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Full Length Research Paper

Decisions for adopting and intensifying the use of chemical fertilizers in cereal production in Burkina Faso

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This article used a Tobit model to analyze what determines the decisions to adopt and intensify the use of chemical fertilizers in cereal production in Burkina Faso. The results show that the main factors that explain the adoption and increased use of chemical fertilizers are: agricultural potential of the area of production, ownership of a radio set, formal education of actives household members, closeness to an earth-built road, amount of credit and membership in a group of producers. The marginal effects showed that the probability of adoption of chemical fertilizers by new entrants is greater than the probability of existing producers intensifying the usage of chemical fertilizers. These results imply that the incentives for the adoption and intensification policies should primarily target producers who have not yet used chemical fertilizers.

Key words: Tobit model, adoption, intensification, fertilizers, cereals.

INTRODUCTION

The liberalization of the economy in 1991 has ended input subsidy policies in Burkina Faso's agricultural sector. Although subsidies were no more available, domestic consumption of chemical fertilizers continued to grow due to the expansion of cotton production. The proportion of farmlands that use chemical fertilizers increased from 7% in 1993 to 30% in 2006. The rate of chemical fertilizers application also increased from 12 to 40 kg/ha over the same period. This increase was transmitted to cereal production for which the rate of chemical fertilizers application increased from 5 to 19 kg/ha due to the diversion of inputs from cotton production[1].

However, consumption of chemical fertilizers for cereal production had strongly decreased since 2006 due to the crisis in the cotton sector. This is an obstacle to the improvement of agricultural productivity, revenue increment and poverty reduction efforts of rural households. These rural households representing about 80% of the population have agricultural production as the main source of livelihood. The poverty profile shows that more than 50% of rural people live below the poverty line[2].

Cereal production (sorghum, millet, maize, rice) occupies more than 88% of farmland and is the main staple food crops for the majority of the population. It is an extensive farming practice that increasingly faces significant constraints such as population pressure, scarcity of arable land, and the degradation of natural resources[3]. Preservation of natural resources and improvement of agricultural productivity necessarily require the adoption and increased use of new technologies. With the 2008 food crisis, the government of Burkina Faso has renewed its interest in subsidizing agricultural inputs for the intensification of cereal

[1] Ministry of Agriculture, Water and Fisheries Resources, 2011

[2] Ministry of Economy and Finance, 2010

[3] Ministry of Agriculture, Water and Fisheries Resources, 2008

production. Thus, the government has implemented a policy based on agricultural intensification and the use of chemical fertilizers and high yielding seed varieties, to fight against recurrent food insecurity. However, there is almost no research on what determines the adoption and the intensity of the use of chemical fertilizers.

An abundant literature has identified the socio-economic, demographic, agro ecological and institutional factors as the key determinants of the decision to adopt new technologies in developing countries (Zegeye et al., 2001; Knepper, 2002; Feder et al., 1985; Moreno and Sunding, 2005). The adoption of a new technology is driven by the profit expected by producers and the availability of information on its implementation and effectiveness. In this regard, it had been found that the formal education increases the probability of technology adoption (Wozniak, 1984; Feder et al., 1985; Doss et al., 2003; Asfaw and Admassie, 2004).

Access to agricultural extension services encourages producers to adopt new technologies in developing their activities (Bacha et al., 2001; Kherallah et al., 2002). In an environment where technology transfer is difficult, the standard of formal education of the actives is critical (Wozniak, 1984; Ersado et al., 2004). The number of actives also plays a key role in the decision to adopt and increase the use of technology (Lee, 2005). Larger households have a greater adoption probability of new technologies (Croppenstedt and Demeke, 1996; Zegeye et al., 2001; Doss et al., 2003).

Availability of off-farm income helps to remove credit constraints and improve the probability of adoption of a new technology (Feder et al., 1985). On the other hand, producers who have low-income or credit constraint are less likely to adopt new technologies that are risky (Adesina, 1996). The research results have also shown that agro-ecological conditions influence the probability of adoption of agricultural technology (Chirwa, 2005; Doss, 2006). Thus, producers located in low rainfall areas are less likely to adopt chemical fertilizers (Freeman and Omiti, 2003; Chianu and Tsujii, 2004).

Although most of these studies address the issue concerning the elements determining the adoption of new technologies, they do not give satisfactory information on the intensity of their use. For this objective, they have used Probit or Logit models to model the adoption decision. The objective of this paper is to identify the effects of factors that influence decisions of adoption and intensification of the use of chemical fertilizers in cereal production in Burkina Faso. To this end, the Tobit model is the most suitable one (McDonald and Moffit, 1980).

Theoretical framework for the adoption and intensification of a technology

The producer establishes his decision to adopt a new technology on the expected profitability. He adopts the new technology only if the expected profitability is higher than that of the non-adoption (Marenya and Barrett, 2007; Nkamleu and Adesina, 2000). The Probit, Logit, and Tobit models are the ones that are most commonly used to identify factors that influence the decision for adopting a new technology (Imai, 2003).

Probit and Logit models allow the modeling of the adoption of a new technology when the dependent variable is binary. The Tobit model enables the modelling of both the adoption and intensification of the use of a technology when the dependent variable is continuous and censored at 0 (Adesina and Zinnah, 1993; Kazianga and Masters, 2002; Anley et al., 2007). The Tobit model is therefore, the most appropriate for understanding the factors that influence the decision of adoption and intensification of the use of chemical fertilizers.

The expected profit (y_i^*) is an unobserved latent variable that depends on the alternative choices and socio-economic, demographic, and institutional characteristics of the producer (X_i). The stochastic form of Tobit model (McDonald and Moffit, 1980; Yilma et al., 2008) can be represented as follows:

$$y_i^* = X_i^{'}\beta + \varepsilon_i \, , \quad i = 1, \dots, n \qquad (1)$$

$y_i = 0$ if $y_i^* \leq 0$, non-adoption of chemical fertilizers

$y_i = y_i^*$ if $y_i^* > 0$, adoption of chemical fertilizers

Where y_i is the observed variable, β a vector of unknown parameters and ε_i is independently and normally distributed error term with mean 0 and constant variance, σ^2.

McDonald and Moffit (1980) specify the expected value of y as follows:

$$E[y] = X^{'}\beta F(z) + \sigma f(z) \qquad (2)$$

They specify the expected value of y for observation over Censorship ($y^* > 0$) as follows:

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Abbreviations: JEL classification: O33, O55, Q12. .

Table 1. Definition of explanatory variables in the model of adoption and intensification of chemical fertilizers.

Description	Expected affects
Agricultural potential of the area (1=area of high agricultural potential, 0=otherwise)	+
Radio set ownership (1=yes, 0=no)	+
Age of head of household (years)	+/-
Non-farm income (FCFA)	+
Average years of education of workers (years)	+
Distance to a land-built road (km)	-
Number of household workers	+/-
Total amount of credit received (FCFA)	+
Member of a group of producers (1=at least one member in a group, 0=otherwise)	+
Quantity of organic manure (Number of carts)	-

Source: Construction of the author from the review of theoretical and empirical literature.

$$E[y^*]= X^{'}\beta + \sigma f(z)/F(z) \quad (3)$$

Where z represents $X^{'}\beta/\sigma$, $f(z)$ the normal density function, and $F(z)$ the distribution of the normal cumulative function. According to the method of McDonald and Moffit (1980), the effect of explanatory variables of Tobit model can be split into decision of adoption and intensification of the use of chemical fertilizers. The marginal effect of each explanatory variable X_i on the expected value of the dependent variable is defined by:

$$\frac{\partial E(y)}{\partial X_i} = F(z)(\delta E(y^*)/\delta X_i) + E(y^*)(\delta F(z)/\delta X_i)$$

The change of the adoption probability of chemical fertilizers due to the variation of an explanatory variable is measured by:

$$\frac{\delta F(z)}{\delta X_i} = \frac{f(z)}{\sigma}\beta_i$$

The change in the intensity of the use of chemical fertilizers due to the variation of an explanatory variable is measured by:

$$\frac{\delta E(y^*)}{\delta X_i} = \beta_i\left[1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right]$$

The parameters of the presented Tobit model can be estimated using the method of the maximum likelihood based on households' data.

VARIABLES FOR ANALYSIS AND METHOD OF DATA COLLECTION

In order to implement the Tobit model of adoption and intensification of the use of chemical fertilizers, appropriate variables have been considered and data have been collected on them through a survey of cereal producers.

Definitions of variables of the model

The producer's decision to adopt a technological innovation depends on complex factors. The most conventionally analyzed ones are the socio-economic and demographic characteristics of the producer, as well as the institutional and agro-ecological factors. The choice of the relevant variables for the present study is based on the theoretical and empirical literature related to technological adoption.

The dependent variable of the Tobit model is defined as the proportion of farmland devoted to cereal production using chemical fertilizers. The main cereals (sorghum, millet, maize, rice) produced in Burkina Faso have been taken into consideration in the analysis. The study focused on the usage of NPK and urea, which are the main chemical fertilizers used in cereals production in the country. The dependent variable is a continuous variable, but its value is between 0 and 1. Table 1 presents the independent variables and the expected signs of the associated parameters.

Source of the data used

The data for this study were collected by the Laboratoire d'Analyse Quantitative Appliquée au Développement–Sahel (LAQAD-S), in the context of collaborative research between the International Food Policy Research Institute (IFPRI), several African universities[4] and the University of Goettingen (Germany). The aim of the project («Convergence») was to conduct researches on maximizing the impact of social service expenditures on agricultural labor productivity and incomes in African countries.

The national scope of the study led to the subdivision of the whole rural area of Burkina Faso into 6 strata based on the quality of social characteristics (health, education, nutrition, access to drinking water) of the populations and the concentration of non-governmental organizations in the community. Thus, 8 of the 45 provinces of Burkina Faso were selected on the basis of their agricultural potential and the weighting given to each stratum.

In each province, 2 departments were selected randomly and in

4 University Ouaga II (Burkina Faso), Sakoine university of agriculture (Tanzania) et National university of Rwanda (Rwanda)

each department 4 or 5 villages were randomly selected depending on its size. In this way, the survey covered 36 villages and in each village, 15 farming households were selected randomly, totaling 540 households. The sampling focused on the spatial distribution of the surveyed villages, in order to take into account the differences in behavior and regional diversities.

The data was collected from farming households from January to February 2011. The survey was conducted using questionnaires on a declarative basis of farming households, generally on a recall period covering the last 12 months. The data contained information on the socio-economic, demographic, and institutional characteristics of the households. Detailed data were collected on the situation of health, education, social safety nets and agricultural production among rural households.

Factors determining the adoption and intensification of chemical fertilizers

This section presents the socio-economic, demographic and institutional factors affecting the decisions of adoption and intensification of the use of chemical fertilizers in cereal production.

Characterization of households according to the use of chemical fertilizers in cereal production

A description of the characteristics of households is presented in Table 2. It shows a general low level of the use of chemical fertilizers. On average, only 31.0% of cereal farmlands received chemical fertilizers; this rate reaches 72.5% if we consider only the producers who used chemical fertilizers in cereal production. Mean-comparison tests indicate a significant difference at the threshold of 5% of socio-economic, demographic, institutional, and agro-ecological characteristics between the producers who adopted and those who did not adopt chemical fertilizers (Table 2). Producers who use chemical fertilizers mostly are those living in areas with high agricultural potential, having at least one radio set, and having working members that have attended formal school. They also live near a land-built road, have the larger number of active members, receive more credit, and have at least, one member in an organization.

RESULTS

Estimation results of the Tobit model for adoption and intensification of the use of chemical fertilizers

The results of the econometric estimation of Tobit model of adoption and intensification of the use of chemical fertilizers are reported in Table 3. The likelihood ratio test indicates that the estimated model is globally significant at 1%. Individual significance tests indicate that the agricultural potential of the area of production, possession of at least one radio set, average number of years of formal education of the workers, proximity to a land-built road, and the amount of credit and membership in an association significantly influence the decision to adopt and intensify the use of chemical fertilizers at a threshold that is lower or equal to 5% and have the expected signs.

However, household's head's age, off-farm income, number of working household members and the amount of organic manure have no significant effects on the adoption and intensification of the use of chemical fertilizers. Apart from the effect of the number of working household members, the results are consistent with the descriptive analyzes that have been done through mean-comparison

tests of the socioeconomic, demographic, agro-ecological and institutional characteristics among the producers who adopted chemical fertilizers and non-adopters. The results of the econometric analyses indicate that the estimated Tobit model is well specified and the socio-economic, demographic, institutional, and agro-ecological factors that have been identified explained significantly the adoption and intensification of the use of chemical fertilizers.

Decomposition of the marginal effects of factors on the use of chemical fertilizers

The program of Cong (2000) was used for implementing the breakdown of the marginal effects of the explanatory variables both on the adoption probability and the intensification of the use of chemical fertilizers.

Table 4 presents the results from the breakdown of the marginal effects of Tobit model. The results indicate that carrying out agricultural activities in an area of high agricultural potential increases significantly at the threshold of 1%, the probability of adopting chemical fertilizers by 0.22. Specifically, this probability increases by about 0.24 for households that were not using chemical fertilizers yet. On the contrary, households that were already using the technology intensify its usage by an increase of 0.16.

Having a radio set increases significantly at the threshold of 1% the probability of adopting chemical fertilizers by about 0.15. This increase is mainly driven by the probability of the adoption of non-user households that increased by about 0.19, against an improvement of 0.12 related to the intensification of use of chemical fertilizers by households that already use it. The level of education has a very significant positive effect at the threshold of 1% concerning the probability of adoption of chemical fertilizers. Each additional year of education of a worker improves the probability of adoption of chemical fertilizers by 0.03. Non-user households contribute mostly with an increase in the probability of adoption by 0.04, against 0.02 related to the intensification of household using chemical fertilizers. These results are contrary to what was reported by Zhou et al. (2010) in Northern China, but support findings by Thuo et al. (2011) in Senegal.

Easy access to an earth-built road increases significantly at the threshold of 1% the probability of adoption of chemical fertilizers. If the distance from a producer to an earth-built road increases by one kilometer, the probability of adoption of fertilizer

Table 2. Characterization of households according to the use of chemical fertilizers in cereal production.

Description	Average	Chemical fertilizers non–users	Chemical fertilizers users	Difference
Proportion of cereal farmlands using chemical fertilizers (%)	31.0	0.0	72.5	-72.5***
Agricultural potential of the area (%)	25.0	13.6	40.3	-26.7***
Possession of a radio set (%)	64.6	56.3	75.8	-19.4***
Age of household head (years)	45.0	45.5	44.4	1.1
Non-farm income (FCFA)	14063	131526	152814	-21288
Average years of education of workers	0.80	0.69	0.95	-0.3**
Distance to a land-built road (km)	7.9	9.1	6.2	3.0***
Number of household workers	3.9	3.7	4.1	-0.5***
Total credit received (FCFA)	38202	15729	68263	-52534***
Belonging to a producers association (%)	46.5	36.6	59.7	-23.2***
Quantity of organic manure (carts)	8.6	8.2	9.0	-0.8

Source: Author's computation based on data of the project "Convergence" / Burkina Faso, 2011. *** Significant at 1%, ** Significant at 5%.

Table 3. Estimation results of the Tobit model for adoption and intensification of the use of chemical fertilizers.

Description	Coefficients	Standard errors	T-statistics
Constant	-0.5051	0.1535	-3.29
Agricultural potential of the area	0.4377***	0.0861	5.08
Possession of a radio set	0.3567***	0.0825	4.32
household head Age	-0.0019	0.0029	-0.68
Non-farm income	0.0000003	0.0000002	1.38
Average years of workers education	0.0736***	0.0263	2.80
Distance to an land-built road	-0.0125***	0.0038	-3.27
Number of household workers	0.0057	0.0186	0.31
Total credit received	0.0000006**	0.0000003	1.96
Belonging to a group of producers	0.2558***	0.0760	3.36
Amount of organic manure	0.0007	0.0025	0.28
Log likelihood		-430.9	
Pseudo R^2		0.1120	
LR test		108.7***	
Number of observations		540.0	
Proportion of users of chemical fertilizers		42.8%	

Source: Author's computation based on data of the project "Convergence" / Burkina Faso, 2011.*** Significant at 1%, ** Significant at 5%

decreases by about 0.006. This effect is greater on the probability of the adoption of non-user producers which decreases by 0.007 when distance to an earth-built road increase by one kilometer, compared to chemical fertilizers users which decreases by 0.004 when distance to an earth-built road increase by one kilometer. These results are consistent with those reported by Zhou et al. (2010) in Northern China, but contrary to findings by Martey et al. (2014) for smallholder farmers in Northern Ghana.

Access to credit has a significant positive effect at the threshold of 5% on the probability of the adoption of chemical fertilizers. An additional FCFA 10 000 credit increases the probability of adoption of chemical fertilizers by 0.003. This effect is mainly attributed to the probability of adoption by non-user households that increase by about 0.003, against an improvement of 0.002 associated with the increased use by households that were already using chemical fertilizers. These results are contrary to what Martey et al. (2014) found on smallholder farmers in Northern Ghana.

Membership to an association of producers improves significantly the probability of adoption of chemical fertilizers by approximately 0.12 at the threshold of 1%.

Table 4. Decomposition of the marginal effects of factors on the use of chemical fertilizers.

Description	Marginal effects	Effects on the probability of adoption	Effect on increasing the use
Agricultural potential of the area	0.2243***	0.2359***	0.1629***
Possession of a radio set	0.1517***	0.1899***	0.1160***
Age of head of household	-0.0009	-0.0011	-0.0007
Non-farm income	0.0000001	0.0000001	0.0000001
Average years of education of the workers	0.0333***	0.0400***	0.0249***
Distance to a land-built road	-0.0057***	-0.0068***	-0.0042***
Number of household workers	0.0026	0.0031	0.0019
Total credit received	0.0000003**	0.0000003**	0.0000002**
Belonging to a group of producers	0.1172***	0.1385***	0.0874***
Quantity of organic manure	0.0003	0.0004	0.0002

Source : Author's computation based on data of the project "Convergence" / Burkina Faso, 2011 *** Significant at 1% ** Significant at 5%.

Non-user households contribute mostly by increasing their adoption probabilities by 0.14 in comparison with the user households for whom the probability of intensification of chemical fertilizers increases by only 0.09. These results are consistent with those reported by Martey et al. (2014) for smallholder farmers in Northern Ghana (Table 4).

CONCLUSION AND POLICY IMPLICATIONS

A Tobit model was used to examine the decision of adoption and intensification of the use of chemical fertilizers in cereals production in Burkina Faso. The parameters of the model were estimated using the method of the maximum likelihood. The results show that the model is well specified and most of the estimated coefficients are significant and have the expected signs.

The results indicate that the decision to adopt and intensify the use of chemical fertilizers increase significantly with the following variables: agricultural potential of the area of production, possession of a radio set, level of formal education of the workers, closeness to an earth-built road, amount of credit received, and membership of a producer group. Splitting up of the marginal effects shows that the effect of the probability of adoption by the non-user producers is prominent than the effect due to the intensification of fertilizers by existing users.

These results allow us to draw several implications for agricultural policy to improve the productivity of cereals production. Policy makers should first focus on dissemination of information, training, and availability of chemical fertilizers. To this end producer groups and radio stations can be used for training and extensions on the use of chemical fertilizers. The second aspect to consider in terms of agricultural policy is about the promotion of support services to grain production. Research - development should be more oriented towards the production and dissemination of chemical fertilizers tailored to each area of agro- ecological production. These various changes should be accompanied by access of cereal producers to agricultural credits and the development of rural roads to facilitate access to inputs and the flow of cereals. These policies recommended for implementation should primarily target cereal farmers who do not as yet resort to chemical fertilizers usage.

Conflict of Interests

The authors have not declared any conflict of interests.

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Smallholder farmers' indigenous knowledge of maize storage pests and pesticidal plant use: The case of Wards 9 and 10 in Bikita District, Masvingo Province, Zimbabwe

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Farmers' indigenous knowledge of storage insect pests and management practices in stored grain protection against insect pests are critical for sustainable food security in the smallholder sector in Zimbabwe. A survey was conducted among 48 and 51 maize farmers in wards 9 and 10 Bikita district respectively, to evaluate their knowledge, attitudes and traditional maize storage management practices against storage insect pests. The selected farmers grew maize and a variety of vegetables for subsistence. Problem storage pests listed in order of prevalence were maize weevil (*Sitophilus zeamais*) 49%, lesser grain borer (*Rhizopertha dominica*) and maize weevil (*Sitophilus zeamais*) complex 25.5%, lesser grain borer (*Rhizopertha dominica*) 17.7% and larger grain borer (*Prostephanus truncatus)* 7.3%. The commonly used botanical pesticides in the two wards were gumtree (*Eucalyptus* spp) (24.6%), tamboti (*Spirostachys africana*) (7.2%), lilac tree (*Melia azedarach)* (4.1%), sunflower (*Helianthus annuus)* ash (5.1%), cow dung (3.1%), lemon bush (*Lippia javanica)* (2%), murwiti (*Rapanea melanophloeos*) (1%), sweet basil (*Ocimum basilicum*) (1%) and finger millet (*Eleucine coracana*) chuff (1%),wood ash (4.1%) and mixtures of the above mentioned botanicals (4.5%). The botanicals are mixed with maize grain before storage either in sealed hessian bags or as loose grain placed in the granary plastered with cow dung. The use of botanicals was more prevalent in Ward 10 (100%) than ward 9 (14.7%). Farmers resort to the use of cheap and locally available botanicals when there is no money to buy synthetic insecticides. There is an urgent need for laboratory evaluation of the efficacy, chemical composition and mode of action in order to come up with dosage guidelines of these ethnobotanicals for the resource poor smallholder farmers.

Key words: Indigenous knowledge, ethnoecological knowledge, ethnobotanicals, *Sitophilus zeamais, Rhizopertha dominica, Prostephanus truncatus,* synthetic insecticides, smallholder farmers.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important grains in the world and it is commonly stored to provide food reserves and also seed materials for planting (Boxal, 2002). Maize is not only important for human consumption, but also for animal feed as well as material for the manufacture of various industrial products. In Zimbabwe, maize is the main staple food crop. Maize is mainly grown in Zimbabwe under different weather conditions in almost all the agro-ecological zones. In Zimbabwe, communal, A1, A2 and commercial farmers usually plant maize during summer time usually from October to January when there is an adequate amount of precipitation. In a normal year harvesting is done around April/May and will be stored until the next harvest.

Despite high maize production, large amounts of maize stored is lost to storage pest attack after harvesting especially among smallholders farmers (Muzemu et al., 2013). This leads to loss of both maize grain quality and quantity and may also reduce future maize production for those who retain grain as seed (lloba and Ekrakene, 2006). Maize storage insect pests cause serious damage on maize if it is not protected and this affects food security in particular and the economy in general (FAO, 1991). This often affects smallholder farmers or people in rural areas who cannot afford to buy synthetic pesticides to protect their stored maize from insect pest attack as pesticides are expensive (Muzemu et al., 2013). Industrial pesticides are not only expensive for the resource poor communal farmer but also pose health hazards to both producers and consumers and the ecosystem where the pests develop resistance to the chemicals (Dent, 2000).

In Zimbabwe, communal farmers face problems in protecting their harvested grain crops from insect pest attack during storage. Alarming storage grain loses of up to 50% in cereals have been reported although the average loses stand at around 20% in the warm climate of tropical Africa (Nukenine, 2010; Derera et al., 2001; Dhliwayo and Pixley, 2003). Grain storage is a way or process by which grain is kept for future use. Food grain needs to be stored from one harvest to the next in order to maintain its constant supply throughout the year and to preserve its quality and quantity until required for consumption. For communal farmers in Zimbabwe, the main purpose of storage is to ensure household food supplies and seed for the next planting. Maize is the staple food for Zimbabwe and its production is seasonal hence the need to store supplies to last the whole year. In Zimbabwe, the maize storage grain insect pest complex is dominated by maize weevil *Sitophilus zeamais* (Motschulsky) and larger grain borer *Prostephanus truncatus* (Horn) (Dhliwayo and Prixley, 2003; Mvumi et al., 2003).

The storage grain insect pest management strategies of these resource poor communal farmers is characterised by a diversity of practices where farmers manipulate and derive advantages from local resources and natural processes. These indigenous knowledge systems or technologies are important and are being used in modern day agriculture by the farming communities from which they emanate from (Mapara and Mazuru, 2015). Indigenous Knowledge is defined by Chapungu and Sibanda (2015) as that knowledge accumulated over generations of living in a particular environment or locality and has been vital in responding to environmental challenges, including floods, diseases and pest infestations and their attendant effects. Indigenous knowledge is local knowledge which is unique to a given culture or society (Warren, 1991), and it contrasts with international knowledge system generated by universities, research institutions and private firms (Chapungu and Sibanda, 2015). According to UNESCO, indigenous knowledge is passed from generation to generation, usually by word of mouth and cultural rituals, and has been the basis for agriculture, food preparation, health care, education, conservation and the wide range of other activities that sustain societies in many parts of the world.

Indigenous knowledge systems is also known by various terms which include traditional knowledge, ethno science, cultural experiences and ethno-based knowledge systems (Dirwai, 2007). According to Dhlamini et al. (2015), indigenous knowledge has various merits which include the fact that it is a cost effective and sustainable mechanism for poverty alleviation and is locally manageable, locally meaningful, ecologically sound and socially acceptable. In addition they argue that indigenous knowledge is easy to acquire as it relies on locally available skills and material that are often more cost effective than introducing exotic technologies since what is needed for immediate survival is taken from the immediate environment.

Many researchers have reported that farming communities possess low cost traditional knowledge systems of controlling grain storage insect pests which include the use of traditional botanical pesticides or ethno botanicals (Dales, 1996; Ogendo, 2000; Chikukura et al., 2011; Nukenine, 2010; Sola et al., 2014). Knowledge of ethno botanicals as grain protectants is likely to be accompanied by an equal informed knowledge of how storage pests can be controlled in a sustainable manner for food and nutritional security as an alternative to the use of synthetic insecticides which are expensive to the poor farmers and not ecofriendly. The strength of farmers' knowledge is that it is the product of frequent observation of grain and insect grain pests during several storage seasons.

Naturally, botanical insecticides are believed to possess

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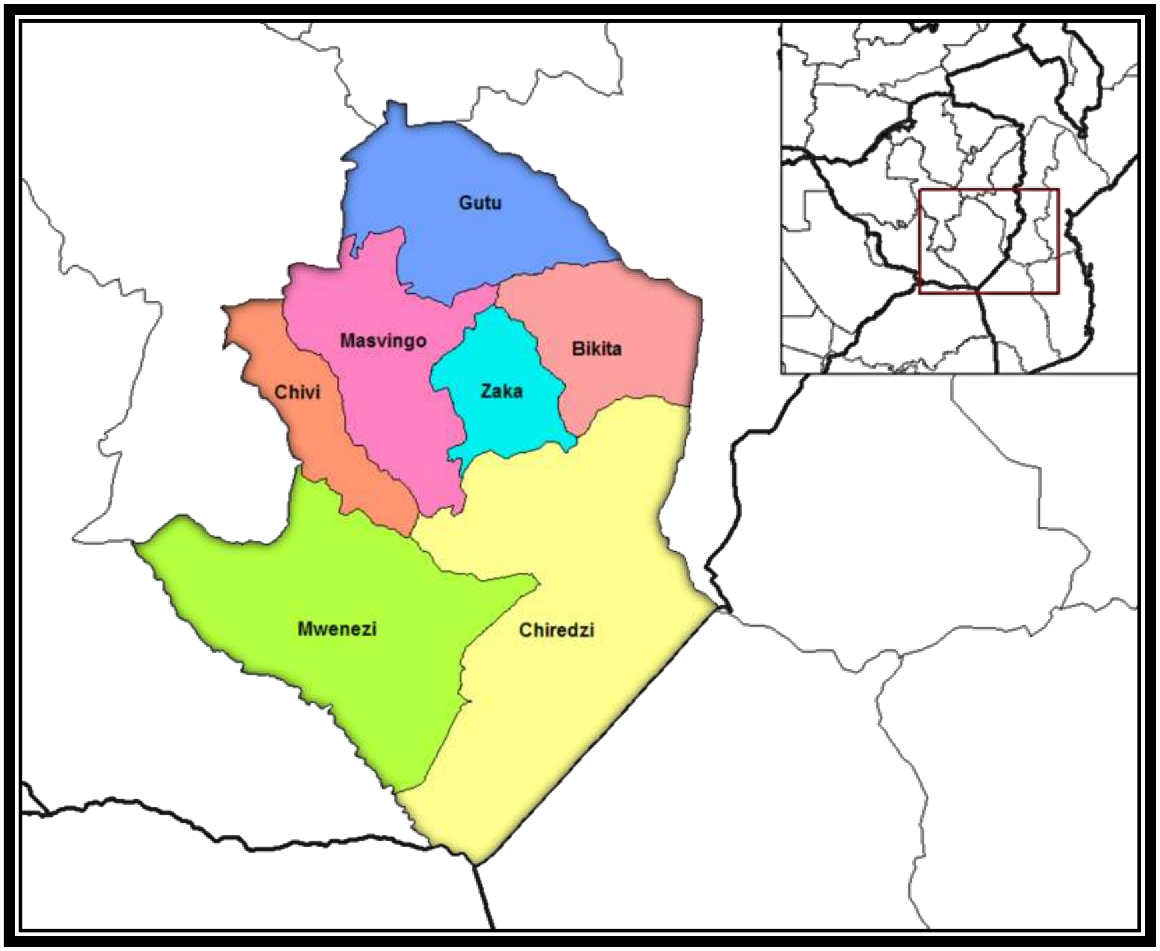

Figure 1. Location of Bikita district in Masvingo Province, Zimbabwe. (Source: Google map).

certain attributes which put them at a higher advantage over conventional insecticides. These include low mammalian toxicity, less persistence in the environment, selectivity towards target pests and nonphytotoxicity (Isman, 2006). These have led to the belief that plant derived insecticides are safer than synthetic products. The documentation and validation of this knowledge is especially useful for various reasons which include to set research agenda, for developing extension messages, planning, and campaign strategies and form the basis for constructive collaboration between researchers and farmers in Masvingo province. Therefore, the objectives of this survey were to:

i) Identify problem maize storage insect pests in two wards in Bikita District for resource poor smallholder farmers.
ii) Identify the various indigenous methods of maize storage insect pest control in Bikita District including use of pesticidal plants by resource poor smallholder farmers.
iii) Identify common post harvest grain storage structures in Bikita District.

MATERIALS AND METHODS

Study areas

The study was conducted in two maize growing wards of Bikita District, namely Ward 9, Mapfuwa village and Ward 10, Bhunu village. These two wards lie largely in natural region III where climatic conditions allow for maize production. Bikita is a district in the Masvingo Province of Zimbabwe (Figure 1). It is located about 80 km east of Masvingo town and its name is probably derived from the Shona word *Dikita* which means *antbear*, which describes the shape of a nearby hill. The district used to be known as Denga which means *up in the clouds.* It is a mountainous region characterized by very steep slopes with sandy-loamy soils. It is the third driest district after Chivi and Chiredzi in Masvingo province. It covers an area of approximately 10,000 km², and has a population of around 200,000 people (Mushore et al., 2013). About 81% of the district is classified as belonging to the natural regions (IV and V) with mean annual rainfall ranging from 400 to 700 mm. Agriculture is the major livelihood activity in the area with maize being the dominant crop grown (Mushore 2013).

Data collection and analysis

Data was collected using a household survey conducted in August

Table 1. Percentage of respondents according to sex, age, education, source of income and maize farming experience in ward 9 and 10 of Bikita district.

Variable	Category	Ward 9 (n= 48)	Ward 10 (n= 51)
Gender	Female	70.8	58.5
	Male	29.2	41.5
	Young (<30 years)	16.7	7.5
Age	Middle (30-50 years)	29.2	43.4
	Old (> 50 years)	54.1	49.1
	None	4.1	0
Education	Primary (Up to Grade 7)	54.2	56.6
	Secondary (Up to Form 4)	37.5	43.4
	Tertiary (College)	4.2	0
	Farming only	39.6	
	Farming + Remittances	22.9	
	Farming + Formal employment	4.2	94.3
Income	Farming + Pension	4.2	5.7
	Farming + Piecework	16.7	
	Farming + Beer brewing	6.2	
	Farming + Vending	6.2	
Maize farming experience	Short (< 10 years)	8.3	60.4
	Long (> 10 years)	91.7	39.6

and September 2015. Semi-structured questionnaires were employed in interviews of randomly selected farmers. A total of 48 and 51 farmers were interviewed in wards 9 and 10 respectively. The respondents were selected with the help of village leaders and Agricultural Technical and Extension (AGRITEX) officers on the grounds that they grow maize among other crops. The questionnaire was designed in English and translated into Shona, which is understood by all the farmers and pretested using small samples of farmers in the same areas before using it in this study.

The data collected included the biodata such as sex, age, district, village, ward, educational background, major source(s) of income from the farm and other sources, crops grown and production per season, duration in farming, maize storage pests, maize storage structures, synthetic maize storage pesticides used and source, ethno-botanical maize storage pesticides used and source and ethno-botanical formulations. Data were recorded between August and September 2015 by the area AGRITEX officers. Statements made on open ended questions that were not coded were also used to substantiate the numerical data.

RESULTS

Characteristics of respondents

The majority of the respondents (64.7%) were females older than thirty years in both wards and had undergone formal education, primary 55.4%, secondary 40.5%, college 2% and only 2% never went to school (Table 1). The major source of household income in both wards was farming supplemented in some households by remittances, vending, pensions, piece work, beer brewing and even formal employment (Table 1). The major crops grown in fields and home gardens in both wards are maize, rapoko, beans, cowpeas and a variety of vegetables. Most farmers (65.7%) were experienced farmers with more than ten years of growing maize (Table 1).

Major grain storage pests

The major maize storage pests were maize weevils (*S. zeamais*) 52.1% reported in ward 9 and 46% in ward 10, lesser grain borer (*R. dominica*), 33.3% in ward 9 and 4% in ward 10, larger grain borer (*P. truncatus*), 14.6% in ward 9 and non reported in ward 10 (Table 2).

Maize storage structures

Only 10% of farmers in ward 9 store their grain in specialized grain storage structures or granaries. Most farmers (90%) in ward 9 and all farmers in ward 10 store their grain in living quarters in sealed 50 or 90 kg hessian bags (Table 3). The living quarters are either made of wooden poles with dagger or brick walls with either thatch

Table 2. Percentage of respondents who reported storage insect pests and common ethnobotanicals used.

Variable	Category	Ward 9 (n= 48)	Ward 10 (n= 51)
Storage insect pest	Maize weevil only	52.1	47
	Maize weevil + Lesser GB	0	51
	Larger grain borer only	14.6	0
	Lesser grain borer only	33.3	2
Ethnobotanicals used	Tamboti (Mutovhoti)	0	14.3
	Lilac tree (Musiringa)	0	8.2
	Lemon bush (Zumbani)	2.1	2
	Cape beech (Murwiti)	0	2
	Gum tree (Mugamu)	6.3	42.9
	Sunflower (Maringazuva)	0	10.2
	Sweet basil (Manhuwe)	0	2
	Ash (Madota)	2.1	6.1
	Dung (Ndove)	2.1	4.1
	Finger millet chuff	0	2
	Tamboti + Sunflower	0	2
	Dung + woodash	0	2
	Gumtree + sunflower ash	0	2
	Gumtree + Lemon bush	2.1	0
	None of the above	85.3	0

Table 3. Percentage storage facilities used by smallholder farmers for maize grain storage.

Storage facility	Ward 9 (N=48)	Ward 10 (N=51)
Ordinary room - bag storage	87.5	84.9
Granaries - pole and plastered with anthill soil; some not plastered	10.5	15.1
Granaries- brick and plastered with mortar	0	0
Bin/drum	2	0
Hermetic bags	0	0
Other	0	0
Total	100	100

Source: This study

grass, iron sheets or asbestos as roofing material.

Crop production patterns

Maize, field beans, cow peas, rapoko, groundnuts, roundnuts, sunflowers and a variety of vegetables were the most commonly grown crops. In ward 9, maize and vegetables were grown by all respondents (100%), cowpeas 60%, rapoko (25%) and field beans 16.7%. In ward 10 the scenario was similar to ward 9 for maize and vegetables. Unlike ward 9, farmers in ward 10 grew groundnuts (17%), mbambara roundnuts (17%) and sunflowers (1.9%). Cereal and legume crops are grown in arable fields while vegetables which include covo, rape, cabbage, tomatoes, onions and curcurbits are grown in home gardens. The cereal and legume crops are grown under rain fed conditions in summer while vegetables are grown all year round where irrigation water is available.

Farmers' knowledge of maize storage pests and control practices

All the respondents in both wards experienced post-harvest grain damage by storage insect pests. According to the survey, the major maize grain storage insect pests are the maize weevil (*S. zeamais*), lesser grain borer (*R. dominica*) and larger grain borer (*P. truncatus*) (Table 2).

In ward 9, 52.1% of the farmers experienced grain

Table 4. Insecticidal dusts currently available in Zimbabwe for admixture to grain.

Trade name	Active ingredient (% are weight for weight)
Hurudza Grain	fenitrothion 1.7% + deltamethrin 0.05%
Shumba Super	fenitrothion 1.0% + deltamethrin 0.13%
Actellic Super Chirindamatura	pirimiphos-methyl 1.6% + permethrin 0.3%
Chikwapuro	pirimiphos-methyl 2.5% + deltamethrin 0.1%
Ngwena Yedura	pirimiphos-methyl 2.5% + deltamethrin 0.2%
Actellic Super Gold Dust	pirimiphos-methyl 1.6% + thiamethoxam 3.6%
Nhovo	malathion 1% dust

Source: This study.

Table 5. Pesticidal plants commonly used in Bikita and how they are used to control maize grain insect pests.

Common name	Vernacular name	Botanical name	How it is used
Sweet basil	Manhuwe	*Ocimum basilicum*	Mix leaves and branches with grain in bag
Lilac tree	Musiringa	*Melia azedarach*	Mix leaves and small branches mixed with grain in bags
Tamboti	Mutovhoti	*Spirostachys africana*	Stem and branches cut into small pieces and place at the bottom, middle and top of the grain in storage bag and seal
Cape beech	Murwiti	*Rapanea melanophloeos*	Mix leaves with branches with grain in the bag
Gum tree	Mugamu	*Eucalyptus* spp	Mix squeezed fresh leaves with grain in the bag
Sunflower	Maringazuva	*Helianthus annuus*	Burn sunflower stem and collect ash and mix it with grain in bag
Finger millet chuff	Hundi yerukweza	*Eleucine coracana*	Mix chuff with grain in bag
Cow dung	Ndove		Plaster granary floor and walls with cow dung and store grain in bags or unbagged/loose grain
Wood ash	Madota		
Lemon bush	Zumbani	*Lippia javanica*	Mix small branches with leaves with grain in sealed bags

Source: This study.

damage due to maize weevil (*S. zeamais*) and 33.3% of the farmers reported damage and loss due to lesser grain borer (*R. dominica*) and 14.6% damage by larger grain borer (*P. truncatus*) were recorded. On the other hand, in ward 10, the incidence of maize weevil only was 47%, with 51% cases of damage by a pest complex of lesser grain borer (*R. dominica*) plus maize weevil (*S. zeamais*) and only 2% damage and loss due to lesser grain borer (*R. dominica*) only. No reports of larger grain borer (*P. truncatus*) were reported in ward 10. The farmers reported that the pests affect maize grain both qualitatively and quantitatively. The market price of the grain is also greatly reduced after attack by insect pests. The insect pests damage the grain by boring holes and producing frass and flour dust. The storage pests attack the grain soon after harvest and throughout the storage period in winter, spring and summer.

All respondents in both wards reported the use of synthetic pesticides to protect their grain in storage. However the pesticides are only used when the cash to buy them is available. The use of synthetic pesticides alone was more prevalent in Ward 9 than ward 10 where both synthetic pesticides and botanical pesticides were used. The commonly used synthetic pesticides are Actellic Super Gold Dust, Actellic Super Chirindamatura, Shumba Super, Hurudza Grain, Chikwapuro, Ngwena Yedura and Nhovo (Table 4). When the cash to buy effective synthetic pesticides is not available, as is always the case in rural areas, the farmers have reported that they resort to using ethno-botanicals and other locally available options like cow dung and wood ash.

All the respondents in ward 10 have at one time or the other used botanicals to protect their stored grain, whilst only 14.7% of the farmers in ward 9 have used botanicals in grain protection. The respondents reported seven different pesticidal plants and three other plant based products. The commonly used pesticidal plants were tamboti (S. africana), Lilac tree (M. azadarach), Lemon bush (L. javanica), Cape beech (R. melanophloeos), gumtree (Eucalyptus spp), sunflower (H. annuus) and

sweet basil (O. basilicum). The local names of the pesticidal plants are given in Table 5. Other traditional plant based grain protection options mentioned were wood ash, cow dung and finger millet (E. coracana) chuff (Table 5).

Amongst the pesticidal plant options for maize grain protection in storage, the gum tree (*Eucalyptus* spp) leaves are the most popular with 42.9% of farmers having used them in ward 10 and 6.3% in ward 9. The least popular option for maize grain protection is finger millet chuff in ward 10 with only 1.9% whilst Lilac tree (*M. azadarach*), sweet basil (*O. basilicum*) and finger millet (*E. coracana*) chuff were not reported in ward 9.

For botanicals, plant parts such as leaves, branches and stems are mixed with grain in sealed bags (Table 5). As for sunflower (*H. annuus*)) the farmers reported that they burn the stems and the resultant ash is mixed with grain and then bagged and sealed. With finger millet ((*E. coracana*)) the farmers roast and pound finger millet grain to remove chuff. The chuff is then mixed with grain before bagging and sealing. Cow dung is used to plaster the interior walls of granaries and the grain is either stored as loose grain or bagged. No specific dosages (quantity per unit mass of grain?) were given by the respondents for the various options.

DISCUSSION

According to the farmers, the major maize storage pests in Bikita are maize weevil (*S. zeamais*), lesser grain borer (*R. dominica*) and larger grain borer (*P. truncatus*). This is consistent with literature from other parts of Zimbabwe (Dhliwayo and Prixley 2003; Mvumi et al., 2003) and southern Africa (Kamanula et al., 2011). *S. zeamais* has been reported to be a common maize storage pest since time immemorial (Derera, et al*.,* 2001) and *P. truncatus* is relatively new in Zimbabwe having been reported in several parts of Zimbabwe mostly during the 2006/2007 season (Nyagwaya, 2009). In this study, the number of farmers who reported the presence of *P. truncatus* was the lowest which seems to suggest that it is still becoming established as a newly introduced pest. The LGB is a serious pest of farm stored maize and dried cassava and can cause up to 40% loss in maize and up to 80% in dried cassava over a period of six months in storage (Golob, 1988). The recent introduction and spread of *P. truncatus* into Zimbabwe has increased maize grain storage problems both on the cob and loose grains.

The study has revealed that there are various traditional methods of controlling maize storage pests. Various researchers have reported the efficacy of a number of pesticidal plants (botanicals) against maize storage pests (Muzemu et al., 2013; Mandudzi and Edziwa, 2016; Chikukura et al., 2011; Kamanula, 2011; Masundire, 2015). Botanicals are toxins and/ or deterrents that are derived or extracted from plants or plant parts. Many botanical insecticides have been known and used since time immemorial but were displaced from the marketplace by synthetic insecticides in the 1950s. This study revealed the use of mainly fresh leaves and stems as fumigants of various botanical pesticides including mutovhoti (*S. africana*), musiringa (*M. azedarach*), zumbani (*L. javanica*), murwiti (*R. melanophloeos*), gumtree (*Eucalyptus spp*), sunflower (*H. annuus*) and sweet basil (*Ocimum basilicum*). The farmers reported that they mix the maize grain with fresh leaves and branches in sealed hessian bags. However, research has shown that the powders and oil extracts are more effective as grain protectants for some of the botanicals. For example, Masundire et al (2015) recommended that *E. grandis* can be used as a natural pesticide in maize storage when it is air dried and ground into powder and admixed with grain at 5 g/kg as a single application at the beginning of the storage season. As a powder, *E. grandis* protection can be guaranteed for at least six months (Masundire et al., 2015). Mandudzi and Edziwa (2016) recommended that *E. tereticornis* leaf powder be used as a pesticide against *S. zeamais* in stored grain and that regular application of the powder was necessary as the efficacy of the powder gets low with time. Various other researchers have also recommended the use of air dried powdered plant parts as superior grain protectants as compared to fresh leaves and other plant parts (Fekadu et al., 2012; Parwada et al., 2012; Islam and Talukder, 2005). Parwada et al*.* (2012) suggest that the powders act by dehydrating and suffocating the weevils and also by restricting weevil movement.

Wood ash has been used since time immemorial as a botanical pesticide against maize storage insect pests. Various researchers have demonstrated that wood ash if mixed with grain in sufficient quantities of 20% or more w/w can effectively protect grain against insect attack (Golob, et al., 1982; Gemu et al*.,* 2013; Archiano et al., 1999; Gadzirayi et al*.,* 2006). In Zimbabwe other sources of ashes are from maize cores, mopane tree, *Colophospermum mopane,* cattle and goat droppings and from the lead wood, *Combretum imberbe*. The ash is either mixed thoroughly with the grain or added to the stored product in various layers. The ash dust is believed to act by inhibiting insect behavior, affecting movement and reproduction by blocking air and space between grains (Gemu et al., 2013) suggesting the need for higher doses in order to submerge the grain. In addition, the abrasive nature of the ashes may desiccate the pests. The use of wood ash, however is only viable for small holder farmers particularly for the preservation of small quantities of seed grains, because of excessive quantities of dust required.

Sweet basil, *O. basilicum* has been reported by Grainge and Ahmed, 1988 as having leaves and seeds rich in pesticidal oils which are repellent, toxic or growth inhibitory to many insect pests.

The insecticidal compounds in wild *Oceium spp* have been identified as eugenol (Chogo and Crank, 1981) and linalool, a terpenoid (Weaver et al., 1991).

L. javanica has been reported to have medicinal (Viljoen et al*.,* 2005), acaricidal (Madzimure et al., 2011) and insecticidal (Chikukura et al., 2011) properties. Medicinally it is taken as a tea to relieve headache, flu and cold. It is used to kill ticks in livestock and as an insecticide against grain storage pests. The insecticidal chemicals are oils such as perillyl alcohol, cis-verbenol, ciscarveol, geraniol, citronellal, perillaldehyde and caryophyllene oxide. Oils are thought to affect target pests in various ways including suffocation due to blocked spiracles, preventing gas exchange in egg membranes, and the fatty acids in oils may disrupt cell membranes thereby disrupting normal metabolism (Buss and Park-Brown, 2009).

S. Africana is traditionally a medicinal pain killer for toothache and is reported not to be very effective as a storage pesticide (Chikukura et al., 2011). Dirwai (2007) has documented its cultural role in conserving flora and fauna in the environment in Zimbabwe. The use of finger millet chaff as a grain protectant however is not well documented.

However respondents reported the use of synthetic chemical pesticides is still the preferred option when funds permit. This observation is in agreement with various literature (Mvumi and Stathers, 2003; Chikukura et al*,* 2011). While synthetic pesticides have been credited for their efficacy as compared to botanicals, they are increasingly receiving negative publicity due to high cost, health and environmental risks (Kamanula et al., 2011). The indiscriminate use of chemical pesticides to protect grain could lead to the increase in the risk of contamination of the home environment, pesticide residues in meals thereby increasing health risks to consumers. This highlights the importance of identifying and promoting safer and low cost locally available alternatives to the synthetic products such as pesticidal plants.

Kamanula, et al*.* (2011), argues that although effectiveness of botanicals may be unfavourable as compared to synthetic pesticides, even moderate efficacy is of great importance to resource poor farmers since alternative to their use may be crop loss and food shortage.

Conclusion

The study provides valuable firsthand information on the maize storage grain insect pest complex and the commonly used pesticides, both synthetic and botanical in Bikita district. Problem maize storage insect pests in Bikita are *S. zeamais*, *R. dominica* and *P. truncatus* which are generally the same pests common in many parts of Zimbabwe. Synthetic pesticides are expensive for most resource poor farmers and are associated with health risks for the farmer as opposed to botanicals which are safer, cheaper and locally available. In addition, the botanicals have medicinal and ritual properties for example lemon bush (*L. javanica*) in Zimbabwe. The efficacy of the botanicals can be greatly improved if farmers in Bikita use powders of plant parts rather than fresh plant parts since research has revealed that powders are more efficacious than whole parts. Also regular applications of the powders may be necessary as the efficacy of most botanical powders diminishes with time. However there is still a lot of research to be done both in the laboratory and on farm to evaluate formulations, dosages, active biomolecules, modes of action and frequency of application for the identified ethnobotanicals. Also efforts to find simple agronomic ways of propagating, growing and even conserving some of these botanical plants should be promoted.

Credible or novel scientific information about the botanicals has the potential to empower farmers in Bikita and in deed in Zimbabwe to influence decision making in sustainable grain protection and food and nutritional security. Embracing traditional approaches in grain protection is a strategic mechanism in supporting sustainable development as enshrined in the UN sustainable development goals 2030.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Analysis of creating value in aquaculture enterprises through economic social and environmental indicators

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Environmental issues play an important role as regard the direction of the economy and public policy. Even though fragmented scientific knowledge does not interact in dialogue and appropriate continuous flow to sustain economic development, it is placed to ensure the need to seek knowledge capable of capturing the multi-causalities and interdependence in the natural order of processes (production) and social (environmental) which determine and delineate technical, economic indicators (competitiveness). This study analyzed the environmental and technical indicators and their degree of influence on the competitive advantage of forming the value chain of aquaculture enterprises in Capitólio/ MG, Brazil. Two economic streams on business strategies guided the study evidence to a competitive advantage. The first was positioning as a performance attribute inside and outside of organizations and the second recognized the collective capabilities as components of a dynamic value chain inter-related to inclusion and recognition of these components by the market. The methods used in this research included the analysis of biophysical, political, cultural and economic dimensions, with a multidisciplinary view of the indicators in the value chain in order to determine how they can generate competitiveness. This approach used the analysis of strengths and weaknesses as an essential step in defining the interventions needed in the value chain. These interventions are defined according to the potential of creating competitive advantage in the production cycle as cost control drivers and or product differentiation drivers in the market. The results showed that strengths and weaknesses were directly related to productive activities such as the amount of administered food, stress diminishing and fish mortality, in addition to nutritional deficiencies that impair the final quality of the fish. These results express the possibility of using market share opportunities through the recognition and improvement of analyzed and defined indicators.

Key words: Value chain, core competencies, competitive, competitive intelligence, strategic planning.

INTRODUCTION

Aquaculture is the fastest growing sector in the world food economy, around 11% per year. During the last decades, this record growth signaled a fundamental change in the diet of people globally (FAO, 2012). The

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use of programs of Practice Management and Monitoring (BPGM) or Good Aquaculture Practices (GAP) in the world, has guaranteed fish farmers to a set of requirements, adjustments and traceable procedures that can be applied to production and accepted as an indicator of environmental performance. GAP in cages should note factors such as sediment, fish removal, product quality, feeding and water resources among others (BNDES Profarma, 2010). In Brazil, the fishing activity regarding economic aggregates and organizational development strategies presents difficulties of socialization of the information sector. The lack of an effective development policy limits the possibilities of technical-economic and environmental analyses of competitiveness and industrial productivity (FAERJ/REDETEC, 2010).

In the global fish market, organizational competitive advantages are evident in corporate strategies of positioning and product differentiation. These strategies emphasize a strong and recognized brand for investments in technological development and innovation, resulting in better quality products that enable greater measurement productivity gains (BNDES, 2008). The spread of these strategies is in pricing, where usually the productivity and cost are reduced with new technologies, are not passed on to the consumer by reducing prices. Examples of application of these strategic differences cod producing Port and Norway, as well as other producers in Chile and China (BNDES, 2008). Norway, a leading global producer of farmed fish, has a market with good infrastructure for storage and transportation of production, high level of scientific research to assure quality, management and the appropriate and necessary administration for the development of the activity.

In the Brazilian industry, they understand the natural habits (environment, beliefs, culture) and the technologies applied to production and are not restricted to the productive dimension, rather inter-relate to the need for technological restructuring, information, training and knowledge, which include socio-cultural changes related to the cultivation, management and also to the way of life of producers (Costa-pierce, 2007). Rodrigues et al. (2013), explained that efficiency of environmental management programs depends on the encompass of the indicators, multiple representative scales in production, knowledge, training, and technology in an interrelationship between the enterprise and the community.

In this regard, following the global market drivers, it is appropriate to find evidence in the analysis of recognition and systematization of indicators for competitiveness. This demonstrates opportunity and differential competitive advantage in training, giving knowledge for environmental management, administration exploring and analyzing how to carry out the cultivation and management activities during the production cycle (identification and compliance with good aquaculture practices). The objective of this study was to analyse the environmental and technical indicators and their degree of influence on the competitive advantage of forming the value chain of aquaculture enterprises in Capitólio/ MG, Brazil.

MATERIALS AND METHODS

The knowledge identification methodology and training of stakeholders involved in the aquaculture value chain was a systematized primary data collected by APOIA / Aquaculture System (Rodrigues et al., 2006) from August 2012. The APOIA / Aquaculture were chosen because it is considered as a milestone in the systemic evaluation of sustainability on the farm and the environment (FAO, 2010). Its dimensions and basic criteria of impact and weaknesses of production reflect a diagnosis, considering a suitable production for GAP or Production Management which is aimed at recognizing the competitive advantage.

The samples analyzed were obtained by interviewing 26 fishermen involved with the activities of the production cycle in net-cages, during training and technical improvements meetings. They were on the shores of Furnas Reservoir, in the middle course of the Rio Grande, covering the municipalities of Guapé, Capitólio, and Pimenta located at Capitólio city, Minas Gerais State.

The competitive advantage of the intervention point of view in the development of indicators and stakeholders in training, management knowledge, and administration were investigated under a set of applied questionnaire variables with stakeholders on specific technical meetings. The primary data used in the construction of the questionnaire (systematized by APOIA / Aquaculture system) was gotten from the following variables: frequency and feeding schedule, amount of feed and consumed feed, sediment quality, planning, production cycle control and used medication, final product control and record, population density tanks, water quality, procedure discarding dead fish, size measurement and weight adjustment type of food, source of fingerlings, health and mortality knowledge, thickening tanks network, and sources of pollution.

The method quantifies the competitive advantage of the indicators attributes in disarray through a technical knowledge to improve the aquaculture activity by seizing the opportunities of the market share. The analysis was carried out by knowledge type into competitive advantage by generating environmental management and knowledge in specific management and administration procedure and also by recognizing what the producer needs to increase the quantity and quality of his product.

In evaluating how and with whom the producers seek guidance for production and commercial problem solving, the responses indicate the existence or nonexistence of continuity and the dialog flow in the value chain between the different agents involved. To recognize the strengths and weaknesses of the SWOT analysis, the indicators expressing relations value chain inter-relationship should be systematized, alongside the degree of influence on the activity and type of expertise, environmental management, and administration.

Thus, with the SWOT analysis results adapted in line with the expectations of stakeholders for production in GAP, the competitive evaluation oriented positioning of companies was organized. This organization of information and integrated data (external and internal elements) allows the organization resulting in a diagnosis of customized information and support that tailored to the needs of knowledge and skills in strategic management and administration for the development of aquaculture.

Table 1. Skills for competitive advantage by the stakeholders*.

Associate and independent producers	Technical support, research rural extension	Public and community manager	Input and equipment suppliers
Management and technical development for productivity and competitiveness	Symmetrical dialogue flow in production costs and quality applied to the production cycle.	Improvement in governance network for public policy. Regulatory and legal compliance and water resources.	Symmetrical dialogue flow in efficient production, consumption and handling of feed and other aspects.

Developed by the author with data analyzes and on-site observation of production.*Prahalad (2009, 2010), Hamel and Prahalad (1993) and Teece (1997), source of competitive advantage for interaction between skills and market opportunities.

RESULTS AND DISCUSSION

The responses of those surveyed and analyzed stakeholders indicated that the institutional environment reacted positively with the introduction of management tools in the properties, and were considered strong inducers to change, either in costs or differential in the product. There was also a consensus that strategies to enter and remain in the markets demand productivity differentials, especially in quality and practices to reduce the final cost of the product. It was also identified that the flow of dialogue between stakeholders was not continuous, indicating the possibility of intervention and improvement. Priori producers share their questions, and their technical and marketing solutions among themselves. This is seen as a strong point for improvements, acceptance of knowledge and training in improved production, and dialogue flow between value chain actors. Two streams of business theories and strategies are in line with the results achieved in the search for a competitive advantage. The first positioning strategy with competitive advantage is an interior performance attribute outside of the organization. This is with the determination that the behavior of agents in the industrial structure is the main cause of failure or competitive organizational success (Porter, 1985).

Complementarily, Prahalad (2009, 2010), Hamel and Prahalad (1993) and Teece et al. (1997) opine that dynamic capabilities are a source of competitive advantage for interaction between skills and market opportunities (routine organizational processes). Table 1 summarizes the challenges and constraints to improve the competitive advantage in the value chain by stakeholders and positively aiming theories explored in producing farms tilapia in cages.The information system development process for knowledge and training in environmental management and administration covered: management, scientific and technological content in continuous dialogue. The flow of stakeholders was involved and presented as challenges that must move towards the recognition of human intelligence and technology in collective synergy. In general, the organizations in their strategic planning have difficulty in collecting and storing information for decision-making, and to process them to become useful in the process (Porter, 1991, 1996; Davenport, 2000; Santos, 2000) (holism view the information environment).

The analyses indicate that there is a natural connection between information management and strategic organizational management, which remains undeveloped as an integration tool in the management of the organization. Table 2 shows inducers strengths, drivers of cost control, and differentiating the product and its correlation influence on the supply chain which allows the identification of the relative production unit in need of intervention. The analysis and definition of the strengths and weaknesses in the production process helped in identifying potential indicators of competitive advantage that can be reduced or eliminated with interventions of knowledge and training processes (Goldschmidt, 2006; Duncan et al., 1998).

The analyzed organizational challenges visualized a greater need for professionalism of producers not only on the production cycle but mainly on environmental management and business administration. This will ratify the need for alignment (vertical and horizontal) in the dialog flow between the value chain stakeholders, improving the relationship of technical information and the effective gains provided by environmental management and administration of companies. Table 3 shows weaknesses in drivers and cost control inductors and product differentiation, highlighting the influence of the indicator in the production chain and its drive for intervention.

Conclusions

The positive indicators of the analysis indicate a direction to better tune with the market and the pursuit of excellence valuing information, knowledge and training, as part of strategic organizational resources capable of providing a competitive edge against competition for rural producers (Prahalad, 2010). Some features such as production cost and differentiation for quality in the value chain and its links for better placement in the market should be improved in rural enterprises.

Identifying the perceptions of stakeholders in the production process in conjunction with the organizational systematization of indicators determines the intervention knowledge and training in management and administration, allowing the adjustment of production and

Table 2. Potential for competitive advantage creation*.

Indicators strengths	Influences on chain production value**	Production cycle step for Intervention
Strengths: Drivers of Cost Control*		
Frequency time feed	The number of daily treatment schedules and fixed supply of feed are important to prevent waste or lack of food and disease.	*** Feeding
Amount of feed and calculation consumption	It is Necessary to monitor the amount of administered food, because it interferes directly on mortality and feed consumption	*** Feeding
Knowledge medicines use	The use of medicines indiscriminately cannot provide effective correction of the problem burdening the cost of production.	Animal health
Population density in the cages	In the ideal growing conditions in cages, it is expected 95 % survival.	*** Feeding
Strengths: Drivers for product differentiation *		
Quality sediments	The amount of phosphorus and nitrate are a record of the cumulative effects of deficiencies with respect to organic matter and other indicators.	Quality of sediments
Planning productive cycle	Track tilapia cultivation in cages contributes to implementation of management and administration in the production strategies.	Management and operations.
Final control and product registration	It allows introduction of traceability technology, indicating the origin of the fish	Animal health

Made with primary research data.* Prahalad, 2010; Porter and Schwab, 2009; Goldschmidt, 2006; Duncan et al., 1998. **FAO, 2010; 2013 and Rodrigues et al., 2006, 2013. *** Feeding: the act of distributing food to planning and rule.

the redirection of competitive advantage of creating sources (Queyras and Quoniam, 2006).

Good aquaculture practices add value to products with management models capable of capturing the basis of competitiveness. This is recognized as an opportunity for skills development involving the collective work, enabling the deployment of creative lower cost solutions, increased efficiency in the value chain and its stakeholders (Prahalad and Hamel, 2009; Montgomery and Porter, 1998). By sharing expertise in management techniques and to develop organizational flexibility, it is easier for the rural organization to adapt to new market models that strive for dialogue with consumers and stake holders. The systemized indicators point to less likely aquaculture owner of intervention necessary for the improvement of competitive differentials in knowledge management and administration of its production (FAERJ/REDETEC, 2010; FAO, 2012; BNDES, 2010; Rodrigues et al., 2013).

The farms directed to sustainable development, need improvement and training for production growth. Small adjustments, better use of synergies and dialogue among stakeholders, should be presented as tools for the exploitation of potential opportunities to create competitive advantage in decision making and planning by landowners (Montgomery and Porter, 1998). An efficient and profitable rural enterprise depends on the producer of the field of process, production techniques and the management of its production, the actions or the production process operations work as product differentiators and consequential cost; thus creating competitive advantages (Davenport, 2000).The analysis of the technical and environmental indicators (BPA) in accordance with the difficulties reported by producers, have access to management tools, management and production costs of the properties. Similarly, the answers point to the producer's need to understand productivity and competitiveness in production through the improvement in food quality and performance of production, improvement in knowledge and training in the management of the activities within the production cycle.

Creative solutions for training and knowledge of producers identified in the analyses are associated with management indicators recognized in the daily actions of training in production cycle (formal and informal), creating and using monitoring sheets, exchange of learning and improving dialogue with stakeholders supplier of input and governance (Costa-pierce, 2007).Thus the results demonstrate that the indicators of environmental management and identified administration in the analysis,

Table 3. Potential competitive advantage creation*

Indicators of strengths	Influences on the value chain **	Intervention in the production cycle
Weaknesses - Drivers of cost control *		
Measuring size and Weight	Biometry of fish every 15 or 30 days and control of dead fish every day.	Fish Removal and Product Quality
Feed type	The nutritional status of the fish depends on the quantity and quality of feed nutrients.	*** Feeding
Health and Mortality	Indicators of nutritional deficiencies that impair growth, and increase the incidence of disease and mortality.	Management and Operations
Densification of fish in the cages	The increase in density interferes with the quality of water and food, limiting productivity.	Space Organization
Distance to source of pollution	Available amounts of oxygen and toxic gas concentration limit productivity.	Space Organization
Weaknesses - Drivers for product differentiation*		
Water quality	Turbidity and dissolved oxygen indicators Interfere with the amount of food consumed by the fish.	Water Quality
Dead fish removal procedure	Dead fish need to be removed and buried.in the cooler hours of the day to minimize stress and fish mortality increases.	Animal Health
Origin of fingerlings	Fish good genetic quality respond positively to the intensive management (cages).	Animal health

Made with primary research data. * Prahalad, 2010; Porter and Schwab, 2009; Duncan et al., 1998. ** FAO, 2010, 2013 and Rodrigues et al., 2006, 2013. *** Feeding: the act of distributing food to planning and rule.

stand out as opportunity for improvement in the production chain efficiency and in the information to understand the natural habits (environment, beliefs, culture) beyond technology applied to production. Also, they are key to achieving competitiveness for tilapia cultivation in cages in the Capitólio/ MG region. Economic indicators, environmental competitiveness in aquaculture companies in tanks - network recognizes important inputs on competitiveness were the proposed systematization. This study only identified the impact of the training and knowledge in environmental management and administration in organizations, using standards GAP.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Treatments for breaking dormancy of the crotalaria seeds (*Crotalaria ochroleuca*)

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The objective of the study was to evaluate the influence of methods in breaking dormancy in the seeds of tropical forage legume *Crotalaria ochroleuca*. The seed treatments were: (T1) water at 100ºC/10 min; (T2) immersed in water for 24 h at ambient temperature, after immersion in water at 100°C/1 min; (T3) acetone (10 min); (T4) ethyl alcohol (10 min); and (T5) intact seeds = control treatment. Data were analyzed using a completely randomized design with two replications, and was adopted for the Tukey test at 5% significance level. Seeds immersed in water for 24 h at ambient temperature before cultivation is enough to ensure germination. The treatments T1, T2 and T5 had the highest speed germination of seeds GSI, which differed ($P<0.05$) from T3 and T4. The T3 treatment was the only one with difference ($P<0.05$) in germination which was 15 days after sowing (Germ15). The T1 and T2 treatment had the highest amount of seed germination ($P<0.05$). The acetone affected the embryo in the tegument negatively.

Key words: Acetone, germination, seed physiology.

INTRODUCION

The presence of legumes in tropical grass pastures increases livestock production, due to the higher protein necessary for the development of microorganisms that digest forage (Gomes et al., 2011; Valente et al., 2015, 2016a). The consortium with tropical grasses can be an alternative for the recovery of degraded grasslands and increase in the pasture's nitrogen which consequently increases forage supplies at certain times of the year. This improves the nutritional quality of pasture, reduces the annual variation of forage supply, increases diversity of grassland beyond reduction in fertilizer usage (Carvalho and Pires, 2008; Valente et al., 2016b). The crotalaria can be used in animal nutrition, because it is a legume with good amount of crude protein (CP) in the range of 13.8 to 19.3%. It is an alternative legume that is widely used in semi-arid regions (Kallah et al., 2000). A study compared used only *Chloris gayana* hay or hay supplemented with *Crotalaria ochroleuca* on the feed intake, growth rate and feed utilization of growing sheep, and the concluded supplementation had a significant ($P < 0.01$) effect on the total and daily gain with the increasing level of crotalaria in the diet. The supplementation

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increases dry matter digestibility and the organic matter of hay with the CP digestibility about three times that of the sheep unsupplemented (Sarwatt, 1990). However, these legumes are more difficult to seed propagation in relation to forage grasses.

A limiting factor to the spread of forage legumes is the deep seed dormancy, which results in slow and uneven germination. This fact is due to the impermeability of the tegument with water, this phenomenon is considered by Popinigis (1985) as one of the most common causes of dormancy in legumes. This can be demonstrated by the low percentage of germinated seeds observed in undamaged seeds (control) (Kramer and Kozlowski, 1972; Bruno et al., 2011).

Secondly, Jayasuriya et al. (2013) seeds of legumes are generally considered to have physical dormancy, but most seed biologists are unaware of the various kinds and combinations of dormancy and storage behaviour in seeds of this family.

To breaking dormancy, various methods have been reported and the most common are: Immersion in water, removal of the seed coat, cut tegument, pierce the tegument, mechanical scarification, soaking in hot or cold water, hydrogen peroxide, chemical scarification sulfuric acid, hydrochloric acid, soda, acetone and alcohol. The treatment with sulfuric acid was done with a highly corrosive product and the tests show that it is capable of scarifying seeds of most legumes. However, the use of sulfuric acid to break dormancy is not common practice, since its high corrosive power require special care during handling, due to the danger, and can only be realized in a laboratory setting (Deminicis, 2005).

The objective of the study is to evaluate the influence of methods for breaking dormancy in the seeds of tropical forage legume *C. ochroleuca*.

MATERIALS AND METHODS

The experiment was conducted in the laboratory of IFGoiano Campus Posse GO - Brazil. The crotalaria seeds (*C. ochroleuca*) were tested for different dormancy breaking methods.

The seeds were collected from the Experimental Station of the Campus Posse, and the seeds after the harvest were selected for the germination tests. The pods with legume seeds were harvested manually during the first hours of the day. The pods were dried in the plant and no chemical product was used to make the drying. The seeds were not stored for any period of time. Seeds with or without the pre-germination treatments were germinated at a constant temperature of 25ºC. The germination test was installed on two sheets of paper moistened with distilled water, the amount equivalent to 2.5 times its dry weight in transparent plastic box 11×11×3 cm, with cover, 2 repetitions of 20 seeds and eight hours photoperiod. It was used as germination chamber for germinating the seed of solab® brand installed in the dependence of IFGoiano Campus Posse-GO, Brazil.

The number of germinated seeds was evaluated daily at the germination criterion radicle protrusion (growth with about 2 cm long of all the emerged seedlings). After knowing the number of germinated seeds daily, the following characteristics were evaluated:

Step 1: Germination count represents the cumulative percentage of germinated seeds on the third day after the start of the test (Germ3);
Step 2: Percentage of germinated seeds that correspond to the total percentage of seeds that germinate until the fifteenth day after the test (Germ15).
Step 3: Germination speed index (GSI), which was calculated with the formula proposed Maguire (1962):

$$GSI = \frac{G1}{N1} + \frac{G2}{N2} + \frac{Gn}{Nn}$$

Where, G1, G2, G3...Gn = number of germinated seeds to the nth observation; N1, N2, N3...Nn = number of days after sowing.

Step 4: Total count of seeds do not germinate after 15 days (NGerm).

The seed treatments were: (T1) Water at 100°C/10 min; (T2) immersed in water for 24 h at ambient temperature, after immersion in water at 100°C/1 min; (T3) acetone 40% (10 min); (T4) ethyl alcohol 90% (10 min); and (T5) intact seeds = control treatment.

The immersion in solvents such as acetone and alcohol corresponds to at least 2.5 times the size of the seed.

Statistical procedures and model evaluation

Data were analyzed using a completely randomized design with two replications according to the Yij = μ + Ti + eij model, where: Yij is the value observed in the jth experimental unit that received the ith treatment; μ is the overall mean; Ti is the fixed effect of the ith treatment; eij is the experimental error related to the experimental unit. The data were subjected to statistical analysis through Analysis System variance - ASSISTAT version 7.7 (Silva and Azevedo, 2009). Means were compared by Tukey test at 5% significance level. The GSI data were transformed into log (X + 0.5) and to check the normal distribution, the Shapiro-Wilk test was applied for alpha = 0.5% normality.

RESULTS AND DISCUSSION

Germination count represents the cumulative percentage of germinated seeds on the third day after the start of the test (Germ3). Within 3 days, 100% of the seeds germinated in T1 and T2, while T5 had 90% germination differs (P <0.05) and T3 to T4 treatment were respectively 65 and 40% germination (Table 1). The faster the seed germinates the better the chance of the seed to prosper (Deminicis, 2009). The speed and uniformity of seedling emergence depend on the seed vigor and the ambient conditions. It is of practical interest to know the intrinsic physiological quality of each seed (Paiva et al., 2008). As noted in this experiment, seeds treated with acetone or alcohol had the germination rate affected for three days (Germ3).

The T3 treatment was the only one with difference (P <0.05) in germination after 15 days of sowing (Germ15). Nasreen et al. (2015) opine that breaking of dormancy is effective when using 25% acetone in sunflower seeds. It differs from this experiment which had the acetone concentration at 40% higher. The T3 treatment had

Table 1. Average values for seeds germination of crotalaria (*Crotalaria ochroleuca*), Germ3, Germ15, GSI and NGerm after different treatments for breaking dormancy.

Treatment	Germ3	Germ15	GSI	NGerm
T1 = Water at 100ºC/10 min	100[a]	100[a]	0.99[a]	-
T2 = Immersed in water for 24 h at ambient temperature, after immersion in water at 100°C/1 min	100[a]	100[a]	1.02[a]	-
T3= Acetone (10 min)	40[b]	50[b]	0.63[b]	50[b]
T4 = Ethyl alcohol (10 minutes)	65[b]	85[a]	0.73[b]	15[a]
T5 = Intact seeds	90[a]	90[a]	0.96[a]	10[a]
F test	10.461*	17.000*	22.983*	17.000*
P-value	0.012	0.004	0.002	0.004
Coefficient of Variation %	14.43	8.32	6.23	47.14

*Significant to 1%. Different letters in line indicate significant difference according to Tukey test (P<0.05).

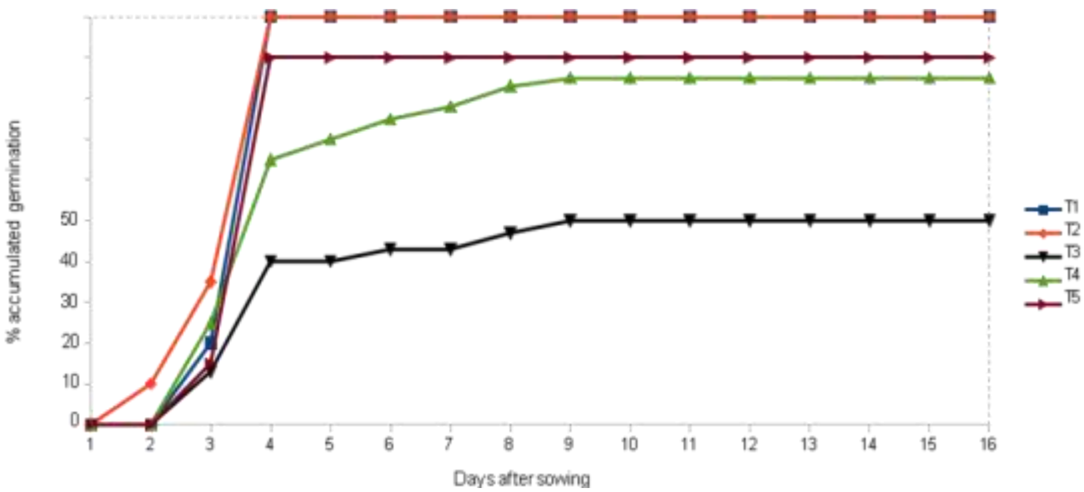

Figure 1. % accumulated germination in all treatments.

decreased germination (P <0.05) and the acetone negatively affected the embryo in the tegument.

The treatment T1, T2 and T5 had the highest speed germination for seeds GSI which differed (P <0.05) between T3 and T4. Treatment T2 had the best result, 100%, of the seeds germinated with a better GSI. The treatments for breaking dormancy in tegumentary seed were efficient because they promoted the rupture of the impermeable layer in the tegument for T1 and T2, thus, enhancing the water absorption by seed and the germination process. The T2 for having been immersed in water for 24 h at ambient temperature had advantage at GSI. Gonçalves et al. (2011) found different results for breaking the dormancy of a leguminous tree, treatment with water at 100°C had the worst result to compare with this experiment. In Figure 1, the representation of % germination during the trial period.

The treatment of immersion in water for 24 h is one of the cheapest techniques, with the main objective anticipate germination breaking dormancy, but is only effective when water enters quickly in the tegument. The technique of hot water to break dormancy is very simple to do, but the results are mixed for most legumes (Seiffert, 1982). The germination process is conceptualized after the end of the physiological seed repose period, after the termination of morphogenetic events that result in the transformation of embryo seedling. A number of processes that transform the seed from a relatively inert structure other active growth; an ordered sequence of metabolic events that results in the restart of embryo development, yielding a seedling; or simply the return of mature seed embryo growth (Santos et al., 2011; Nascimento and Oliveira, 1999). Since the germination dependent on the same environmental conditions depends on vegetative growth, water availability and oxygen, the temperature must be appropriate and should not be inhibitory substances in the soil (Smith, 2013). However, many seed germination is impeded due to the presence of a hard out tegument or due to the presence of inhibitory substances, and often by external factors, all of which require the dormancy state. Thus, even a viable seed cannot germinate, even with all the favorable environmental conditions. Seed dormancy leads to a time delay in the germination process (Deminicis, 2009).

The T3 treatment had 50% of non-germinated seeds (NGerm). There was no difference between the T1, T2, T4 and T5 treatments (P>0.05). Acetone can be effective to break the dormancy (Amritphale et al., 1993). However, the level of 40% was detrimental to germination *C. ochroleuca*, this response is variable depending on the hardness of the cover legume seed coat.

The most tropical legume has a high percentage of hard seeds, or seeds which do not germinate after sowing. The evidenced percentage of hard seeds is between 69 and 90%. The response to the germination of 90% of the control treatment (T5) is due to the fact that the seeds are used soon after the harvest. In this way, they were easier to germinate due to the lower maturity of the seed, consequently lower hardness of the tegument protection cover. This dormancy is due to the presence of a waterproof cover for water penetration, preventing the germination to a certain extent, so that some seeds germinate in each period and contribute to ensure the survival of the species (Bewley and Black, 1994). Recent studies show that manipulations can improve the breaking of dormancy as the case of rupture of the tegument to increase the water permeability, can induce an increased sensitivity to light and temperature, permeability to gases, removal inhibitors, and influences the metabolism of the seeds and thus the dormancy (Mayer and Poljakoff-Mayber, 1989, Kumar et al., 2015).

Conclusion

Seeds immersed in water for 24 h at ambient temperature, after immersion in water at 100°C/1 min before cultivation is enough to ensure germination. Acetone decreases germination and the seeds negatively affect the embryo in the tegument.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Tractor operator anthropometric profile of the Brazilian Northeast State

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Due to the agricultural modernization,some crops already have their production process fully realized byfarm machinery. In order to enhance operational performance and reduce both fatigue and accident risk, itis fundamental to provide a safe and adequate working environment. Therefore, the working station must be adapted to the operator's anthropometric and mechanical characteristics. The present study aimed to evaluate the anthropometric profile of agricultural tractor operators in the macro-region of Ceará state's west coast, and check whether the tractors are up to ISO and NBR ISO standards as well as to assess the risks of heart disease to which these drivers are exposed from epidemiological studies. The experiment was conducted in nine farms located along the macro-region of the Ceará state's west coast, in the following cities, Itapipoca, Itarema, Acaraú and Camocim with 39 agricultural tractor operators. For the samples, statistical analysis calculated were the minimum and maximum found values, mean, standard deviation, coefficient of variation, the amplitude and the percentiles of 5, 50 and 95%. The operators of the macro-region of the Ceará west coast had a lower height average than both the national average of 1.73 m and the Ceará state mean of 1.69 m. From the ISO and NBR ISO standards specifications evaluated, it is possible to saythat the standards are either inadequate or partially unsuitable for the operators evaluated.

Key words: Ergonomics, safety in agriculture, agricultural tractor, anthropometry.

INTRODUCTION

Currently, Brazil isachieving high productivity levels in agriculture and manual labour is being increasingly replaced by farm machinery. The current agricultural sector requires the constant increase in both productivity and food quality, which makes companies to seek ways to improve the production system. Modern machinery is usually cited as the main way, and may have the following desirable characteristics, reduction in losses, better operation quality and better workstations.

When the workstation is not suitable, the operator cannot easily handle all tractor commands and is more susceptible to increased physical and mental stresses, which may increase the operational errors, accidents and the development of various occupational diseases may

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alsoreduce both the operation efficiency and quality.

According to Rossi et al. (2011), the farm machinery operation is a very stressful activity, most of the time the operator has long work shifts and is passive to undesirable weather conditions that may affect the operation itself as well as the operational productivity. To mitigate the harmful consequences, the tractor workstation must have the minimum conditions for the work to be performed in such a way that the driver is not exposed to both health and accident risks.

According to Pheasant (1998), the correct human scaling to the machine need to ensure that within the workstation there are enough space for any operator that may use the tractor. Regardless of physical characteristics, the operator must be comfortable and have an easy access to all tractor's controls for a proper operation.

Currently, regarding technological developments in agricultural machinery projects, there is a tendency related to ergonomics and safety aiming to improve working conditions and reduce both fatigue and accident risk. The optimization of ergonomic factors may play an important role in increasing efficiency of the human-machine system. According to Victor et al. (2002), anthropometric measurements are the most important considerations in designing ergonomically appropriate agricultural machineries.

There is no exact anthropometric standard for humans. In fact, is possible to realize a diversification of these standards as compared to people from different countries and the standards may also change within the same country.

In Brazil's case, besides the continental size, the country underwenta colonization process from different countries and Santos (1995) stated that the landscape separated the different ethnic groups, which may generate a significant physical difference between individuals. Oliveira (1998) argued that anthropometry plays a key role in the ergonomic context because it is possible for adequate operation of the workstation.

The workstation has countless variables related to its sizing, which impede an ideal model implementation that is fully compliant to the anthropometric diversity. Due the anthropometric variance, the operator station needs to be adjustable for the different driver who might work in the enterprise.

However, Schlosser et al. (2002) claimed that each operator has measures that could either fit or not in an ideal model, which makes it more difficult to project a coherent workstation. The projects of operating stations are sized from standards (ISO and NBR ISO) which are developed to ensure a national representation; however, the physical specificities of individuals from each region are not taken into account. Thus, different operators may not be appropriately fitted in as the specify limit that may or may not meet the individual needs. The correct way to check the driver's adjustment is testing and developing anthropometric profiles.

When the workstation is not suitable, the operator cannot easily handle all tractor commands and is more susceptible to both physical and mental stresses. This situation may increase operational errors, accidents and the development of various occupational diseases as well as may reduce both operational efficiency and quality.

Worldwide, many anthropometric studies have been conducted. Ghaderi et al. (2014) developed a harvester seat based on Iranian operators' anthropometric data. Mugisa et al. (2016) evaluated anthropometry to design labour-saving tools. Syuaib (2015) conducted an anthropometric study of farm workers in Indonesia in order to design novel farm tools and equipment.

The study aimed to evaluate the agricultural operators anthropometric profile in Ceará State and to verify whether tractors workstations are in accordance with both International and Brazilian standards (ISO and NBR ISO) as well as to assess the heart diseases risk that these operators are exposed to, from epidemiological studies**.**

MATERIALS AND METHODS

The experiment was conducted in nine farms located along the macro-region of the Ceará state's west coast, in the following cities, Itapipoca, Itarema, Acaraú and Camocim; these cities were chosen because of their large number of operators.

Prior to the data collection, all participating operators were informed about the survey content and methodology. To obtain the anthropometric profile, in each operator, 21 measurements (height, body mass, arms raised reach, height at eye level with the operator standing, height at eye level with the operator sitting, height at ear level with the operator standing, height at ear level with the operator seated, foot distance from the ground, hip width, hip circumference, waist circumference, height at shoulder level, distance from the foot to the knee, arm reach, forearm reach, sacral-knee, back length, back width, hand length, foot length and age) were done according to Kroemer and Gradjean (2005).

The operators were shirtless and wore shorts for the measurements. The measuring time was approximately 10 to 15 min per driver. The measurements were performed with measuring tape, rulers (linear and L format), digital balance, stadiometer, chair with right bottom and forms for the data collection. Measurements were carried out in two stages: the operator while standing and the operator seated (legs formed at 90° angle).

To determine the amount of operators required for sampling, the operational characteristic curve method was utilized (Equation 1) from which, it is possible to find the (d) value at 5% significance level.

$$d = \frac{|\mu - \mu_0|}{\sigma} \quad (1)$$

Where: d = sample number;μ = population mean;μ_0 = sample mean;σ = standard deviation.

From the 'd'value obtained, it was possible to find the minimum sample amount using the graph of operational characteristic curves (Montgomery and Runger, 2012). For the current study, the minimum amount of samples required according to the methodology used was nine samples, and the total amount acquired was thirty nine, which demonstratesthat the collected samples are representative of the total population.

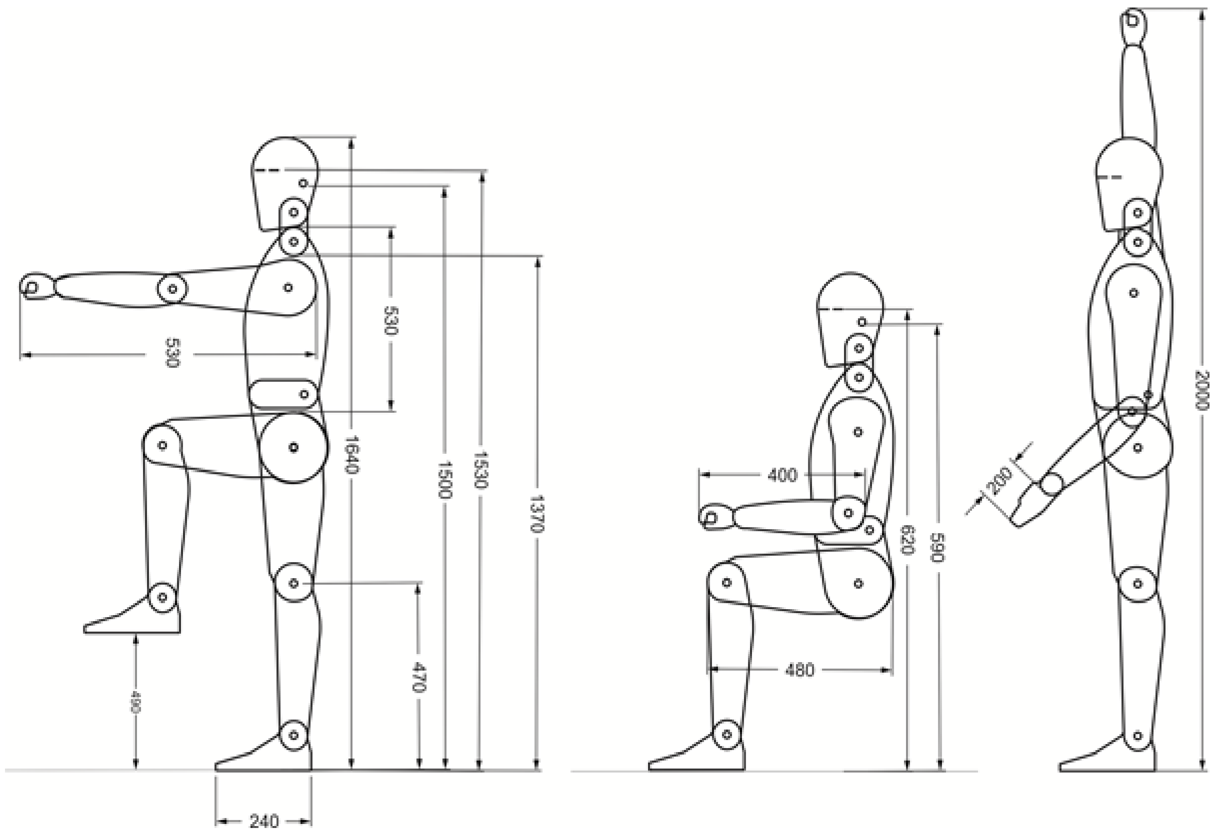

Figure 1. Average operator anthropometric profile of the macro region of the Ceará state's west coast in millimetres (mm).

For the samples, statistical analysis done were the minimum and maximum values, mean, standard deviation, coefficient of variation, the amplitude and the percentiles of 5, 50 and 95%, generating an anthropometric profile of agricultural tractor operators in the macro-region of the Ceará state's west coast.

The evaluation of obesity and the risk of heart disease was performed using the body mass index (BMI) method (Equation 2) and the waist-hip ratio (WHR) (Equation 3) through the gathered data.

$$IMC = \frac{m}{L^2} \quad (2)$$

Where:BMI = body mass index;m = body mass;L^2 = stature.

$$RCQ = \frac{ca}{q} \quad (3)$$

Where:WHR = Waist-hip ratio;Ac = abdominal circumference;q = hip circumference.

The standards utilized in the projects of operating stations, ISO and NBR ISO standards, were chosen for the operation station scaling.

The selected standards were as follows: NBR ISO 26322-1: Agricultural and Forestry Tractors - Safety Part 1: Conventional Tractors (ABNT, 2011a). NBR ISO 26322-2: Agricultural and Forestry Tractors - Safety Part 2: Small and narrow gauge Tractors (ABNT, 2011b). NBR ISO 4252: Farm Tractors - Operator workstation, access and exit - Dimensions (ABNT, 2011c). ISO 15077: tractors and machinery for agriculture and forestry: operator controls: actuating forces, displacement and their location (ISO, 1996). ISO 4253: Agricultural tractors: operators' seating accommodation: dimensions (ISO,1993). ISO4254-1: Agricultural machinery: safety: Part 1: General requirements (ISO, 2008).

After reviewing the standards, ten specifications which determine far-reaching measures were chosen, in order to be compared with the assessed operators' profile.

The evaluated specifications were as follows, maximum height of external controls from the ground, power take-off (PTO) external control, height of the cabin access, the first step above the ground height, longitudinal seat adjustment for the middle position, width total seat cushion (bottom), lumbar back seat length, lumbar backrest full width, driver foot reach and filler tank height.

RESULTS AND DISCUSSION

The 39 operators evaluated could perform all the necessary functions, although with limited access to certain tractor controls and limited movement during operation. Figure 1 shows the mean profile of the macro region of Ceará state's west coast operators.

The anthropometric profile (Table 1) showed that the agricultural tractor operators stature of the macro-region of Ceará state's west coast is less than both the national average of 1.73 m and the Ceará state average of 1.69 m according to the IBGE (2014), for the group aged 30-34

Table 1. Operator anthropometric profile of the macro region of the Ceará state's west coast in millimetres (mm) (body mass (kg) and age are not included).

Measures	Percentiles			Min.	Max.	Mean	Standard deviation	CV (%)	Amplitude
	5%	50%	95%						
body mass	55	71	89	53	90	73	9.97	13.65	37 kg
Age	23	32	45	21	52	33	7.32	22.23	31 years
stature	1540	1650	1750	1540	1770	1640	0.06	3.53	230
height at eye level	1430	1530	1610	1430	1660	1530	0.06	3.75	230
height at ear level	1410	1500	1580	1400	1630	1500	0.06	3.67	230
height at shoulder level	1300	1370	1450	1280	1540	1370	0.05	4.01	260
arms raised reach	1860	2010	2110	1830	2170	2000	0.07	3.53	340
foot – knee distance	420	470	510	410	520	470	0.03	5.57	110
hand length	190	200	210	190	220	200	0.01	4.52	35
forearm reach	360	410	430	360	490	400	0.03	6.53	130
arm reach	640	720	760	630	820	720	0.04	5.02	190
waist circumference	720	870	1050	710	1110	880	0.10	11.07	400
hip circumference	890	990	1080	800	1111	990	0.056	5.72	220
back width	420	470	520	390	600	480	0.04	8.78	210
back length	470	530	580	420	590	530	0.03	6.16	170
foot distance from the ground	410	490	550	380	580	490	0.44	9.16	200
hip width	310	470	580	290	590	450	0.09	10.59	300
sacral-knee	410	490	540	380	580	490	0.2	9.35	200
foot length	220	240	260	220	270	240	0.01	4.87	45
height at eye level (seated)	550	650	690	490	740	620	0.05	4.63	250
height at ear level (seated)	520	620	660	460	710	590	0.05	4.18	250

years.

Schlosser et al. (2002) reported that changes in anthropometric patterns can significantly occur within the same country (different regions) due the different ethnic colonization of each region. Therefore, the tractor workstation which has been designed according to specifications defined by national standards may provide an inadequate working environment for the operator due to the previous mentioned anthropometric diversity within the country.

According to the standards utilized in the present study, the external tractor controls should be located where the operator can activate them while remaining standing outside the hazard area between the tractor and agricultural equipment to be connected. These controls must to be at a maximum height of 1,800 to 2,000 mm from the ground. By analysing the following measurement, operator arms raised in the anthropometric profile, which is possible to observe that all operators are able to achieve these controls to a height of 1,800 mm, but the 5% of the total drivers has shorter range than 1.860 mm and they would not be able to reach the controls on the limit of 2,000 mm high.

According to the rules, there must be an external control located where the operator is able to switch the PTO off of the tractor and this device height must be up to 2,000 mm in height from the ground. However, whether the device is located after 1,860 mm, would be inaccessible to the 5% of the profiled operators previously mentioned and may cause serious accidents with the PTO, even lead to death of the victim.Handrails and the filler tank must be placed at a maximum height of 1,500 mm from the ground, which would be accessible to all operators, bearing in mind the operators' lower reach with arms raised at 1,830 mm.

Tractor accesses as steps and handrails must be only provided whether the vertical height of operating platform is 550 mm above ground level. By looking at the measured distance from the ground to the operator foot (leg lifted) it is possible to argue that the steps are not accessible to all operators as 50% of the studied operators have a 490 mm range which indicates they do not reach the minimum range of 550 mm. In order to access the tractor the operators need to raise the leg at an angle greater than 90° which, according to Silva et al. (2005), is harmful due the recommended angle range should vary from 45° to a maximum of 90°, and the closer to 45° the better the comfort when climbing. Couto (2008) reported that approximately 20% accidents in agriculture are related to tractors, of which 54% are minor accidents due either to inappropriate equipment conditions or the safety items not suitable for the operator. For instance, the large distance between the first step and the soil may cause imbalances and may lead to injury.

According to the standards, the operator’s foot range is defined by a hemispherical radius of 800 mm starting from the seat cushion front edge, with the seat in its central position. The maximum range obtained in the studied operators’ profile (when the seat accommodates the entire hip and thighs) is 570 mm, having 95% of the profiled operators with 510 mm radius range. The results indicate that the closer the pedals to the limit of 800 mm, the greater the operator challenges in accessing it. In order to reach the pedals, the operator must protrude forward the seat which may generate an injury due to poorpostureandmayreducetheoperational productivity.

The longitudinal seat adjustment for the middle position can range from a minimum of 75 mm to a maximum of 100 mm, which may increase the operator reach facilitating the both feet and hands access. However, for the profiled operators, the feet would not reach 800 mm radius still, but about 670 mm bearing in mind the maximum seat adjustment. Therefore, the operator may not have full access to the pedals, depending on the arrangement made by the manufacturer.

The vehicle's seat should provide the operator a comfortable controlling posture, appropriate vision and safe access to different pedals and controls. Correct sitting posture has been acknowledged as an important factor for the prevention of musculoskeletal problems (Cranz, 2000). According to the standards, the seat cushion total width must be at least 450 mm. However, 31% of the evaluated operators’ back widthhavevalues above 450 mm, reaching up to 580 mm. Therefore, a small seat can cause immense discomfort, especially due to the seat arms.

Kroemer and Gradjean (2005) reported that the backrest length should be sufficient to support both the sacrum area and lower back areas; however, a high backrest length may also be unfavourable because it creates movement limitations of the operators’ back and shoulders.

According to the standards, the backrest length is at least 260 mm and there is no prescribed maximum value. The operators’ backs average length was 530 mm, so standard accommodates the minimum value less than a half of the length of the operators’ back. The lumbar backrest width is at least 450 mm, the operators profile average is 480 mm, up to a 600 mm maximum, which shows that due the high body mass, the operator does not fit in the minimum limits specified for the seat width both the cushion and the lumbar back. Ghaderi et al. (2014) affirmed that this condition may lead to both pain and discomfort and tend to increase the risk of musculoskeletal problems.Regarding to the BMI results, it was observed that none of the operators presented obesity classes II and III, but 21% of the operators presented obesity class I (Figure 2).

Regarding weight, 30% of the operators are at proper weight, 49% are in a pre-obesity and 21% are in obesity class I which is an alarming fact. According to Mendonça and Angels (2004), cardiovascular risk factors are intrinsically related with obesity and these risks may be enhanced by excessive physical efforts. Additionally, Larsson et al. (2002) presentedthe obesity decreases quality of life and life expectancy (KOCH, 2011). Kroemer and Gradjean (2005) stated that overweight may cause worse damage because physical efforts become even higher for overweight people as compared to normal weight operators.

According to Sorof et al. (2004), the body overweight is one of the factors that increase hypertension risk and the increasing obesity rate is becoming a major public health problem worldwide (Kelishadiet al., 2014; Cavaco et al., 2014).Operators in the macro-region of Ceará state’s west coast are usually young, having a 33 year-old population average, however the following measure, waist circumference had high values, an average of 87 cm, reaching up to 111 cm, which are worrying values because the abdomen fat is usually associated with chronic diseases (WHO, 2000).

Pereira et al. (1999), in a study conducted in Rio de Janeiro, showed that men with a 95 cm waist circumference had a high predisposition to high blood pressure and among the operators of the Ceará West Coast, 25% have higher waist circumference values than 95 cm.The operators’ waist-hip ratio (Figure 2) showed that 79% of the operators may be at moderate to very high heart disease risk and only 21% are at low risk.

The high values found at BMI and WHR tests are representative of the entire macro-region of the Ceará west coast, which indicates a public health problem in the region. Therefore, awareness campaigns should be carried out in the region due to the high number of heart disease and other diseases related to obesity. Operators with overweight, especially with abdominal fat, are more likely to cardiovascular risk diseases and consequently may have a higher death risk if diet changes are not taken (Rezende, 2006).

According to Cabrera and Filho (2001) and Mendonça and Angels (2004), weight maintenance and a healthy diet are extremely important for the prevention and/or the control of cardiovascular disease in operators.

Conclusions

1. The operators of the macro-region of the Ceará west coast had a lower height average than both the national average of 1.73 m and the Cearástate mean of 1.69 m.
2. From the ISO and NBR ISO standards specifications evaluated, it is possible to argue that the standards are either inadequate or partially unsuitable for the operators evaluated.
3. According to both methodologies, the body mass index (BMI) and the waist-hip ratio (WHR), the evaluated operators were highly predisposed to heart diseases, as 70% of the operators are above the appropriate weight

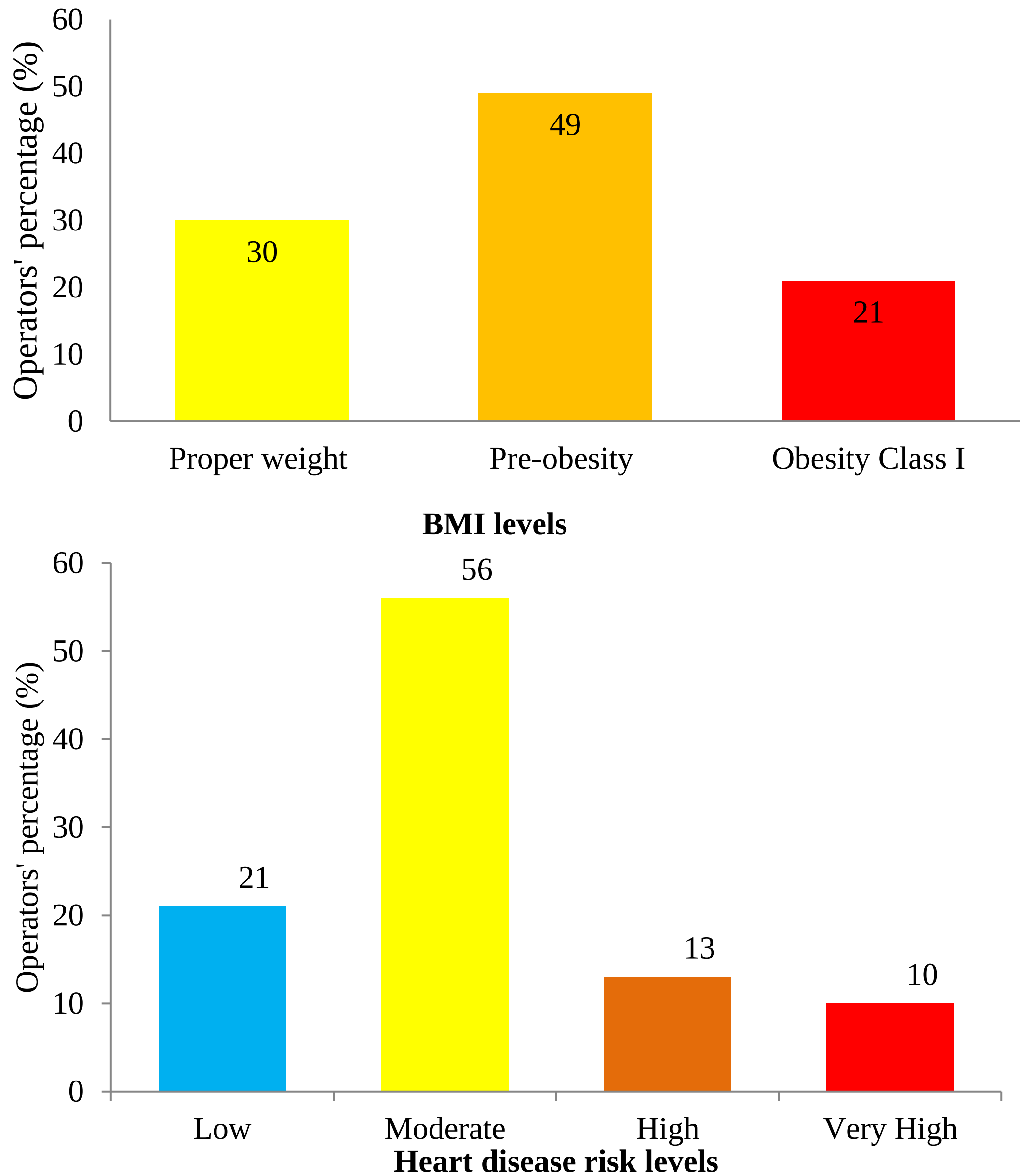

Figure 2.BMI and WHR results in percentage for tractor operators of the macro region of the Ceará state's west coast.

and 79% had moderate to high risk for heart disease onset.

Conflict of interests

The authors have not declared any conflict of interests.

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