strategic planning, PD funding)
ix. Resource management (library staffing, budget, centralization, classroom libraries, inventory per language-general reference, fiction and non-fiction, newspaper and periodicals, loan arrangements; computers available, IT staffing, IT resources, Mother Tongue resources, PD resources)
x. Implementation of the program. This section differs between Form A and Form B.

a. Form A asks for the approximate date of submission of Form B as well as the development of a 3 year action plan.
b. Form B asks for the action plan as well as a reflection on and description of the school's current situation in relation to each of the IB Standards. Lastly it asks schools to comment on how the teaching and learning at the school contribute to the development of the IB Learner Profile attributes as well as what PYP implementation give to the school and local community.

1. Given that the Schools belong to a group of schools, Form A was filled in at Institution level with the help of the PYP Coordinators in the Schools. In contrast, Form B was filled in by the PYP Coordinators first then reviewed at Institution level.
2. IB Reports: The formats of the IB reports include a description of the school addressing and summarizing information provided in all but the tenth areas of Forms A and B after checking for evidence that verifies the data. As with Form A, the Preliminary and Authorization Reports also had institutional similarities that the visitors kept repeating. The IB facilitated the service of the visits to try to coordinate more than one visit within the same dates, taking advantage of the same visitors. Given that there are very few IB visitors who speak Spanish in the International Baccalaureate Africa, Europe, Middle East (IBAEM) region, the IB needed to find personnel who may not have had the language level necessary to do the visit or they looked to the International Baccalaureate Americas (IBA) region for help. The first situation led to final oral reports given, at times, in English with a Spanish translation. This report also submitted to the IB Regional Office in English took some time to translate into Spanish. The second situation led to greater costs in order to bring visitors over from Latin America. Either situation could be improved by training more Spanish speaking visitors in the IBAEM region for these responsibilities.
3. Parent opinion survey: Schools administered surveys at the end

of the school year to determine parent satisfaction on the school programs in general. Items on the parent opinion survey seem more aligned to Spanish inspectorate needs rather than those of PYP implementation. Schools chose which items to send to parents. Parent participation was voluntary and varied from school to school and year to year.

In an attempt to improve the surveys, the Education Quality and Regulation Department (Departamento de Calidad y Regulación Educativa) changed the format over the years. In 2009-10, the format was changed to a scatter graph. In 2011-12, the items changed to align more to the changing needs of the schools. School 2 used the results from the parent survey run by Endicott College for CIS accreditation. Aligning these results to previous years was subjective; therefore, the surveys have been analyzed among schools and within schools, trying to overcome the difficulty of not being exactly the same survey. The results are provided in the general document analysis as well as the document analyses for each of the Schools.

A coding system was devised to compare the documents between and across Case Study Schools. Themes for the codes followed the prescribed sections of the IB Standards and practices and categories aligned with fundamental elements of the program. The initial coding scheme was revised and refined with the analysis of the documents of each School. The codes used to categorize the information from the documents generated the headings or outlines to categorize the Case Study Reports. Individual Case Study Reports for each site were then written up using the coding document. These in turn were used to write the final overall Case Study Interview Report.

Data collection for the six Case Study Schools was conducted over the period of time when the implementation process, application and authorization levels took place, which was from June 2007 to December 2012. Documents were gathered throughout the program implementation process as follows: In the Consideration phase, the Schools were organized into two implementation groups. A feasibility study was carried out to identify resources that supported the process as well as possible deterrents in line with the IB philosophy and standards and practices. A Preliminary Visit was organized to report on the findings of this study. Schools received relevant PYP publications and a PYP coordinator was designated in each school. IBO-approved training for the PYP Coordinators, school leadership teams, as well as teachers was programmed. Schools also arranged to visit PYP authorized schools in the IBAEM and IBA regions. Around the time of the preliminary visit, preparation of Form A and supporting documents was underway. Application fees were rendered by the finance department of the institution.

Once schools completed the consideration phase, they were then authorized to implement the PYP over a trial period. During this time, schools needed to undergo further training, beyond the introductory workshop. The Department of International Programs oversaw which to offer and made necessary arrangements for the schools. It should be noted that the IBAEM Regional Office offered the first workshop in Spanish, The Written Curriculum, in March 2008 to support the further training needs for the Schools. Schools began curriculum development. PYP Coordinators and PYP School leadership teams met in Madrid to begin the preparation of the program of inquiry and first units of inquiry. School leadership teams were given unofficial training in PYP Pedagogical Leadership to better understand scheduling needs, in particular, ensuring horizontal and vertical collaborative planning sessions. These teams were made aware of the paradigm shift they were about to take in relation teaching methodology, materials and assessment. Parent support was necessary and, given the cultural background, moving away from single texts and number grades was going to be a challenge. The Case Study Schools give institutionally posed opinion surveys to parents called the “Voz del Cliente” (Voice of the Client) supporting this regulation. The Departamento de Calidad y Regulación Educativa (Education Quality and Regulation Department) at the University of Camilo José Cela (UCJC) provided data from these surveys, starting with the 2007-08 academic year, when the PYP began, and ending with 2011-12 when all schools had undergone the full process. Information from each Case Study School was pulled in relation to its implementation, though, in all but one case, the relationship was not explicit. School leaders looked to the PYP coordinator’s handbook for guidance on the roles and responsibilities of the new position in the organizational structure. As PYP Coordinators took on these functions, they increased their understanding of the making the PYP happen manual to support teachers. They received access to the OCC (IB online curriculum center) and solicited and distributed passwords for it to all staff, encouraging them to enter into the platform to access other PYP documents and join in discussion forums.

Given the scope of the schools’ implementation under the umbrella of one group, the Department of International Programs decided to undergo a pre-authorization consultation visit for one school then determine the need for the others. The IB Regional Office left it to the discretion of the Institution whether this visit was deemed necessary. As with all visits, the timing was at the discretion of the regional office in consultation with the school. Once again, application fees were rendered by the finance department of the institution.

Final phase school visits were arranged through the IB Regional Office with input on dates from the schools. The Form B applications and submission of documents proved favourable and the visits and follow-ups of these took place. At the end of the visit, the visitors gave an oral report of the findings. These were summarized and shared across the Institution by the Department of International Programs.

A comparative review of the documentation was carried out to analyze the stages and level of difficulty of different aspects of the PYP implementation process within and across Case Study Schools using the codes developed. The review took place from January 2013 to March 2013.

The quantitative survey instrument was developed over the period of May 2012 to March 2013. The instrument was developed for two stakeholders: School leaders and teachers. The first addressed the school leadership team (directors, principals and coordinators) and was designed to collect information about their perception of teachers’ need in the IB PYP implementation process. The second addressed the classroom and specialist teachers and was designed to collect information about respondents’ knowledge and level of perceived difficulty related to the IB PYP implementation process. The two interrelated online surveys were aligned to the IB Standards and Practices (IBO, 2009) as this was the reference for regulating the implementation of the PYP at the time of the study.

A preliminary survey was sent to PYP Coordinators in July 2012 for their input on relevance and clarity of items. This survey looked at both questionnaires simultaneously to facilitate the process and asked for open comments. The input from the PYP Coordinators was positive and no changes were made on this first draft.

In December, this draft was sent for validation to university professors from Spain, USA, UK and Cuba with expertise in research methodology, the IB and the PYP to assess the clarity and relevance of the items. Three of the professors were PYP experts, two were PYP knowledgeable, two were IB program knowledgeable and four were research methodology experts. Their input was gathered from January 2013-March 2013. The instrument used for validation rated relevance (whether the question is significant for the information it is designed to gather) and clarity (in writing, language used, and expression) using the following scale: The

Table 1. Statistics of reliability (Cronbach's Alpha).

Section	N	Alpha
IB	7	0.811
PYP	9	0.889
The written/ planned curriculum	15	0.904
The taught curriculum: Teaching	15	0.900
The taught curriculum: Organization/ infrastructures	4	0.702
The assessed curriculum	9	0.791

criterion for validating items was decided as follows:

1. Those items that at least one expert rated as 0 in relevance were excluded.
2. Items with scores of 2 and lower in clarity were reworded.
3. Items with more than 40% in ratings of 0 and 1 for relevance or clarity were excluded.
4. Those items with an average less than 2 for relevance and clarity were excluded.
5. All suggestions given to reword, combine or add items were taken into consideration.

The feedback given proved all items relevant to the study. However, there was an obvious lack of clarity related to both ratings and the way the questions revolved around "understanding".

The only item that did not meet the validation criteria for relevance was "To what extent do the teachers understand the principles of international mindedness." It should be noted that two evaluators omitted validating the item. No explanation was provided for the omission in either case. A comment was made concerning whether international mindedness was a "principle". International mindedness is a very significant concept in the PYP and was not removed because of this feedback but rather incorporated into the question on overall philosophy of the IB in the second draft.

Based on this input, the questionnaire was refined. Comments from the validators explained that determining a percentage of teachers was subjective as the word "understanding" is impossible to measure. As these items did not meet the validation criteria, they were removed from the survey instrument.

The second concern expressed by most of the validators was that the survey addressed cause rather than effect. Again, asking participants to judge their understanding was seen as subjective. The wording of the questions and the ratings needed to be rethought. Comments from one of the PYP experts gave rise to investigating the difficulty of each of the items in the implementation process rather than understanding. The ratings were revised accordingly and became: 1. Very difficult; 2. Somewhat difficult; 3. Somewhat easy; 4. Very easy.

Finally, the questions addressed a range of curricular areas of implementation that carried no organizational structure. Likewise, a comment was made on the inconsistency for ensuring "understanding" and "use" of various aspects of the curriculum. Another comment led to adding a section addressing classroom organization, that is, grouping strategies, use of space, time and resources. The questions were rethought, organized and sections devised related to familiar curriculum components, incorporating these suggestions.

In consequence, the following eight sections were developed for a second validation: General personal information, The International Baccalaureate (IB) in general, The PYP in general, The Written/ Planned Curriculum, The Taught Curriculum 1 (teaching), The Taught Curriculum 2 (classroom organization/ infrastructures), The Assessed Curriculum, and Global Assessment of Curriculum components.

Cronbach's alpha was used to measure the internal consistency for the sections and determine correlation values. Table 1 shows the results of the findings.

Although the personal information in section 0 was validated, a few changes were made from comments given. The name of the participant was removed to ensure anonymity.

The second draft of the survey instrument was sent out to another set of international experts for validation. These included three of the same professors who validated the first instrument, one a PYP expert and two experts in research methodology as well as two new experts, one knowledgeable of the PYP and the other a PYP expert.

An on-line survey method was used to increase accessibility for the collection of quantitative data. Although there were almost 60 items presented, the format of the questionnaire was kept simple in the hope that teachers and leaders could complete the survey in less than 15 min. An email was sent to Directors in April 2013 seeking permission to carry out the survey with teachers through the PYP Coordinator. A letter was provided to PYP Coordinators as a suggestion of how to present the survey to the teachers. The first request was sent in April but the greatest number of responses was received at the end of the academic year. Response was checked weekly to track participation and reminders sent to schools accordingly.

In early June, it was observed that the participation rate was relatively low. A follow-up email was sent to directors with copies to sub directors of learning and development and the PYP Coordinator to encourage more participation; the survey remained active. During the June 2013 PYP workshops, participants were further encouraged to fill out the questionnaire. Survey data collection ended for this study July 31st. A total of 30 responses were collected for the leaders' survey and a total of 124 responses for the teachers' survey.

When the closing date had passed, data from the online platform was downloaded as an Excel file as well as the graphs and percentages provided by the survey instrument. The analyses were run from September 2013 to November 2013 using tests in SPSS version 20. Descriptive and comparative analyses were run on the quantitative data. Descriptive analyses included percent response, calculated means and frequencies. The comparative tests used included: T Student Test of independent samples, ANOVA for one factor, the Levene test of homogeneity of variance, Welch, Games-Howell, HSD of Tukey and the Mann-Whitney U Test for independent samples. Results of the items were calculated for all participants then broken down by leaders and teachers to analyze the descriptive and comparative differences.

Population and sample

The quantitative investigation took place across six private Spanish

Table 2. Teachers' and leaders' participation across all schools and by individual schools.

Group	All schools	School 1	School 2	School 3	School 4	School 5	School 6
Teachers	114	10	23	26	26	20	9
Leaders	23	3	3	6	4	3	4

national curriculum schools belonging to three autonomous communities and one institution. Subjects included a sample of 114 full-time teachers from a population of 255 and 23 leaders comprising directors, principals, coordinators and heads of department from a population of 44 among these schools. Teachers and leaders from the schools were involved in the investigation on a voluntary basis. Classroom teachers and specialists were included but only those who taught full-time. The human resources department provided data for the number of teachers in the PYP for each school in the 2012-13 academic year. The choice of leaders was left to the discretion of each school in line with their organizational structure. Some overlap was seen where more than one person held a given post over the years of implementation. Leaders may hold more than one position depending on the needs of the school. Directors may retain responsibilities of sub direction. PYP Coordinators may also be area coordinators and in School 1 hold the post of a sub director. Leaders may also have teaching responsibilities. The current leader for each school was filtered into the analysis of the data where appropriate. Table 2 provides an overview of the population and sample from this study.

RESULTS

Although the results of the research are favourable in relation to ease of perception of most fundamental aspects, perceived differences between teachers and leaders arose across Section A, the IB philosophy and specific items, namely the roles of inquiry, transdisciplinarity, action, scope and sequence documents and language policy. Similarly, differences in perception were found in use of a variety of assessment tools and strategies; reflection on the planner; planning student use of transdisciplinary skills and attitudes; student use of the IB Learners Profile and transdisciplinary skills; and student understanding of the central idea and lines of inquiry.

Documents analysed provided the first set of inputs for each of these. Relating to aspects of Section A-IB philosophy, preliminary reports refer to the alignment of the schools' philosophy with that of the IB and the continuation of the IB programs in Schools 2, 3 and 5 strengthen this. All preliminary reports showed the governing body of the institution committed to the implementation of the program. Authorization reports reiterated this alignment for all schools. Concern was raised that School 1's administration needed to further their understanding of the philosophy and teaching. Parent survey reference to the educational system encompassed the IB expectations. On a 10-point scale, parent value never dropped below 7.74 and was as high as 9.27 showing its importance, though less so in some schools than others. The range of overall satisfaction was from 6.87 to 8.90. Form B question 10d, asked schools to comment on how the teaching and learning contributes to student development of the IB Learners' Profile attributes. Most schools gave a general description of curriculum inclusion, teacher modeling, and variety of opportunities. School 1 outlined how each attribute was met. Parent survey reference to educational principles can be seen as those values that drive the mission and vision of the school seen in the learners' profile. The value never dropped below 8.57 and was as high as 9.80. The range of overall satisfaction was from 7.28 to 9.10. Authorization reports encouraged schools to continue to promote the attributes throughout the school community. CIS accreditation reports for Schools 3 and 4 proposed deepening an understanding of international and intercultural awareness beyond a market driven product. Parent value given to international program never dropped below 8.57 and was as high as 9.80. The range of overall satisfaction was from 7.28 to 9.10.

International mindedness as reflected in additional language acquisition arose in related comments about the language policy. For the most part, schools initiated the development of these at administration level, usually involving language and PYP Coordinators. As matters to be addressed, Schools 1 and 2 were asked to revise their language policies to clearly align with the PYP perspective on language teaching, learning and evaluation whilst ensuring all stakeholders share the beliefs and values expressed there. School 6 was commended for the importance given to the co-official languages and introduction of two additional languages in Primary. Schools 2 and 6 were asked to consider how the co-official and additional languages fragmented the learning process. Language policies were not used in coordination meetings observed.

Parent value given to language learning never dropped below 7.39 and was as high as 9.90. The range of overall satisfaction was from 6.00 to 9.00.

Preliminary reports for Schools 1, 2, 4, 5 and 6, noted more teacher-directed activities were observed than student initiated ones. Form B for School 1 identifies an understanding of inquiry particularly related to the subjects of Mathematics and Spanish language learning as a difficulty encountered. Visits to schools corroborated this. Where the planner asked for evidence of student initiated inquiries, most reiterated activities suggested by

the teachers. Authorization reports for all schools comment on the need for a deeper understanding of inquiry across all subjects and for all teachers. Unofficial workshops promoting inquiry in Mathematics were given to address the issue early in the implementation process. Authorization reports recommended that Schools 1, 2, 3 and 4 promoted inquiry in the subject disciplines which showed a continuing need in this area. Parent value given to teaching strategies never dropped below 7.54 and was as high as 9.50. The range of overall satisfaction was from 7.04 to 9.10. CIS accreditation reports for Schools 3 and 4 noted the need for greater student voice. Meetings and schedules showed the effort made by schools to adjust to a transdisciplinary model. Preliminary reports of Schools 1, 2, 3, 4 and 5 mentioned fragmented timetables. Teacher time was blocked for teachers across bilingual and trilingual models. The PoI transdisciplinary framework was developed at institutional level with PYP Coordinators from all schools. Authorization reports for all schools made concrete suggestions to improve, that is, ensure all teachers' constant participation, address international mindedness, articulate vertically and horizontally, integrate disciplines and watch for appropriateness. In developing this first draft, conceptual understanding was determined the most difficult aspect to address because of cultural dissonance. Preliminary reports for Schools 1, 2, 3 and 5 refer to a focus on skills rather than the development of conceptual understanding.

Authorization reports recommended that all schools perfect the Units of Inquiry (UoIs) in the PoI, specifying certain components, that is, perfecting central ideas to develop the transdisciplinary theme and allow inquiry. Authorization reports reminded schools about identification of key concepts, lines of inquiry and exploration through multiple perspectives. Authorization reports for all schools commended the easy access to planners in an electronic format supporting collaborative planning. Schools 1, 3 and 4 were advised that all teachers use the planner as the only process for planning and that all stages of the planner be completed. Schools 3, 5 and 6 were asked to refrain from using the planner for documenting the learning of skills and knowledge that were not implicit in an inquiry. Preliminary reports of Schools 1, 2, 3, and 5 noted that teachers had limited experience in the practice of reflection. In addressing a revision of the planners, Schools 3, 5 and 6 were asked to ensure documentation of understanding, knowledge and skills pertaining to disciplines within the inquiries developed.

Preliminary reports noted the lack of teachers' experience in the development of curricula in all schools. Form A for Schools 1 and 2 noted adapting curricular contents to the PYP curriculum framework as a major difficulty. Forms B for Schools 1 and 2 continued to see it as a concern. Curricula were developed over the summer months by teachers chosen by school leaders at institutional level then passed on to all schools. Curricular areas of the PYP were carefully aligned to the legislated changes as they came into effect (Portellano, 2008b). Development did not involve all staff. UoIs developed were checked for content knowledge addressed by law. Parent value given to learning basic subjects varied greatly between infant and primary parents. It never dropped below 6.20 and was as high as 9.88. The range of overall satisfaction was from 6.86 to 9.00. The authorization reports asked schools to ensure scope and sequence documents were coherent with the expectations of the PYP and written for each subject area.

Form A for School 5 mentioned the need for more books in the library. Using manipulatives and developing resources to reduce text use was a challenge. Preliminary reports to Schools 1, 2, 3, and 5, mentioned lack of a library, limited literature collections and the need for subject area additions representing a variety of cultural perspectives. Preliminary reports for all schools mentioned textbook dependence as an obstacle. Schools 1 and 2 were asked to make manipulatives and artifacts accessible to students. School 5 mentioned the need for more international resources. Preliminary reports for Schools 1, 2, 3 and 5 mentioned ICT resources supported implementation. Form B for School 1 mentioned amplifying the computer room. Acquisition of resources was systematically planned in 2007 by the Department of International Programs (DPII) to address the needs. Form B for Schools 1, 3, 5 and 6 mentioned enabling the library and increasing materials. School 1 still saw the use of different textbooks difficult. The parent value given to resource materials never dropped below 7.33 and was as high as 9.33. The range of overall satisfaction for this area was from 6.19 to 9.60. The parent value given to cultural visits never dropped below 7.60 and is as high as 8.96. The range of overall satisfaction for this was from 7.83 to 8.73. Results were only for Infants. The authorization report for School 1 recommended as a "matter to be addressed" that the library be recognized and used to support implementation of the PYP and for School 6 that the librarian's workload be revised. The authorization report for School 3 asked for a move away from textbook reliance.

Other considerations regarding resources for implementation included physical space, its use and different aspects of time. Both the Preliminary Report and Form B for School 6 noted classroom size and distribution as obstacles. School 1 noted the reorganization of space to meet the needs of the program in Form B. Authorization reports for Schools 4, 5 and 6 suggest the use of a single room to integrate learning experiences rather than having students move from a Spanish to an English classroom. It was recommended that all schools use learning centers, meaning changes to

space for differentiated grouping. Kagan cooperative learning workshops took place in all schools providing a range of tools to group students for different purposes. Grouping was observed more often in UoIs than subject specific classes

Time was the most valued resource. Form A for all schools stated how collaborative meetings would be facilitated. Mostly schools commented on team and departmental meetings, only School 4 specified times. Preliminary reports for all schools mentioned the lack of time for collaborative planning. In Schools 1, 2, 3 and 5, concern was expressed in relation to teacher time used for supervision and extracurricular activities that could be made available for planning and reflection. Time to reflect also needed to be ensured in Schools 1 and 6 as per their reports. Form B for Schools 2, 3, 5 and 6 showed the disposition of time for collaborative planning as a continued difficulty. School 5 was very clear that time was an issue for planning and developing a concept-based curriculum with fewer texts as well as incorporating specialist teachers into planning sessions. Authorization reports for Schools 1, 2 and 6 asked leaders to guarantee all teachers time for reflection and planning as a “matter to be addressed”. In some cases, the schools were asked to systematize planning, to ensure other responsibilities did not interrupt.

Form A outlined the PYP coordinators’ non-teaching time and responsibilities. This ranged from 5 hours teaching time to 10 periods, with and without Tutor group responsibilities. In School 3, it was left vague and School 4 touted another leadership post. Authorization reports of Schools 1 and 2 asked to ensure the resources, including time, necessary to carry out the roles and responsibilities of PYP coordinator as a “matter to be addressed”. The School 6 report was more direct, stating the PYP coordinator’s time be increased.

Preliminary reports for Schools 3 and 5 identified constructivism as supporting the bid for candidacy. For Schools 1, 2, 3 and 5 they also noted assessment practices focused more on skill acquisition. Required for the Spanish Ministry, schools developed assessment policies. authorization reports recommended that Schools 1, 5 and 6 deepen their understanding of assessment’s role in planning and teaching, ensuring tools and strategies were recorded and appropriateness reflected upon. Schools 1 and 4 were also asked to ensure their Assessment policy addressed the beliefs and values of the PYP, addressed summative and formative assessment, registered and reported on the essential elements as well as student development of the attributes of the learners’ profile. More importantly it asked that the philosophy be seen in practice. School assessment policies began to show evidence of the variety of tools and strategies being used.

Although, by law, assessment is continuous, national exams still focused on results based on content knowledge. Schools 1, 3 and 5 tracked these results. Form B in School 6 mentioned the difficulty of moving teachers from results-based to process-based assessment. It also mentioned lack of student work displays as evidence of learning. Informal visits to the schools supported the need to display more student work. Authorization reports for Schools 2, 3, 4 and 6 recommended summative assessments allow for understanding of the central ideas. All schools were cautioned that conceptual development be addressed and acknowledged in practical ways.

Report cards were tailored to allow for students, parents and teachers to reflect on the learning process within the units of inquiry. Authorization reports commended the schools on their reports noting that they communicated progress as well as outcomes. The parent value given to reports never dropped below 6.92 and was as high as 9.28. The results of satisfaction across School 2 were 9.59. Authorization reports for Schools 5 and 6 noted the need to see the portfolio as a tool for learning that reflects progress.

Authorization reports reminded Schools 2, 5 and 6 that the objective of learning is the understanding of concepts. Authorization reports for Schools 1, 2, 4, 5 and 6 referred to the need to deepen an understanding of action as the outcome of learning and put the action cycle in practice. Schools 2 and 3 were asked to record spontaneous, student initiated action. Schools 2 and 4 were asked to facilitate student initiatives. The workshop on action in the PYP was provided officially in Spanish in IBAEM for the first time in February 2012. The number of participants was minimal. A few schools sent bilingual teachers to participate in the Action workshop in English at the Regional workshops in Lisbon in 2008

Form B for School 6 noted that one of the difficulties encountered was changing the teachers’ philosophy about education. Participation in IB official workshops were meant to support this. Attendees were usually chosen by the school leadership teams, at times training the same personnel rather than spreading the training amongst staff. School leaders were given samples of rotational plans to use as a support to ensuring equity of participation. The parent value given to teacher preparation and training never dropped below 7.83 and is the only item that reached a maximum of 10.00. The range of overall satisfaction was from 7.46 to 9.20. Workshop offers were made by the DPII based on perceived need from school observations, feedback from the preliminary reports and conversations with leaders.

Assessment and methodology were the two Category 2 areas with the most difficult paradigm shifts becoming the focus for training after introductory workshops. Schools were encouraged to send bilingual teachers to PYP regional workshops outside of Spain. Unfortunately, the number of Spanish monolingual teachers in the schools necessitated official professional development in their

Table 3. Teachers-leaders perceptions of difficulty.

Group	All schools	School 1	School 2	School 3	School 4	School 5	School 6
N (*Sig.p)*	7	2	0	2	1	4	5

Sig.p, Across all and individual schools.

native language. Although three teachers were sent to a workshop in Buenos Aires, financing was much greater issue than attending workshops in the IBAEM region. Workshops offered in Spanish increased to meet demand. At the IBAEM's March 2008 PYP workshops in Lisbon, 41 participants came from the case study schools. Twenty-five of those attended the first PYP Spanish Category 2 workshop offered in the region. Only two participants in this workshop were not members of one of the Case Study Schools.

Acknowledging this, and the financial effort made, the IB PYP Regional Director suggested that the institution investigate offering IB In-Cooperation workshops. Category 1 workshops were maintained to ensure all new teachers were trained prior to authorization. In June 2009, the first PYP IB In-cooperation workshop in Spanish was offered (assessment in the PYP). The Department of International Programs registered 70 participants from the Case Study Schools. The following year, a second PYP In-Cooperation workshop in Spanish was offered (teaching and learning in the PYP). The Department of International Programs registered 105 participants from Case Study Schools. The Regional Office, realizing the extent of professional development needed, approached the Institution to suggest it become an IB Official Professional Development Provider. The first contract was signed in 2010. Finding dates for the workshops was difficult. Teachers did not want to give up vacation days and leaders did not want to take days off the school calendar. Category 3 workshops were introduced in June 2012. In June 2013, subject specific inquiry workshops were offered in response to difficulties seen. The workshops were well attended but schools began looking for other ways to support professional development. Authorization reports for Schools 1, 2 and 6 suggested planning opportunities be used to question pedagogy and develop professional learning experiences.

In Form A, School 5 commented on the need to clarify roles and responsibilities. This arose in the preliminary reports for Schools 1, 2, 3 and 5. Roles and responsibilities of all positions are found in the 'Reglamento de Regimen Interior' though schools adapted these in line with the PYP Coordinator notes and PYP Pedagogical Leadership manual. Schools outlined in Form B question 7bi, to varying degrees of specificity, the responsibilities of the PYP Coordinator. In Form B, Schools 3 and 6 noted the diverse changes that took place in the leadership team during the trial implementation. In the six-year period of implementation several changes were made in PYP coordination. School 6 was the only one not to undergo any change and School 5 remained stable through the PYP implementation process. School 3 was on their 5th PYP coordinator as of the 2013-14 school year.

Authorization was granted to four of the Case Study Schools, three of which were required to submit reports on "matters to be addressed". Authorization was postponed for two of the Case Study Schools and a return visit was required. The IB regional office revoked the return visit requirement for one school after the submission of the follow-up report. At the end of the study, all schools were moving into the next evaluation phase, School 2 being the first to undergo the process and visit in October 2013. This visit, organized by the regional office, was to take place three years after receiving the authorization; however, as schools were caught in IB changes, some visits were put on the four-year cycle. Self-evaluations were planned in Schools 1 and 4 for 2013 as the process needed to be underway six months prior to the visit. Some schools adjusted the process so that one multiple program visit could be made by the IB delegation rather than a series of individual program visits.

While the documents analysed highlighted some areas of difficulty, it was the quantitative comparison that emphasized significant differences in perceived difficulty of program implementation between teachers and leaders. Table 3 provides an overview of the number of significant results from this study across all schools and individually.

Table 4 identifies seven items perceived by teachers as easy and leaders as difficult, listing these from greatest to least mean difference as given by the descriptive and comparative analyses. This split in teachers' (T) and leaders' (L) perceptions of difficulty are presented as items where leaders underestimated teachers' perceived difficulty of implementation. The column to the far right gives the significant *p* for the difference in each item. The table shows three items perceived as significantly easier for teachers than leaders.

Table 5 identifies items perceived by teachers as difficult and leaders as easy. Splits where a teacher finds something difficult but a leader expects them to find it easy resulted in seven items of leader overestimation in the descriptive analysis. Items, listed from the greatest to

Table 4. Leader underestimation.

Question	T	$\dot{x}$	L	$\dot{x}$	$\dot{x}$ diff.	Sig. *p*
A3 The role of inquiry	E	2.95	D	2.43	0.513	**0.002**
B4 The role of transdisciplinarity:	E	2.69	D	2.26	0.432	**0.020**
F5 Use of varied assessment tools and strategies	E	2.60	D	2.22	0.379	**0.024**
B7 The role of action	E	2.53	D	2.35	0.178	0.329
D8 Guide students to understand lines of inquiry	E	2.65	D	2.48	0.171	0.300
A1 The IB philosophy	E	2.59	D	2.48	0.109	0.566
D9 Guiding students to understand the central idea	E	2.54	D	2.43	0.100	0.537

T, Teacher; L, Leader; E, Easy; D, Difficult; E, Split across all schools.

Table 5. Leader overestimation.

Question Item	T	$\dot{x}$	L	$\dot{x}$	$\dot{x}$ diff.	Sig. *p*
C13 Teacher reflection on the planner	D	2.32	E	2.78	-0.458	**0.003**
C7 Planning student use of transdisciplinary skills	D	2.32	E	2.70	-0.371	**0.018**
C8 Planning student use of the attitudes	D	2.48	E	2.83	-0.344	**0.047**
B8 The role of scope and sequences	D	2.41	E	2.57	-0.153	0.338
D13 Student use of transdisciplinary skills	D	2.47	E	2.65	-0.178	0.286
A6 The role of the language policy	D	2.48	E	2.57	-0.083	0.639
D14 Student daily use of the ib learners' profile	D	2.47	E	2.52	-0.048	0.783

T, Teacher; L, Leader; E, Easy; D, Difficult; E, Split across all schools.

the least mean difference, show the split in teachers' (T) and leaders' (L) perceptions of difficulty. The column to the far right gives the significant *p* for the difference in each item. The table shows three items being perceived significantly more difficult for teachers than leaders.

The last significant result between these teachers and leaders arose as shown in the Table 6. Both groups perceived using a variety of teaching/learning strategies as easy though teachers perceived it as significantly easier than leaders.

On a positive note, the study showed alignment of perceived difficulty between teachers and leaders for 45 of the 59 items. Of these, 26 items were perceived as difficult and 19 were perceived as easy by both groups. Table 7 gives an overview of the perceptions of difficulty between teachers and leaders across all sections. The only section in which perceptions differed across all items was Section A: IB philosophy.

The investigation also showed various instances of leaders being completely split amongst themselves as a group as well as areas where teachers were completely divided in perceived difficulty. The areas in which teachers felt confident were those items with ratings over 2.50 and receiving a greater than 50% response. These items were identified as demonstrating positive self-efficacy. These are found in Table 8. Contrarily, the areas in which teachers felt uncertain were those items with ratings under 2.50 and receiving a greater than 50% response. These items were identified as demonstrating negative self-efficacy. These are found in Table 9.

The greater the percentage, the closer the agreement among teachers. The closer items were to 50% response, the greater the divergence in perception of difficulty. Items highlighted in Table 8 present the highest rating of all items in that section or the items perceived as easiest. Items highlighted in Table 9 present the lowest rating of all items in that section or the items perceived as the most difficult.

DISCUSSION

The mismatch in teachers' and leaders' perceptions of difficulty could lead to problems in supporting the needs of teachers for personal professional development and consequently improvements in teaching and learning throughout the school. Leaders' overestimating or underestimating need can lead to disappointment on the part of either the teacher or the leader and emotional undercurrents that may undermine unconditional positive regard between individuals.

Section A, the IB philosophy, resulted in being the only overall section where teacher-leader perceptions did not align. Its abstract and elusive nature (Halicioglu, 2008)

Table 6. Teacher-Leader Easy - Easy Split across all schools and significant p

Question Item	T	$\dot{x}$	L	$\dot{x}$	$\dot{x}$ diff.	Sig. *p*
D7 Use varied teaching/learning tools and strategies	E	3.04	E	2.70	0.348	**0.036**

T, Teacher; L, Leader; E, Easy; D, Difficult; E, Split across all schools.

Table 7. Teacher-leader perceived difficulty and significant *p* across sections.

Position	N	A	*p*	B	*p*	C	*p*	D	*p*	E	*p*	F	*p*
Teachers	114	2.62	0.162	2.59	0.757	2.29	0.415	2.59	0.552	2.88	0.760	2.34	0.545
Leaders	23	2.45		2.55		2.38		2.53		2.91		2.28	

Table 8. Teachers 'easy' items.

	Item	Means ($\dot{x}$)	Percentages
Positive teacher self-efficacy: Knowledge confident	D6 Inquiry: Other stimuli	3.25	88
	E3 Use a variety of resources	3.21	88
	D11 Students work in groups	3.10	82
	E1 Using different student groups	3.04	82
	E2 Using space as a resource	3.04	80
	D7 Teacher use of a variety of tools and strategies	3.04	76
	D5 Inquiry: Teacher Questions	2.88	70
	D12 Inquiry: Students' own	2.83	64
	B6 Role of Attitudes	2.82	70
	A2 Role of IB learners' profiles	2.79	63
	A4 Reflection: Role	2.78	67
	B1 Constructivism: Role	2.77	61
	B2 Program of inquiry: Role	2.73	65
	D10 Inquiry: Students' in UoI	2.62	59
	B5 Transdisciplinary skills role	2.62	55
	F3 Pre-assessments: Writing	2.61	56
	F4 Using formative assessment with students	2.59	57
	D15 Student use attitudes day to day	2.52	56
	C12 Planner: Teacher contribution	2.51	52

and non-specificity (Gigliotti-Labay, 2010) may, in part, explain this; however, per documents analyzed, the IB philosophy aligned with the Institution's and Schools'. Therefore, differences in perception are best explained in the ratings of its components.

Inquiry was a prevalent issue across all subjects and teachers in documents analyzed supporting Ozer's (2010) study. Teachers' perceived understanding of its role may not translate into practice which may have led to the leaders' perception of difficulty. Not all levels of inquiry (Schwab, 1960; Banchi and Bell, 2008) were observed. However, the highest rated item in teacher self-efficacy was use of different stimuli for introducing inquiry. It was evident that teachers had a relatively high degree of instructional freedom supporting Pinto (2005). Positive self-efficacy was also seen in related items, that is, understanding the role of the program of inquiry, and putting into practice teacher questions, student inquiry in the Units of Inquiry and guiding students in self-initiated inquiries (IBO, 2009). While the latter were not observed in documents analyzed, the increased participation in workshops addressing inquiry may have led to the desired results. This may not have been perceived by leaders.

Policy development as seen in the documents analyzed was a top down process with little teacher

Table 9. Teachers 'difficult' items.

	Item	Means ($\dot{x}$)	Percentages
Negative teacher self-efficacy: Knowledge uncertain	**F8** Report cards	2.47	51
	A7 Assessment Policy: Role	2.46	57
	B3 PoI: Role of components	2.38	57
	C6 Writing lines of inquiry	2.36	61
	B9 S&S: Role of components	2.36	62
	C14 Use language policy in planning	2.35	59
	D2 Student connection TT and central ideas	2.34	59
	F6 Portfolios: Student use	2.32	54
	C15 Assessment Policy: Use to plan	2.32	61
	F2 Sum. Assessment: Student involvement	2.29	64
	F1 Writing summative assessment tasks	2.29	65
	A5 Concept-driven curriculum	2.27	67
	C1 Key concept choice in UoI	2.28	68
	C4 Related concept choice in subjects	2.26	68
	C3 Related concept choice in UoI	2.33	69
	C2 Key concept choice in subjects	2.23	71
	E4 Using time as a resource	2.22	62
	C5 Writing central ideas	2.22	65
	C10 S&S: Use to plan	2.22	68
	C9 Planning action in the planner	2.16	72
	F9 Standardized tests	2.09	70
	D3 Student use of key concepts	2.09	75
	D4 Student use of related concepts	2.06	76
	C11 Planner: Completion of all stages	2.02	80
	D1 Student use of transdisciplinary themes	1.99	82
	F7 Student-led conferences	1.78	84

input explaining leaders' ease in perception. Language policies were not communicated with nor used by teachers to build ownership so their perception of difficulty is understandable supporting Chance (2009). Concepts were perceived as difficult across both sectors. All related items appeared in the list of negative self-efficacy for teachers including identifying key and related concepts, writing central ideas and lines of inquiry, understanding the role of concept-driven curriculum and guiding students in making connections between the central idea and transdisciplinary theme. Documents analyzed showed cultural dissonance and posed challenges (Drake, 2004; Lee et al., 2011). IB reports continually referenced the need to deepen understanding. However, when put into practice, that is guiding students to an understanding of the central idea and lines of inquiry, teachers demonstrated a degree of positive self-efficacy. Leaders not directly involved in classroom practice perceived these as difficult. Constructivism was perceived positively in document analysis and survey results; however, Coll's (1990) fundamental ideas about student responsibility for learning and teacher facilitator in constructing knowledge were not observed in documents analyzed. This was evident in the Section F, Assessment. How the curriculum was being taught (Boix-Mancilla and Gardner, 1997) was still being developed. Specific to the PYP, mismatch in perceived difficulty in Section B revolved around the role of transdisciplinarity and scope and sequence documents. Teachers were engrossed in implementing the program of inquiry and corresponding units. Their first-hand experience with it may explain their perceived ease with its role. Leaders on the other hand, being caught up in the legalities of curriculum alignment and parent perceptions, may have developed a concern as reflected in their perceived difficulty. The balance of disciplinary and transdisciplinary work arose frequently in the documents analyzed, supporting Venville et al. (2009) with parents having a better understanding of the "basics". Documents showed that, as in policy development, this was a top-down process. Leaders' perceived ease with scope and sequence documents is related as they also had a greater investment in their development.

Addressing the planned or written curriculum, difference in national curriculum expectations led to perceived difficulty in planning student use of transdisciplinary skills, attitudes and reflection on the planner. Teachers' first-hand experience again contrasts that of leaders' second-hand accounts. The understanding of transdisciplinarity in language acquisition when responding to the CLIL movement, especially in Case Study Schools in Andalusia, Catalunya and Galicia, may have complicated teaching in developing the modes (MEC, 2013). Although the Spanish Ministry moved toward competency based learning and the introduction of attitudes (MEC, 2007), it had not yet impacted practice. Leaders may have perceived both these changes as easily implemented reflecting their rating. The difficulty seen in planning student use of attitudes paralleled teachers' perceived difficulty in promoting students' daily use of the IB Learners' profile attributes. Lastly, written curriculum documentation in Spain was not prescribed but in the PYP, planners needed to be developed with stages unfamiliar to teachers. Documents showed the lack of culture in reflecting on practice. Other areas of the planner and just the practice of developing them was foreign to all teachers supporting Twigg (2010). Leaders not directly involved in completing them may not understand the difficulties that arose. Some of this was related to ensuring time for their completion.

Teachers' and leaders' perceived items in infrastructures as easy for the most part. Although Beane (1996) saw these as challenges, financial solvency and investment made the difference. Time as a resource was the one item in that section perceived by both groups as difficult.

Assessment in Section F was perceived by both groups globally as difficult. Mismatch arose in relation to the use of a variety of assessment tools and strategies. Documents analyzed showed improvements in the development of assessment policies and reporting. Workshops focused on assessment early into program implementation. While some national curricular expectations supported assessment practices in the PYP and Gu's (2010) culturally relative approach, national exams and league tables were obstacles. Student-led conferences, giving voice to students, rated lowest on negative teacher self-efficacy. It was evident that teacher prior knowledge was lacking (Pinto, 2005; Powell and Anderson, 2002). Action, an assessment as the outcome of learning, was perceived as difficult by leaders. Documents analyzed showed action did not exist as part of the Spanish national curriculum. Workshops were offered to support an understanding of this essential element. While planners did not evidence action, teachers' work with it led to a greater understanding of its role in the PYP. Action service, as advocated by Berger-Kaye (2004), may allow students to further develop transdisciplinary skills, IB attributes and PYP attitudes, but teachers were cautioned that fundraising as action service limited personal growth and commitment. Indices conceptualized by Hofstede (2008) could explain how values in the workplace are influenced by independent preference. Although Hofstede and Minkov (2013) warn that the "…dimensions do not directly predict any phenomena… [as]… there is no quick fix to understand social life", he does say "the dimensions, when well understood, do allow to predict a little better what is likely to happen." Therefore, the study takes on a lesser dimension in addressing schools rather than countries in the hope of being able to make inferences in comparison to the results. That said, although the context of this study is Spain, it is of interest to look at Hofstede's findings for other Spanish-speaking countries, especially those showing interest in the International Baccalaureate programs like Argentina, Colombia, Ecuador and Mexico. Table 10 shows results from Hofstede's work for these countries across the two dimensions. When the index is small, the PDI or UAI is weak. When the index is large, the PDI or UAI is strong. While Spain shares some cultural history with countries in the Americas, the results of Hofstede's findings show independent preferences across them vary less in relation to the Uncertainty Avoidance Index (UAI) than in the Power Distance Index (PDI). In relation to the UAI, with the exception of Ecuador, the countries chosen show a preference to avoid confronting change and the personal stress it may entail. Their populous is less likely to take risks or place themselves in ambiguous, undefined situations than they are to choose paths that are stable and diminish future concerns. They are less likely to want to take control preferring rules that regulate any given situation. However, if those rules make life too complex, they are also avoided.

The PDI, however, showed particularly high scores for Mexico and Ecuador where society is perceived more strongly as hierarchical with the inequalities inherent in this kind of organization. People accept this order as well as being told what to do by the boss with no questions asked. Argentina and Spain are closer to the middle where less powerful members of society are not as likely to expect or accept the unequal distribution of power.

How might this translate to the Spanish Case Study Schools and the findings? Splits where the teacher finds something easy but leaders perceive it as difficult may infer an underestimation on the part of the leader. Hofstede's findings in relation to a high Uncertainty Avoidance Index (UAI) would suggest that Spanish teachers may unquestioningly accept decisions their leaders made. Teachers with a high Power Distance Index (PDI) may equally accept being told what to do thus leading to maintaining the status quo. The result would be no vested interest in creating change or supporting innovation, having teachers become every bit the

Table 10. Hofstede results.

Country	Power distance index	Uncertainty avoidance index
Argentina	49	86
Colombia	67	80
Ecuador	78	67
Mexico	81	82
Spain	57	86

Source: Accessed 12 July 2016 at http://www.geerthofstede.nl/dimension-data-matrix.

underachievers they find so frustrating when seen in students. As Paskavich said, *"I admit it in school I was an underachiever and it was so easy to do* (*GoodReads, 2014)."* As Michelangelo said, *"The greatest danger for most of us is not that our aim is too high and we miss it, but that it is too low and we reach it* (*GoodReads, 2014)."*

In any case, it can be inferred that leaders in this situation are probably faced not only with teacher disinterest but also unnecessary spending of funds when, for example, chosen professional development does not meet a real need. Teachers confident in items of high self-efficacy may accept the leaders' judgment and participate in rather than lead related training.

That said, if an individual's UAI and the PDI are low, the teacher may question the decision of the leader to address other interests and areas in self-perceived need of personal professional development that may not align with the leaders' expectations. These teachers are often perceived to be contentious. Chomsky noted that the system "weeds out" those who "do not know how to be submissive" when he said:

"The whole educational and professional training system is a very elaborate filter, which just weeds out people who are too independent, and who think for themselves, and who do not know how to be submissive, and so on because they're dysfunctional to the institutions (*GoodReads, 2014)."*

These same teachers may run into conflict with their conscience if compromising their beliefs in order to appease the leader. Would not it be far better to support these teachers as leaders in their own right supporting Edison when he said, *"If we all did the things we are really capable of doing, we would literally astound ourselves…*(*GoodReads, 2014).."* Or confirming Collini where *"A different voice may be particularly effective in disturbing the existing participants into re-examining matters they had come to take for granted* (*GoodReads, 2014)."* School leaders should consider using teachers confident in items of high self-efficacy to support those who need a better understanding of these.

On the other side of the spectrum, items perceived by teachers as difficult and leaders as easy can be inferred to be leaders' overestimation of teacher capacity. Leaders, who may themselves feel more comfortable with these items, should attempt to discover why their perceptions differ, then lead discussions to promote moving staff and individuals forward. If not, caution should be taken not to discourage or judge teaching professionals when uncertainty is high. Judgments can crush attempts at addressing areas perceived as difficult. As the Roman poet Ovid (43 BC-18 AD*)* said, *"A new idea is delicate. It can be killed by a sneer or a yawn; it can be stabbed to death by a quip and worried to death by a frown on the right man's brow* (*GoodReads, 2014)."* High UAIs and PDIs ensure teachers follow along with the leaders' initiatives; however, this blind acceptance does not support modeling critical thinking, which is fundamental to deep change and innovation.

Low UAIs and PDIs may support this critical thinking if leaders allow for free exchange of ideas and critical discussions. Hassan (2010) suggests 20 phrases that kill innovation. In discussion with teachers, leaders should refrain from using these in order to provide support for initiatives in areas where perceived difficulty is high. One of these phrases which comes up in education settings often and should be refuted, especially by leaders, is: We've never done it that way. Leaders should consider how to best support teachers in areas new to them like reflecting on the planner, as well as planning student use of the transdisciplinary skills and PYP attitudes. Dialogue with teachers could prove insightful as to the different possibilities: Formal and informal professional development opportunities, sharing across schools, across grade levels, providing dedicated time, etc.

Implicit in developing shared understandings would be a guarantee by school leaders that stakeholders are rating the same thing. For example, do they all agree on the definition of inquiry, concepts, international mindedness or transdisciplinarity? Do they agree on what these look like and where they are evidenced in planning, teaching and assessing? They should share and critic their own examples and non-examples. Teachers and leaders should reflect on readings and observations of

practice to determine that they are rating the same outcomes. As much as possible, these should be backed up with essential agreements, procedures and policies. Through the development of shared definitions, policy and practice, balanced perceptions can be more easily reached.

Agreement is important not just between teachers and leaders. On items showing complete splits in perceived difficulty within groups of leaders and teachers, introspection is necessary. Leadership teams need to discuss first where their own perceptions do not align before approaching staff development. Misalignment amongst leaders may lead to giving mixed messages to staff and confusion regarding expectations. This introspection can be taken on first by leaders then between teachers before moving on to the differences between the two groups. Documents analyzed demonstrated lack of clarity in leaders' roles and responsibilities. If a strong leadership team is crucial to supporting teachers (Hall et al., 2009; Riesbeck, 2008), surely the first step is ensuring clarity in these.

Conclusion

The good news is that there was alignment of perceived difficulty between teachers and leaders for 45 of the 59 items. Sections on PYP fundamentals, teaching practice and teaching infrastructure were perceived easy in general where items in sections on the written and assessed curriculum difficult. Many of the difficulties can be attributed to cultural dissonance. Although the number of items perceived as difficult (26) was greater than those perceived as easy (19), the alignment of items perceived difficult should allow for agreed upon support systems between teachers and leaders for moving forward in their implementation and school improvement.

Bennis notes that "Leadership is the capacity to translate vision into reality" (GoodReads, 2014). That reality will take place more efficiently and effectively if the perception of those visions are shared or at least understood across teachers and leaders in school settings. This is especially true in countries like Spain where the Uncertainty Avoidance Index is high and for those individuals in schools who perceive greater Power Distance. Schools should take time to develop tools to determine perceived need across stakeholders. These tools may be surveys or self-assessments. Personal professional development procedures could be used in the identification and follow through. Comparisons of these perceptions to better understand the constituents can then lead to differentiation of professional development, the creation of concrete professional communities including book share and peer coaching. By sharing the results and providing appropriate and timely personal professional development, possible repercussions of mismatch may be avoided regardless of the culture to which one belongs.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Restoring soil fertility in previously sugarcane cropped farms for maize production in Butere- Kakamega County

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The depletion of fertility in tropical soils of sub Saharan Africa (SSA) is mainly due to continuous cropping without proper nutrient replenishment. This study was intended to find ways of restoring soil fertility towards sustainable maize production in previously sugarcane cropped fields in Butere-Kakamega County. Field experiments were conducted in Butere and Bukura sites located in Kakamega County in the long rains of 2014. The field experiments consisted of twelve treatments with one control. The treatments included *Tithonia diversifolia* (a green manure), Di ammonium phosphate (DAP) filter mud, and bagasse (both sugarcane processing by products), each to supply 39 kg P ha^{-1} and eight other treatments consisting of a combination of either two of the above materials to supply either 26 or 39 kg P ha^{-1} treated either with or without lime using a split plot arrangement in a randomized complete block design (RCBD). Lime was allocated in the main plot and the treatments as the sub plots. The experiment was replicated three times in each site. Application of lime, with the consequent use of either filter mud or *Tithonia* in combination with DAP was quite significant in raising maize grain yield as compared to the control. The best treatment was the one consisting of lime (3 tons ha^{-1}) with a combination of filter mud + DAP (to supply 39 kg P ha^{-1}) which yielded 5.14 and 5.23 tons ha^{-1} in Bukura and Butere sites, respectively. This being attributed to high levels of organic matter and suitable pH of 6.0 in filter mud that improved the physical and chemical properties of the soil. Farmers are thus advised to consider applying filter mud together with appropriate mineral fertilizers as filter mud can be supplied freely from sugar factories.

Key words: Soil fertility, bagasse, filter mud, lime, *Tithonia*.

INTRODUCTION

In Kenya, maize, *Zea mays* L, is recognized as the staple food among most communities serving as human food (Guantai et al., 2007). Low maize yields in the Country are strongly associated with soil acidity and phosphorus (P) deficiency (Kisinyo et al., 2014).

In the entire sub Saharan Africa (SSA), Kenya

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included, grain yields have been highly variable and low; for instance, between 2011 and 2013, the average yield was estimated at 1.8 mg ha^{-1} (Beyene et al., 2015).The major climatic divisions in SSA are tropics, sub tropics, temperate and boreal. But the tropics occupy more than 50% of the whole area of SSA; hence, maize can be grown in most of this region as it grows well in such a climate (Research Institute, 2010). Edaphic characteristics such as levels of macro and macro nutrients, soil parameters such as pH, organic carbon content, soil texture and cation exchange capacity vary depending on altitudinal gradients. This means for maximum maize yields one has to get an understanding on the altitude levels (Njuguna et al., 2015). Poor soil fertility is a major limitation to crop production (Kisinyo et al., 2014). This has resulted to widespread food insecurity in most parts of Kenya.

In western Kenya, the major problem causing poor maize yields is attributed to continuous mining of macronutrients due to cropping, without proper replenishment of the soils. The current status of most soils in western Kenya is that the amount of organic matter has gone down, hence less humus in the soil. In Butere region, the Acrisol soils with reasonable proportions of clay and organic matter and a fairly moderate cation exchange capacity of 35 to 45 cmol kg^{-1}, have now deteriorated. These soils are less fertile due to the low pH of <5.0, hence fixation of phosphorus is common (Oyamo et al., 2016).

MATERIALS AND METHODS

The study was on farm and the experiment was carried out on a farmer's field in Shihaka sub location in Butere Sub County. This experiment was also replicated on station at Bukura Agricultural College. The two sites are both in Kakamega County of western province and have a bimodal rainfall pattern. Both sites are suitable for maize and sugarcane production. The experiment was run between January 2014 and August 2014.

Experimental treatments

There were two levels of phosphorus (26 and 39 kg P ha^{-1}) supplied through the mineral fertilizer Di ammonium phosphate (DAP) and three organic materials. These organic materials were incorporated in the soil thoroughly three months prior to planting to allow for mineralization. The quantity of nitrogen was topped up by calcium ammonium nitrate (CAN) so that each treatment received a uniform rate of 75 kg N ha^{-1} during top dressing. The experiment thus consisted of thirteen treatments as shown in Table 1.

Experimental design

The design was Randomized Complete Block Design (RCBD) with a split plot arrangement where the main plot was with or without lime and the sub plots were the treatments. The experiment was replicated three times with a replication consisting of 13 plots with lime and 13 plots without lime totaling to 26 plots.

Statistical analysis

Crop yield, soil and plant data obtained were subjected to analysis of variance (ANOVA) with the mixed procedures using statistical analysis system (SAS) for windows 9.1 service pack 4 (SAS institute 2011). Means were separated by way of contrast and correlations were done.

Statistical model

$$Y_{ijkl} = \mu + L_i + R_j + LR_{ij} + S_k + LS_{ik} + F_l + FS_{lk} + €_{ijklm} \quad (1)$$

where Y=observations on experimental unit on ijkl rows, μ = General mean, L = Effect due to i^{th} level of lime, R= Effect due to j^{th} replication, S = Effect due to k^{th} site, F = Effect due to l^{th} amendment (fertilizer), LR_{ij} = Error term 1, and $€_{ijklm}$ = Error term 2.

Economic analysis

After computing the grain yield (tons ha^{-1}) for each treatment, gross returns were calculated based on the prevailing market price of maize in the region.

Total costs were also computed after adding up all the costs from land preparation, farm inputs, labour, etc. Benefit cost ratio (BCR) was then calculated by the formulae:

$$BCR = \frac{Gross\ returns}{Total\ costs} \quad (2)$$

RESULTS

Initial soil characterization for the study sites

Soil properties at the experimental sites are presented in Table 2.

The treatments with filter mud supplying 39 kg P ha^{-1} (FL_1) significantly increased the soil pH in both sites. In Bukura site limed plots, this treatment, that is, FL_1 (filter mud alone; 39 kg P ha^{-1}) raised the pH from 5.67 (control) to 5.80 where as in the same site for the unlimed plots the treatment raised the pH from 5.18 to 5.30. Effect of lime on available P was significant ($p < 0.0001$) and was able to raise the soil extractable P (in Bukura site) from 5.27 mg kg^{-1} (control without lime) to 13.55 mg kg^{-1} (control with lime) as shown in Table 3.

Effect of treatments on maize grain yield

Lime application was significant ($p < 0.0001$) in raising the maize grain yield in both sites, where it raised yields from 1.38 to 2.16 tons ha^{-1} and from 1.52 to 1.95 tons ha^{-1} in Bukura and Butere sites, respectively. The average of all the treatments with lime (L_1) produced a mean grain yield of 3.24 tons ha^{-1} where as those without lime (L_0) produced a mean grain yield of only 2.27 tons ha^{-1} in Butere site. For Bukura site, the treatments with lime (L_1) yielded 2.92 tons ha^{-1} whereas those without lime (L_0) yielded only 2.30 tons ha^{-1}.

Table 1. Treatments in the experiment, their codes and rate of phosphorus per treatment.

S/N	Treatment	Code	Rate of P (Kg $P_2 0_5$ ha^{-1})
1	Control	C	0
2	Tithonia alone	TN_1	39
3	Bagasse alone	BG_1	39
4	Filter mud alone	FL_1	39
5	DAP alone	D_1	39
6	Tithonia + DAP	TN/D_2	26
7	Bagasse + DAP	BG/D_2	26
8	Filter mud + DAP	FL/D_2	26
9	Tithonia + Bagasse	TN/BG_2	26
10	Tithonia + DAP	TN/D_1	39
11	Bagasse + DAP	BG/D_1	39
12	Filter mud + DAP	FL/D_1	39
13	Tithonia + Bagasse	TN/BG_1	39

Table 2. Initial chemical and physical characteristics of the soils from the sites.

Parameter	Butere	Bukura
pH 1:2.5 soil: water	4.66	5.35
Exchangeable acidity ($cmol_c$ kg^{-1})	0.3	0.4
Organic carbon (%)	1.35	1.65
Clay (%)	38	30
Sand (%)	25	30
Silt	37	40
Textural class	Clay loam	Clay loam
Available P (mg kg^{-1})	3.81	5.88

The effect of treatments was highly significant in both sites ($p < 0.0001$) where treatment FL/D_1 (Filter mud + DAP: 39 kg P ha^{-1}) yielded the highest in both sites. This treatment (FL/D_1) raised the yield from 2.16 (control-L_1) to 5.14 tons ha^{-1} in limed treatments (L_1) in Bukura site and raised the yield from 1.38 (control- L_0) to 3.52 tons ha^{-1} in the unlimed treatments (L_0) in the same site. In Butere site, the same treatment (FL/D_1) increased the yields from 1.95 to 5.23 tons ha^{-1} in the limed treatments (L_1) and raised the yield from 1.52 to 3.68 tons ha^{-1} in the unlimed treatments (L_0) as shown in Figures 1 and 2.

The closest treatment in performance from this one was TN/D_1 (*Tithonia* + DAP: 39 kg P ha^{-1}) that increased the yield from the control value of 1.95 to 4.56 tons ha^{-1} for treatments where lime was applied (L_1) in Butere site. In Bukura site, the same treatment (TN/D_1) also increased yields from 2.16 to 4.57 tons ha^{-1} in the limed treatments (L_1).

Correlation between grain yield and available phosphorus

Maize grain yield in Bukura had a high correlation with available P with an r of 0.65 where as in Butere site the coefficient of determination (r) was 0.66 as seen in Figure 3.

Correlation between nitrogen percentage and yield in the two sites

The level of nitrogen (%N) was strongly correlated with the yield in both sites with r = 0.60 and 0.81 for the Bukura and Butere sites, respectively as shown in Figure 4.

On average of the two sites, lime was significant ($p = 0.001$) by raising the BCR from 0.64 (unlimed treatments) to 0.78 (limed treatments).

For Bukura site treatments with lime (L_1), the two treatments: FL/D_1 (Filter mud + DAP: 39 kg P ha^{-1}) and TN/D_1 (*Tithonia* + DAP: 39 kg P ha^{-1}) were the only ones with BCR over 1.0, having BCR of 1.32 and 1.30, respectively. For Butere site, in the limed treatments (L_1), the three treatments: FL/D_1 (filter mud + DAP: 39 kg P ha^{-1}), TN/D_1 (*Tithonia* + DAP: 39 kg P ha^{-1}) and TN_1 (*Tithonia* alone: 39 kg P ha-1) were the only ones with BCR of over 1.0 by attaining BCR of 1.35, 1.30 and 1.09, respectively (Tables 4 and 5).

Table 3. The influence of organic resources on pH and available P in Bukura and Butere sites during the 2014 long rains season.

Lime	Bukura site			Butere site		
	Organic resources (Treatments)	pH (H_2O)	Available P (mg kg^{-1})	Organic resources (Treatments)	pH (H_2O)	Available P (mg kg^{-1})
Lime-1 (3 tons ha^{-1})	1 (C)	5.47	13.55	1 (C)	5.20	16.55
	2 (TN_1)	5.69	23.84	2 (TN_1)	5.57	22.79
	3 (BG_1)	5.78	17.94	3 (BG_1)	5.69	18.27
	4 (FL_1)	5.80	20.17	4 (FL_1)	5.77	26.31
	5 (D_1)	5.64	27.00	5 (D_1)	5.38	31.70
	6 (TN/D_2)	5.66	18.97	6 (TN/D_2)	5.54	15.80
	7 (BG/D_2)	5.63	22.60	7 (BG/D_2)	5.45	22.04
	8 (FL/D_2)	5.51	17.52	8 (FL/D_2)	5.67	16.87
	9 (TN/BG_2)	5.71	18.38	9 (TN/BG_2)	5.67	17.07
	10 (TN/D_1)	5.64	27.61	10 (TN/D_1)	5.56	25.33
	11 (BG/D_1)	5.70	19.54	11 (BG/D_1)	5.60	22.89
	12 (FL/D_1)	5.78	29.24	12 (FL/D_1)	5.74	30.07
	13 (TN/BG_1)	5.64	20.74	13 (TN/BG_1)	5.55	18.57
Mean	-	5.70	21.32	-	5.64	21.88
SED (treatment)		0.04**			0.71***	
SED (lime)		n.s			0.71***	
SED (lime * trt)		0.04***			n.s	
SED (site)		n.s			1.90***	
SED (site*trt)		n.s			1.94**	
SED (site*lime*trt)		n.s			n.s	
CV		2.90			18.05	

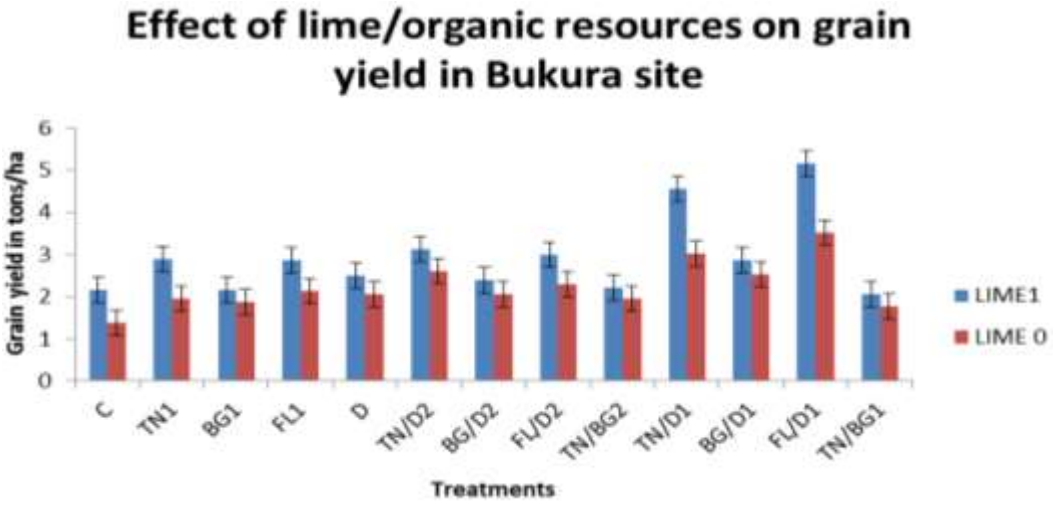

Figure 1. Effect of lime/organic resources on mean maize grain yield in Bukura site during long rains season of 2014. Where LIME 1 = Lime applied at the rate of 3.0 tons ha^{-1} and LIME 0 = No lime applied.

DISCUSSION

Effect of treatments on selected soil properties

Application of lime was significant ($p < 0.0001$) in both sites in raising the pH from 5.18 to 5.47 and 4.66 to 5.20 in Bukura and Butere sites, respectively. This is supported by Kisinyo et al. (2014), who found out that lime application increases soil pH and available P because Ca^{2+} ions contained in lime displaces the H^{+}

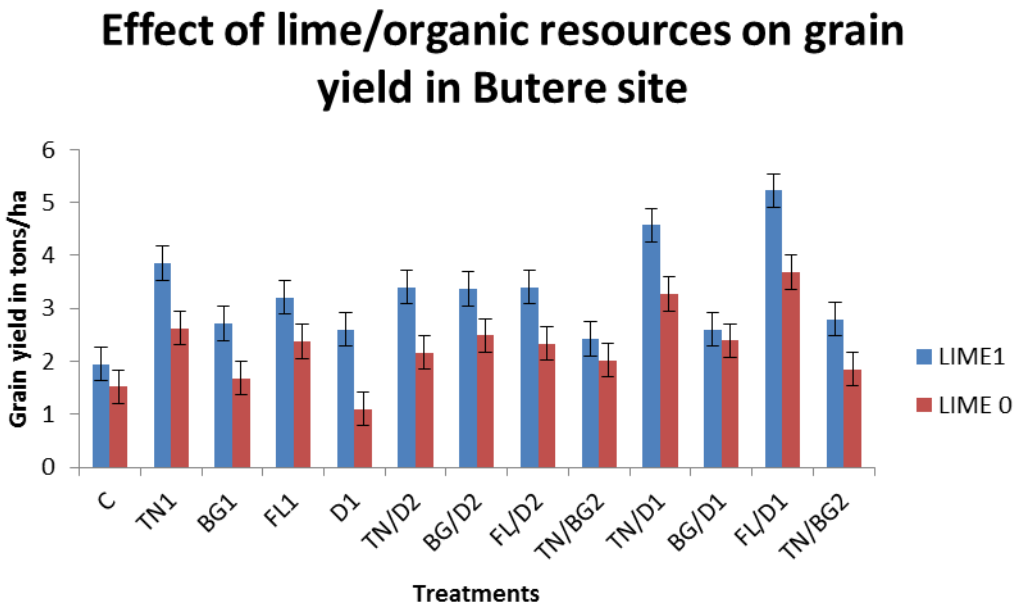

Figure 2. Effect of lime/organic resources on mean maize grain yield in Butere site during the long rains season of 2014.

Mn^{2+}, Fe^{3+} and Al^{3+} ions from the soil sorption sites resulting into increased soil pH.

Effect of treatments on soil pH

Filter mud was very effective in raising the pH mainly because it had a high pH of 8.82 and also high levels of organic matter, that is, 69.4% which probably due to its ability to reduce exchangeable Al resulted in raising the pH as documented by Opala et al. (2009) in his previous research in the same area while working with farm yard manure.

Effect of treatments on soil available P

Results in this study indicate that lime (calcitic) was able to raise the extractable P from 5.27 mg p kg^{-1} (control without lime) to 13.55 mg P kg^{-1} (control with lime). Lime enhanced the availability of more P by the Ca^{2+} contained in lime displacing H^{+}, thus resulting in a reduction in acidity implying less solubility of Al^{3+} that had fixed P. This is supported by Muindi et al. (2015) who found out that application of lime results in increase of soil pH and extractable P and decrease of P adsorption levels leading to replacement of hydrogen ions on the soil surface by Ca^{2+}.

It was found out in this study that, limed treatments of *Tithonia* and filter mud having 39 kg P ha^{-1} significantly raised the available P in both sites. This is due to a likelihood that both *Tithonia* and filter mud being organic materials were able to liberate low molecular organic acids such as malic and citric acids which bind on Al^{3+} in solution thus reducing P sorption as clarified by Opala (2011).

Mean maize grain yield as affected by lime in the two sites

In general, lime increased the maize grain yields in both Bukura and Butere. There is a high possibility that the Ca^{2+} in lime displaced the Al^{3+} H^{+} and Fe^{3+} in soil colloids thus reducing the P sorption and hence increasing its availability with the resultant positive response in maize yield. This is confirmed by Kanyanjua et al. (2002) who stated that use of lime is highly recommended to enhance food production in the Kenyan acid soils.

Influence of treatments on mean maize yield

This study indicates a very high superiority of combining filter mud and DAP in maize production as compared to all the other treatments. Where DAP was used alone (D_1) the yield increase was from 2.16 to only 2.51 tons ha^{-1} and where filter mud was used alone (FL_1) the yield increase was also from 2.16 to only 2.90 tons ha^{-1} for the limed plots. Now when this inorganic fertilizer (DAP) is combined with the organic material (Filter mud) the yield shoots to 5.14 tons ha^{-1}. This implies there is something found in combining DAP and filter mud that is not available when the two are used separately. This could

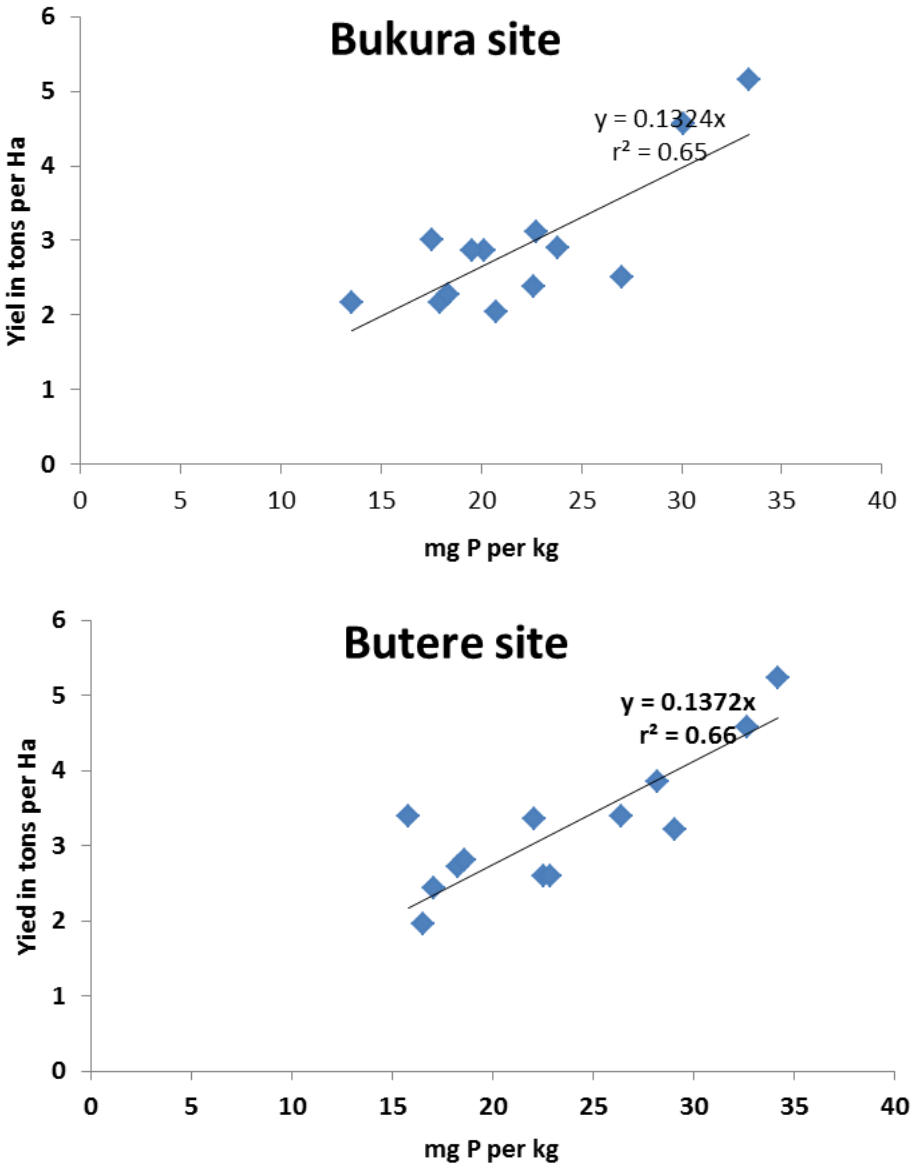

Figure 3. Correlation between available P and yield in Bukura and Butere sites.

be the synchronizing effect in the release of nutrients when the two are judiciously applied together and is in agreement with the view held by Muambole (2013) who affirmed that combination of mineral fertilizers with organic nutrient sources are superior in increasing fertilizer use efficiency as a result of the organic resources enhancing the soil organic matter status and the functions it supports while mineral resources supply key limiting nutrients. This improved synchronization of nutrient release and uptake by the crop. The other reason for the superiority in filter mud and *Tithonia* treatments is attributed to their ability to provide micronutrients not present in DAP and improve both physical and chemical properties of the soil which ultimately reflect positively on nutrient acquisition and plant growth (Haynes and Mokolobate, 2001).

Comparison in maize grain yield for the two sites

The highest treatment in the grain yields in the limed plots for both sites was the combination of filter mud and DAP to supply 39 kg P ha. This treatment yielded 5.15 and 5.23 tons ha^{-1} in Bukura and Butere sites, respectively. The Butere site (Humic Acrisol) had superior yields than Bukura site (Orthic Ferralsol) probably due to the higher cation exchange capacity of Arisol soils as compared to Ferralsol soils in Bukura. This is in agreement with Harlemink et al. (2008) who found out that the fertility of Ferralsols that had been in continuous

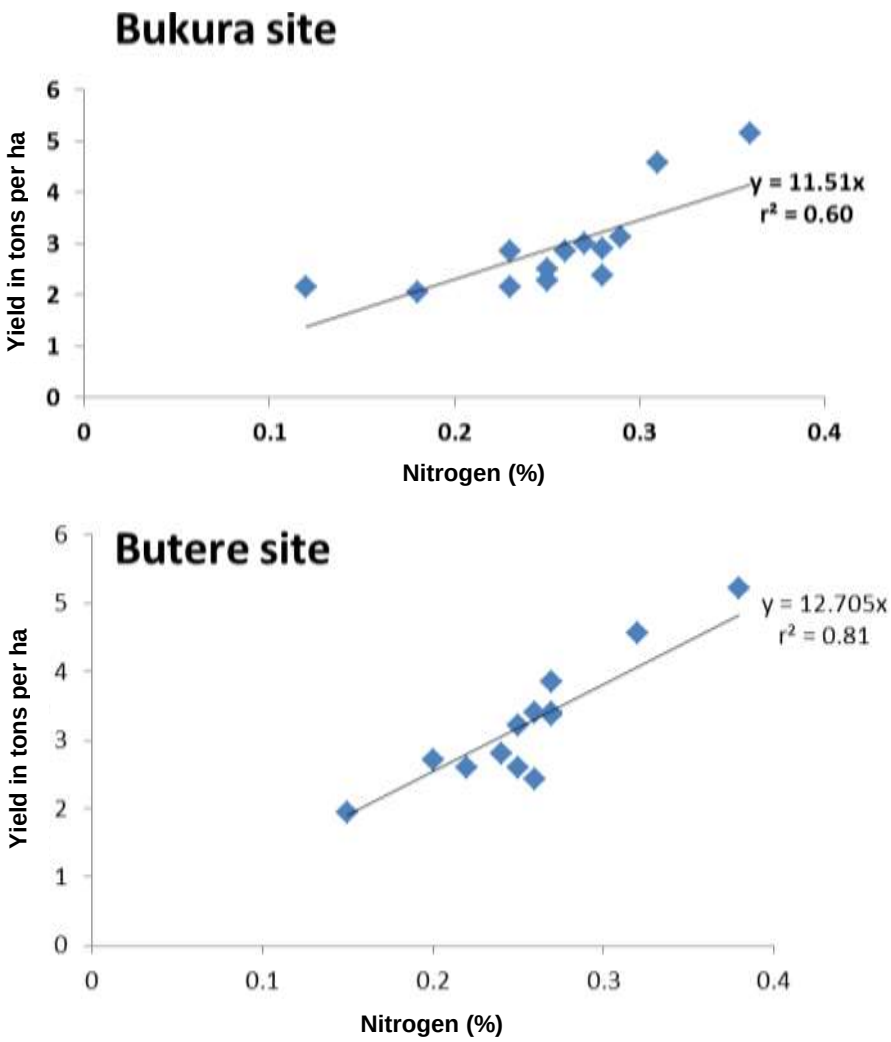

Figure 4. Correlation between % nitrogen and yield in Bukura and Butere sites.

cultivation was extremely low as compared to Acrisols which were less depleted due to their intrinsic fertility.

Correlation between grain yield and available phosphorus

Maize grain yield was significantly correlated with available soil P in both Bukura and Butere sites. This is likely due to maize taking up phosphorus for its rapid fast growth in roots and stems translating into high yields. This is in agreement with Onasanya et al. (2009) who affirmed that phosphorus plays an important role in many physiological processes in a developing and a maturing plant.

Economic analysis

In Bukura site where lime was applied together with either TN/D_1 (*Tithonia*+ DAP; 39 kg P ha^{-1}) or FL/D1 (Filter mud + DAP 39 kg P ha^{-1}) the economically viable returns of BCR of 1.30 and 1.32, respectively imply that KES. 1.0 invested in the production of maize using these treatments would generate a profit of 30 and 32%, respectively.

Conclusions

(1) Application of lime significantly raised the pH and was very effective in reducing P sorption in both sites.
(2) The limed treatments with filter mud and *Tithonia* each in combination with DAP were the best in raising available phosphorus. In Butere site, these treatments: FL/D_1 (Filter mud + DAP; 39 kg P ha^{-1}) and TN/D_1 (*Tithonia* + DAP; 39 kg P ha^{-1}) raised the available P from 16.55 mg kg^{-1} P (control) to 30.07 and 25.33 mg kg^{-1} P, respectively.
(3) These two treatments: FL/D_1 and TN/D_1 yielded the

Table 4. Effect of treatments/lime on net returns and benefit cost ratio in Bukura site during the 2014 long rains.

Lime/Treatment/Code		Grain yield (tons Ha^{-1})	Gross returns (KES)	Total costs (KES)	Net returns (KES)	Benefit cost ratio
L_1 lime (3 tons ha^{-1})	1.C	2.16	86,400	132,995	-46,595	0.60
	2.TN_1	2.90	116,000	140,911	-24,911	0.82
	3.BG_1	2.16	86,400	201,325	-114,925	0.43
	4.FL_1	2.86	114,400	171,326	-56,926	0.67
	5.D_1	2.50	80,400	139,661	-59,261	0.58
	6.TN/D_2	3.12	98,000	137,995	-39,995	0.71
	7.BG/D_2	2.38	95,200	157,994	-62,794	0.60
	8.FL/D_2	3.00	120,000	147,828	-27,828	0.81
	9.TN/BG_2	2.27	90,800	157,994	-67,194	0.57
	10.TN/D_1	4.57	182,800	140,495	+42,305	1.30
	11.BG/D_1	2.86	114,400	170,494	-56,094	0.67
	12.FL/D_1	5.15	206,000	155,494	+50,506	1.32
	13.TN/BG_1	2.05	82,000	171,327	-89,327	0.48
L_0 (0 lime)	1.C	1.38	55,200	122,495	-67,295	0.45
	2.TN_1	2.78	111,200	130,411	-29,211	0.85
	3.BG_1	1.87	74,800	190,825	-116,025	0.39
	4.FL_1	2.13	85,200	160,826	-75,626	0.53
	5.D_1	2.05	82,000	129,161	-47,161	0.63
	6.TN/D_2	2.60	104,000	127,495	-23,495	0.82
	7.BG/D_2	2.05	82,000	147,494	-65,494	0.56
	8.FL/D_2	2.28	91,200	137,328	-46,128	0.67
	9.TN/BG_2	1.94	77,600	147,494	-69,894	0.53
	10.TN/D_1	3.01	120,400	129,995	-9,595	0.93
	11.BG/D_1	2.53	101,200	159,994	-58,794	0.63
	12.FL/D_1	3.52	140,800	144,994	-4,194	0.97
	13.TN/BG_1	1.76	70,400	160,827	-90,427	0.44

Table 5. Effect of treatments/lime on net returns and benefit cost ratio in Butere site during the long rains of 2014

Lime/Treatment/Code		Grain yield (tons ha^{-1})	Gross returns (KES)	Total cost (KES)	Net returns (KES)	Benefit cost ratio
LIME -1 (L_1) (3 tons lime ha^{-1})	1.C	1.95	78,000	132,995	-54,995	0.59
	2.TN_1	3.85	154,000	140,911	+13,089	1.09
	3.BG_1	2.72	108,800	201,325	-92,525	0.54
	4.FL_1	3.21	128,400	171,326	-42,926	0.75
	5.D_1	2.60	104,000	139,661	-35,661	0.74
	6.TN/D_2	3.40	136,000	137,995	-1,995	0.99
	7.BG/D_2	2.37	94,800	157,994	-63,194	0.60
	8.FL/D_2	3.40	136,000	147,828	-11,828	0.92
	9.TN/BG_2	2.43	97,200	157,994	-60,794	0.62
	10.TN/D_1	4.57	182,800	140,495	+42,305	1.30
	11.BG/D_1	2.60	104,000	170,494	-66,494	0.61
	12.FL/D_1	5.23	209,200	155,494	+53,706	1.35
	13.TN/BG_1	2.80	112,000	171,327	-59,327	0.65
LIME -0 (L_0) (0 lime)	1.C	1.52	60,800	122,495	-61,695	0.50
	2.TN_1	2.63	105,200	130,411	-25,211	0.81

Table 5. Contd.

	3.BG_1	1.68	67,200	190,825	-123,625	0.35
	4.FL_1	2.38	95,200	160,826	-65,626	0.59
	5.D_1	1.10	44,000	129,161	-85,161	0.34
	6.TN/D_2	2.17	86,800	127,495	-40,695	0.68
	7.BG/D_2	2.49	99,600	147,494	-47,894	0.68
	8.FL/D_2	2.34	93,600	137,328	-43,728	0.68
	9.TN/BG_2	2.02	80,800	147,494	-66,694	0.55
	10.TN/D_1	3.27	130,800	129,995	+805	1.01
	11.BG/D_1	2.39	95,600	159,994	-64,394	0.60
	12.FL/D_1	3.68	147,200	144,994	+2,206	1.02
	13.TN/BG_1	1.85	74,000	160,827	-86,827	0.46
SED (site)			n.s.			
SED (trt)			0.036			
SED (lime)			n.s			
SED (lime*trt)			n.s			
C.V.			10.57			

highest among the twelve treatments tested in this experiment. They raised the yields from 2.16 tons ha^{-1} (control) to 5.14 tons ha^{-1} and 4.57 tons ha^{-1}, respectively for the Bukura site limed plots. In Butere site limed plots the two treatments FL/D_1 and TN/D_1 out shined the rest by increasing the yields from 1.95 tons ha^{-1} (control) to 5.23 and 4.56 tons ha^{-1}, respectively.

(4) Liming at a rate of 3 tons ha^{-1} with the consequent use of filter mud or *Tithonia* in combination with DAP to each supply 39kg P ha^{-1} (on 1: 1 ratio of organic: in organic fertilizer) can be viable as profits can be realized.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

RECOMMENDATIONS

(1) Lime requirement for various areas in Butere should be established so that farmers are able to know the specific quantities of lime to apply in their respective fields.

(2) Farmers should be encouraged to judiciously apply in organic and organic fertilizers in their plots for soil fertility restoration. For this case, those farmers near sugarcane factories can use filter mud as an organic material and those far away can use *Tithonia* as it is readily available on farm hedges and then combine them with inorganic P fertilizers like NPK.

(3) For their maize enterprises to be viable, farmers can use filter mud or *Tithonia* in combination with an in organic P fertilizer (at a ratio of 1:1) to supply 39 kg P ha^{-1} with lime applied at the rate of 3 tons ha^{-1}.

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Full Length Research Paper

Growth and yield responses of sesame to organic fertilizer under tropical conditions

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The use of cattle manure and other organic compounds can be a profitable and efficient alternative in sustainable agriculture. The aim of this work was to evaluate the development and production of sesame 'BRS Seda' for organic fertilization at different doses, under the conditions of soil and climate found in Catolé do Rocha, in the State of Paraíba, Brazil. The following characteristics were evaluated: number of leaves and pods; plant height; stem diameter; number of flowers; dry weight of the leaves, stems, roots, pods and seeds; number and length of secondary branches; height of the first fruit; seeds per pod; pod length; and emergence percentage and speed of the produced seedlings. The different doses of cattle manure influenced pod length, number of seeds per pod, and emergence percentage and speed of the produced seedlings, with better results for the dose of 40 t ha^{-1}.

Key words: *Sesamum indicum* L., fertilization, morpho-agronomic characterization, organic production.

INTRODUCTION

Sesame (*Sesamum indicum* L.) shows great adaptation to the conditions of soil and climate of the northeastern region of Brazil, which generally presents good yield even under irregular and scarce rainfall observed in this region (Pereira et al., 2017). This crop develops well when there is an adequate supply of nutrients in the soil; it is therefore essential to provide the correct fertilizer for each planting situation. Under the conditions of soil and climate found in the semi-arid region of the Northeast, sesame is easy to grow and offers excellent yield and oil quality at low cost. In addition, facing the relevant increase of this oil crop, a high demand for quality seeds

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has been required as well (Arruda et al., 2015; Silva et al., 2017).

The addition of manure to the soil to improve the organic matter content is a long-standing practice. Filho et al. (2010), in a study on the cultivar CNPA G3 in the Seridó region of Paraíba using amounts of corral manure ranging from 0 to 40 t ha^{-1} under a rainfed regime, found an effect on the number of fruits and on plant height, with responses at the lowest level of available soil water. Silva et al. (2017) also observed benefits provided by organic fertilization in sesame. These authors studied the effects of cattle manure (0 to 60 t ha^{-1}) fertilization in sesame 'BRS Seda' cultivar under rainfed conditions and reported that seed vigor was positively influenced by cattle manure application in the soil.

Because it is a species which is often recommended as an alternative for generating income in the Brazilian semi-arid region (Silva et al., 2016), it is extremely important to know the response to organic fertilization. Therefore, the use of cattle manure and other organic compounds may be a cheaper alternative for improving the physics and chemical properties of the soils in semiarid regions.

The aim of this work was to evaluate development and production in the sesame cultivar BRS Seda for different doses of organic fertilizer, under the conditions of soil and climate in Catolé do Rocha, PB.

MATERIALS AND METHODS

The work was carried out in the experimental area of Campus IV of the State University of Paraíba (UEPB), in the city of Catolé do Rocha, Paraíba State, Brazil (PB). The region is at an altitude of 272 m above sea level, at coordinates 6°20'38" S and 37°44'48" W. According to the Köppen classification, the climate in the region is of type BSw'h', with an average annual precipitation of 870 mm, and an average temperature of 27°C.

The chemical properties of the soil and manure used in this study are shown in Table 1, and were determined in the Soil and Plant Nutrition Laboratory of Brazilian Agricultural Research Corporation. The manure used for fertilization was collected from crossbred cows fed on forage (elephant grass) in the UEPB at the same campus. Chemical analysis (macro- and micronutrients) of the cattle manure used in the experiment was carried out at the Soil and Plant Tissue Analysis Laboratory, Centre for Agrarian Science of the UEPB (Table 1).

For this study, the BRS Seda cultivar was used, which was grown under field conditions, carried out in 60 L plastic pots with a height of 57 cm, upper diameter of 40 cm and lower diameter of 26.5 cm. Four seeds were planted per pot, which were later thinned at 15 days after emergence, leaving one plant per pot.

Irrigation was carried out daily, using graduated containers to leave the soil at field capacity. In the initial phase, in addition to the daily irrigation, the pots were cleaned manually to avoid the accumulation of invasive plants.

Partial data were collected 120 days after planting the sesame, when the following variables were analysed: a) number of pods/plant – by counting the pods on each plant manually to determine the total; b) plant height (cm) - measured from the stem collar to the apex of the plant, with the aid a millimetre rule; c) stem diameter (mm) - determined by measuring 1 cm above the stem collar using a manual calliper; d) number of leaves/plant - also determined individually for each plant; e) number of flowers/plant – determined by counting the sesame flowers in each treatment.

Evaluations such as the dry-matter weight of the roots, shoots, pods and seeds, were carried out during harvesting. An electronic weigh with an accuracy of 0.001 g was used to weigh the material. The height of the first fruit (cm), length of the secondary branches (cm), the number of secondary branches, seed yield and pod length was also evaluated. Shoot dry matter (stem, branches and leaves) and root-system dry matter were determined after drying at 65°C for 48 h in an air circulation oven. Yield was determined by collecting the fruits when they were completely dry, with the mean value for the replications extrapolated to kg ha^{-1}. After harvesting, the seeds were analysed to determine germination and vigour, through the variables first count germination and germination speed index (Silva et al., 2017.

For the germination test, plastic trays with a length of 40 cm, a width of 25 cm and a depth of 6.5 cm were used, where four replications of 50 seeds were sown in each tray. Irrigation was divided into two applications of 250 ml per tray. To obtain emergence percentage, the following equation was used:

$$PE = \frac{NGSx100}{Ns}$$

Where: PE = percentage emergence (%); NGS = number of germinated seeds; Ns = number of seeds sown. The experimental design was of randomised blocks, with the treatments represented by five doses of cattle manure (0, 10, 20, 30 and 40 t ha^{-1}) with 4 replications, giving a total of 20 lots, represented by the pots containing 40 kg of air-dried soil.

Data for the variables were submitted to analysis of variance by F-Test, and the mean values evaluated by regression analysis at 5% probability. Where necessary, the data as percentages were transformed into arcsine $\sqrt{X}$ /100. Statistical analysis was carried out using the SISVAR 5.0 software.

RESULTS AND DISCUSSION

According to the results of the statistical analysis, represented by a summary of the analysis of variance (Table 2), the various levels of cattle manure did not differ when analysed for number of leaves, number of pods, stem diameter, plant height or number of flowers in the sesame.

There were statistical differences between doses for the number of leaves; however, Lima (2006) found a statistically significant difference when the mean values were analysed. The author obtained a mean value for number of leaves of 14.25 leaves per plant when evaluating growth and production in the G3 cultivar as a function of zinc and boron.

The number of pods, although not influenced by the doses of cattle manure, showed higher values than those found by Maia Filho et al. (2010) in the Seridó region of Paraiba, who obtained a maximum value of 55 fruits/plant at a dose of 28 t ha^{-1} cattle manure. Perin et al. (2010), evaluating the performance of sesame as a function of NPK fertilization and soil fertility, found a mean value of 31.64 fruits/plant. The author explained that the behaviour displayed by the sesame is similar to results obtained by other authors (Ávila and Graterol, 2005), and

Table 1. Chemical characterisation of the manure used in the experiments.

Soil											
pH	**Ca^{+2}**	**Mg^{+2}**	**Na^{+}**	**K^{+}**	**S**	**H+Al**	**T**	**Al^{+3}**	**V**	**MO**	**P**
(H_2O)	**---------- mmolc/ dm^3 ----------**									**-- g/kg --**	**mg/dm^3**
8.4	78.3	22.2	5.2	9.5	115.2	0.00	115.2	100	0.0	14.1	100.2
Manure											
N	**P**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Cu**	**Mn**	**Zn**	**Na**	**B**
	---------- g kg^{-1}----------						**---------- mg kg^{-1}----------**				
8.93	1.85	1.95	4.39	2.50	13.29	4213	5.94	698	203	262.6	23.29

Soil and plant tissue analysis laboratory. Federal University of Paraiba, Areia, Brazil.

Table 2. Summary of the variance analysis and mean values of number of leaves (NL), number of pods (NP), stem diameter (SD), plant height (PH) and number of flowers (NF).

Source of Variation	DF	Mean square				
		NL	**NP**	**SD**	**PH**	**NF**
Treatment	4	11913.87^{NS}	5342.87^{NS}	3.57^{NS}	142.17^{NS}	17.92^{NS}
Block	3	33784.20	4619.93	9.93	238.58	33.91
CV (%)		10.30	15.09	11.69	7.50	22.95
Dose		**Observed mean values**				
				mm	**cm**	
0 t ha^{-1}		795.50	407.50	24.75	149.75	19.00
10 t ha^{-1}		696.50	358.25	27.00	143.25	17.75
20 t ha^{-1}		703.25	347.00	25.50	156.25	15.50
30 t ha^{-1}		798.00	415.50	26.50	141.00	19.25
40 t ha^{-1}		804.25	429.25	26.75	147.00	21.25

DF– Degrees of freedom. ^{NS}- not significant by F-Test.

no significant effect was found from the mineral or organic fertilizers on the number of pods per plant.

As regards stem diameter, the results found here agree with those seen by Silva et al. (2016), when studying the effect of organic and mineral fertilizers on sesame crop; the author found that the treatments employed had no effect on this variable. Similarly, there were no statistical differences found among the doses used in this study for plant height. According to the summary table of the analysis of variance (Table 3), there were no differences between the various doses of cattle manure when analysed for leaf, stem, root, pod and seed dry weight.

Although, no effect was seen from the doses of manure on leaf dry weight or stem dry weight, the mean values found were higher than those found by Severino (2002), when analysing the phenology of the sesame cultivar GNPA G4, the author explained that the biomass of the stems plus the leaves also continued to increase until day 75, from when it tended to decrease, possibly due to the translocation of reserves for filling out the fruit and loss of the older leaves.

The result for pod dry weight was satisfactory as compared to that obtained by Severino (2002), when he analysed this variable as a function of the phenology of sesame, and obtained a mean value of 36 g. Fruit biomass displayed significant growth from 60 to 100 days, increasing at a rate of 0.78 g day^{-1}. From day 100, the fruit showed no further tendency towards an increase in dry matter, despite only reaching maturation around 120 days.

The seed weight (Table 3) showed satisfactory yield when the results were compared with those obtained by Drumond et al. (2006), who explained the low productivity (61g) as due to the low rainfall that occurred during the growing period. Jan et al. (2014), on the other hand, observed that sesame plots treated with 100 kg P ha^{-1} produced maximum 1000 seeds weight of 3.64 g.

Satisfactory values for root dry weight, as compared to Santos and Silva (2009) studying dry-weight production in soybean fertilised with pig slurry, demonstrated that the application of organic fertilizer had a significant effect on this crop. The authors obtained the highest yields for root dry weight when two different treatments were used (mineral fertilizer and 50 m^3 ha^{-1} pig slurry + N residue). The results of the statistical analysis (Table 4) show that the various doses of cattle manure did not differ

Table 3. Summary of the analysis of variance and mean values of leaf biomass (LB), stem biomass (SB), root biomass (RB), pod biomass (PB) and seed weight (SW).

Source of variation	DF	Mean square				
		LB	SB	RB	PB	SW
Treatment	4	113.279^{NS}	799.344^{NS}	52.4120^{NS}	504.710^{NS}	134.600^{NS}
Block	3	205.7727	1176.802	17.98183	142.0333	98.48317
CV (%)		46.263	24.541	57.487	28.900	20.61
Dose		**Observed mean values**				
				g		
0 t ha^{-1}		46.7750	121.2500	27.0750	74.8500	49.4250
10 t ha^{-1}		43.2250	118.3750	23.1000	63.4750	37.6000
20 t ha^{-1}		37.9250	109.9000	22.9500	54.0000	37.5000
30 t ha^{-1}		34.9750	108.0000	19.4500	53.3750	36.2000
40 t ha^{-1}		34.6500	85.3250	17.7500	45.6000	35.250

DF- Degrees of freedom. ^{NS}- not significant by F-Test.

Table 4. Summary of the variance analysis for the number of secondary branches (NSB), secondary branch length (LSB) and height of the first fruit (HFF).

Source of variation	DF	Mean square		
		LB	SB	RB
Treatment	4	2.325000^{NS}	0.902138^{NS}	87.700^{NS}
Block	3	3.333333	0.213360	136.317
CV (%)		19.181	19.054	10.56
Dose		**Observed mean values**		
0 t ha^{-1}		8.7500	0.9183	55.50
10 t ha^{-1}		8.0000	0.9083	52.00
20 t ha^{-1}		7.2500	0.8546	48.00
30 t ha^{-1}		7.0000	0.8308	50.75
40 t ha^{-1}		7.0000	0.8100	43.00

DF– Degrees of freedom. ^{NS}- not significant by F-Test.

when analysed for the number of secondary branches, length of the secondary branches or height of the first fruit.

Values found for the number of secondary branches were greater than those observed by Lima (2006), who obtained an average of approximately three branches in the G3 cultivar of sesame at 45 days after emergence for concentrations of zinc in solution. Further, in relation to the number of secondary branches, satisfactory results were also found as compared to the mean values obtained by Severino (2004) at 80 days after emergence when analysing the phenology of the sesame cultivar CNPA G4 (*Sesamum indicum* L.).

As to the length of the secondary branches, values were found that were also greater than those found by Severino (2002), who obtained an average of 38 cm per plant. According to the author, the growth of the secondary branch accompanies that of the main stem of the plant, initiating elongation at about 30 days and maintaining the same pattern until about 80 days of age. The production of secondary branches is of great importance, and even the tertiary branches contribute to production in the sesame crop.

In the present work, values for the height of the first fruit stand out from values found by Silva (2006) when analysing the residual effect of organic and mineral fertilizers on a second-year crop of sesame. However, they did not differ from the results found by Lima (2006) when studying growth and production in the sesame cultivar G3 as a function of zinc- and boron-based fertilizers. On the other hand, the number of seeds per pod showed a statistical difference between treatments, with a tendency to increase as the doses of cattle manure increased, its greatest value is seen at the dose of 40 t ha^{-1} (Figure 1A). Similar results were found by Jan et al. (2014). The values for pod length displayed differences when the sesame plants were submitted to the treatments. Positive linear behaviour was seen as the

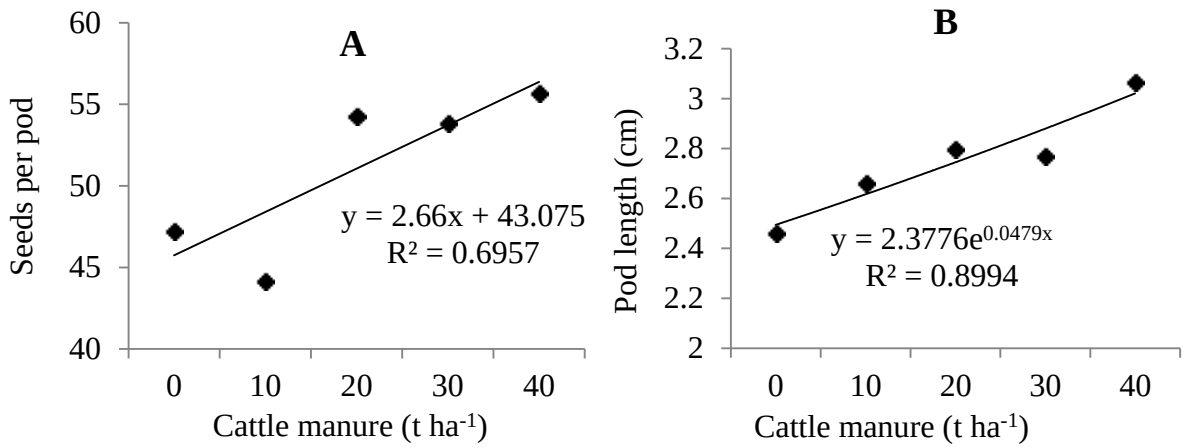

Figure 1. Number of seeds per pod (A) and pod length (B) in sesame for doses of cattle manure.

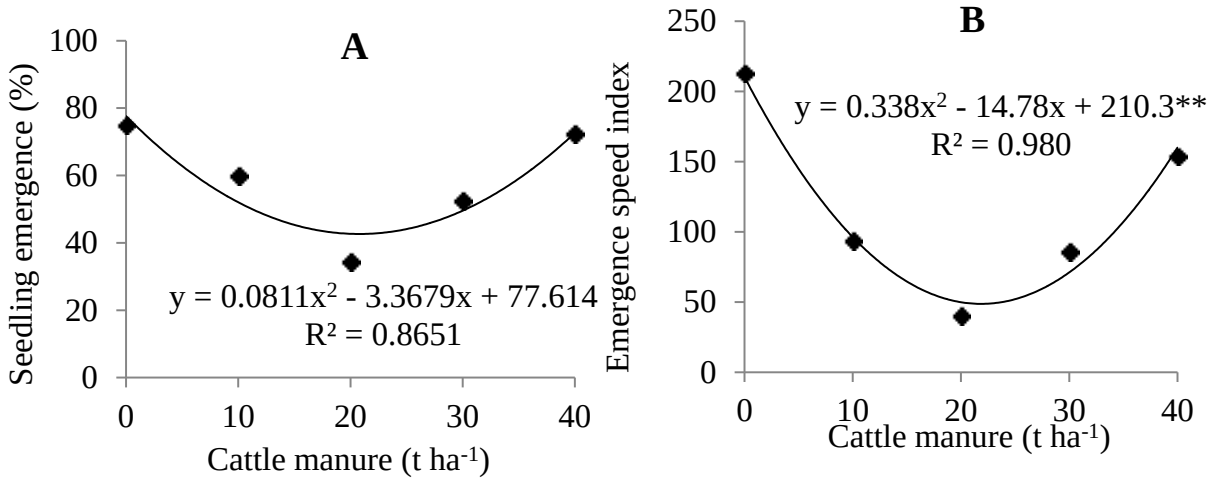

Figure 2. Seedling emergence (A) and emergence speed index (B) in sesame for doses of cattle manure.

doses were increased, reaching maximum length at the dose of 40 t ha^{-1} cattle manure (Figure 2B).

With the germination and speed of emergence index of the sesame, a quadratic effect was seen, showing a decrease in the values of these variables up to the dose of 20 t ha^{-1}, after which there was an increase up to the dose of 40 t ha^{-1} (Figure 2).

Regarding germination of the sesame seeds as a function of the doses of cattle manure, the results corroborate those found by Dornelas et al. (2005) when evaluating the production and seed quality of lima beans as a function of the use of cattle manure in the presence and absence of NPK, as the same authors found germination responses for the doses of cattle manure. The authors reported highest rates for seed germination at 40 t ha^{-1}, in the presence and absence of NPK, with high germination percentages of 93 and 95%, respectively.

Conclusion

The different doses of cattle manure had an influence on pod length, number of seeds, percentage emergence and emergence of produced seedlings, with better results at the dose of 40 t ha^{-1}.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Response of yield and yield components of tomato (*Solanum lycopersicon* L.) to different inter and intra-row spacing at Merebleke, Northern Ethiopia

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A field experiment was conducted at Aksum Agricultural Research Center Merebleke irrigation testing site for two years, 2014 and 2015 cropping calendar under irrigation condition. The objective of the study was to determine the effect of Inter and intra-row spacing on growth, Yield and fruit characteristics of Melkashola variety of tomato. The trial was laid out in factorial randomized complete block design in three replications. The treatment comprises of twelve treatment combination (20, 30 and 40 cm intra row spacing and 60, 80, 100 and 120 cm inter row spacing). Combined analysis of variance showed that except days to 50% flowering, all traits did not show significant interaction effect. However, main effect of inter and intra row spacing showed significant differences for days to maturity, plant height, number of fruits per plant, fruit weight and marketable fruit yield. The highest number of fruits per plant was found from 40 cm intra row spacing (74) but it is statistically at par with 30 cm intra row spacing (68). Fruit size was significantly affected by intra row spacing; the largest fruit size was recorded from 30 cm intra row spacing (71.1 g) while the smaller size found from 20 cm intra row spacing (67.5 g). However, fruit size didn't show significant difference for different inter row spacing. The highest marketable yield was obtained from 60 cm inter row spacing (654.60qt ha^{-1}) which is statistically not significant with 80 cm inter row spacing (611.7 qt ha^{-1}). Similarly, the narrow intra row spacing that is, 20cm scored highest marketable yield (651.4 qt ha^{-1}) which is also statistically at par with 30 cm intra row spacing (597.4 qt ha^{-1}). Considering fruit size and marketable yield, 60 cm inter row spacing and 30 cm intra row spacing are appropriate for higher marketable fruit yield and better fruit size in Merebleke wereda.

Key words: Inter and intra-row spacing, tomato, Melkasholla, Mrebleke, marketable yield.

INTRODUCTION

Tomato (*Solanum lycopersicon L.)* belongs to Solanacea family. It is an herbaceous plant, usually sprawling plant of the nightshade family that is typically cultivated for its edible fruit (Ayres, 2008). It originated from elevated

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regions of Peru and Ecuador (Steven and Celso, 2007).

Tomato is a warm season crop that requires very stable temperature ranges with minimums and maximums not being too wide apart. Temperature variation might result in poor fruit quality or reduced yield. The minimum temperature is around 10°C and the maximum being 34°C. Optimum temperatures are around 26 to 29°C (Ayres, 2012). The crop gives good results when grown in well-managed sandy loams and heavy clay loams free of hardpan but best results are obtained in deep, well-drained loams. The soil should be rich in organic matter and plant nutrients, with a pH value of 6 to 7.

Tomato is rich in nutrients such as vitamins, minerals and antioxidants, which are important to well-balanced human diets. Tomato is also an important dietary component because it contains high level of lycopene, an antioxidant that reduces the risks associated with several cancers and neurodegenerative diseases (Srinvasan, 2010).

According FAOSTAT (2016), production of tomato in Ethiopia showed a decreasing trend from 2011 (81,738 tons) to 2013 (55,000 tons) cropping season. Possible reasons for yield reduction are disease and pests (such as infestation of tuta absoluta and late blight), poor agronomic practices, shortage of improved varieties and shortage and poor quality seeds and poor postharvest handling practices.

The central zone of Tigray, especially Merebleke area is one of the potential districts for tomato cultivation. Moreover, the regional government of Tigray has constructed a dam which has a capacity to cultivate more than 3000 hectare. However, farmers in the study area cultivate tomato in a traditional way. That means they do not follow appropriate plant population, improved cultural practices and postharvest management practices. The use of improper plant spacing is among the reasons of low productivity of tomato, and it greatly influences growth, yield, and quality parameters of tomato. A number of authors viz; Awas et al. (2010); Balemi, 2008; Mamnoie and Dolatkhahi, 2013; Ogundare et al., (2015) have conducted trials on the effect of inter and intra row spacing on yield and yield components of tomato for specific agroecology and soil type. However, in Merebleke area no inter and intra row spacing trial was conducted so far for tomato hence, the objective of the experiment was to study the interactive effect of inter- and intra- row spacing, and to determine optimum inter- and intra-row spacing for fruit yield and yield components of Melkashola variety of tomato.

MATERIALS AND METHODS

Description of the experimental site

The experiment was conducted at Aksum Agricultural Research center, Mereblekhe irrigation experimental station. Merebleke is located 1101 km from Addis Ababa and 77 km to the north of Axum city, at14°409'38"N" latitude and 38°735'45"E longitude, and has an altitude of 1395 m.a.s.l, The annual rainfall ranged from 400 to 700 mm and the average temperature of the area varied from 23 to 30°C. The soil type of the experimental site is sandy loam (Merebleke BoARD, 2014).

Experimental design and treatments arrangements

The experiment was laid out in 4 x 3 factorial arrangements. Factor one: inter-row spacing with four levels (60, 80,100 and 120 cm) and factor two: intra-row spacing with three levels (20, 30 and 40 cm) were used in randomized complete block design (RCBD) with three replications. Melkasholla variety of tomato was used as experimental unit. The variety was released nationally by Melkassa agricultural research center in 1988, and recommended by Axum agricultural Research Center for the study area. It has semi determinate growth habit. The size of each experimental plot was 3x4.8m=14.4m^2. Each plot contained different number of seedlings depending on the inter and intra-row spacing capacity in order to obtain specified number of plants per plot.

Experimental procedures

Seeds of melkashola tomato variety were sown in 15 cm row spacing on well prepared seed bed of 1m x 5 m nursery area. The seed was covered with light soil and mulching grasses with the aim to protect seeds from washing away during watering. Beds were watered with watering can followed by surface irrigation. Proper management (weeding, watering) practices were followed to produce healthy and vigorous seedlings. Land preparation was practiced in advance for better seedling establishment and to expose the soil to solar treatments that could be useful to reduce diseases and insect pest incidence. Healthy and uniform seedlings with 3 to 4 leaf number were transplanted at the age of 35 days after sowing. The seedlings were irrigated after transplanting. Inorganic fertilizers, Di Ammonium phosphate (DAP) and urea were applied to each plot at the rate of 92 kg ha^{-1} P_2O_5 and 69 kg ha^{-1} N, respectively according to the recommendation of the crop (Lemma, 2002). The whole amount of phosphorus fertilizer was applied at transplanting, whereas half rate of nitrogen was applied during transplanting, and the remaining was applied during the flowering stage of the plant.

Data collected

Data were collected from randomly selected and tagged plants from the central row excluding the border rows. The parameters that were considered were: days to 50% flowering, days to maturity, plant height (cm), fruit Length (cm) and diameter (cm), number of branch per plant ,number of cluster per plant, number of fruit per plant, average fruit weight(g), marketable yield (qt ha^{-1}), unmarketable yield (qt ha^{-1}) and total yield (qt ha^{-1}).

Data analysis

Combined Analysis of Variance (ANOVA) was made using SAS version 9.2 (SAS institute, 2008) after testing the ANOVA assumptions. Means that showed significant difference were compared using Duncan;s Multiple range Test (DMRT).

RESULTS AND DISCUSSION

Combined mean square of ANOVA for inter and intra row spacing of tomato showed that there were no

Table 1. Combined ANOVA of inter and intra row spacing of tomato evaluated for two years in Merebleke Wereda, central zone of Tigray.

Source of variation	Df	Mean square								
		Days to 50% flowering	Days to maturity	Plant height (cm)	No. of fruits plant $^{-1}$	Fruit diameter (cm)	Fruit length (cm)	Marketable fruit yield (qt ha^{-1})	Unmarketable yield (qt ha^{-1})	Total yield (qt ha^{-1})
Block	2	0.54	4.86	106.72	47.2	0.26	1.547^{ns}	9352	364.2	10378
Intra row (1)	2	3.17*	15.29*	112.08**	971.6**	0.001^{ns}	0.349^{ns}	68479**	904.4**	81728**
Inter row (2)	3	15.94**	73.68**	121.92**	2010.8**	0.0761^{ns}	0.347^{ns}	62936**	1293.7**	76015**
Year (3)	1	445.01**	21.13*	501.39**	305.9^{ns}	0.0383^{ns}	42.013**	311^{ns}	1580.5**	490^{ns}
1* 2	6	2.20*	4.63^{ns}	6.41^{ns}	132.5^{ns}	0.0382^{ns}	0.331^{ns}	9363^{ns}	321.3^{ns}	11263^{ns}
2*3	2	7.06**	30.54**	56.71^{ns}	668.0*	0.0046^{ns}	0.019^{ns}	29104^{ns}	297.0^{ns}	33506^{ns}
1*3	3	0.68^{ns}	0.83^{ns}	33.81^{ns}	296.7^{ns}	0.2141^{ns}	0.209^{ns}	3788^{ns}	124.7^{ns}	5116^{ns}
1*2*3	6	0.28^{ns}	3.13^{ns}	24.46^{ns}	44.6^{ns}	0.072^{ns}	0.075^{ns}	3650^{ns}	91.0^{ns}	3811^{ns}
Residual	46	0.95	4.397	24.69	135.1	0.1022	0.2968	11763	165.2	12570
Total	71	-	-	-	-	-	-	-	-	-

Df= degree of freedom, *= significant, **= highly significant, ns= non significant.

significant interaction effects ($p<0.05$) for most of the traits except days to 50% flowering. On the contrary, combined main effect of inter and intra row spacing was significant ($p<0.05$) for most of the traits except fruit diameter and fruit length. In line with this, Getahun and Biki (2015) found non significant difference for fruit length and width for five intra row spacing (20, 30, 40, 50 and 60 cm) tested in Fogera wereda, Ethiopia. The effect of year was significant for some of the responses such as days to 50% flowering, days to maturity, plant height, fruit length and unmarketable yield indicating that performance of the experiment varied across season for the aforementioned traits. It could be due to high infestation of blight disease in 2013 as compared with 2014, and this resulted in poor performance of the crop (Table 1).

Interaction effect of inter and intra row spacing on days to 50% flowering

Combined interaction effect of inter and intra-row spacing showed significant ($p<0.05$) difference on days to 50% flowering. A combination of 30cm intra row and 120 cm inter row space took the earliest (48 days) while 30 cm intra raw and 60 cm inter row space took the longest (52 days) time to reach days to 50% flowering. Generally, as the inter-row spacing increases from 60 to 120 cm, and intra-row spacing increases from 20 to 40 cm, days to 50% flowering showed an increasing trend (Table 2). Similarly, Getahun and Bikis (2015) found that as intra row spacing increased from 20 to 60 cm the number of days required to reach 50% flowering increased from 42 to 47 days.

Main effect of intra row spacing on different responses of tomato

The combined main effect of intra row spacing had significant difference ($p<0.05$) for days to maturity, plant height, fruit number per plant and single fruit weight. 40 cm intra row spacing took the highest number of days (92 days) to mature. Generally, as the intra row spacing increased from 20 to 40 cm it showed an increasing trend in days required to maturity. The tallest (59.9 cm) plant length was recorded from 20 cm intra row spacing while the shortest (55.8 cm) was obtained from 40 cm intra row spacing. This was because as plants get narrow spacing they compete to get sunlight and forced to increase their length. Similarly, Balemi (2008) found that highest plant length was found from narrow spacing (80*30 cm) inter and intra row spacing as compared to wider spacing (100* 30 cm).

The highest number of fruits per plant (74) was found from 40 cm intra row spacing, but it was statistically at par with 30 cm spacing (68). This is because as the plants get optimum space the number of fruits increase in comparison with the narrow intra row spacing, that is, 20cm. Fruit size is significantly affected by intra row spacing. The largest fruit size (71.2 g) was found from intra row space of 30cm which is statistically not significantly different from 40 cm (66.3 g) while the least size was scored from intra row spacing of 20 cm (64.7 g).

This revealed that competition effect for nutrient, space, and air is minimal at wider space and this

Table 2. Combined interaction effect of inter and intra-row spacing on days to flowering, fruit diameter (cm) and fruit length (cm) .

Intra * inter row spacing (cm)	Days to 50% flowering			Fruit diameter (cm)			Fruit length (cm)		
	2013	2014	Combined	2013	2014	Combined	2013	2014	Combined
20*60	47.3	51.0^{ef}	49.2^{def}	4.0	4.5	4.3	8.1	6.8	7.5
20*80	48.0	51.7^{def}	49.8^{cde}	4.3	4.5	4.4	8.5	6.8	7.7
20*100	47.3	52.0^{cde}	49.7^{cde}	4.5	4.3	4.4	8.5	6.8	7.7
20*120	48.7	52.3^{cde}	50.5^{abc}	4.5	4.2	4.3	8.4	7.0	7.7
30*60	46.0	50.3^{f}	48.2^{f}	4.2	4.4	4.3	8.9	7.2	8.0
30*80	46.3	51.7^{def}	49.0^{ef}	4.3	4.5	4.4	8.7	6.9	7.8
30*100	48.0	53.3^{abc}	50.7^{abc}	4.3	4.4	4.4	8.7	7.1	7.9
30*120	49.3	54.0^{ab}	51.7^{a}	4.4	4.1	4.3	8.2	7.1	7.7
40*60	46.3	52.7^{bcd}	49.5^{cde}	4.5	4.4	4.5	8.3	6.9	7.6
40*80	47.7	53.0^{abcd}	50.3^{bcd}	4.3	4.5	4.4	8.2	6.8	7.5
40*100	47.3	54.0^{ab}	50.7^{abc}	4.3	4.5	4.4	9.3	7.3	8.3
40*120	48.3	54.3^{a}	51.3^{ab}	4.2	4.0	4.1	8.5	7.1	7.8
CV (%)	2.1	1.6	1.9	5.2	9.1	7.4	7.2	6.7	7.0
SEM (±)	0.56	0.49	1.13	0.13	0.23	0.13	0.35	0.27	0.22
Level of sig.	ns	*	*	ns	ns	Ns	ns	ns	Ns

CV= coefficient of variation, SEM= standard error of the mean, *= significant, **= highly significant, Ns= non-significant. Means followed by the same letter within the same column are not significantly different at 5% level of significance.

favored the plant to increase fruit size. This is in agreement with the finding of Mamnoie and Dolatkhahi (2013) who found significant different for fruit number per plant and single fruit weight (g) for four intra row spacing (30, 40, 50 and 60 cm) for two tomato varieties evaluated in Iran. They reported that highest number of fruits per plant and larger fruit size were found from 60 cm intra row spacing.

Main effect of inter row spacing on different traits of tomato

Combined main effect of inter row spacing had significant difference for days to maturity, plant height and fruit number per plant while it showed non-significant different for single fruit weight. 120 cm inter row spacing took the highest number of (93.2) days to maturity whereas the smallest number of days for maturity (88.6) was recorded from 60 cm inter row space. Similar to intra row spacing effect, the influence of inter row spacing on maturity showed an increasing trend when the spacing increased from 60 to 120 cm. the highest number of fruits (81) was scored from the wider inter row spacing, 120 cm and the least (55) was recorded from 60 cm spacing (Table 3).

Combined main effect of intra row spacing on fruit yield of tomato

Combined main effect of intra row spacing was significant for marketable, unmarketable and total fruit yield per hectare. The highest marketable fruit yield (619.4 qt ha^{-1}) was recorded from 20 cm intra row spacing, which is statistically not different with 30 cm intra row spacing (597.4 qt ha^{-1}). The least marketable yield was found from 40 cm intra row spacing (Table 4). This might be because the narrow intra row spacing had higher plant population as compared to wider spacing. On the contrary, fruit size was significantly smaller in 20 cm intra row as compared to 30 and 40 cm intra row spacings. This is in agreement with the finding of Mammoie and Dolatkhahi (2013) who found that as intra row spacing increased from 30 to 60 cm fruit size increased from 126.5 to 166.5 gram. Generally, relatively higher yield with larger fruit size was obtained from 30 cm intra row spacing in the study area.

According to Lemma (2002), fruits with cracks, damaged by insect, disease, birds, small size fruits and sun burn are considered as unmarketable. Hence, the highest (65.86 qt ha^{-1}) unmarketable yield was found from 20 cm intra

Table 3. Combined main effect of inter and intra row spacing on yield and yield component of tomato evaluated for two years.

Inter row spacing (cm)	Days to maturity			Plant Height (cm)			Fruit no. per plant			Single fruit weight (g)		
	2013	2014	Combined	2013	2014	Combined	2013	2014	Combined	2013	2014	Combined
60	88.2^{b}	88.9^{c}	88.6^{c}	59.3	49.9^{b}	54.6^{b}	62^{b}	48^{c}	55^{c}	64.8	67.6	66.2
80	89.6^{b}	91.2^{b}	90.4^{b}	60.4	56.0^{a}	58.2^{a}	67^{ab}	65^{b}	66^{b}	64.8	71.2	68.0
100	91.4^{a}	92.6^{ab}	92.0^{a}	62.5	58.7^{a}	60.6^{a}	72^{ab}	68^{b}	70^{b}	69.6	71.3	70.5
120	92.8^{a}	93.7^{a}	93.2^{a}	61.2	57.6^{a}	59.4^{a}	78^{a}	83^{a}	81^{a}	65.3	64.3	64.8
SEM (±)	0.46	0.39	0.494	1.55	1.18	1.17	3.6	3.7	2.7	2.63	3.18	2.196
Level of sig	**	**	**	ns	**	**	*	**	**	ns	ns	ns
Intra row spacing (cm)												
20	91.3^{a}	89.8^{a}	90.5^{b}	63.6^{a}	56.1^{a}	59.9^{a}	69^{ab}	54^{b}	66^{b}	62.1^{b}	67.2	64.7^{b}
30	89.3^{b}	92.0^{b}	90.7^{b}	59.9^{ab}	58.1^{a}	59.0^{a}	65^{b}	71a	68^{ab}	71.3^{a}	71.1	71.2^{a}
40	90.9^{a}	93.0^{b}	92.0^{a}	59.0^{b}	52.5^{b}	55.8^{b}	76^{a}	72a	74^{a}	65.0^{ab}	67.5	66.3^{ab}
CV (%)	1.5	2.5	2.3	7.64	7.4	8.5	15.6	16.8	17.1	11.9	13.9	13.8
SEM (±)	0.40	0.67	0.428	1.34	1.68	1.01	3.1	3.2	2.4	2.28	2.76	1.902
Level of sig	**	**	*	*	**	**	*	**	**	*	ns	*

CV= coefficient of variation, SEM= standard error of the mean, *= significant, **= highly significant, Ns= non significant. Means followed by the same letter within the same column are not significantly different at 5% level of significance.

Table 4. Combined main effect of inter and intra row spacing on yield of tomato.

Inter row spacing (cm)	Marketable fruit yield (qt ha^{-1})			Un marketable yield (qt ha^{-1})			Total yield (qt ha^{-1})		
	2013	2014	Combined	2013	2014	Combined	2013	2014	Combined
60	654.6^{a}	607.4^{ab}	631^{a}	69.1^{a}	71.2^{a}	70.18^{a}	723.7^{a}	678.7^{a}	698.2^{a}
80	611.7^{a}	616.2^{a}	613.9^{a}	52.7^{b}	66.8^{ab}	59.72^{b}	664.3^{a}	683.0^{a}	673.6^{ab}
100	563.9^{ab}	575.2^{ab}	569.6^{ab}	45.7^{b}	54.7^{b}	50.23^{c}	609.6^{ab}	630.0^{ab}	619.8^{bc}
120	491.2^{b}	505.9^{b}	498.5^{b}	49.2^{b}	61.5^{ab}	55.36^{bc}	540.4^{b}	567.3^{b}	553.9^{c}
SEM (±)	37.36	28.93	22.14	3.64	3.87	3.03	38.45	30.5	26.43
Level of sig	**	**	**	**	**	**	*	**	**
Intra row spacing (cm)									
20	651.4^{a}	587.4^{ab}	619.4^{a}	65.2^{a}	66.5	65.86^{a}	716.6^{a}	653.9^{a}	685.3^{a}
30	561.3^{ab}	633.6^{a}	597.4^{a}	49.9^{b}	62.9	56.42^{b}	611.2^{b}	696.5^{ab}	653.9^{a}
40	528.3^{b}	507.5^{b}	517.9^{b}	47.4^{b}	61.3	54.34^{b}	575.7^{b}	568.8^{b}	572.2^{b}
CV	19.3	17.4	18.8	20.2	21.1	21.8	18.2	16.5	17.6
SEM (±)	32.3	28.93	25.56	3.15	3.87	2.62	33.2	30.48	22.89
Level of sig	**	**	**	**	ns	**	*	**	**

CV= coefficient of variation, SEM= standard error of the mean, *= significant, **= highly significant, Ns= non significant. Means followed by the same letter within the same column are not significantly different at 5% level of significance.

row spacing and the least from 40 cm spacing (54.34 qt ha^{-1}). This is because narrow intra row spacing had high population density and resulted in competition for nutrient, space and sunshine, which in turn resulted in small sized, deformed and unmarketable fruits.

Combined main effect of inter row spacing on fruit yield of tomato

Similar to the effect of intra row spacing, inter row spacing also had highly significant difference on marketable, un-marketable and total fruit yield per hectare of tomato. 60 cm inter row spacing had the highest marketable yield (631 qt ha^{-1}), and the least yield was obtained from 120 cm spacing (498.5 qt ha^{-1}). This may be due to high population in the narrow inter row spacing, and fruit size was not significantly different among the four inter row spacing which resulted in high marketable yield.

In line with this, Harnet et al. *(*2015) found the least marketable yield of tomato from 120*40 cm inter and intra row spacing while the highest marketable yield was found from interaction effect of 50*20 cm inter and intra row spacing at southern Tigray, Ethiopia. Similarly, Balemi (2008) reported that highest total fruit yield (78.6 kg $plot^{-1}$) was found from 80*30 cm inter and intra row spacing whereas the least yield (67.6 kg $plot^{-1}$) was obtained from 100*30 cm inter and intra row spacing for the study conducted at Ambo University, Ethiopia.

On the contrary, highest unmarketable yield (70.18 qt ha^{-1}) was found from 60 cm inter row spacing while 120 cm scored the least (55.36 qt ha^{-1}). This might be associated as inter row spacing increase from 60 to 120 cm fruit size showing an increasing trend, even though it is not statistically and it might result in higher unmarketable yield.

Conclusion

Tomato is among the most important vegetable crops in low land central zone of Tigray, especially Merebleke wereda. Farmers get lower yield mainly due to the use of in-appropriate agronomic practices Plant spacing greatly influenced growth, yield, and quality parameters of tomato. Considering this problem, an experiment was conducted for two years aiming to investigate the effect of inter-row and intra-row spacing on yield and yield component of tomato.

Combined mean results of the two year study showed that the highest marketable yield was recorded from 60 cm inter row spacing (654.60qt ha^{-1}) but it is statistically at par with 80 cm inter row spacing (611.7 qt ha^{-1}). Similarly, narrow intra row spacing that is, 20 cm scored highest marketable yield (651.4 qt ha^{-1}) but significantly smaller fruit size (67.5 g) as compared to 30 cm intra row spacing (71.1 g). On the other hand, inter row spacing didn't show significant difference in fruit size. Therefore, it is recommended that 60 cm inter row spacing and 30 cm intra row spacing are appropriate for higher marketable fruit yield and fruit size in central zone of Tigray, Merebleke wereda.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Pollination activity and foraging behavior of local honeybee (*Apis mellifera)* under open and caged conditions in Mekelle, Tigray, Ethiopia

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Locally there is cultivation of vegetables in greenhouse as a production system; however it is not common to use honeybee as pollinators. This might be due to a fear of low pollination efficiency or activity of local bees under caged condition. Moreover there is no research related to the foraging behavior of local honeybee under caged condition. Hence, this investigation was designed to study foraging behavior of honeybees (*Apis mellifera*) and their pollination efficiency under managed condition. Pollination efficiency of the local bees was determined by comparing the seed yield and quality of self-pollinated crops with crops caged with honeybee. This was done during the blooming time of *Guzzotia abyssinica*. Data related to foraging behavior and seed yield and quality was analyzed using repeated measure analysis of variance and t-test, respectively using Genstat 14th version statistical software. Crops caged with honeybee had higher yield (200.3 g) compared to crops prevented from insect pollinators (115.2 g).The highest foraging rate of bees was recorded at 14:30-15:30pm (12.02 flowers /five minute), while the lowest foraging rate was recorded at 8:30-9:30am (8.15 flowers/five minute). The overall foraging trend of bees was similar under caged and open conditions. Finally, the use of local honeybees' pollination under managed condition was recommended for improving the seed yield and quality of *G. abyssinica* seeds.

Key words: Caged, foraging, honeybee, pollination.

INTRODUCTION

Honeybee pollination services benefits agricultural production significantly and important in crop production as water or fertilizer (Jacobs et al., 2006). The need for insect pollination in greenhouses or enclosures increased from time to time to produce uncontaminated seed or to increase seed or fruit following insect visits (Free, 1993). Due to the reduction of natural pollinator population by agrochemicals pollinating honeybee play important roles in modern agriculture (Mattu et al., 2012). Although many species are known to provide pollination services,

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honeybees (*Apis mellifera*) are often assumed to provide the majority of these services to agriculture (Breeze et al., 2011).

Previous research also indicates that honeybees (*A. mellifera*) are a feasible alternative to bumble bee pollination for greenhouse crops and financially viable for growers (Sabara and Winston, 2003). To use honeybees for such purposes however, the question arises among research workers whether the foraging and pollination efficiency of honeybee differs under such artificial conditions from the natural condition (Devkota and Thapa, 2005).

Moreover; locally it is not also common to use honeybee as pollinators in greenhouse cultivation of vegetables as a production system. This might be due to a fear of low honeybee pollination efficiency or foraging activity under cage or since there is no research related to the foraging behavior and pollination activity of honeybee (*A. mellifera*) under controlled condition. The great value of honeybees' pollinators is not also appreciated and understood locally (Jacobs et al., 2006). Better understanding of managed honeybee foraging behavior and pollination activity, however, can contribute to the improvement of management practice that aims to enhance crop pollination. Hence, this study was designed to study the foraging behavior and pollination activity of honeybees (*A. mellifere)* in *G. abyssinica* crop under caged and open conditions.

MATERIALS AND METHODS

Study area

The study was carried out at the Mekelle Agricultural Research Center farm, Illala site. Illala is geographically found in the North east of Mekelle city at elevation of 1970 m.a.s.l at 250° 51' N latitude and 390° 61' longitude.

Agronomic practice

The crop (*G. abyssinica*) was planted with a seed rate of 10 kg/ha, 40 cm, 10 cm distance between rows and between plants. Diammonium phosphate and urea were applied immediately after sowing and two weeks after sowing, respectively at a rate of 100 kg/ha.

Experimental management

To evaluate the foraging behavior of honeybee under open and caged conditions, the crop (*G. abyssinica*) was planted in a plot size of 3 m × 3 m and replicated four times. The crops caged with honeybee (five framed hive) and without honeybee were considered as treatment. In both treatments, plots were covered with mesh cages (3 m wide x 2 m long x 2 m high) shortly before flowering. After caging the plots, five framed hive colonies were placed on the respective experimental plots starting from its initial blooming (5 to 10%) to its final blooming period. This stage of flowering was selected to secured feed (pollen and nectar) for honeybees.

The pollination efficiency or activity of honeybee was determined by comparing yield and quality of *G. abyssinica* seeds obtained from crops caged with honeybee and crops caged without honeybee.

Foraging behavior of honeybees was studied in the crops caged with five framed hive and in the open plots. This was done during the blooming time of *G. abyssinica* (starting from first to third weeks). The foraging behaviors of honeybees in both conditions were studied in terms of foraging rate, time spent/flower, pollen and/or nectar preference and their abundance. This observation was done five times a day: 8:30-9:30 am, 10:30-11:3 am, 12:30-13:30 pm, 14:30-15:30 pm and 16:30-17:30 pm at two hours intervals. Each observation time was considered as a treatment.

Abundance of honeybees was determined by counting the number of honeybee visiting in a station holding of five plants/five minutes. Foraging rate of honeybee was studied by counting the number of flowers visited by a bee/minute. Time spent by a bee/flower was determined by recording time from starting on landing on a flower to leaving that particular flower using a stopwatch.

Data analysis

Data associated to foraging behavior of honeybee (foraging rate, time spent, pollen and nectar preference and abundance) were analyzed using repeated measure analysis of variance. Mean comparison among means of hours of the day was done using least significant difference (LSD). Seed yield and quality of the crop under caged and open conditions was analyzed using t-test using Genstat 14th version statistical software.

RESULTS AND DISCUSSION

Effect of honeybees' pollination on yield and quality of *G. abyssinica* seeds

There was significant difference between crops caged with honeybee and without in relation to seed yield/plot and seed germination rate (Table 1). Crops caged with honeybee had higher yield (200.3 g) compared to crops caged without honeybee (115.2 g). This indicates that crops caged with honeybee had 42.5% yield increment over crops caged without honeybee. In the same crop, Sattigi et al. (2004) also reported higher yield in crops caged with honeybees compared to crops caged without bees.

Crops caged with honeybee also had higher germination rate (81.5%) than crops excluded from honeybee (55.5%) (Table 1). This showed that seeds from that caged with honeybee had 29.8% increment on seed viability over seeds excluded from insects. Dhurve (2008) also revealed higher germination rate in crops caged with honeybee over crops caged without honeybee. In onion, seeds from open pollinated crops also had higher germination rate than crops excluded from insect visitors (Adel et al., 2013). Regarding oil content and 1000 seed weight of *G. abyssinica* seeds, however, significant difference was not found between the crops caged with honeybee and without honeybee (Table 1) and this is similar to Dhurve (2008).

Table 1. Effect of honeybee pollination on seed yield and quality of *G. abyssinica.*

Variable	Mean	SD	t	df	p
Yield per plot (1.2 m^2)			3.98	6	0.007
With bee	200.3	26.87			
Without bee	115.2	33.19			
1000 seed weight			0.325	6	0.756
With bee	5.075	0.15			
Without bee	4.975	0.59			
Germination rate			3.57	6	0.012
With bee	86.2	5.56			
Without bee	60.50	13.30			
Oil content			1.66	6	0.147
With bee	41.49				
Without bee	38.98				

Table 2. Foraging behavior of honeybees under caged and open condition during the blooming time of *G. abyssinica.*

Treatment	Time spent	Foraging rate	Pollen	Nectar	Pollen and nectar
Caged	7.04^a	11.09^a	1.27^b	16.38^a	1.89
Open	6.03^b	5.89^b	2.06^a	13.47^b	3.93
P value	0.021	<0.001	0.026	<0.001	<0.001
LSD	0.855	0.5872	0.687	0.982	0.800

Figures in rows with the same letters are not significantly different at 5% level by LSD.

Foraging behavior of honeybees during blooming period of *G. abyssinica* under open and caged condition

There was significant difference between honeybees under caged and open condition related to foraging rate, time spent per flower, pollen and nectar preference of honeybees (Table 2). Bees under cage had higher foraging rate (11.09 flowers/min) and time spent/flower (7.04) compared to foraging rate (5.89 flowers/min) and time spent/flower (6.03) of bees under open condition. The difference on foraging rate between the bees under open and caged conditions might be related to the presence of other insect pollinators under the open condition. Awraris (2009) also stated that foraging behavior of honeybees was affected by other insect pollinators. This study also revealed that honeybees foraging time per head when interacting with other pollinators was significantly lower than interaction among honeybees only.

As demonstrated in Table 2, nectar preference of bees under caged condition had higher nectar preference (16.38) than bees in open condition (13.47). Adjaloo and Yeboah-Gyan (2003) also revealed that bees work slowly when collecting pollen than when they are collecting nectar.

Time of the day also had significant effect on foraging rate, pollen and/or nectar preference of honeybees under both caged and open conditions (Tables 2 and 3). The highest foraging rate was recorded at 12:30-13:30 pm for both bees under caged (12 flowers/min) and open conditions (12.6 flowers/min), while the lowest foraging rate was recorded at 8:30-9:30am for both bees under caged (6.42 flowers/min) and open conditions (11.4 flowers/min). Kunjwal et al. (2014) also stated that the foraging rate of bees varies with time.

As demonstrated in Table 3, across the same hours of the day, bees under caged condition had higher foraging rate than bees under open conditions. However, time of the day had no significant effect on time spent/flower or flowering speed of bees under both caged and open conditions (Tables 2, 3 and 4). The time spent per flower of the local honeybees ranged from 6.02 to 7.95 s and 5.9 to 6.3 s under caged and open conditions, respectively. As regards average time spent per flower, Devkota and Thapa (2005) also found non-significant difference for honeybee (*A. mellifera*) under caged and open conditions.

The maximum numbers of honeybees collecting pollen was observed at 8:30-9:30 am under caged (6.23) and open conditions (7.7), while the least number of honeybees' collected pollen from 10:30-11:3 am to 16:30-17:30 pm under both conditions. This indicates that honeybees were vising the plants for its pollen in the

Table 3. Foraging behavior of honeybees across different hours of the day under caged condition.

Time	Time spent	Foraging rate	Pollen	Nectar	Pollen and nectar	Abundance
8:30-9:30AM	7.95	10.58^{b}	6.23^{a}	6.23^{b}	7.93^{a}	62.53^{ab}
10:30-11:3AM	7.42	11.00^{b}	0.00^{b}	19.90^{a}	0.19^{b}	68.53^{a}
12:30-13:30PM	6.79	12.00^{a}	0.00^{b}	19.53^{a}	0.21^{b}	56.80^{b}
14:30-15:30PM	6.02	10.77^{b}	0.15^{b}	19.07^{a}	0.88^{b}	44.27^{c}
16:30-17:30PM			0.00^{b}	19.89^{a}	0.23^{b}	21.27^{d}
LSD	1.99	0.83	1.31	1.44	1.57	5.80
P value	0.187	0.010	<0.001	<0.001	<0.001	<0.001

Column means with different superscript letters are significantly different (P<0.05).

Table 4. Foraging behavior of honeybees across different hours of the day under open condition.

Time of the day	Time spent	Foraging rate	Pollen	Nectar	Pollen and nectar	Abundance
8:30-9:30AM	6.0	11.4^{b}	7.7^{a}	5.3^{d}	7.0^{a}	28.3^{ab}
10:30-11:3AM	6.3	11.5^{b}	0.68^{b}	16.5^{ab}	2.9^{cb}	34.0^{a}
12:30-13:30PM	6.0	12.6^{a}	0.14^{b}	18.1^{a}	1.9^{cb}	24.0^{b}
14:30-15:30PM	5.9	11.6^{b}	0.48^{b}	16.0^{ab}	3.3^{b}	9.2^{c}
16:30-17:30PM			1.40^{b}	2.5	1.4^{b}	1.5^{d}
SE	0.23	0.28	0.46	1.02	0.97	2.88
P value	0.45	0.026	<0.001	<.001	0.017	<0.001

Column means with different superscript letters are significantly different (P<0.05).

Table 5. Effect of cage on foraging behavior of honeybees across the same hour of the day during blooming period of *G. abyssinica* under caged.

Time	Foraging rate					Time spent				
	Open	Caged	Grand mean	P value	SEM	Open	Caged	Grand mean	P value	SEM
8:30-9:30AM	5.71^{b}	10.58^{a}	8.15	<0.001	0.432	5.9	7.95	7.15	0.056	1.023
10:30-1:3AM	5.75^{b}	11.09^{a}	8.38	<0.001	0.406	6.4	7.42	7.03	0.198	0.774
12:30-3:30PM	6.29^{b}	12.09^{a}	9.15	<0.001	0.387	6.1	6.79	0.55	0.221	0.55
14:30-5:30PM	5.79^{a}	10.82^{a}	8.30	<0.001	7.44	5.8	6.02	5.94	0.812	0.917

Column means with different superscript letters are significantly different (P<0.05).

early morning. This might be due to the reason that, the flower of *G. abyssinica* opens and liberates pollen early in the morning (Weiss, 2000). Other authors also stated that pollen collection of honeybees varies significantly with time of day (Nascimento and Nascimento, 2012). Verma and Partap (2010) revealed that pollen collectors outnumbered nectar collectors during the morning.

In relation to nectar preference, honeybees were collecting nectar highly at 12:30-13:30 pm under both caged (18.83) and open conditions (18.1), while the least number was recorded at 8:30-9:30 am under both caged (5.78) and open conditions (5.3) (Table 5). This might be due to the reason that a floret of *G. abyssinica*, which is the nectar source, emerges about midday and this makes it possible for honeybees to collect nectar at midday (Weiss, 2000)(Figure 1).

In bees both under caged and open conditions, time of the day had significant effect on the abundance of honeybees/flower/min (Tables 2 and 3). The highest abundance of bees was recorded at 10:30-11:3 am under both open (34.0) and caged (68.53) conditions. However, bees had lowest abundance towards the evening, 16:30-17:30 pm in both conditions.

Although under open and caged conditions bees showed a slight deviations in their foraging rate and time spent across different hours of the day, the overall foraging trend was similar under caged and open conditions across the different hours of the day (Tables 2 and 3).

CONCLUSIONS AND RECOMMENDATION

1) Honeybees' pollination had significant effect on increasing seed yield and germination rate of *G.*

Figure 1. Five framed hive under cage during blooming time of *G. abyssinica.*

abyssinica seeds and crops caged with honeybee had higher seed yield and germination rate compared to crops caged without honeybee.

2) Time of the day had a significant effect on the foraging rate of honeybee. The highest foraging rate of bees was recorded at 14:30-15:30 pm (12.02 flowers/five minute), while the lowest foraging rate was recorded at 8:30-9:30am (8.15 flowers/five minute).

3) Bees under open and caged conditions bees showed a slight deviation in their foraging rate and time spent across different hours of the day; however the overall foraging trend was similar under caged and open conditions.

4) Hence, there is need to consider honeybees as efficient pollinators under managed condition to improve seed yield and quality of *G. abyssinica* seeds.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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