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Full Length Research Paper

Sero-epidemiological survey on toxoplasmosis in cattle, sheep and goats in Algeria

Amina Samia Dechicha[1,2], Fatma Bachi[3], Ismail Gharbi[1], Edmee Gourbdji[3], Djamila Baazize-Ammi[1], Mohamed Brahim-Errahmani[4] and Djamel Guetarni[5]*

[1]Institute of Veterinary Sciences, University of Blida 1, Algeria.
[2]Institute of Veterinary Sciences, University of Tarf, Algeria.
[3]Service de Biologie Parasitaire, Institut Pasteur d'Algérie, Algeria.
[4]Faculty of Sciences, University of Blida 1, Algeria.
[5]Department of Biology, Faculty of Nature and Life Sciences, University of Blida 1, Algeria.

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Toxoplasmosis is a parasitic disease with worldwide distribution and a major public health problem. In Algeria, human toxoplasmosis is screened in pregnant women and immunosuppressed persons; however, no information is available on the animal infection and a probable implication of the parasite in abortions occurring in the field. This sero-epidemiological cross-type survey on toxoplasmosis in cattle (332), sheep (276) and goats (106) revealed the presence of anti-*Toxoplasma* antibodies based on the indirect fluorescent antibody test (IFAT), at the respective rates of 3.92, 11.59 and 13.21%. The likelihood of acquiring *Toxoplasma gondii* infection was higher in sheep and goats (OR=3.22, 95% confidence interval [CI]: 1.65-6.27 and OR= 3.73, [CI]: 1.69-8.24 respectively) than in cattle (p<0.001). However, the difference between sheep and goats is not significant. At herd level, 5 herds out of 41 (12.19%), 11 herds out of 19 (57.89%) and 4 herds out of 6 (66.66%) showed at least one seropositive case in cattle, sheep and goat herds, respectively. Statistical comparison between genders and age groups showed no significant difference in the three species. The highest serological titers obtained are 1:64, 1:2048 and 1:4096 for cattle, sheep and goats, respectively. Suspicion of the parasite's role in abortions has been investigated, the seroprevalence showed no significant difference between abortive and non abortive females for cattle and goats; however, it was significantly higher in ewes that have not aborted as compared to those having abortions, a high suspicion was done for one abortive ewe whose antibody titer reached 1:1024. The presence of anti-*Toxoplasma* antibodies has been highlighted for the first time in livestock in Algeria, indicating a contamination with the parasite.

Key words: *Toxoplasma gondii*, seroprevalence, cattle, sheep, goats, abortion, Algeria.

INTRODUCTION

Toxoplasmosis occurs worldwide and is present in a benign form in most animals. However, it is being recognized as a major cause of reproductive failure in several countries (Blewett and Watson, 1984; Dubey and Beattie, 1988; Dubey, 2004). Infection with *Toxoplasma gondii* seems to be the cause of embryonic resorption,

*Corresponding author. E-mail: dguetarni@gmail.com

mummification, abortions, neonatal deaths or birth of weak and non viable newborns.

The protozoan distribution varies widely according to species, farms and countries. Sheep, goats and pigs are the most sensitive species which record the highest seroprevalences and constitute a potential danger to humans (Tenter et al., 2000; Dumetre et al., 2006; Opsteegh et al., 2010). Contamination of human is usually done by ingestion of tissue cysts in undercooked meat (Smith, 1993; Cook et al., 2000) or by oocysts in soil or water that have been contaminated with cat feces (Bahia-Oliveira et al., 2003; Dubey, 2004; Jones et al., 2005; de Moura et al., 2006). Indeed, according to Roberts et al. (1994) and Mead et al. (1999), *T. gondii* is one of three pathogens (together with *Salmonella* and *Listeria*) which account for up to 75% of all deaths due to food borne disease in the USA.

Human toxoplasmosis occurs most often asymptomatically, inducing an underestimation of its prevalence. However, the use of serology shows seroprevalences that vary from one country to another; the lowest values are being recorded in the Northern countries, 5 and 10%, respectively in Sweden and Norway (Evengard et al., 2001; Jenum et al., 1998) and those higher in the south, 60 and 74.5% in Ivory coast and Brazil, respectively (Adoubryn et al., 2004; Spalding et al., 2005).

In Algeria, human seroprevalence is being estimated at 51.56% and prophylaxis of congenital toxoplasmosis is part of a national surveillance program for pregnant women, with medical care of toxoplasmic seroconversions or evolutive toxoplasmosis (Bachi et al., 2010). By contrast, there is no study available concerning the seroprevalence of animal toxoplasmosis and its implication as the probable origin in the abortions observed on the site, because only Brucellosis is investigated in this case (Dechicha et al., 2010).

The aim of this study is to investigate the toxoplasmosis antibodies in cattle, sheep and goats, and to test a probable implication of the parasite in abortions occurring in the field.

MATERIALS AND METHODS

Study population

The sample comprised of three main animal species considered as the primary sources of red meat in Algeria. Cattle (332) originated from 41 farms located in Blida province, whilst the sheep (276) and goats (106) came from 19 and 6 farms, respectively, located in Djelfa province (agro-pastoral region).

For each species and from each farm, all females with a history of recent abortion, ten percent of reproductive female and reproductive males were selected. Blood was collected from the jugular vein and the separated serum was stored at -20°C until used. Animals in this study were treated according to the ethical standards of Algerian research centers and universities (MESRS, Algeria). Blood collections were carried out in compliance with EU legislation on research involving animals (EU, 2010).

Serological test

Toxoplasma antibodies were detected by the indirect fluorescent antibody test (IFAT) according to OIE Terrestrial Manual (2008). Slides were coated with whole tachyzoites of "RH" strain of *T. gondii* maintained by continuous passages in BALB/c mice and collected intraperitoneally. Test sera deposited on slides were diluted in PBS (0.3 M PBS, pH 7.4) starting from 1:16. Positive and negative control and also a PBS sample were included on each test slide. Species-specific IgG for cattle (Sigma F7887), sheep (Sigma F7634) and goats (Sigma F7363) conjugated to fluorescein isothiocyanate diluted in 0.2% Evans Blue (in PBS), were used appropriately as secondary antibody. The reaction was examined under a fluorescence microscope, and a sample was considered positive if at least 80% of the parasites were surrounded by a continuous peripheral strip of fluorescence at a dilution level of 1:64. Positive sera were subsequently titrated until the maximum positive dilution titer was reached.

Statistical analysis

Statistical analysis was performed using "Statistica 10.0" of Statsoft Inc., Tulsa, USA and "IBM SPSS Statistics 20.0," IBM Corp., USA. The degree of significance of the link between the seroprevalence and age, sex and the abortive/non abortive status for the females was performed by the χ^2 test or Fischer Exact test where values in one or more cells are ≤ 5. These links were considered significant for $p < 0.05$. The degree of dependence of the disease on various factors was determined by the odds-ratios (with confidence intervals).

RESULTS

Individual seroprevalences were estimated at 3.92, 11.59 and 13.21% respectively in cattle, sheep and goats. At herd level, 12.19, 57.89 and 66.66% herds showed at least one seropositive case in cattle, sheep and goats, respectively. Within-herd seroprevalence ranged from 11.76 to 30.76% in cattle; 4.54 to 63.63% in sheep and 20 to 42.85% in goat herds.

Statistical analysis shows that sheep and goats seroprevalences at individual or herd level are significantly higher than cattle seroprevalence ($p<0.001$). However, the difference between sheep and goats is not significant (Table 1).

Statistical comparison between age groups and gender of animals showed no significant difference in the three species (Table 2). The link between the seroprevalence and the abortive/non abortive status of the females showed no significant difference for cattle and goat. Whereas, the seroprevalence of non abortive ewes is significantly higher ($p<0.05$) than those having abortions (Table 3).

Titration of positive sera showed a maximum titer of 1:64 for cattle, 1:2048 for sheep and 1:4096 for goats (Figure 1).

DISCUSSION

The presence of anti-*Toxoplasma* antibodies has been

Table 1. Toxoplasmosis seroprevalences in cattle, sheep and goats.

Species	Tested	Positive (%)	95% CI	OR	95% CI	P-value
Individual level						
Cattle	332	13 (3.92)[a]	2.10-6.60	Ref		<0.001
Sheep	276	32 (11.59)[b]	8.07-15.97	3.22	1.65-6.27	
Goats	106	14 (13.21)[b]	7.41-21.17	3.73	1.69-8.24	
Herd level						
Cattle	41	5 (12.19)[a]	5.32-25.54	Ref		<0.001
Sheep	19	11 (57.89)[b]	36.28-76.86	9.90	2.68- 36.52	
Goats	6	4 (66.66)[b]	30- 90.32	14.40	2.07- 100	

(%): seroprevalence; OR: odds-ratio; CI: confidence interval; Ref: reference; a: seroprevalence significantly different than b.

Table 2. Seroprevalences distributions according to age and gender.

Animals factors	(n)	Positive	Sero (%)	95% CI	OR	95% CI	P-value
Cattle							
Age group							
0 - 4 years	86	1	1.16	0.00-6.31	Ref		0.256
4 - 6 years	101	4	3.96	1.09-9.83	3.51	0.38-32.24	
≥ 6 years	145	8	5.52	2.41-0.58	4.96	0.90-40.83	
Gender							0.852
Male	4	0	0				
Female	328	13	3.96	2.13-6.68			
Sheep							
Age group							0.084
6 - 12 months	14	0	0				
12 - 36 months	74	5	6.76	2.23-15.07			
> 36 months	188	27	14.36	9.68-2020			
Gender							0.593
Male	14	1	7.14	0.18-3.39	Ref		
Female	262	31	11.83	8.18-16.37	1.75	0.218-13.98	
Goats							
Age group							
6 - 12 months	29	3	10.34	2.19-27.35	Ref		0.44
12 - 36 months	44	8	18.18	8.19-32.71	1.93	0.455-8.153	
> 36 months	33	3	9.09	1.92-24.33	0.87	0.156-4.801	
Gender							0.52
Male	54	6	11.11	4.19-22.63	Ref		
Female	52	8	15.38	6.88-28.08	1.46	0.459-4.61	

(n): number tested; Sero: seroprevalence; OR: odds ratio; CI: confidence interval; Ref: reference.

highlighted for the first time in livestock in Algeria, indicating a contamination with the parasite. In cattle, the seroprevalence estimated in the study is relatively low (3.92%), it is comparable to rates found in Brazil (1.96%), Iran (1.6%) and Poland (3.15%) as reported by Luciano et al. (2011), Raeghi et al. (2011) and Holec-Gąsior et al.

Table 3. Toxoplasmosis seroprevalences according to abortive status of females.

Female	Status	(n)	Positive	Sero (%)	95% CI	OR	95% CI	P-value
Cattle	Abortion	11	0	0	--			0.636
	Non abortion	317	13	4.10	2.20-6.91			
Ewes	Abortion	68	3	4.41	0.92-12.36	Ref		0.028
	Non abortion	194	28	14.43	9.81-20.18	3.66	1.07-12.54	
Goat	Abortion	3	0	0	--			0.599
	Non abortion	49	8	16.33	7.32-29.66			

(n): number tested; Sero: seroprevalence; OR: odds ratio; CI: confidence interval; Ref: reference.

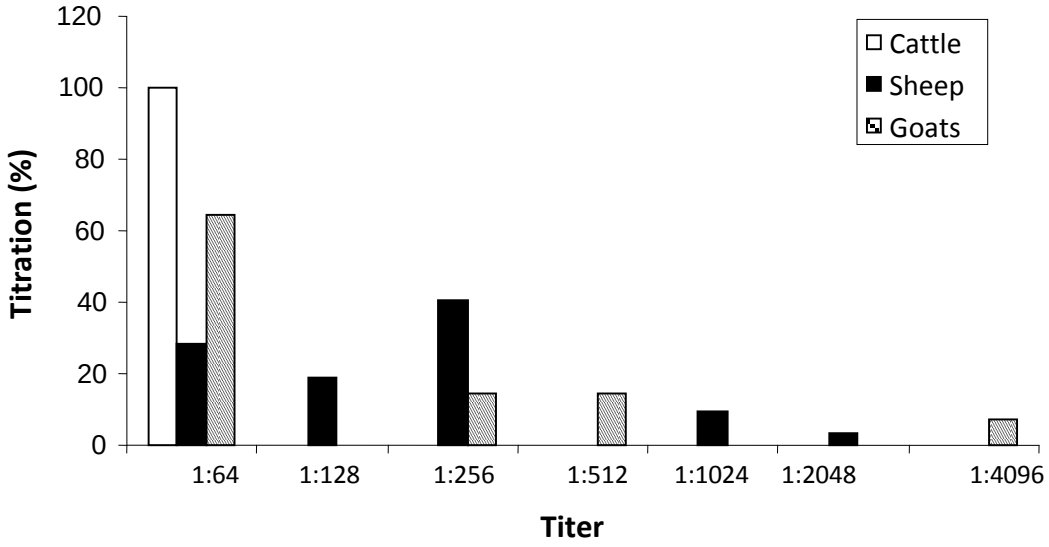

Figure 1. Distribution of toxoplasmosis serological titers in cattle, sheep and goats.

(2013), respectively. This seroprevalence and the rate of infected herds (12.82%) may reflect a low distribution of the parasite in the farms of the study area. In this species, natural infection does not appear to cause clinical disease, however the seroprvalences reported in the literature range from 0 to 92% (Tenter et al., 2000). Indeed, cattle are considered a poor host for *T. gondii*; although they can be successfully infected with oocysts, the parasite is eliminated or reduced to undetectable levels within a few weeks (Dubey, 1986), perhaps due to innate resistance (Dubey and Jones, 2008).

Distribution of seroprevalence according to age showed no significant difference even if the odds ratio shows that it is 4.96 times higher in subjects aging ≥ 6 years. Rozette et al. (2005) report a similar finding in contrast to those of El fahal et al. (2013) who found a higher seroprevalence in cattle aging less than 1 year, thing that could be explained by the capacity of this species to eliminate the parasite with age. The distribution of seroprevalence according to gender showed no significant difference what is in agreement with the reports of Klun et al. (2006) and Garcia et al. (1999); however, those of Nematollahi and Moghddam (2008) showed that seropositivity is higher among males. The low antibody titer of 1:64 suggests that toxoplasmosis spreads in these farms in a latent form; it is similar to the findings of Santos et al. (2013). However, the low titer obtained is adequate with the hypothesis regarding the rapid removal of cysts by cattle.

In sheep, seroprevalence at individual level (11.59%) and at herd level (57.89%) reflects a strong environmental contamination and a wide distribution of the parasite in these farms. According to Ruiz and Frenkel (1980) and Dubey et al. (1996), the ground of farms can be strongly contaminated with oocysts as demonstrated in numerous studies. Indeed, animals kept on pastures with an increased pressure of infection due to contamination of the environment with oocysts show

high seroprevalences in many areas of the world (Tenter et al., 2000).

The difference between age groups was not significant and is in agreement with reports of Sevgili et al. (2005). However, other studies reported a significant increase of the prevalence with the age of animals which could be explained by a greater possibility for the older subjects to be exposed to environment oocysts (Clementino et al., 2007; Vesco et al., 2007). In fact, according to Dubey and Kirkbride (1989), most of sheep acquire the infection before the age of 4 years; however, only one third of the older females remain seronegative in heavily contaminated farms. As well, we found no significant difference between sexes; a similar observation was reported by Khezri et al. (2012) and Gebremedhin et al. (2014), unlike Clementino et al. (2007) who reported a higher seroprevalence in females.

The antibody titers obtained are higher as compared to cattle, with a maximum titer of 1:2048; a similar titer was reported by Rossi et al. (2011) and higher titers reaching 1:65536 were reported by Garcia et al. (1999). A high antibody level would favor an acute toxoplasmosis or a reactivation of latent toxoplasmosis after an immunosuppressed conditions.

For goats, the seroprevalence of 13.21% is similar to rates reported in China (14.1%), Saudi Arabia (12%) and Ethiopia (19.7%) respectively by Zhao et al. (2011), Al Mohammed (2011) and Zewdu et al. (2013). At herd level, two thirds of the farms (66.66%) presented at least one seropositive case, which also goes in favor of a strong environmental contamination. In fact, this large distribution of the parasite among sheep and goat herds could be attributed to cats residing on site and the access of animals to contaminated feed and water. Indeed, according to Dubey and Frenkel (1972), cats can shed as many as 500 million oocysts after ingesting one *T. gondii* infected mouse under laboratory conditions. Furthermore, while only a few cats may be shedding *T. gondii* oocysts at any given time, the enormous numbers produced and their resistance to destruction assures widespread contamination (Dubey, 2004).

The difference between age groups was not significant in contrast to studies which showed a significant increase in seroprevalence with age as in the case of sheep (Figueiredo et al., 2001; Kamani et al., 2010; Zewdu et al., 2013). We observed no significant difference between genders as found by Bisson et al. (2000) and Carneiro et al. (2009), while the report of Swai and Kaaya (2012) showed that females are more infected than males. The majority of subjects have shown a titer ranging from 1:64 to 1:512, indicating a latent form of toxoplasmosis, the highest titer recorded is of 1:4096 expressing an acute form of toxoplasmosis. In fact, much higher titers reaching 1:8192 and 1:16384 were reported in other studies by Figueiredo et al. (2001) and Neto et al. (2008), respectively.

The statistical comparison between species showed that cattle are the least infected species as compared to sheep and goats ($p<0.001$); this situation has already been described worldwide (Pita Gondim et al., 1999; Sharif et al., 2007). However, the comparison between sheep and goats showed no significant difference in contrast to Mahboub et al. (2013) whom observed a higher rate in sheep that could be explained by the variability of the species sensitivity and methods of farming.

Whatever the seroprevalence obtained, a particular attention should be given to the risk of human infection through consumption of undercooked meat (Halos et al., 2010; Boughattas et al., 2014) or raw goat and sheep milk (Camossi et al., 2011; Lafi et al., 2014). In fact for cattle, ingestion of beef or dairy products is not considered important in the epidemiology of *T. gondii* because cattle are not a good host for this parasite. However, we cannot be sure that beef does not play a role in *T. gondii* transmission as only relatively small amounts of beef have been tested for viable parasites (Dubey and Jones, 2008).

Furthermore, according to Smith (1993), meat from infected sheep and goat milk are shown to be primary sources of infection for men. In Algeria, the consumption of undercooked meat appeared as a major risk factor for toxoplasmosis infection in pregnant women (Messerer et al., 2014). Therefore, investigation of *T. gondii* in livestock is required in order to detect potential risk for human infection, especially where consumption of undercooked meat and raw milk is a popular tradition. To date, no protective measures have been taken by the farmers for herds because the sanitary and economic repercussions of this disease are unknown.

For cattle, no female that abort was seropositive; in fact, *T. gondii* is not recognized as an abortive agent in cattle (Dubey, 1986). Contrarily, for sheep and paradoxically to what has been reported in the literature, where toxoplasmosis is presented among the leading causes of abortion in many countries (Dubey and Kirkbride, 1989; Jackson and Hutchison, 1989) the seroprevalence of non-abortive ewes is significantly higher than of the abortive ones (14.43% *vs.* 4.41%). Hamzy El Idrissi et al. (1995) reported a seroprevalence rates that are equal between the abortive females (8.8%) and the normal lambing females (9.7%), while Benkirane et al. (1990) found a significantly higher rate in the abortive ewes (21%) as compared to normal lambing females (8%). The highest seroprevalence obtained in non-abortive ewes could be explained by the fact that the female is able of giving birth to a viable but infected lamb if it contracted the parasite in late gestation, and it would abort if it contracted the parasite for the first time during mid-gestation. Moreover, whether pregnant or not, it would develop an immunity that will prevent it from miscarrying during subsequent pregnancies. Probable hypothesis is that our non-abortive females have contracted the parasite during a previous gestation, or

outside a gestation period, as they are all multiparous and aged between 3 and 6 years (Data not shown). As concerns the abortive and seropositive ewes, we cannot blame *T. gondii* as the unique responsible agent for these abortions, because the serology of the fetal fluids and further examination of aborted fetuses were not practiced, nevertheless the suspicion is high for one of the abortive ewes whose antibody titer reached 1:1024.

In goats, the disease is a common cause of abortion and neonatal mortality (Tenter et al., 2000; Lindsay and Dubey, 2007). However, in the present study, abortive females are seronegative; abortion may be due to another cause, whereas the seropositivity of the non-abortive females (16.33%) would have the same arguments as those given for the sheep. According to Ndiaye et al. (1996), toxoplasmosis in goats contributes more to neonatal deaths (82%) than to other types of loss, namely: abortions (44%) and weakness (56%).

Conclusion

In Algeria, anti-*Toxoplasma* antibodies were revealed for the first time, in cattle, sheep and goats proving thereby the farm contamination by oocysts. The parasite has never been incriminated before because no research has been carried out, it could be responsible for one part of reproductive disorders, such as embryonic mortality and observed abortions. Further studies are needed to assess its involvement as an abortive agent other than *Brucella.*

A positive serology of livestock would favor contamination of their products and the high human seroprevalence recorded in Algeria could be partly explained by the consumption of contaminated animal products.

Conflict of Interest

The authors have not declared any conflict of interest.

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Phytosociological survey of weed in cassava cultivation in Southwestern Bahia, Brazil

Maurício Robério Silva Soares[1]*, Alcebíades Rebouças São José[2], Aderson Costa Araujo Neto[1], Raelly da Silva Lima[1], Eduardo de Souza Moreira[1] and Thiago Reis Prado[1]

[1]Postgraduate Program of Agricultural Sciences of the Universidade Estadual do Sudoeste da Bahia (State University of Southwestern Bahia), Vitória da Conquista, Bahia, Brazil.
[2]Crop and Animal Production Department of the Universidade Estadual do Sudoeste da Bahia (State University of Southwestern Bahia), Vitória da Conquista, Bahia, Brazil.

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Phytosociological surveys are basis for weed management in agricultural crops. We aimed in this study to survey weed within a cassava cultivation field in the city of Vitória da Conquista, Southwestern Bahia, Brazil. The crop was grown for 18 months (from January 2013 to July 2014), with samples at 35, 70 and 105 days after planting (first year cultivation), and at 350, 385 and 420 days after planting (second year cultivation). Sampling was performed according to inventory square method, in which a 0.25 m^2 iron frame is thrown randomly on the cropland. Then, weed within this metal square area are cut at ground level, identified, quantified and afterwards placed into an oven at 65°C during 72 h to obtain dry mass of each species. Evaluated phytosociological parameters were frequency, relative frequency, density, relative density, abundance, relative abundance and importance value index. The main identified families in the survey were Malvaceae, Asteraceae and Poaceae. In total, it was assessed 14 families, 32 genera and 38 species of weeds. The highest importance value index was found for *Sida rhombifolia*, *Cynodon dactylon* and *Brachiaria plantaginea*. Regarding dry mass, *Panicum maximum*, *B. plantaginea* and *S. rhombifolia* had the largest values. It was concluded that weed control methods must focus on species and consider reinfestations in the second crop year.

Key words: *Manihot esculenta* Crantz, infesting community, competition, weed-competition.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a crop with great social and economic importance in Brazil, being cultivated in more than 1.9 million hectares and its production is intended mainly to the production of flour, starch and *in natura* consumption (IBGE, 2013). The great social importance of this crop is due to its exploitation in regions with dry seasons and/or poor soils, where occur the lowest levels of human development index (HDI) of Brazil and the world (Silva et al., 2014).

On national scenario, Bahia is one of the main producing states, generating near 1.85 million tons, 8.72% of national production, which is 21.22 million tons, and a yield of 13.91 tons ha^{-1} (IBGE, 2014). Vitória da Conquista city is home to a prominent micro region of

*Corresponding author. E-mail: mauriciouesb@hotmail.com, Tel: (55) 77 34248632.

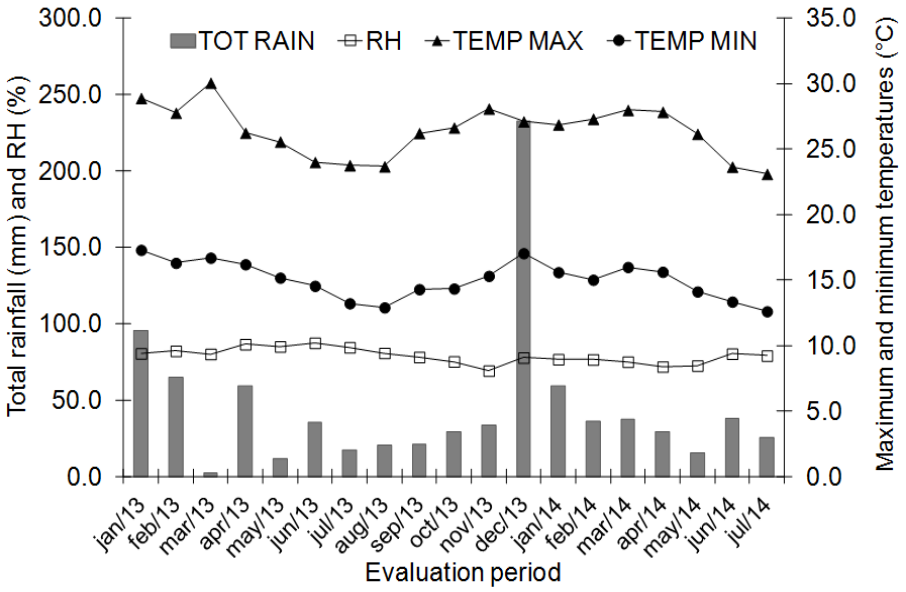

Figure 1. Monthly average of rainfall (mm), air relative humidity (%) and maximum and minimum temperature (°C), in Vitória da Conquista-BA, Brazil. From January 2013 to July 2014. *Source: National Institute of Meteorology - INMET/ Vitória da Conquista, BA, Brazil, 2014.

cassava production, accounting for approximately 10% of the state production (IBGE, 2008). However, despite its importance, the root yield is considered low when compared with the crop production potential of up to about 90 t ha^{-1} of roots (Cock et al., 1979).

Low production rates are common in other Brazilian regions, in which the main limiting factors are; little adoption of adequate agronomic technology, low fertility of soils, low quality planting material, unproductive varieties and/or poorly adapted to the region, weed competition, among others (Cardoso et al., 2013).

Weed in cassava cultivation has been reported as one of the main factors affecting crop yield. According to Albuquerque et al. (2008), root yield can be reduced by more than 90% in absence of weed control. This is due mainly to a slow initial growth of cassava plants, which facilitates weed species development, favoring the competition for water, light, nutrients, carbon dioxide and physical space (Azevêdo et al., 2000). In addition, cassava harvest can occur up to two years after planting, when roots are delivered to processing industry (Silva et al., 2012). Because of long cultivation and the soil partial covering by the plant, several weed infestations can occur within the planting area, which might increase crop yield losses (Johanns and Contiero, 2006). According to Cruz and Pelacani (1993), shading by weeds increases plant height, without increase in shoot biomass accumulation and reduction of leaf area index. They concluded that, with less exposure to light, cassava stem and leaf dry mass and root yield are compromised.

For a proper weed management, local species should be identified, as well as the knowledge of those which are most important (Oliveira and Freitas, 2008). Such information can be achieved by means of phytosociological surveys (Tuffi Santos et al., 2004). From this survey, it is possible to assess the plant composition and their frequency, density, abundance and relative importance index of the species and determine an optimal period for controlling them; which can increase control efficiency, streamline costs and reduce environmental impact of cassava production (Isaac and Guimarães, 2008; Guglieri et al., 2009).

Given the above, the authors aimed to identify and quantify the main species of weed in cassava cultivation field in Vitória da Conquista, Bahia, Brazil.

MATERIALS AND METHODS

The survey was carried out from February 2013 to July 2014, in the experimental field of the State University of the Southwestern Bahia, Campus in Vitória da Conquista, BA, Brazil. It located at 14° 51' S, 40° 50' W geographical coordinates and at 941-m average altitude. According Köppen, local climate is classified as *Cwa* type (high-altitude tropical climate) with annual rainfall of 741 mm. Local soil is classified as Dystrophic Yellow Oxisol, with loam-clay-sand texture over a plain relief (EMBRAPA, 2006).

Figure 1 displays weather data of the assessed period related to rainfall, relative humidity, maximum and minimum temperature. Soil preparation was made in conventional way with plowing, harrowings and furrowing. Fertilization was performed according soil analysis and recommendations for cassava crop (Nogueira and Gomes, 1999), applying in the first year 40 kg ha^{-1} P_2O_5, directly in planting furrow; 70 kg ha^{-1} N and 30 kg ha^{-1} K_2O, in top-dressing, 60 days after planting. In the second year, 60 Kg N and 60 Kg K_2O

were applied as top-dressing in the beginning of the rainy season. Planting was manually performed in January 2013, using 'Caititê' variety with about 2 to 3 cm stem diameter, 20 cm length and seven buds. Plant spacing was 1.0 m between rows and 0.6 m between plants, totaling 16,666 plants ha^{-1}.

Crop was grown for 18 months with evaluations every 35 days since planting; thus, there were evaluations at 35, 70 and 105 days after planting. Weeds were characterized at the crop initial stage (first year), and at 350, 385 and 420 days, in the second crop year, when weed reinfestation might occur due to when rainy season begin.

Weeds were identified and quantified by the inventory square method (Braun-Blanquet, 1979). A metal squared frame of 0.5 × 0.5 m (0.25 m^2) was thrown randomly within plots. Each plot had 33.6 m^2 (8.4 m long × 4 m wide), totaling 604.8 m^2. Eighteen samplings were performed for each period, with 108 samplings.

Weed from each sample were removed by cutting shoot at the ground level, packaging them in paper bags and transferred to the Laboratory of Biotechnology, where they were identified based on specialized bibliography (Lorenzi, 2008; Kissmann and Groth, 2000). Then, they were counted and dried in an air-forced oven at 65°C for 72 h for dry matter measurements.

From species identification, phytosociological parameters were determined according to Curtis and Mcintosh (1950) and Mueller-Dombois and Ellenberg (1974). Such parameters were:

(a) $$\text{Density (D):} \frac{\text{Total number of plants per species}}{\text{Total number of squares (total area)}}$$

(b) $$\text{Relative Density (Dr):} \frac{\text{Species density x 100}}{\text{All species total density}}$$

(c) $$\text{Frequency (F):} \frac{\text{Number of squares with certain species}}{\text{Total number of squares (total area)}}$$

(d) $$\text{Relative Frequency (Fr):} \frac{\text{Species frequency x 100}}{\text{All species frequency}}$$

(e) $$\text{Abundance (A):} \frac{\text{Number of plants per species}}{\text{Number of squares with certain species}}$$

(f) $$\text{Relative Abundance (Ar):} \frac{\text{Species abundance} \times 100}{\text{All species total abundance}}$$

(g) Importance Value Index (IVI): Relative frequency + relative density + relative abundance

RESULTS AND DISCUSSION

According to the phytosociological survey, local weed community was composed by 38 species, divided into 32 genera and 14 families in a total of 3413 plants. Concerning species number, Malvaceae (nine), Asteraceae and Poaceae (both seven) can be highlighted, which had 60.5% of total number of weed species (Table 1). Some families found in this survey are common in cassava crops, being also reported in other surveys such as Otsubo et al. (2002), Albuquerque et al. (2008) and Guglieri et al. (2009), point out these families as the richest families in weed species found in cassava cultivations.

Weed community was considered heterogeneous, when compared to Albuquerque et al. (2014) research, who evaluated weed occurrence in cassava fields of Roraima (Boa Vista/ RR, Brazil). The authors found 27 weed species distributed into 21 genera and 8 families. Huziwara et al. (2009) surveyed weed communities in Campos de Goytacazes-RJ and identified only 10 species from nine genera and nine families in cassava crops.

S. rhombifolia, *Cynodon dactylon* and *Brachiaria plantaginea* were predominant with a high number of plants along the six evaluations. *S. rhombifolia* was 33.60% of all surveyed plants (1.147), followed by *C. dactylon* with 14.36% (490) and *B. plantaginea* with 13.39% (457) (Table 1).

Concerning the phytosociological parameters (Tables 2, 3 and 4), it can be seen that *S. rhombifolia* had relative abundance value smaller than *C. dactylon* only at 35 DAP, presenting the highest phytosociological index of the survey, and IVI values varying from 58.92 to 71.7% and average of 65.03%.

S. rhombifolia widespread occurrence within experimental area can be attributed to its high infestation potential, once the species has high seed production and ease to disperse. As stated by Pitelli (1985), relative importance degree of infesting species at a certain location is given by balance of phytosociological indexes; therefore, it is the most weighted evaluation of a plant population. Furthermore, unsuitable plant density, slow growth varieties and inadequate planting area management are related to increased competition between weeds and cassava plants (Almendra, 2005).

S. rhombifolia grows together with annual and perennial crops, being extremely competitive due to its extensive root system that may reach 50 cm depth (Lorenzi, 2008; Kissmann and Groth, 2000). Some studies reported that this plant might produce near 28.2 thousand seeds m^{-2} during a single summer cycle as soybean crop weed (Fleck et al., 2003). The species was mentioned as weed in cassava plantations by Azevêdo et al. (2000) and Albuquerque et al. (2008), in corn field (Macedo et al., 2003), sugarcane (Oliveira and Freitas, 2008) and soybean (Voll et al., 2005).

C. dactylon and *B. plantaginea* alternated for the highest phytosociological indexes, and *B. plantaginea* showed the highest relative frequency, while *C. dactylon,* the highest relative density and abundance. These indexes reflect that in cassava field, *C. dactylon* keeps concentrated in "spots". This weed is considered one of the most important grassy weeds, mainly for sugarcane crop in Brazil as it is hard to eradicate them once

Table 1. Phytosociological survey of weed species in a cassava cultivation field. Plants were identified by common name, family, scientific name and number of plants per species. Vitória da Conquista / BA, Brazil (2014).

Common name	Family/Species	Number of plants per species						
		Coexistence period (DAP)						
		35	70	105	350	385	420	Total
Caruru gigante	**Amaranthaceae**							
	Amaranthus retroflexus L.	-	3	-	-	-	-	**3**
	Asteraceae							
Carrapicho rasteiro	*Acanthospermum australe* (Loefl.) Kuntze	51	26	42	14	17	16	166
Picão preto	*Bidens pilosa* L.	10	5	10	3	-	-	28
Picão grande	*Blainvillea rhomboidea* Cass.	77	38	63	20	5	-	203
Falsa serralha	*Emilia sonchifolia* (L.) DC.	10	-	-	-	5	1	16
Picão roxo	*Eupatorium ballotaefolium* Kunth	-	-	-	-	-	6	6
Botão de ouro	*Siegesbeckia orientalis* L.	9	-	-	-	-	-	9
Agrião do pasto	*Synedrellopsis grisebachii* Hieron. & Kuntze	-	-	-	3	-	-	3
	Brassicaceae							
Mentrusto	*Lepidium virginicum* L.	-	-	-	-	2	-	2
	Chenopodiaceae							
Anserina-rendada	*Chenopodium carinatum* R. Br.	-	-	-	2	-	-	2
	Commelinaceae							
Trapoeraba	*Commelina benghalensis* L.	-	-	-	-	3	-	3
	Euphorbiaceae							
Burra leiteira	*Chamaesyce hyssopifolia* (L.) Small	-	-	-	1	-	-	1
Quebra-pedra rasteira	*Euphorbia prostrata* Aiton	-	-	-	-	-	1	1
	Fabaceae							
Angiquinho	*Aeschynomene denticulata* Rudd.	3	-	6	-	-	-	9
Fedegoso	*Senna obtusifolia* (L.) H.S. Irwin & Barneby	25	9	11	-	4	-	49
	Malvaceae							
Falsa guanxuma	*Malvastrum coromandelianum* (L.) Garcke	6	-	4	-	-	-	10
Malva rasteira	*Pavonia cancellata* (L.) Cav.	36	6	3	5	9	3	62
Vassoura	*Pavonia sidifolia* Kunth	-	-	-	4	-	-	4
Guanxuma	*Sida cordifolia* L.	16	6	3	8	9	23	65
Guanxuma	*Sida rhombifolia* L.	321	235	314	126	72	79	1147
Guanxuma	*Sida spinosa* L.	-	-	1	-	-	-	1
Guanxuma branca	*Sida glaziovii* K. Schum.	-	-	-	4	-	-	4
Guanxumona dourada	*Sida urens* L.	-	-	2	-	-	6	8
Malva branca	*Waltheria indica* L.	1	-	8	1	-	-	10
	Molluginaceae							
Molugo	*Mollugo verticillata* L.	1	-	-	7	2	-	10
	Nyctaginaceae							
Agarra pinto	*Boerhavia diffusa* L.	2	-	-	-	-	-	2
	Poaceae							
Capim-marmelada	*Brachiaria plantaginea* (Link) Hitchc	86	122	165	37	20	27	457
Capim-carrapicho	*Cenchrus echinatus* L.	83	41	88	6	18	26	262
Grama-seda	*Cynodon dactylon* (L.) Pers.	144	154	90	55	20	27	490
Capim-colchão	*Digitaria horizontalis* Willd.	-	-	-	1	-	-	1
Capim-colonião	*Panicum maximum* Jacq.	-	-	-	7	6	7	20
Capim favorito	*Rhynchelytrum repens* (Willd.) C.E. Hubb.	-	-	-	-	4	5	9
Capim rabo de raposa	*Setaria geniculata* P. Beauv.	-	-	-	-	5	4	9
	Portulacaceae							
Beldroega	*Portulaca oleracea* L.	60	59	44	29	11	-	203
Onze-horas	*Portulaca mucronata* Link	-	-	-	1	-	-	1
	Rubiaceae							

Table 1.Contd.

Mata-pasto	*Diodia teres* Walter	31	15	10	25	15	14	110
Poaia-do-cerrado	*Richardia scabra* L.	1	-	7	15	1	2	26
	Solanaceae							
Caiçara	*Solanum erianthum* D. Don	1	-	-	-	-	-	1
	Total	974	719	871	374	228	247	3413

Table 2. Presence in square (PS), relative frequency (Fr), relative density (Dr), relative abundance (Ar) and importance value index (IVI) of weeds sampled at 35 and 70 days after planting (DAP) in cassava field. Vitória da Conquista / BA, Brazil (2014).

Species	35 DAP					70 DAP				
	PS	Fr	Dr	Ar	IVI	PS	Fr	Dr	Ar	IVI
		---------- % ----------					---------- % ----------			
Acanthospermum australe	10	8.47	5.24	4.38	18,1	5	6.02	3.62	6.31	15.95
Aeschynomene denticulata	3	2.54	0.31	0.86	3,71	-	-	-	-	-
Amaranthus retroflexus	-	-	-	-	-	1	1.20	0.42	3.64	5.26
Bidens pilosa	2	1.69	1.03	4.29	7,01	1	1.20	0.70	6.07	7.97
Blainvillea rhomboidea	10	8.47	7.91	6.61	22,99	8	9.64	5.29	5.76	20.69
Boerhavia difusa	1	0.85	0.21	1.72	2,77	-	-	-	-	-
Brachiaria plantaginea	8	6.78	8.83	9.22	24,83	14	16.87	16.97	10.57	44.41
Cenchrus echinatus	9	7.63	8.52	7.91	24,06	5	6.02	5.70	9.95	21.68
Cynodon dactylon	7	5.93	14.78	17.65	38,37	11	13.25	21.42	16.99	51.66
Diodia teres	8	6.78	3.18	3.33	13,29	5	6.02	2.09	3.64	11.75
Emilia sonchifolia	3	2.54	1.03	2.86	6,43	-	-	-	-	-
M. coromandelianum	3	2.54	0.62	1.72	4,87	-	-	-	-	-
Mollugo verticillata	1	0.85	0.10	0.86	1,81	-	-	-	-	-
Pavonia cancellata	11	9.32	3.70	2.81	15,83	5	6.02	0.83	1.46	8.31
Portulaca oleracea	12	10.17	6.16	4.29	20,62	9	10.84	8.21	7.96	27.00
Richardia scabra	1	0.85	0.10	0.86	1,81	-	-	-	-	-
Senna obtusifolia	5	4.24	2.57	4.29	11,09	3	3.61	1.25	3.64	8.51
Sida cordifolia	3	2.54	1.64	4.58	8.76	2	2.41	0.83	3.64	6.88
Sida rhombifolia	17	14.41	32.96	16.2	63.57	14	16.87	32.68	20.37	69.92
Siegesbeckia orientalis	2	1.69	0.92	3.86	6.48	-	-	-	-	-
Solanum erianthum	1	0.85	0.10	0.86	1.81	-	-	-	-	-
Waltheria indica	1	0.85	0.10	0.86	1.81	-	-	-	-	-
Total	118	100	100	100	300	83	100	100	100	300

established (Carbonari et al., 2005; Ferreira et al., 2011). This species presented high value among the evaluated parameters, which may be due to its underground breeding structures, which enables growth retaken after some days. Moreover, Cardoso et al. (2013), who performed a phytosociological survey in the studied city, mentioned it as one of the main infesting plants in cassava cultivation.

B. *plantaginea* demonstrated great adaptability and aggressiveness and had high phytosociological indexes in all evaluations. This African grass is mainly propagated through seeds with primary dormancy during maturation (Lorenzi, 2008). This way germination is spread all over the time being of difficult control (Kissmann, 1997).

Compared to the first crop year, the second showed a reduction in weed number, frequency, density and abundance (Tables 2, 3 and 4). This reduction showed greater competition during the initial phase of cassava development. This fact underscores the importance of maintaining the crop free of weeds during this period. This fact is possibly connected to a slow initial growth of cassava plants, which associated with a wide planting space, provides low competitive ability with weeds, especially with regard to soil coverage, allowing weeds to emerge along a period of time (Lorenzi and Dias, 1993). Biffe et al. (2010) obtained similar results, in which they

Table 3. Presence in square (PS), relative frequency (Fr), relative density (Dr), relative abundance (Ar) and importance value index (IVI) of weeds sampled at 105 and 350 days after planting (DAP) in cassava field. Vitória da Conquista / BA, Brazil (2014).

Species	105 DAP					350 DAP				
	PS	Fr	Dr	Ar	IVI	PS	Fr	Dr	Ar	IVI
	---------- % ----------					---------- % ----------				
Acanthospermum australe	7	7.87	4.82	5.33	1802	4	4.88	3.74	4.9	13.52
Aeschynomene denticulata	2	2.25	0.69	2.66	5.60	-	-	-	-	-
Bidens pilosa	1	1.12	1.15	8.88	11.15	1	1.22	0.80	4.20	6.22
Blainvillea rhomboidea	9	10.11	7.23	6.22	23.56	3	3.66	5.35	9.33	18.34
Brachiaria plantaginea	14	15.73	18.94	10.47	45.14	7	8.54	9.89	7.40	25.83
Cenchrus echinatus	7	7.87	10.10	11.17	29.13	3	3.66	1.60	2.80	8.06
Chamaesyce hyssopifolia	-	-	-	-	-	1	1.22	0.27	1.40	2.89
Chenopodium carinatum	-	-	-	-	-	1	1.22	0.53	2.80	4.55
Cynodon dactylon	7	7.87	10.33	11.42	29.62	7	8.54	14.71	11.00	34.24
Digitaria horizontalis	-	-	-	-	-	1	1.22	0.27	1.40	2.89
Diodia teres	4	4.49	1.15	2.22	7.86	6	7.32	6.68	5.83	19.83
M. coromandelianum	2	2.25	0.46	1.78	4.48	-	-	-	-	-
Mollugo verticillata	-	-	-	-	-	2	2.44	1.87	4.90	9.21
Panicum maximum	-	-	-	-	-	6	7.32	1.87	1.63	10.82
Pavonia cancellata	3	3.37	0.34	0.89	4.60	4	4.88	1.34	1.75	7.96
Pavonia sidifolia	-	-	-	-	-	1	1.22	1.07	5.60	7.89
Portulaca mucronata	-	-	-	-	-	7	1.22	0.27	1.40	2.89
Portulaca oleracea	7	7.87	5.05	5.58	18.5	1	8.54	7.75	5.8	22.09
Richardia scabra	2	2.25	0.80	3.11	6.16	3	3.66	4.01	7.00	14.67
Senna obtusifolia	3	3.37	1.26	3.26	7.89	-	-	-	-	-
Sida cordifolia	3	3.37	0.34	0.89	4.60	4	4.88	2.14	2.80	9.82
Sida glaziovii	-	-	-	-	-	2	2.44	1.07	2.80	6.31
Sida rhombifolia	14	15.73	36.05	19.92	71.7	15	18.29	33.69	11.76	63.74
Sida spinosa	1	1.12	0.11	0.89	2.13	-	-	-	-	-
Sida urens	1	1.12	0.23	1.78	3.13	-	-	-	-	-
Synedrellopsis grisebachii	-	-	-	-	-	2	2.44	0.8	2.1	5.34
Waltheria indica	2	2.25	0.92	3.55	6.72	1	1.22	0.27	1.4	2.89
Total	89	100	100	100	300	82	100	100	100	300

found that weed interference in cassava is greater between 18 and 100 days after planting.

Despite the reduction in plant number in the second year, there was a steady increase in dry mass of the remaining weeds along the evaluations (Figure 2). This behavior can be explained by cassava shading on weeds or competition among weeds. According to Radosevich et al. (1996), as weed density and development increases, especially those that germinated and emerged at the beginning of the crop cycle such as cassava, intraspecific and interspecific competition increases, so that the highest and most developed weeds become dominant, while the smaller ones are removed or die. This behavior explains plant number reduction and weed dry mass increase in the second year.

Table 5 shows averages of dry mass by weed species, in which the greatest values belong to *Panicum maximum*, *B. plantaginea* and *S. rhombifolia*, totaling 829.9, 437.2 and 278.5 g m^{-2}, respectively.

Among the grasses with higher dry matter accumulation, *P. maximum* had significant growth in second crop year (350, 385 and 420 DAP), showing its great competitive power as a function of biomass production capacity compared to the other species. Such an occurrence is probably related to the weed presence in neighboring areas, defoliation of cassava plants during maturation and seed dispersal of this species, applied fertilizer and the beginning of rainy season. These conditions certainly favored its establishment and development within the area, once the weed is very demanding in light, fertility and soil moisture. On the other hand, *B. plantaginea* had high dry matter accumulation in all evaluations, which indicates its good adaptation to the environment. According to Maciel et al. (2010), several species of Poaceae family are perennial and produce many seeds, increasing its spread and colonization

Table 4. Presence in square (PS), relative frequency (Fr), relative density (Dr), relative abundance (Ar) and importance value index (IVI) of weeds sampled at 385 and 420 days after planting (DAP) in cassava field. Vitória da Conquista / BA, Brazil (2014).

Species	385 DAP					420 DAP				
	PS	Fr	Dr	Ar	IVI	PS	Fr	Dr	Ar	IVI
	---------- % ----------					---------- % ----------				
Acanthospermum australe	3	4.29	7.46	10.06	21.8	4	5.48	6.48	8.46	20.42
Blainvillea rhomboidea	3	4.29	2.19	2.96	9.44	-	-	-	-	-
Brachiaria plantaginea	9	12.86	8.77	3.95	25.57	10	13.7	10.93	5.71	30.34
Cenchrus echinatus	6	8.57	7.89	5.33	21.79	7	9.59	10.53	7.85	27.97
Commelina benghalensis	1	1.43	1.32	5.33	8.07	-	-	-	-	-
Cynodon dactylon	4	5.71	8.77	8.88	23.36	5	10.96	10.93	7.14	29.03
Diodia teres	5	7.14	6.58	5.33	19.05	8	6.85	5.67	5.92	18.44
Emilia sonchifolia	2	2.86	2.19	4.44	9.49	1	1.37	0.40	2.11	3.89
Eupatorium ballotaefolium	-	-	-	-	-	3	4.11	2.43	4.23	10.77
Lepidium virginicum	2	2.86	0.88	1..78	5.51	-	-	-	-	-
Euphorbia prostrata	-	-	-	-	-	1	1.37	0.40	2.11	3.89
Mollugo verticillata	1	1.43	0.88	3.55	5.86	-	-	-	-	-
Panicum maximum	6	8.57	2.63	1.78	12.98	7	9.59	2.83	2.11	14.54
Pavonia cancellata	4	5.71	3.95	4.00	13.66	2	2.74	1.21	3.17	7.13
Portulaca oleracea	3	4.29	4.82	6.51	15.62	-	-	-	-	-
Rhynchelytrum repens	1	1.43	1.75	7.10	10.29	1	1.37	2.02	10.57	13.97
Richardia scabra	1	1.43	0.44	1.78	3.64	1	1.37	0.81	4.23	6.41
Setaria geniculata	-	-	-	-	-	3	4.11	1.62	2.82	8.55
Senna obtusifolia	2	2.86	1.75	3.55	8.16	-	-	-	-	-
Setaria geniculata	1	1.43	2.19	8.88	125	-	-	-	-	-
Sida cordifolia	5	7.14	3.95	3.20	14.29	7	9.59	9.31	6.95	25.85
Sida rhombifolia	11	15.71	31.58	11.62	58.92	12	16.44	31.98	13.92	62.34
Sida urens	-	-	-	-	-	1	1.37	2.43	12.69	16.49
Total	70	100	100	100	300	73	100	100	100	300

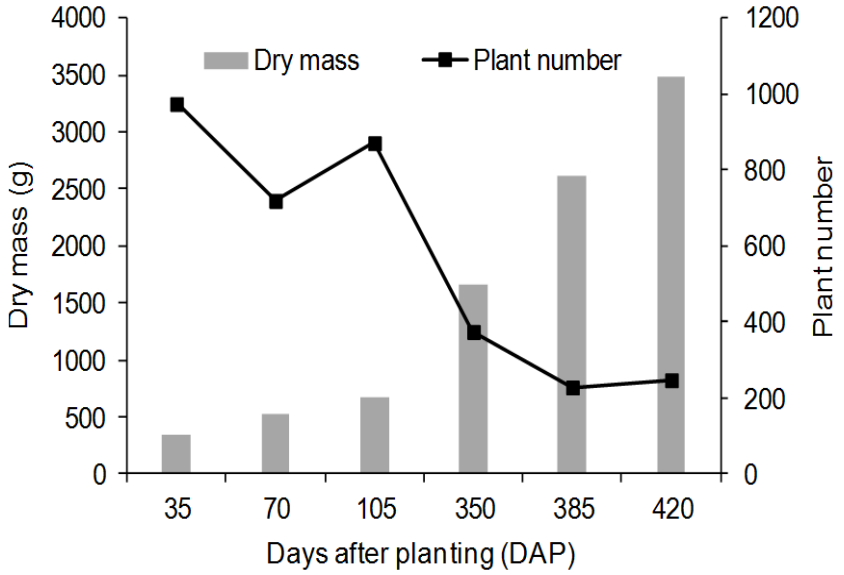

Figure 2. Weed plant number and dry mass (g) sampled at 35, 70, 105, 350, 385 and 420 days after planting (DAP) in cassava cultivation. Vitória da Conquista / BA, Brazil (2014).

Table 5. Dry mass (g m^{-2}) of each weed species sampled at 35, 70, 105, 350, 385 and 420 days after planting (DAP) in cassava cultivation. Vitória da Conquista / BA, Brazil (2014).

Species	Dry mass (g m^{-2})						
	35	70	105	350	385	420	Total
Acanthospermum australe	11.60	2.80	4.04	7.01	4.17	19.39	49.02
Aeschynomene denticulata	0.13	—	1.13	—	—	—	1.26
Amaranthus retroflexus	—	0.10	—	—	—	—	0.10
Bidens pilosa	0.46	0.45	0.87	0.20	—	—	1.99
Blainvillea rhomboidea	3.37	5.03	15.25	12.61	2.86	40.60	79.71
Boerhavia diffusa	0.05	—	—	—	—	—	0.05
Brachiaria plantaginea	11.07	36.38	52.29	56.94	153.47	127.09	437.22
Cenchrus echinatus	6.01	9.67	13.87	15.53	17.06	24.14	86.28
Chamaesyce hyssopifolia	—	—	—	0.08	—	—	0.08
Chenopodium carinatum	—	—	—	4.42	—	—	4.42
Commelina benghalensis	—	—	—	—	11.24	—	11.24
Cynodon dactylon	22.18	27.96	26.27	28.59	22.45	33.49	160.95
Digitaria horizontalis	—	—	—	2.00	—	—	2.00
Diodia teres	0.77	2.21	1.20	3.79	13.58	10.64	32.21
Emilia sonchifolia	0.58	—	—	—	9.28	0.25	10.11
Eupatorium ballotaefolium	—	—	—	—	—	33.41	33.41
Euphorbia prostrata	—	—	—	—	—	3.31	3.31
Lepidium virginicum	—	—	—	—	0.98	—	0.98
Malvastrum coromandelianum	0.29	—	0.12	—	—	—	0.41
Mollugo verticillata	0.02	—	—	0.87	0.07	—	0.96
Panicum maximum	—	—	—	153.65	283.00	393.27	829.93
Pavonia cancellata	1.09	0.71	0.57	7.51	23.34	5.50	38.72
Pavonia sidifolia	—	—	—	2.59	—	—	2.59
Portulaca mucronata	—	—	—	0.23	—	—	0.23
Portulaca oleracea	12.20	23.77	4.24	25.91	10.34	—	76.47
Rhynchelytrum repens	—	—	—	—	2.22	3.33	5.55
Richardia scabra	0.04	—	0.87	5.26	0.37	0.41	6.95
Senna obtusifolia	8.51	5.06	7.10	—	1.30	—	21.97
Setaria geniculata	—	—	—	—	13.29	42.45	55.75
Sida cordifolia	1.43	1.34	0.40	8.97	17.42	47.33	76.89
Sida glaziovii	—	—	—	0.69	—	—	0.69
Sida rhombifolia	7.35	14.66	36.83	77.79	67.17	74.78	278.58
Sida spinosa	—	—	0.16	—	—	—	0.16
Sida urens	—	—	0.86	—	—	11.54	12.39
Siegesbeckia orientalis	0.18	—	—	—	—	—	0.18
Solanum erianthum	0.09	—	—	—	—	—	0.09
Synedrellopsis grisebachii	—	—	—	1.06	—	—	1.06
Waltheria indica	0.01	—	1.08	0.06	—	—	1.14
Total	87.42	130.15	167.14	415.76	653.63	870.92	2325.02

potential at different environments. *S. rhombifolia* and *C. dactylon* showed dry matter values lower than the first two and had the highest phytosociological indices (Table 5).

Several other authors conducted phytosociological surveys in the cassava crops along Brazil. In these surveys, they identified numerous weed species of distinct genera and families (Azevêdo et al., 2000; Johanns and Contiero, 2006; Albuquerque et al., 2008; Guglieri et al., 2009; Huziwara et al., 2009; Pinotti et al., 2010; Biffe et al., 2010; Cardoso et al., 2013; Albuquerque et al., 2014). The species identified in the study cited above varied according to planting period, management, location and land history. Although, there are common species in various parts of the country, each site had a peculiarity regarding the dominant species. In

the present study, we verified few predominant species (*S*. *rhombifolia*, *C*. *dactylon* and *B*. *plantaginea*). This fact can be attributed to rainfall irregularities, high temperatures and soil type. Therefore, such studies should be performed in several producing regions, since weed community composition differs among seasons and different places.

Significant part of cassava production costs can be attributed to weed control, which may vary according to weed species and population densities. In this context, the knowledge of weed community distribution and composition is important for solving problems related to potential infestations, being directly connected to the control strategy (Pinotti et al., 2010; Aguiar et al., 2011). Thus, understanding the weed population dynamics based on phytosociological parameters is essential for an ideal crop management (Oliveira and Freitas, 2008).

Despite the greater number of plants was observed for up to 105 days after planting cassava (75.12% of total), grasses in the second year were significant and had high dry matter values. Therefore, in crops with aggressive grass species such as *P*. *maximum* and *B*. *plantaginea*, as found in this survey, we recommend a weed management plan taking into account the two crop years. Given the above mentioned, it can be said that dry matter data complemented the phytosociological survey.

Conclusions

The weed community composition was considered heterogeneous presenting 38 species belonging to 32 genera and 14 families. The families with the largest number of species identified were Malvaceae, Asteraceae and Poaceae, predominating the species *S. rhombifolia*, *C. dactylon* and *B. plantaginea*.
The occurrence of grasses such as *P. maximum* and *B. plantaginea* during the crop cycle indicates the need for a weed management plan focusing on both crop years.

Conflict of Interest

The authors did not pronounce any conflict of interest.

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Carcass pH and color of Horro rams under different management practices at Ambo University, Ethiopia

Chala Merera*, Ulfina Galmessa, Tesfaw Ayele and Lemma Fita

Department of Animal Science, Ambo University, P. O. Box 19, Ethiopia.

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This study was conducted to evaluate and determine the carcass pH and color of Horro rams under different management practices at Ambo University. A total of 24 Horro rams were randomly assigned to the following three treatments: T1 (Day 1 rest before slaughter), T2 (Rhodes hay *ad libitum)* and T3 (Rhodes hay *ad libitum* + 400 g concentrate per head/day). Carcass pH was determined at 15 min, 24, 48, and 72 h post slaughter using pH Meter. Data were analyzed using the General linear model procedures of Statistical Analysis System Software 9.2 (SAS, 2009). The ultimate carcass pH of concentrate supplemented Horro rams (pH24 = 5.67) was lower (P < 0.001) than rams fed on Rhodes hay *ad libitum* and animals slaughtered immediately after day 1 rest of transportation to experimental site (5.88, and 5.87, respectively). The majority of sensory panelists (> 62%) reported that carcass color was bright red for supplemented Horro rams and red color for those fed on Rhodes hay *ad libitum* and slaughtered immediately after one day rest of transportation. Carcass darkness/discoloration was not observed up to four days post slaughter from values of carcass pH, color estimation of this experiment and from comparisons of carcass pH measures with values in the literatures. Concentrate supplementation had significant and positive influence on carcasses pH and color of Horro rams. This study disproved the dispute or claim about the problem of early darkening of carcasses of highland animals. Thus, management practices like optimum feeding along sufficient rest after transportation would improve the carcass pH and color.

Key words: Carcass, pH, color, concentrate, Horro lambs.

INTRODUCTION

In Ethiopia, sheep population is estimated at 25.5 million (CSA, 2013). But, their productivity is low due to feed shortage, diseases, lack of animal welfare and inadequate market information. Based on customer feedback or anecdotal evidence, personnel of many abattoirs in Ethiopia exporting small ruminant carcasses to markets in the Middle East have stated that carcass shelf-life is shorter for animals from highland than lowland areas. Furthermore, it is claimed that the problem of early darkening of carcasses of highland animals exists for both sheep and goats (Girma et al., 2010). Goat and sheep carcasses from highland areas of Ethiopia may darken more quickly compared with lowland areas, and 1 or 2 days of rest before slaughter can increase lightness

*Corresponding author. E-mail: chmerera@gmail.com

of the surface of goat carcasses. Carcasses of goats and sheep from the highland area were darker than those from the lowland area (Girma et al., 2010). In this regard, Merera et al. (2010) suggested that in some instances commercial animal harvest might occur with rest of less than one day, which could prevent recovery from stress such as replenishment of muscle glycogen.

There is a huge loss of earning foreign income and some attempts have been made to investigate carcass darkening of few goat and sheep breeds (Ameha, 2008; Girma et al., 2010; Merera et al., 2010). But, this 'defect' has not been well investigated. Above all, there is no information on carcass pH and color of Horro sheep. The most carcass color that has been preferred is bright or red and the universal acceptable meat pH ranges from 5.5-5.9. Thus, it is timely and an urgent needs to properly investigate and understand the mutton color and pH of Horro sheep.

Thus, the objectives of this study were:

1. To evaluate and determine the carcass pH and color of Horro rams under different management practices at Ambo University;
2. To generate adequate information for sheep producers, mutton exporters and importers.

MATERIALS AND METHODS

Location and facilities of experimental site

The study was conducted at Ambo University sheep farm, which is approximately 115 km west of Addis Ababa, Ethiopia. Slaughter and associated measurements were performed at facilities of Animal Sciences Laboratory of the Ambo University. Rest and feeding of animals took place at sheep feedlot facility of the University.

Experimental animals and treatments

Horro sheep are the long fat tailed highland sheep mainly found in Horro Guduru zone of western Ethiopia. Horro rams with approximately similar age (1 year) and average initial body weight (21.31 ± 2.16 kg) and conformation were purchased from 'Gabaa Sanbataa' market found in Horro district of the Horro Guduru zone, approximately 190 km from Ambo University. Animals were transported as procedures for procurement, transportation and handling the once used by abattoirs in Ethiopia. A total of 24 Horro rams were randomly assigned to the following three treatments with 8 replicates. The treatments were Day 1 rest after transportation from local market to Ambo University and before slaughter (T1), Rhodes hay *ad libitum* (T2) and Rhodes hay *ad libitum* + 400 g concentrate per head/day (T3).

Horro rams randomly assigned for 90 days fattening treatments were drenched with an anthelmintic (half doze Albendazole) and sprayed with diazinon for external parasites. There was no health problem encountered during the experiment period. The composition of concentrate is 49.5% noug (*Guizotia abyssinica*) cake, 49.5% ground maize grain and 1% salt (Solomon et al., 1991). Water and moderate quality grass hay provided *ad libitum* for all treatments until slaughter approximately 12:00 h the day preceding slaughter.

Measurements

The initial, fortnight and slaughter live body weight were taken at the initial, fortnightly and at the end of the feeding trial. The experimental animals were slaughtered after one day rest of arrival at experimental site and at the end of 3 months fattening period. Carcass pH was determined at 15 min, 24, 48, and 72 h post slaughter using pH Meter. The loin cut was chilled at 4°C for the preservation of the carcass in the refrigerator. Muscle pH was measured with a handheld pH meter (Model IQ150; IQ Scientific Instruments, Inc., Carlsbad, CA, USA) in both *longissimus dorsi* muscles after trimming the surface fat in the area of pH measurement, with duplicate readings, at 15 min, 24, 48 and 72 h after slaughter (Figure 1).

After pH was measured on the day of harvest, a loin was cut between the 11th and 13th ribs to expose the surface of *longissimus dorsi* muscle. Following a 15-min 'bloom' time, subjective color estimations were made by trained sensory panelists. Then carcass color was assessed subjectively using 5 point scale (1=light/bright, 2=Light red, 3=red, 4=dark red, and 5=dark). At 0, 1, 2, and 3 days post-slaughter, the same color estimations were made on the surface of loin cuts.

Statistical analysis

Data were analyzed using the General linear model procedures of Statistical Analysis System Software 9.2 (SAS, 2009). During analysis, treatment was considered as independent variable whereas average daily weight gain, carcass pH and color considered as dependent variables. Means were separated by least significant difference (LSD).

RESULTS AND DISCUSSION

Growth performance of Horro rams

Concentrate supplementation had significant effect on average daily weight gain (ADG) and as expected, the ADG was greater ($P < 0.001$) for the supplemented Horro rams compared to animals fed Rhodes hay *ad libitum* (Table 1). The change in live body weight/growth curve was substantially increased up to 30 days fattening duration and then after increased slightly which could be explained as compensatory growth in the first days of fattening periods.

The ADG of concentrate supplemented Horro rams obtained in this experiment (117.36 g/day) was greater than the ADG reported by previous studies of Ewnetu et al. (2006) and Kassahun (2000), who reported 47.3 and 70.9 g/day per animal for Horro male lambs, respectively. In line with this result, the previous study reported that daily live weight gains were greater ($P < 0.05$) for Horro ewe lambs supplemented with *Leucaena pallida* and concentrate compared with the un-supplemented treatment (Chala et al., 2013).

Carcass pH and color

Concentrate supplementation had significant positive

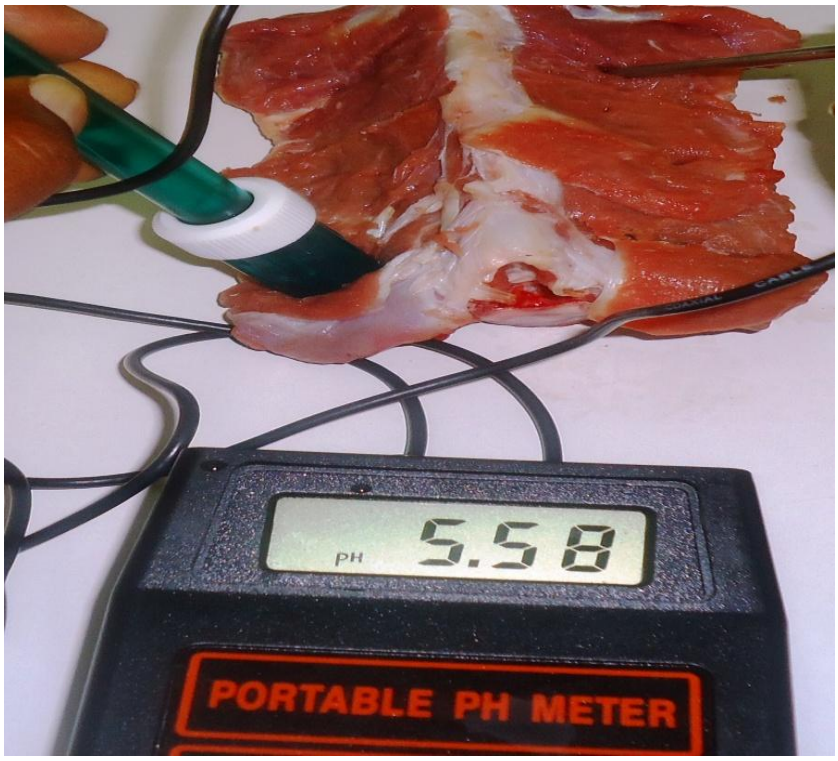

Figure 1. Ultimate Carcass pH (24 h post slaughter) value of fattened Horro rams.

Table 1. Live body weights and average daily gain of Horro rams under different management practices.

TRT	Initial live weight (kg)	Final live weight (kg)	ADG
1	21.63	----	----
2	21.64	22.64[b]	11.11[b]
3	21.45	32.00[a]	117.36[a]
SE	2.16	2.49	24.21
CV	----	9.03	15.72
R^2	----	80.12	84.69

T1: Animals slaughtered after Day 1 rest of transportation; T2: Rhodes hay *ad libitum* and T3: Rhodes hay *ad libitum* + 400 g concentrate per head/day. [ab] Means within columns without common superscript differ significantly at P < 0.001.

influence on carcass pH (Table 2). The carcass pH of concentrate supplemented Horro rams was lower (P < 0.001) than rams fed on Rhodes hay *ad libitum* and those slaughtered immediately after Day 1 rest of transportation to experiment site. For all treatments, carcass pH was appreciably decreased (P < 0.001) from day 0 to 1 and for concentrate supplemented treatment (Table 2 and Figure 2). The ultimate pH values observed on Day 1 post slaughter indicate that there was adequate muscle glycogen in the mutton of sheep with all treatments for production of normal lactic acid levels. Ultimate carcass pH (24 h post slaughter) values obtained from this study were within the international acceptable range of meat pH (5.5-5.9) for export/import market, indicating the glycogen levels in the muscle of the mutton was high enough to develop optimum level of lactic acid causing a fall in pH and thereby improving the shelf life of the mutton.

The results of this study are in agreement with the previous findings, who reported that the pH values found could be considered within the normal pH range, between 5.5 and 5.9 when the pH measurement was made 24 h after slaughter (Teixeira et al., 2005). The pH values, particularly the values obtained 24 h after slaughter, could be considered according to earlier recommendation, within the normal pH range assuming that an ultimate pH value greater than 5.9 is regarded as undesirable (Devine et al., 1993). The longissimus muscle ultimate pH tended to be higher for the grass

Table 2. Least square Mean values of carcass pH of Horro Rams under different management practices.

TRT	Days post slaughter			
	Day 0 (15 min)	Day 1 (24 h)	Day 2 (48 h)	Day 3 (72 h)
1	6.99 [b]	5.88[c]	5.87[c]	5.85[c]
2	7.01[b]	5.87[c]	5.88[c]	5.86[c]
3	6.90[a]	5.67[d]	5.54[e]	5.54[e]
Overall Mean	6.97	5.80	5.76	5.74
SE	0.04	0.07	0.04	0.05
CV	0.63	1.24	0.73	0.81
R^2 (%)	56.58	68.35	94.37	92.68
P-value	0.0002	0.0001	0.0001	0.0001

T1: Animals slaughtered after Day 1 rest of transportation; T2: Rhodes hay *ad libitum* and T3: Rhodes hay *ad libitum* + 400 g concentrate per head/day. [abcde] Means within rows and/or columns without common superscript differ significantly at P < 0.001.

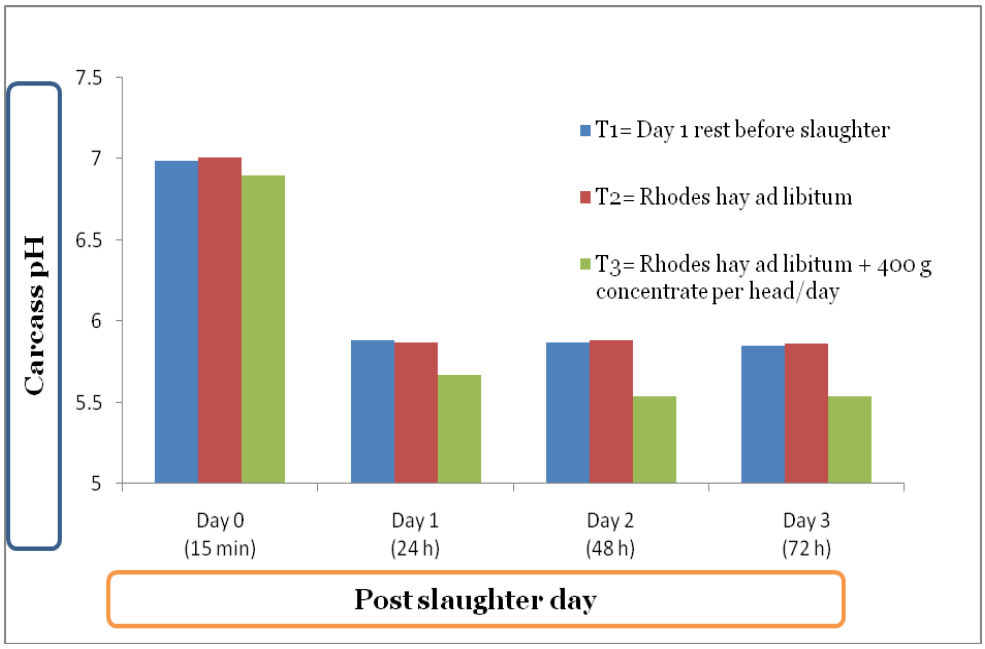

Figure 2. The change in carcass pH of Horro Rams on different post slaughter days.

lambs (pH24=5.62) compared to the stall lambs (pH24=5.57) (Priolo et al., 2002). High-energy diets protect animals from potentially glycogen-depleting stressors has been reported by Immonen et al. (2000). In general, the pH values on Day 0, 1, 2, and 3 post slaughter for all treatments were within the acceptable range of meat pH and comparable with several findings (Archimede et al., 2008; Hoffman et al., 2003; Johnson et al., 2005; Scerra et al., 2001; Teixeira et al., 2005).

As for carcass pH, concentrate supplementation had improved the redness color of carcass from Horro rams (Table 3). The majority of sensory panelists (> 62%) reported that carcass color of Horro rams was bright red for supplemented animals and red for animals fed on Rhodes hay *ad libitum* and slaughtered immediately after Day 1 rest of arrival/transportation to experiment site.

The current finding was in agreement with the previous study, who reported that feeding for 4 weeks before slaughter increased (P < 0.05) surface carcass lightness (L*=39.2) on day 3 post slaughter regardless of species and origin of goats and sheep (Girma et al., 2010). They were also reported that surface carcass redness (a*) on Day 3 post-slaughter was greater for sheep than for goats, indicating a greater degree of redness for sheep. All correlations between pH of the *longissimus dorsi* muscle at 24 h post-slaughter and color measures for the

Table 3. The frequency (%) values of Carcass color of Horro Rams under different management practices using sensory panelists.

TRT	Sensory panelists estimation (%) on post slaughter days												
	Day 0 (15 min)				Day 1 (24 h)			Day 2 (48 h)			Day 3 (72 h)		
	L*	La*	a*	da*	La*	a*	da*	La*	a*	da*	La*	a*	da*
1		23.08	71.79	5.13	20.83	54.17	25	20.83	62.5	16.67	29.17	50	20.83
2		9.52	52.38	38.10	19.05	42.86	38.10	14.29	71.43	14.29	8.33	58.33	33.33
3	4.17	66.67	29.17	---	62.5	37.5	----	70.83	29.17	---	66.67	33.33	---

Five color Scales: Light/Bright (L*), Light/Bright Red (La*), Red (a*), Black/dark Red (da*) and Black/dark (d*) carcass color. T1: Animals slaughtered after Day 1 rest of transportation; T2: Rhodes hay *ad libitum* and T3: Rhodes hay *ad libitum* + 400 g concentrate per head/day.

carcass surface on Day 3 were significant ($P < 0.05$). Similarly, meat from grass-fed lambs was darker ($P < 0.05$) in color (lower L*=46.1) than meat from stall animals (L*=49.23) up to 24 h of display and meat from stall fed animals was more tender and juicier than meat from grass-fed animals ($P < 0.01$) (Priolo et al., 2002). They also reported meat lightness (L*) was positively correlated with 6 days display for stall-fed lambs. In agreement to the above results, researchers revealed that the difference in meat lightness could have been partially caused by the slight difference in the ultimate pH since high pH meat tend to have a darker color, although meat from stall lambs had a significantly higher fat content than in grass lambs (Ledward et al., 1986).

In general, from this study, carcass darkness/discoloration was not observed up to four days post slaughter and from values of carcass pH and color estimation of this experiment. There was no evidence of short shelf life or early darkening carcasses of Horro rams. In addition to this, carcass darkening was not detected from comparisons of carcass pH measures with values in the literatures. Therefore, this study disproved the dispute or claim about the problem of early darkening of carcasses of highland animals.

CONCLUSIONS AND RECOMMENDATIONS

The study was conducted to evaluate and determine the carcass pH and color of Horro rams under different management practices at Ambo University. The ultimate carcass pH of concentrate supplemented Horro rams (pH24=5.67) was lower ($P < 0.001$) than rams fed on Rhodes hay *ad libitum* and animals slaughtered immediately after Day 1 rest of transportation to experimental site (pH24=5.88, and 5.87, respectively). The majority of sensory panelists (> 62%) reported that carcass color was bright red for supplemented Horro rams and red for animals fed on Rhodes hay *ad libitum* and slaughtered immediately after one day rest. Carcass darkness/discoloration was not observed up to four days post slaughter from values of carcass pH, color estimation of this experiment and from comparisons of carcass pH measures with values in the literatures. Concentrate supplementation had significant and positive influence on carcasses pH and color of Horro rams. This study disproved the dispute or claim about the problem of early darkening of carcasses of highland animals. Thus, management practices like optimum feeding along sufficient rest after transportation would be provided to improve the quality and yield of mutton.

Conflict of Interest

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

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Full Length Research Paper

Evaluation of antioxidant activity of *Malus domestica* fruit extract from Kashan area

Sara Jelodarian[1]*, Abdolrasoul Ebrahimabadi[2], Ahmad Khalighi[1] and Hossain Batooli[3]

[1]Islamic Azad University, Science and Research Branch, Faculty of Agriculture and Natural Sources, Tehran, Islamic Republic of Iran.
[2]Essential Oils Research Institute, University of Kashan, Post Code 87317-51167 Kashan, Islamic Republic of Iran.
[3]Isfahan Research Center of Natural Sources and Agriculture, Kashan Station, Kashan, Islamic Republic of Iran.

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Antioxidants are considered as the main factors in the inhibition of unwanted oxidation reactions. In this research the antioxidant potential of the fresh fruits of 4 cultivars of *Malus domestica* cultivated in the Kashan, Qamsar area was evaluated. The antioxidant activity of the samples were evaluated using two complementary antioxidant assays: 2,2-diphenyl-1-picrylhydrazyl (DPPH) and *β*-carotene/linoleic acid tests and the results were compared with the synthetic standard antioxidant butylated hydroxytoluene (BHT). Total phenolic contents of the samples are also estimated by Folin-Ciocalteu's phenol test. In both DPPH *β*-carotene/linoleic acid tests in the concentration of 2 mg/ml, only samples from Hossain cultivar showed moderate antioxidant activity with 63.92 ± 0.42 and 6.02 ± 0.03 inhibition percentages, respectively and other samples were only weekly active. The Folin-Ciocalteu's phenol test was also showed very little phenolic compounds for the fruits. In conclusion, week antioxidant activity was estimated for the studied apple cultivars.

Key words: Apple, *Malus domestica*, extract, antioxidant activity, total phenolic content.

INTRODUCTION

Free radicals are present in biological systems and may oxidize all the biological molecules present in our body, such as nucleic acids, proteins, lipids, initiating degenerative diseases (Cook and Samman., 1996; Harborne and Williams.,2000; Heim et al.,2002). Antioxidants are substances that neutralize free radicals and their negative effects. Antioxidants can inhibit or delay the oxidation of oxidizable substrates and this appears to be very important in the prevention of oxidative stress which is suggested as the leading cause of many oxidation related diseases (Bamoniri et al., 2010). Also antioxidants are substances that are able to prevent or retard the oxidation of lipids, proteins and DNA; and to protect the compounds or tissues from damage caused by oxygen or free radicals (Hasbay et al., 2007). Therefore, their health promoting effects reduce the risk of various diseases (Manach et al., 2004). Recently, antioxidant activity has been determined in

*Corresponding author. E-mail: sjelodarian@yahoo.com, Tel/Fax: +989131636427.

many species of fruits, vegetables, herbs, cereals, sprouts and seeds (Kahkonen et al., 1999; Velioglu et al., 1998).

A special attention is paid to fruits, as rich sources of phenolic compounds (Kalt et al., 1999; Robards et al., 1999; Wang and Lin., 2000). Among others, the antioxidant properties of apple polyphenols have been extensively examined (Ju and Bramlage, 1999; Lu and Foo, 2000; Robards et al., 1999). Apples have the highest levels of antioxidant activity (Chinnici et al., 2004). Activity and concentration of antioxidants in fruit differ among cultivars, the part of the fruit, the growth stage and environmental conditions (Awad et al., 2001a,b,c; Sluis et al., 2001). Apple fruit contain several health and sensory related constituents including dietary fibre, sugars, vitamins and phenolic compounds (Hagen et al., 2007). The antioxidant capacity of apple is mostly attributed to phenolic compounds such as flavonoids and phenolic acids (Eberhardt et al., 2000; Lee et al., 2003).

Malus domestica Borkh. is one of the most commonly consumed fruit worldwide (Shoji et al., 2004) and we collected samples named Hossain, Sayyed Babaeei, Shekareh and Golab from Iran. These samples have been cultivated since foretime are medium in size with a circular shape. The yellow–pink skins are thin, rather wax-like, and the white fleshes are soft, juicy, aromatic and sweet. Because of staying on the tree, the skin color of these 4 apple cultivars changes gradually and becomes red. Thus, the present research reports the *in vitro* profile of the antioxidant activity of the fruit extracts using two complementary assays: DPPH radical and β-carotene linoleic acid tests; the total phenolic content of the fruit extracts, expressed as gallic acid equivalents.

MATERIALS AND METHODS

Fruit collection

Fresh fruit samples from Hossain, Sayyed Babaeei, Shekareh and Golab apple cultivars were collected in the Kashan, Qamsar area in the June 2008 when the fruit had just been harvested.

Extraction procedure

Apples characterized by plant taxonomist, immediately transported to the laboratory, washed, dryed, cut manually with a knife into small pieces, whole fruit except seeds extracts were obtained using a kitchen-type blender (Moulinex, France) and concentrated with a rotary evaporator.

Solvents and chemicals

2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical, β -carotene, linoleic acid, 2,6-di-tert-butyl-4-methylphenol butylated hydroxytoluene (BHT) and gallic acid were procured from Sigma–Aldrich Chemie (Steinheim, Germany). Analytical grade methanol, ethanol, and dimethylsulfoxide (DMSO), HPLC grade chloroform, standard Folin–Ciocalteu's phenol reagent, sodium carbonate, Tween 40, and all cultures media were obtained from Merck (Darmstadt, Germany). Ultra pure water was used for the experiment.

Antioxidant activity

DPPH radical scavenging

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical assay usually involves hydrogen atom transfer reaction but, based on kinetic data, an electron transfer mechanism has also been suggested for this assay (Huang et al., 2005; Foti et al., 2004). Radical scavenging activities of the plant essential oil and extract were determined using a published DPPH radical scavenging activity assay method (Sarker et al., 2006) with minor modifications.

Briefly, stock solutions (10 mg/ml each) of the extracts and the synthetic standard antioxidant BHT were prepared in methanol. Dilutions are made to obtain concentrations ranging from 1 to 5×10^{10} mg/ml. Diluted solutions (1 ml each) were mixed with 1 ml of a freshly prepared 80 µg/ml DPPH radical methanol solution and allowed to stand for 30 min in the dark at room temperature for any reaction to take place. Absorbance values of these solutions were recorded on an ultraviolet and visible (UV–Vis) spectrometer (Cintra 6, GBC, Dandenong, Australia) at 517 nm using a blank containing the same concentration of DPPH radicals. Inhibitions of DPPH radical in percent (I%) were calculated as follow:

$$I\% = [(A_{blank} - A_{sample})/A_{blank}] \times 100$$

In this research, dilution was not performed due to low concentration of extracts and low inhibitory percentage.

Where A_{blank} is the absorbance value of the control reaction (containing all reagents except the test compound) and A_{sample} is the absorbance values of the test compounds. The sample concentration providing 50% inhibition (half-maximal inhibitory concentration, IC_{50}) was calculated by plotting inhibition percentages against concentrations of the sample. It is interesting to note that in this research, the related graphs and some other necessary calculations like IC_{50} performed due to low concentration of extracts and inhibitory percentage.

β-Carotene/linoleic acid bleaching

The β-carotene/linoleic acid test evaluates the inhibitory effect of a compound or a mixture on the oxidation of β-carotene in the presence of molecular oxygen (O_2). Assay of the remained β-carotene gives an estimation of the antioxidant potential of the sample. The method described by Miraliakbari and Shahidi (2008), was used with slight modifications. A mixture of β-carotene and linoleic acid was prepared by adding together of 0.5 mg β-carotene in 1 ml chloroform (HPLC grade), 25 µl linoleic acid and 200 mg Tween 40. The chloroform was then completely evaporated under vacuum and 100 ml of oxygenated distilled water was subsequently added to the residue and mixed gently to form a clear yellowish emulsion.

The essential oil, extract and BHT (positive control) were individually dissolved in methanol (2 g/L) and 350 µl volumes of each of them were added to 2.5 ml of the above emulsion in test tubes and mixed thoroughly. The test tubes were incubated in a water bath at 50°C for 2 h together with a negative control (blank) contained the same volume of methanol instead of the extracts. The absorbance values were measured at 470 nm on an ultraviolet and visible (UV–Vis) spectrometer (Cintra 6, GBC, Dandenong, Australia). Antioxidant activities (inhibitions percentage, I%) of the samples were calculated using the following equation:

$$I\% = (A_{\beta\text{-carotene after 2-h assay}}/A_{\text{initial }\beta\text{-carotene}}) \times 100$$

Where $A_{\beta\text{-carotene after 2-h assay}}$ is the absorbance values of β-carotene after 2 h assay remaining in the samples and $A_{\text{initial }\beta\text{-carotene}}$ is the absorbance value of β-carotene at the beginning of the

Table 1. DPPH radical scavenging activity (percentage ± SD) of 4 apple cultivars in the concentration of 2 mg/ml.

Sample	Inhibition (%)
Hossain	63.92 ± 0.42
Sayyed Babaeei	39.60 ± 0.75
Shekareh	19.99 ± 0.24
Golab	43.16 ± 1.92
BHT[a]	96.65 ± 0.15

[a] In concentration of 0.5 mg/ml.

Table 2. Antioxidant activity of β-carotene/linoleic acid bleaching assay method (percentage ± SD) of 4 apple cultivars in the concentration of 2 mg/ml.

Sample	β-carotene bleaching (%)
Hossain	6.02 **±** 0.03
Sayyed Babaeei	4.24 **±** 0.56
Shekareh	1.00 **±** 0.05
Golab	3.16 **±** 0.08
BHT	96.40 **±** 0.07

Table 3. The contents of total phenol of 4 apple cultivars.

Sample	Total phenol contents (µg/mg)
Hossain	0
Sayyed Babaeei	0
Shekareh	0
Golab	1.5

experiments. All tests were carried out in triplicate and inhibition percentages were reported.

Total phenolics

Total phenolics content was determined using Folin-Ciocalteu reagent as reported in the literature (Slinkard and Singleton, 1977). A solution of the extract (0.1 ml) containing 1000 µg of the extract was pipetted into a 50 ml volumetric flask, 46 ml distilled water and 1 ml Folin–Ciocalteu's phenol reagent were added, and the flask was thoroughly shaken. After 3 min, 3 ml of 2% Na_2CO_3 solution was added and the mixture was allowed to stand for 2 h with intermittent shaking. Absorbance values were measured at 760 nm. The same procedure was repeated for all the standard gallic acid solutions (0–1000 lg/0.1 ml) and a standard curve obtained with the following equation:

Absorbance = 0.0012 × gallic acid (µg) + 0.0033

Total phenols of the extract, as gallic acid equivalent, was determined by using the absorbance value of the extract measured at 760 nm as input to the standard curve and the equation. Test was carried out in triplicate and gallic acid equivalent value was reported.

RESULTS AND DISCUSSION

DPPH

DPPH radical scavenging activity potentials of fruit extract were evaluated for the assessment of their antioxidant capacities and compared with BHT (the standard commercial synthetic antioxidant). Among the extracts, the best radical scavenging effect against DPPH was observed in Hossain cultivar (63.92 ± 0.42%) in the concentration of 2 mg/ml. The results of 4 apple cultivars and BHT are presented in Table 1.

β-Carotene/linoleic acid

The potential of the plant to inhibit lipid peroxidation was evaluated using the β-carotene/linoleic acid bleaching test. In *β*-carotene/linoleic acid tests in the concentration of 2 mg/ml, only samples from Hossain cultivar showed 6/015 ± 0/003 inhibition percentages. The results of 4 apple cultivars and standard (BHT) are presented in Table 2.

Total phenolic constituents

Total phenolic content of the plant extracts were determined using a colorimetric assay method based on Folin–Ciocalteu reagent reduction. The Folin-Ciocalteu's phenol test was also showed very little phenolic compounds for the fruits. The amounts of total phenols found in the fruit extracts are shown in Table 3.

DPPH assay and β-Carotene/linoleic acid

The measurement of the antioxidant capacity of food extracts and pure compounds is commonly performed using several methods. Each method relates to the generation or use of a different radical that is directly involved in the oxidative process, acting through a variety of mechanisms. Among the various assays, we selected the DPPH and β-Carotene/linoleic acid assays to determine the antioxidant activity of fruit extracts.

During 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical test, the capacity of the samples to donate hydrogen atom and/or electron to this blue/purple stable radical and converting it to yellow diphenylpicrylhydrazine molecule was measured (Tepe et al., 2005). This reaction is used for measuring the ability of the extracts or pure molecules (such as BHT) to scavenge free radicals. Our results estimate a mild antioxidant potential for the Hossain cultivar while other samples were weakly active.

Results of antioxidant test of 4 apple cultivars showed that none of 4 samples have high antioxidant properties at 2 mg/ml concentration but only Hossain cultivar showed 64% inhibitory power. It is to be noted that

extracts were prepared with high concentration, therefore samples were not diluted. These findings are in agreement with measured total phenolic contents of the samples (Drogoudi et al., 2008; Lata, 2007; D´Abrosca et al., 2007; Tsao et al., 2005; Vieira et al., 2009). β-Carotene/linoleic acid test of 4 apple cultivars showed the same results as antioxidant test with the exception 0f Hossain cultivar which showed greater inhibitory power 6% compared to DPPH procedure. This finding is in contradiction with the findings of Garcia et al. (2009); Lata et al. (2009); Lee et al. (2003); Bandoniene and Murkovic (2002) and Kondo et al. (2002); which might be due to different cultivars they have selected under different climatic condition.

Total phenolic contents

The basic structure of the phenols and other structural factors play a fundamental role in the mechanism by which these compounds are able to scavenge free radicals (Sadeghipour et al., 2005). As underlined also by Lata et al. (2009) and Lata (2008), it is difficult to compare the content of apple phenolic among different studies, as many variations can be principally caused by different growth period, geographic location, storage type, genetic diversity and many other factors. The results, expressed as gallic acid equivalents, were 0 and 1.5 ± 0.6 µg/mg for the extracts of apples, respectively.

These values are comparable to the values reported in literature for other apple cultivars, such as Golden Delicious, Stark Delicious, Mora, Nesta, Panaia-red and Ruggine (Iacopini et al., 2009) and others. Phenolic compounds normally play main role in the antioxidant activity of the plant extracts, thus, low DPPH antioxidant activity of our samples may be related to their negligible total phenolic compounds contents. Folin–Ciocalteu test showed that there is low percentage of phenolic compounds in all samples which is in accordance with antioxidant tests. Overall conclusions was that all samples did not show high antioxidant power however Hossain cultivar showed higher antioxidant power, which might be due to presence of phenolic compounds.

Conclusions

Fruits have long been regarded as having considerable health benefits, particularly due to their antioxidant properties, which can protect the human body against cellular oxidation reactions. In our study, we have focused on antioxidant activity and total phenolic compounds of apples. They are the most common compounds in fruits and vegetables and have a strong antioxidant capacity. Fresh fruits of 4 cultivars of *M. domestica* cultivated in the Kashan, Qamsar area was selected. The antioxidant activity of the samples were evaluated using two complementary antioxidant assays: 2,2-diphenyl-1-picrylhydrazyl (DPPH) and *β*-carotene/linoleic acid tests and the results were compared with the synthetic standard antioxidant BHT. Total phenolic contents of the samples are also estimated by Folin-Ciocalteu's phenol test. In both DPPH *β*-carotene/linoleic acid tests in the concentration of 2 mg/ml, only samples from Hossain cultivar showed moderate antioxidant activity with 63.92 ± 0.42 and 6.02 ± 0.03 inhibition percentages, respectively and other samples were only weekly active. The Folin-Ciocalteu's phenol test also showed very little phenolic compounds for the fruits.

We therefore conclude that the phenolic content, the radical-scavenging and antioxidant properties of old local apple varieties demonstrate that these neglected cultivars could be a good source of phytochemicals, bioactive compounds with important protective properties. This local apple cultivars could be also considered as an important source of genes for apple breeding program and for the production of value added apple cultivar. So that being, further studies on local and ancient varieties have to be encouraged so that those varieties with the most technological interest can be selected.

Conflict of Interest

The authors have not declared any conflict of interest.

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Morphological Characterization of Indigenous Woyto-Guji goat type in Loma district, Southern Ethiopia

Yaekob Lorato*, Kirman Manzoor Ahmed and Birhanu Belay

Jimma University, College of Agriculture and Veterinary Medicine, P.O. Box: 307, Jimma, Ethiopia.

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This study was conducted on 810 goats in three agro ecological zones (Highland, Midland and Lowland) of Loma district in southern Ethiopia were considered with sex and age groups factor to characterize morphologically Woyto Guji goat types in their home tract. A pre-tested questionnaire was used for recording morphological features, body weights and linear body measurements. Both qualitative and quantitative traits were recorded on randomly sampled goats from three agro ecologies and the data were analyzed using SPSS and SAS software. The goat type in the study area was characterized by higher proportion of plain coat patterns (91.2%) with brown coat color (45.7%), straight head profile (80.6), semi pendulous ear formation (69.8%) and long ear type (97.3%). The horns were characterized by backward orientation with a straight shape. Body weight of the goats' changes at increasing rate at 0PPI to 3PPI and gradual increase was observed at older ages. Sex, age, agro ecological zones, sex by age and age by agro ecologies interaction had a significant ($p<0.05/p<0.01$) effect on body weight and many of the linear body measurements. The mean live body weight (BWT), heart girth (HG), height at wither (HW), chest width (CW), pelvic width (PW), rump height (RH), rump length (RL), ear length (EL), and horn length (HL) of females were 26.53±2.91 kg, 57.48±0.64 cm, 70.20±0.21 cm, 64.12±0.18 cm, 13.74±0.07 cm, 13.20±0.19 cm, 66.04±0.52 cm, 11.97±0.13 cm, 13.74±0.16 cm and 11.20±0.10 cm, respectively. The corresponding values for male counterpart were 27.16±0.70 kg, 60.13±1.17 cm, 74.98±0.33 cm, 68.34±0.05 cm, 14.48±0.41 cm, 13.25±0.37 cm, 68.37±0.50 cm, 12.83±0.43 cm, 14.02±0.020 cm and 13.22±0.47 cm respectively. Heart girth had the highest correlation with body weight at various ages and in both sexes compared with other parameters, except in females of zero dentition was not significant. The regression equation for pooled overall age groups was estimated as Y = (-28.20) + 0.74 X; (where X stands for HG), with R^2 value of 0.68 for female and Y = (-39.12) + 0.88 X; (where X stands for HG), with R^2 value of 0.78 for male goat in the present study. The result indicated that phenotypic characterization, body weight and linear body measurement description could help as an input for efficient utilization, conservation and designing improvement strategy for this genetic resource in the community.

Key words: Age, agro ecology, body weight, linear body measurements, sex.

INTRODUCTION

Ethiopia is home for diverse indigenous goat populations. Studies estimated that about 15 breeds of goat exist in Ethiopia though the goat characterization is not exhaustive (IBC, 2004). Based on phenotypic and molecular characterization, there are four families and 12 different types (FARM-Africa, 1996; Tesfaye, 2004). The

goat population of Ethiopia is estimated at 22.78 million heads (CSA, 2011). Goat production is one of the integral parts of livestock farming activities of the country. It has been estimated that about 70% of the goat population is found in the lowlands and the rest 30% is found in the highland Agro ecologies (Alemayehu, 1993, Workneh and Rowlands, 2004). Currently studies revealed that an increasing trend of goat in all agro ecologies (Aschalew et al., 2000).

According to Kiwuwa (1992), the broad genetic variability of African small ruminant breeds enables them to survive under stressful environmental conditions, including high disease incidence, poor nutrition and high temperature. The environmental pressure also maintains a wide range of genotypes, each adapted to a specific set of circumstances. Thus, improvement of local animal genetic resources holds promise for feasible mechanism of conservation through addressing the self-sustaining incentive of improved livelihood for the keepers (Grum, 2010).

Morphological characterization is one of the crucial means for describing the goat breeds. It is essential to characterize a breed for its conservation (Bizhan et al., 2010). Body measurement in addition to weight estimate describe the individual or population than do the conventional methods of weighing and grading small ruminant (Salako, 2006). Body dimensions have been used to indicate breed, origin and relationship through the medium of head measurements (Itty et al., 1997).

The available information of "*Woyto-Guji*" goat breed was not sufficient to describe the breed and morphological characterization carried so far have not covered all the production environments including Loma districts rather have focused on specific areas of the population besides the information was undertaken before two decades (Workneh, 1992; Farm-Africa, 1996). Indigenous livestock breeds are considered, for diverse reasons, as treasured genetic resources that tend to disappear as a result of new market demands, crossbreeding or breed replacement and mechanized agricultural operations (Halima et al., 2012, Dereje et al., 2013). Therefore, with these all scenarios and the current global animal genetic resource mix up through inbreeding, interbreeding and environmental change it is important to characterize over different agro-ecological zones. The objective of this study was to characterize morphologically the Woyto-Guji goat type in their home areas (Figure 1).

MATERIALS AND METHODS

The study was conducted in Loma district, located in Dawuro zone at 6.59° -7.34° N latitude and 36.68° - 37.52° E longitudes with altitudinal range of 501 to 3300 m above sea level in Southern Nations, Nationalities and Peoples Region (SNNPR) (Mathewos, 2008). The district was, selected based on its potential for goat production, diversified Agro ecological zones which encompasses lowland, midland and highland and its varied production system. The total surface area of the district is 116,280ha; with the mean annual rainfall of 900-1800 mm, with bimodal and erratic distribution and temperature ranges from 14 to 30°C (LAR, 2013).

Data collection

Before the commencement of the study, a rapid field survey was conducted by a team of researchers to assess the distribution and population of the goat in different Agro ecology of the study areas. Multi-stage stratified sampling techniques were employed in the present study. In the first stage, district was stratified into three agro ecologies namely lowland with altitude of <1500masl, midland with altitude of 1500-2300 masl and highland with > 2300 masl (MOA, 2000). The Agro ecologies were identified based on altitude and production system of the district. In the second stage, three kebeles were randomly selected from each agro-ecology. In the third stage, a total of 810 goats selected randomly in all direction after every eight to twelve households based on the number of household per each Kebels.

About 12 qualitative characters (head profile, ear formation, ear type, coat color pattern, coat color type, horn shape, horn orientation, ages, presence of wattle, ruff, bear and horn) and 10 quantitative characters, live body weight (BWT), heart girth (HG), height at wither (HtW), chest width (CW), pelvic width (PW), rump height (RH), rump length (RL), ear length (EL), horn length (HL) and scrotal circumference (SC) were collected from a total of 810 goats based on the standard description of the Food and Agriculture Organization of the United Nations list (FAO, 2011). Goats were purposively grouped into 5 age categories based on dentition. These age groups were goats with no pairs of permanent incisors (0PPI) at weaning age below 12 to 14 months, one pair of permanent incisors (1PPI) at age of 15 to 23 months two pairs of permanent incisor (2PPI) at age of 24 to 35 months, three pairs of permanent incisors (3PPI) at age of 36 to 48 months and four pairs of permanent incisors (4PPI) at age of over 48 months (Tatiana, 1999) and sex groups (male and female).

Data analysis

Statistical package for social Science (SPSS) computer software (SPSS ver.20, 2013) was applied to analyze qualitative data. The General Linear Model (GLM) procedures of SAS ver.9.2 were employed to analyze quantitative data and ascertain the effect of sex, site (agro ecology) and age (SAS, 2010). Mean separation was undertaken when it was significant to reveal the difference between means using Tukey-Karamers method.

$$Yijk = \mu + Ai + Sj + Dk + (AS)ij + (AD)ik + (SD)jk + eijk \quad \ldots\ldots \quad \text{Model 1}$$

Where: Y_{ijk} = l^{th} observation on i^{th} production site, j^{th} sex class and k^{th} age group; μ = Overall mean

A_i = Fixed effect of i^{th} Agro ecology (i= 1, 2, 3), Where 1=lowland, 2=midland and 3 = Highland)

S_j = Fixed effect of j^{th} sex (j =1, 2 where 1 = male, 2 = female); D_k = Fixed effect of k^{th}; dentition (k =1, 2,3,4,5 where 1= 0PPI,2= 1PPI, 3

*Corresponding author. E-mail: yakob.lorato@yahoo.com

Figure 1. Mature Woyto -Guji Doe and buck.

= 2PPI, 4 = 3PPI and 5 = 4PPI); $(AS)_{ij}$ = fixed effect of interaction between Agro ecology and sex $(AD)_{ik}$ = fixed effect of interaction between Agro-ecology and dentition; $(SD)_{jk}$ =fixed effect of interaction between sex and dentition, e_{ijk} = random error;
Correlations (Pearson's correlation coefficients) between body weight and different linear measurements were computed for the population within each sex and dentition categories.
The stepwise REG procedures of SAS ver.9.2 was used to predict live weight from body measurements for pooled data, separate sexes and for each age categories (SAS, 2010). The choice of the best fitted regression model was selected by using coefficient of determination (R^2) and Mean standard error (MSE).

$Yj = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + ej$ Model 2 (Female)

$Yj = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \beta_{11}X_{11} + ej$ ……. Model 3 (Male)

RESULTS AND DISCUSSION

Goat population characterization

The average age of different categories of goats in terms of the eruption of permanent pairs of incisors (PPI) was assessed. The present study revealed that the average ages of goat with 0PPI, 1PPI, 2PPI, 3PPI and 4PPI were around 9±4.12, 18.4±3.19, 30.11±6.98, 41.4±8.86 and 49.83±12.55 months, respectively. The result in the current study was comparable with earlier study indicated 7±2.12, 16.4±4.19, 27.11±5.98 and 38±6.86 and 50.83±14.55 months, respectively in Harrarghe highland goats (Dereje et al., *2013)*. The variation of eruption of incisors and corresponding age could be caused due to variation in breed, environment, feeding habit and production system (Table 1).

Qualitative characteristics

The participatory descriptions of qualitative characters for both female and male goats are presented in Table 2. The result showed that both female and male goat exhibited white, brown, black, grey and cream white coat color type but in varying proportion in either same sex or across two sexes. In all white, brown, black, grey and creamy white coat color type were observed in the sampled goats. The overall (pooled) results showed that proportion of brown, black, white, cream white and grey coat colour were in descending order in the sampled goats. The highest proportion of brown coat colour indicated that farmers prefer this coat colour and have selected these animals favourably. Three coat colour patterns, viz: plain, patchy and spotted, were found in sampled goats. The plain coat colour pattern was dominant with 91.2 % (overall / pooled) occurrence in the

Table 1. Total number of goats sampled per sex and location at different age groups.

Age	Agro ecology						Overall	
	Lowland		Midland		Highland			
	Male	Female	Male	Female	Male	Female	Male	Female
0ppi	13	25	13	10	3	16	29	51
1ppi	25	22	19	21	12	37	56	80
2ppi	22	36	10	35	11	64	43	135
3ppi	11	52	9	34	7	44	27	130
4ppi	27	57	21	88	17	49	65	194
Totally	98	192	72	188	50	210	220	590

PPI= Pairs of Permanent Incisors.

Table 2. Summary of the qualitative traits in the female and male sample goats.

Characters	Factors level	Female		Male		Total	
		N	%	N	%	N	%
Coat color type	White	125	21.2	36	16.4	161	19.9
	Brown	259	43.9	111	50.5	370	45.7
	Black	124	21.0	39	17.4	163	20.1
	Grey	39	6.6	14	6.4	53	6.5
	Cream white	43	7.3	20	9.1	63	7.8
Coat color pattern	Plain	541	91.7	198	90.0	739	91.2
	Patchy	40	6.8	11	5.0	51	6.3
	Spotted	9	1.5	11	5.0	20	2.5
Head profile	Straight	473	80.2	180	81.8	653	80.6
	Slightly convex	93	15.8	30	13.6	123	15.2
	Concave	24	4.1	10	4.5	34	4.2
Ear formation	Rudimentary	2	0.3	1	0.5	3	0.4
	Short ear	8	1.4	11	5.0	19	2.3
	Long ear	580	98.3	208	94.5	786	97.3
Ear type	Semi pendulous	411	69.7	154	70.0	565	69.8
	Horizontal	179	30.3	66	30	245	30.3
Horn orientation	Rudimentary	58	9.8	13	5.9	71	8.8
	Front	57	9.7	21	9.5	78	9.6
	Backward	428	72.5	159	72.3	587	72.5
	Lateral	47	8.0	27	12.3	74	9.1
Horn shape	Straight	403	68.3	175	79.5	578	71.4
	Polled	64	10.8	16	7.3	80	9.9
	Spiral	123	20.8	29	13.2	152	18.8
Beard	Present	521	88.3	215	97.7	736	90.9
	Absent	69	11.7	5	2.3	74	9.1
Wattles	Present	51	8.6	52	23.6	103	12.7
	Absent	539	91.4	168	76.4	707	87.3
Ruff	Present	531	90.0	201	91.4	732	90.3
	Absent	59	10.0	19	8.6	78	9.6

sampled goats. The other two coat colour patterns (patch and spotted) were less common.

The head profile observed were straight, slightly convex and concave among the sampled goats in the present study. The straight head profile is dominant (overall average = 80.6%) followed by slightly convex (overall average = 15.2%) and concave (overall average = 4.2%). The ear formation showed that long ear were highly predominant (overall average = 97.0%) in population of goats studied. Similar finding were reported for the goat types (FARM-Africa, 1996).

Quantitative characteristics

Effect of sex

The effect of sex was highly significant ($P < 0.01$) on body weight and all body measurements. Perusal of least square means (Table 3) showed that body weight and all body measurements in male goats were consistently higher in magnitude than the corresponding values in females. The mean BWT, BL, HG, HW, CW, PW, RH, RL, EL and HL of females were 23.74±0.14 kg, 55.64±0.22cm, 70.07±0.20 cm, 64.03±0.18 cm, 13.68±0.07 cm, 12.47±0.06 cm, 64.23±0.18 cm, 11.90±0.08 cm, 13.45±0.05 cm and 11.19±0.14 cm, respectively. The corresponding values for male counterpart were 26.34±0.21 kg, 3.17±0.033 cm, 59.72±0.34 cm, 74.37±0.31 cm, 68.03±0.05 cm, 14.27±0.12 cm, 68.10±0.12 cm, 12.52±0.13 cm, 13.86±0.08 cm, and 12.99±0.16 cm, respectively.

The effect of sex in favor of males on body weight and body measurements in present study was in agreement with previous results (Semakula et al., 2010, Solomon, 2014, Vargas et al., 2007). The sex related differences might be partly a function of the sex differential hormonal effect on growth. In addition to that, the differentials obtained in the morphological traits of the sexes could be attributed to sexual dimorphism (Semakula, 2010). Peter et al. (2012) reported that most dimorphism developed post-weaning because of faster mass gain by males during the age of 1 to 2 years. They also suggested that males might have a longer season of mass gain each year throughout their lives, while females divert annual resources into reproduction, rather than body mass.

Effect of age groups

The effect of age was highly significant ($P < 0.01$) on body weight and all other body measurements. Perusal of least square means showed that both body weight and linear body measurements have shown a consistent increase with advancement in age from the youngest age (0PPI) to the oldest age (4PPI) in the present study. These results were in agreement with earlier reports of increase in live body weight and linear body measurements with increase in age of animal in all breeds of goat as (Semakula *et al.,* 2010, Solomon, 2014).

Effect of agro ecology

The effect of Agro ecologies were highly significant ($P < 0.01$) for all traits, studied, except ear length and scrotal circumference were not significant ($P \geq 0.05$). Perusal of least square means showed a consistently ascending trend in the measurements from lowland to highland Agro ecologies for BL, HG, HtW, CW, PW and RH. In other traits no such consistent trend was observed. General lower values were observed in most of the linear measurements for lowland Agro ecologies compared to other. This might, to some extent, be explained by environmental factors such as nutrition. In this regard, the reported shortage of grazing areas in the site could be implicated. Grazing lands in the area have been under increased encroachment by the mounting industrial and settlement buildings in line with expansion of the urban core. Owing to the fact that the farming system is dependent on extensive grazing without supplementation, the size and productivity of the grazing land can be taken as the sole component of the environmental factors affecting livestock productivity. The present finding reflected that there were wide variations among the three Agro ecologies which influenced all the quantitative traits studied. The present results were in agreement with earlier study showed that the effects of Agro ecologies was significantly affected on body measurements in indigenous goat breeds (Solomon, 2014; Grum, 2010).

Effect of sex x age groups interaction

The interaction between sex and age groups were either highly significant ($P < 0.01$) or significant ($P < 0.05$) on body weight and all body measurements except scrotal circumference which was not studied. The results (Table 3) showed that the magnitude of values of body weight and all other body measurements were consistently higher in males of different age groups than corresponding values for females of various age groups. The pairwise comparison of means showed variable trends in all the traits studied. The present findings were in agreement with earlier studies of (Fajemilehin and Salako, 2008; Dereje, 2011) which reported significant influence of sex and age interaction on body measurements. Hence, this finding should be considered in improvement program to increase meat yield from goat via sex disintegrated improved management.

Effect of agro ecology X age group interaction

The interaction between Agro ecologies and age groups was either highly significant ($P < 0.01$) or significant ($P <$

Table 3. Least squares means±standard errors of body weight (kg) and other body measurements (cm) for Woyto-Guji goat.

Effects and levels	N	Body weight	Body Length	Heart girth	Height at Wither	Chest Width
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	810	26.7±3.10	58.20±4.73	73.11±4.37	66.65±4.011	14.34±1.68
CV		11.62	8.13	5.97	6.02	11.77
R^2		0.79	0.48	0.63	0.588	0.45
Sex		**	***	***	***	***
Male	220	26.34±0.21	59.72±0.34	74.37±0.31	68.03±0.29	14.27±0.12
Female	590	23.74±0.14	55.64±0.22	70.07±0.20	64.03±0.18	13.68±0.07
Age group		***	***	***	***	***
0ppi	80	14.40±0.36^{a}	48.66±0.57^{a}	61.58±0.53^{a}	56.83±0.48^{a}	11.11±0.20^{a}
1ppi	136	20.38±0.26^{b}	55.98±0.41^{b}	69.98±0.38^{b}	64.45±0.35^{b}	13.39±0.14^{b}
2ppi	178	27.06±.24^{c}	59.51±0.41^{c}	73.55±0.38^{c}	67.36±0.35^{c}	14.42±0.14^{c}
3ppi	157	30.25±0.26^{d}	61.44±0.50^{d}	76.63±0.46^{d}	70.06±0.42^{d}	15.01±0.17^{d}
4ppi	259	33.11±0.20^{e}	62.81±0.34^{e}	79.37±0.31^{e}	71.42±0.28^{e}	15.94±0.12^{e}
Agro ecology		**	***	***	***	***
Lowland	290	25.31±0.19^{a}	56.05±0.30^{a}	71.17±0.27^{a}	64.73±0.25^{a}	13.44±0.10^{a}
Midland	260	24.74±0.22^{b}	57.46±0.34^{b}	71.44±0.31^{a}	65.54±0.28^{b}	13.73±0.12^{ab}
Highland	260	25.07±0.23^{a}	59.52±0.35^{c}	74.05±0.33^{b}	67.80±0.30^{c}	14.75±0.13^{b}
Sex *Age		***	**	***	**	***
0ppi	M	14.52±0.59^{b}	49.59±0.92^{b}	63.43±0.85^{b}	58.99±0.78^{b}	10.94±0.33^{a}
0ppi	F	13.74±0.43^{a}	47.72±0.68^{a}	59.73±0.62^{a}	54.67±0.57^{a}	11.27±0.24^{b}
1ppi	M	21.12±0.41^{c}	57.82±0.64^{c}	71.57±0.59^{d}	65.84±0.54^{d}	13.70±0.23^{c}
1ppi	F	19.49±0.34^{bc}	54.14±0.54^{cb}	68.40±0.49^{c}	63.05±0.45^{c}	13.09±0.19^{c}
2ppi	M	27.16±0.46^{d}	61.60±0.73^{d}	74.95±0.67^{e}	68.85±0.62^{e}	14.71±0.26^{d}
2ppi	F	26.15±0.26^{d}	57.42±0.41^{c}	72.15±0.38^{d}	65.88±0.35^{de}	14.12±0.14^{d}
3ppi	M	31.37±0.58^{e}	63.70±0.91^{e}	79.03±0.43^{f}	72.34±0.77^{f}	15.15±0.32^{e}
3ppi	F	28.99±0.26^{ed}	59.17±0.41^{dc}	74.23±0.39^{e}	67.78±0.35^{e}	14.87±0.15^{d}
4ppi	M	36.17±0.37^{f}	65.88±0.58^{f}	82.88±0.54^{f}	74.11±0.49^{f}	16.86±0.21^{f}
4ppi	F	31.20±0.22^{e}	59.74±0.34^{dc}	75.86±0.32^{e}	68.74±0.29^{e}	15.01±0.12^{e}
Agro eco*Age		**	**	***	***	***
Lowland	0PPI	14.57±0.50^{a}	46.88±0.79^{a}	58.79±0.73^{a}	54.36±0.67^{a}	10.55±0.28^{a}
	1PPI	21.20±0.44^{b}	53.40±0.69^{b}	67.43±0.63^{b}	62.21±0.58^{b}	12.58±0.24^{b}
	2PPI	26.56±0.40^{c}	57.97±0.63^{c}	73.06±0.58^{c}	66.18±0.53^{c}	14.00±0.22^{c}
	3PPI	30.21±0.43^{d}	60.75±0.67^{d}	77.01±0.62^{d}	69.73±0.57^{d}	14.95±0.24^{c}
	4PPI	33.94±0.33^{e}	61.24±0.52^{e}	79.57±0.48^{e}	71.14±0.44^{e}	15.12±0.18^{c}
Midland	0PPI	13.50±0.61^{a}	47.80±0.90^{a}	58.96±0.89^{a}	54.67±0.81^{a}	10.46±0.34^{a}
	1PPI	19.46±0.47^{b}	55.17±0.74^{bc}	68.95±0.69^{b}	63.85±0.63^{b}	13.18±0.26^{b}
	2PPI	26.25±0.45^{c}	58.96±0.71^{c}	72.67±0.66^{c}	66.74±0.60^{c}	13.82±0.25^{c}
	3PPI	30.41±0.50^{d}	61.36±0.79^{e}	76.7±0.73^{d}	70.60±0.67^{d}	14.75±0.28^{c}
	4PPI	34.36±0.32^{e}	64.02±0.51^{f}	79.95±0.47^{e}	71.86±0.43^{e}	16.46±0.18^{d}
Highland	0PPI	14.33±0.73^{a}	51.30±0.15^{ab}	67.00±0.66^{b}	61.45±0.97^{b}	12.31±0.41^{b}
	1PPI	20.25±0.45^{b}	59.36±0.71^{d}	73.57±0.65^{c}	67.29±0.60^{c}	14.43±0.25^{c}
	2PPI	27.15±0.40^{c}	61.60±0.63^{e}	74.91±0.58^{cd}	69.17±0.53^{d}	15.34±0.22^{cd}
	3PPI	29.93±0.48^{d}	62.21±0.75^{ef}	76.19±0.69^{d}	69.84±0.63^{d}	15.43±0.26^{cd}
	4PPI	32.74±0.37^{e}	63.16±0.59^{f}	78.59±0.54^{e}	71.26±0.50^{e}	16.22±0.21^{d}

Effects and levels	N	Pelvic width	Rump height	Rump length	Ear length	Horn length	SC (N=220)
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	810	13.21±1.46	66.67±3.94	12.53±1.80	13.81±1.19	12.48±2.24	16.56±2.77

Table 3. Contd.

CV		11.07	5.91	14.41	8.66	17.94	16.74
R^2		0.56	0.57	0.45	0.28	0.53	0.29
Sex		***	***	***	***	****	
Male	220	13.00±0.10	68.10±0.28	12.52±0.13	13.86±0.08	12.99±0.16	
Female	590	12.47±0.06	64.23±0.18	11.90±0.08	13.45±0.05	11.19±0.14	
Age group		***	***	***	***	***	***
0ppi	80	9.83±0.17^{a}	57.31±0.48^{a}	9.70±0.21^{a}	12.12±0.14^{a}	7.38±0.27^{a}	14.10±0.44^{a}
1ppi	136	11.62±0.12^{b}	64.76±0.34^{b}	10.98±0.15^{b}	13.39±0.10^{b}	10.96±0.19^{b}	15.40±0.30^{b}
2ppi	178	13.25±0.13^{c}	67.42±0.34^{c}	12.36±0.16^{c}	13.84±0.10^{bc}	12.97±0.20^{c}	16.95±0.40^{c}
3ppi	157	14.01±0.15^{c}	70.02±0.42^{cd}	13.94±0.19^{d}	14.34±0.12^{c}	14.33±0.23^{d}	17.29±0.50^{d}
4ppi	259	14.95±0.10^{c}	71.32±0.28^{d}	14.07±0.13^{d}	14.60±0.08^{c}	14.80±0.16^{d}	18.50±0.34^{e}
Agro ecology	***	***	***	Ns	***	Ns	
Lowland	290	12.51±0.09^{a}	64.57±0.25^{a}	12.56±0.11^{a}	13.74±0.07	12.00±0.14	15.86±0.29
Midland	260	12.61±0.10^{a}	65.87±0.28^{b}	12.57±0.12^{a}	13.61±0.08	11.16±0.16	16.74±0.34
Highland	260	13.09±0.11^{b}	68.05±0.29^{c}	11.50±0.13^{b}	13.62±0.08	12.86±0.16	16.75±0.44
Age*Sex	**	***	***	**	**		
0ppi	M	9.95±0.28^{a}	59.04±0.77^{b}	9.54±0.35^{a}	12.13±0.23^{a}	8.32±0.43^{b}	
0ppi	F	9.71±0.21^{a}	55.58±0.56^{a}	9.86±0.26^{a}	12.10±0.17^{a}	6.44±0.32^{a}	
1ppi	M	11.93±0.19^{b}	65.92±0.53^{c}	11.08±0.24^{b}	13.49±0.16^{b}	11.55±0.30^{c}	
1ppi	F	11.31±0.16^{b}	63.61±0.45^{c}	10.86±0.20^{b}	13.29±0.13^{b}	10.38±0.25^{c}	
2ppi	M	13.50±0.22^{c}	68.84±0.61^{d}	12.42±0.28^{c}	13.93±0.18^{c}	13.55±0.34^{d}	
2ppi	F	13.00±0.12^{c}	65.99±0.34^{c}	12.30±0.15^{c}	13.75±0.10^{c}	12.40±0.19^{cd}	
3ppi	M	13.98±0.28^{d}	72.60±0.76^{e}	14.36±0.34^{d}	14.69±0.23^{d}	15.53±0.43^{e}	
3ppi	F	14.07±0.13^{d}	67.43±0.35^{d}	13.53±0.16^{d}	13.99±0.10^{c}	13.14±0.19^{d}	
4ppi	M	15.63±0.18^{f}	74.12±0.49^{f}	15.19±0.22^{e}	15.09±0.14^{e}	15.99±0.27^{e}	
4ppi	F	14.28±0.10^{d}	68.52±0.29^{d}	12.94±0.13^{cd}	14.10±0.08^{d}	13.62±0.16^{d}	
Agro eco*Age	***	***	***	**	Ns	Ns	
Lowland	0PPI	9.67±0.24^{a}	54.61±0.66^{a}	10.31±0.30^{a}	12.19±0.20^{a}	6.82±0.37	13.30±0.70
	1PPI	11.50±0.21^{b}	62.20±0.57^{b}	11.57±0.26^{b}	13.13±0.17^{b}	10.66±0.32	14.56±0.55
	2PPI	12.99±0.19^{c}	65.87±0.52^{c}	12.86±0.24^{c}	13.94±0.16^{b}	13.11±0.30	16.22±0.58
	3PPI	13.95±0.20^{d}	69.27±0.56^{d}	14.68±0.25^{d}	14.67±0.17^{c}	14.38±0.32	17.18±0.83
	4PPI	14.44±0.16^{d}	70.90±0.44^{e}	13.37±0.20^{cd}	14.79±0.13^{c}	15.01±0.25	18.03±0.53
Midland	0PPI	9.51±0.29^{a}	55.83±0.80^{a}	9.86±0.36^{a}	12.04±0.24^{a}	6.37±0.45	14.00±0.34
	1PPI	11.05±0.23^{b}	64.49±0.62^{c}	10.57±0.28^{a}	13.29±0.18^{b}	10.32±0.35	15.15±0.63
	2PPI	12.93±0.22^{c}	67.03±0.59^{d}	12.32±0.27^{bc}	13.68±0.18^{b}	12.09±0.33	16.40±0.63
	3PPI	14.12±0.24^{d}	70.43±0.65^{e}	14.79±0.30^{d}	14.34±0.20^{c}	13.94±0.37	18.00±0.87
	4PPI	15.42±0.15^{d}	71.58±0.42^{e}	15.30±0.19^{e}	14.69±0.12^{c}	14.33±0.24	19.57±0.60
Highland	0PPI	10.32±0.32^{a}	61.49±0.96^{b}	8.93±0.44^{a}	12.12±0.29^{a}	8.94±0.54	14.00±0.60
	1PPI	12.30±0.21^{c}	67.61±0.60^{d}	10.78±0.27^{a}	13.76±0.17^{b}	11.92±0.33	16.50±0.83
	2PPI	13.83±0.19^{d}	69.35±0.52^{d}	11.90±0.24^{b}	13.89±0.16^{b}	13.72±0.30	16.63±0.46
	3PPI	13.97±0.23^{d}	70.34±0.62^{e}	12.35±0.28^{bc}	14.02±0.19^{c}	14.69±0.35	17.89±0.40
	4PPI	15.00±0.18^{e}	71.48±0.50^{e}	13.53±0.22^{cd}	14.31±0.14^{c}	15.07±0.27	18.71±0.47

^{a,b,c,d,e,f} means on the same column with different superscripts, within the specified class variable, are significantly different ($p<0.05$); Ns = non-significant $P>0.05$; *$P< 0.05$; ** $P< 0.01$ ***$P<0.001$; 0ppi = 0 Pair of permanent incisors, 1PPI =1 Pair of permanent Incisors; 2PPI = 2 Pairs of Permanent Incisors; 3PPI = 3 Pairs of Permanent Incisors; 4PPI = 4 Pairs of Permanent Incisors; AE =agro ecology; CV=coefficient of variation, R^2= coefficient of determination.

Table 4. Coefficients of correlation (r) between body weight and other body measurements within sex and age groups of Woyto-Guji goat.

Measurements		Body weights									
		Female					Male				
		Age groups					Age Groups				
		0PPI	1PPI	2PPI	3PPI	4PPI	0PPI	1PPI	2PPI	3PPI	4PPI
BL	r	0.58**	0.51**	0.30**	0.46**	0.64**	0.49**	0.26*	0.44**	0.76**	0.45**
	N	51	80	135	130	194	29	56	43	27	65
BCS	r	0.13NS	0.23*	0.05NS	0.68**	0.44**	0.63**	0.15NS	0.46**	0.31**	0.37*
	N	51	80	135	130	194	29	56	43	27	65
HG	r	0.26NS	0.80**	0.83**	0.53**	0.86**	0.71**	0.81**	0.83**	0.79**	0.88**
	N	51	80	135	130	194	29	56	43	27	65
HtW	r	0.29*	0.43**	0.37**	0.44**	0.36**	0.80**	0.48**	0.65**	0.38*	0.62**
	N	51	80	135	130	194	29	56	43	27	65
RH	r	0.22NS	0.40**	0.29**	0.39**	0.31**	0.75**	0.48**	0.65**	0.37*	0.62**
	N	51	80	135	130	194	29	56	43	27	65
RL	r	0.63**	0.65**	0.15NS	0.48**	0.13NS	0.49*	0.40*	0.41**	0.12NS	0.40*
	N	51	80	135	130	194	29	56	43	27	65
CW	r	0.27*	0.28*	0.15NS	0.27**	0.43**	0.49*	0.23*	0.37**	0.31*	0.40*
	N	51	80	135	130	194	29	56	43	27	65
PW	r	0.84**	0.54**	0.53**	0.36**	0.23**	0.82**	0.43**	0.51**	0.26*	0.51**
	N	51	80	135	130	194	29	56	43	27	65
EL	r	0.06NS	0.26*	0.19*	0.31**	0.13NS	0.25NS	0.24NS	0.22NS	0.24NS	0.17NS
	N	51	80	135	130	194	29	56	43	27	65
HL	r	0.63**	0.70**	0.50**	0.40**	0.24**	0.68	0.45**	0.60**	0.45*	0.18NS
	N	51	80	135	130	194	29	56	43	27	65
SC	r	NA	NA	NA	NA	NA	0.35NS	0.31*	0.33**	0.37*	0.24*
	N	NA	NA	NA	NA	NA	29	56	43	27	65

*P<0.05;** P<0.01; 1PPI = 1 pair of permanent incisors; 2ppi = 2 pair of permanent incisors; 3PPI = 3 pair of permanent incisors; 4PPI = 4 pair of permanent incisors; BL = body length; BCS = body condition score, HG = heart girth, HtW = height at wither, RH = rump height, RL= rump length, CW = chest width, PW = pelvic width, EL = ear length, HL= horn length, SC = scrotal circumference; NS = non-significant; NA = Not -available; N= number of observation ; r=coefficient of correlation.

0.05) on body weight and all body measurements except horn length and scrotal circumference. These results indicated that effect of Agro ecologies was different in different age groups and thus variation in the Agro ecologies has a strong effect on quantitative traits. There are several advantages of considering this interaction from genetic improvements and conservation perspectives. Advantage of Agro ecologies by age interaction is primarily the active breeding of animal populations for food and agriculture, such that diversity is best utilized in the short term and maintained for the longer term. In addition to that it is useful to conserves both the genetic material and the processes that give rise to the diversity in its production environment with age group.

Correlation between body weight and body measurements

Heart girth had the highest correlation with body weight at various ages and in both sexes compared with other parameters, except in females of zero dentition was not significant correlated as indicated in Table 4. The high correlation between body weight and heart girth, observed in majority of age groups, in present study suggested that heart girth could be used to obtain more reliable prediction estimate of body weight for the population. The present results were also supported by reports of Grum (2010), Dereje (2011), Badi et al. *(*2002), Slippers et al. (2000) and Halima et al. (2012) where they found that chest girth was best parameter for estimating

Table 5a. Live weight prediction equations at different age groups in female Woyto-Guji goat.

Age group	Equation	β_0	β_1	β_2	β_3	β_4	β_5	β_6	R^2	R^2 change	MSE
1PPI	HG	-36.94	0.82						0.64	0.000	2.87
	HG+RH	-63.42	0.73	0.52					0.75	0.003	2.23
	HG+RH+PW	-52.9	0.58	0.38	0.74				0.84	0.004	1.67
2PPI	HG	-25.60	0.72						0.65	0.000	2.22
	HG+RH	-45.23	0.54	0.49					0.71	0.005	1.89
	HG+RH+PW	-38.21	0.47	0.38	0.44				0.76	0.005	1.66
	HG+RH+PW+CW	-38.11	0.43	0.34	0.39	0.41			0.83	0.007	1.53
3PPI	HG	-20.02	0.66						0.28	0.000	2.56
	HG+BC	-18.80	0.62	0.57					0.44	0.006	2.13
	HG+BC+PW	-22.13	0.55	0.43	0.63				0.59	0.01	1.55
	HG+BC+PW+HW	-57.72	0.44	0.36	0.53	0.67			0.68	0.001	1.43
	HG+BC+PW+HtW+BL	-38.66	0.34	0.33	0.43	0.24	0.32		0.81	0.006	1.16
4PPI	HG	-28.33	0.78						0.74	0.000	3.18
	HG+BC	-25.73	0.72	0.68					0.81	0.001	2.24
0-4PPI	HG	-28.20	0.74						0.68	000	3.51
	HG+PW	-23.80	0.44	1.34					0.75	0.07	2.62
	HG+PW+BC	-16.39	0.34	1.19	0.53				0.78	0.001	2.48
	HG+PW+BC+RH	-55.22	0.32	0.98	0.46	0.67			0.84	0.001	2.22
	HG+PW+BC+RH+HtW	-76.44	0.30	0.96	0.39	0.57	0.46		0.88	0.001	2.13
	HG+PW+BC+RH+HtW+RL	-70.59	0.26	0.89	0.32	0.54	0.43	0.16	0.94	0.005	1.60

BL= body length; HG = heart girth; CW = chest width; HW = height wither; PW = pelvic width; RH = rump height, RL= rump length; EL = ear length; BC = body condition score; 0PPI = 0 pair of permanent incisors, 1PPI =1 pair of permanent incisors; 2ppi = 2 pairs of permanent incisors; 3PPI = 3 pairs of permanent incisors; 4PPI = 4 pairs of permanent incisors.

body weight due to high correlation estimates.

Multiple regression analysis

Perusal of results revealed that heart girth (HG) has been selected across four age groups in female (1PPI, 2PPI, 3PPI and 4PPI), five age groups in male (0PPI, 1PPI, 2PPI, 3PPI and 4PPI) and pooled overall age groups in both sex as presented in Table 5a and b, the first regressor because of its high contribution in terms of R^2 values. The regression equation for pooled overall age groups was estimated as Y= (-28.20) + 0.74 X; (where X stands for HG), with R^2 value of 0.68 for female and Y = (-39.12) + 0.88 X (where X stands for HG), with R^2 value of 0.78 for male goat in the present study. This finding showed that an increase of 1 cm of HG resulted in an increase of 0.74 and 0.78 kg of live weight in female and male goats, respectively.

The role of other body measurements' in predicting live body weight differed in different age groups across the two sexes vis-à-vis their order in these equations. Thus it seems that body measurements other than HG may not possibly be used in general prediction equations. However the parameter estimates in multiple linear regression models showed that subsequent inclusions of other body measurements together with HG (First variable in all equations) kept the R^2 values improving although the change had a pattern of diminishing marginal rate. This suggested that body weight could be more accurately predicted by combinations of two or more measurements than heart girth alone. The earlier reports have also shown improvement in R^2 values with subsequent addition of more linear measurements (Gul et al., 2005; Fikrte, 2008; Zewdu, 2008). Nevertheless, measurement of traits also has cost implications and it will be impractical to consider many traits under farmer's conditions. Under such conditions, the most practical prediction accuracy may be obtained through the use of heart girth alone.

CONCLUSION AND RECOMMENDATION

All the body measurements in male goats were consistently higher than females for all variables. The effect of sex, age and agro ecologies was highly significant ($P < 0.01$) on body weight and majority of body measurements. This should be considered in improvement program to increase production and

Table 5b. Live weight prediction equations at different age groups in male goat Woyto-Guji goat.

Age group	Equation	β_0	β_1	β_2	β_3	β_4	β_5	β_6	R^2	R^2 change	MSE
0PPI	HG	-28.1	0.68						0.50	0.000	2.66
	HG+PW	-29.55	0.61	0.57					0.68	0.005	1.93
	HG+PW+HtW	-30.9	0.48	0.32	0.21				0.77	0.003	1.45
1PPI	HG	-6.02	0.38						0.66	0.000	2.11
	HG+RL	-5.60	0.34	0.42					0.69	0.002	1.56
2PPI	HG	-10.33	0.50						0.69	0.000	2.68
	HG+BC	-9.70	0.46	0.85					0.73	0.001	2.42
	HG+BC+PW	-9.81	0.37	0.71	0.54				0.78	0.001	2.02
	HG+BC+PW+BL	-37.51	0.33	0.63	0.46	0.52			0.80	0.002	1.85
3PPI	HG	-19.20	0.64						0.62	0.000	2.33
	HG+RH	-48.86	0.51	0.55					0.71	0.001	1.89
	HG+RH+HtW	-68.82	0.46	0.53	0.35				0.78	0.003	1.64
	HG+RH+HtW+PW	-58.02	0.42	0.44	0.28	0.26			0.88	0.004	2.14
	HG+RH+HtW+PW+BL	-55.45	0.41	0.32	0.24	0.23	0.16		0.93	0.005	2.44
4PPI	HG	-17.14	0. 64						0.77	0.000	1.65
	HG+PW	-12.84	0.54	0.26					0.86	0.001	1.44
0-4PPI	HG	-39.12	0.88						0.78	0.000	2.44
	HG+BC	-17.48	0.55	0.92					0.80	0.001	2.34
	HG+ BC + PW	-15.28	0.36	0.70	0.97				0.83	0.002	1.66
	HG+ BC + PW +RL	-35.20	0.34	0.67	0.74	0.44			0.94	0.002	1.33
	HG+ BC + PW +RL+HtW	-30.13	0.32	0.53	0.62	0.38	0.26		0.96	0.004	1.24
	HG+ BC + PW +RL+HtW+BL	-33.21	0.26	0.43	0.52	0.23	0.21	0.25	0.97	0.007	1.12

BL= body length; HG = heart girth; CW = chest width; HW = height wither; PW = pelvic width; RH = rump height, RL= rump length; EL = ear length; BC = body condition score; 0PPI = 0 pair of permanent incisors, 1PPI =1 pair of permanent incisors; 2ppi = 2 pairs of permanent incisors; 3PPI = 3 pairs of permanent incisors; 4PPI = 4 pairs of permanent incisors.

productivity from goat via sex, Age and Agro ecologies disintegrated improved management. The results of the present investigation could assist farmers and genetic improvement specialists when conducting management, selection and preservation programs for the Woyto-Guji goats. The goats have shown variation across agro ecologies that might be because of various environmental stress, feeding system, prevailing breeding practices, practice of grazing land and management. Therefore, attention should be given for their improvement, conservation, breeding management and for proper utilization to further explore the potential of this genetic material through improving genetic and husbandry management.

Conflict of Interest

The authors have not declared any conflict of interest.

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Determinates of small holder farmers willingness to pay for agricultural extension services: A case study from Eastern Ethiopia

Daniel Temesgen[1]* and Teferi Tola[2]

[1]Department of Agricultural Extension and Rural Development, Ambo University, Ethiopia.
[2]Oromia Agricultural Research institute, Fedis Agricultural Research Center, Addis Ababa, Ethiopia.

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As a result of inability of public extension services to be responsive to the needs of farmers, a new paradigm is emerging. This study was designed to assess farmers' willingness to pay for extension services and to identify factors influencing the willingness to pay for agricultural information delivery services among the farmers. To achieve the objectives of the study, four PAs were included in the study purposively. A total of 140 households were selected randomly using probability proportional to size technique and interviewed using interview schedules. The proportion of the respondents was increased to 64.2% when the improvement in the quality of the services was stated. Analysis of determinants of the willingness to pay from logit model showed a significant positive relationship between willingness to pay (WTP) and household income, and farm size. Other household characteristics such as age of household head, media exposure, and family size were found to be negative but significantly related to WTP.

Key words: Willingness to pay, agricultural extension, commercialization, public service.

INTRODUCTION

The importance of agricultural extension in rural development is widely acknowledged, particularly in developing countries like Ethiopia where the majority of the population lives on Agriculture as the main source of livelihood. Agriculture in this part of the world is very complex and facing a number of serious problems in present era for which it is not easy to find good solutions (Anderson, 2007). Van den Ban and Hawkins (1996) noted that everywhere the farming system is changing rapidly and only efficient farmers are to survive. Agricultural extension services take the lions share to create competent and efficient farmers who are able to increase productivity by making effective use of knowledge and information which is available from or can be generated by several different information sources.

Agricultural production in Ethiopia has, for long, remained subsistence with limited market orientation and poor institutional support. Farmers produce for various valid reasons, with little market-orientation (Azage et al., 2005). However, the rate of agricultural growth in Ethiopia

*Corresponding author. E-mail: danieltemesgen2011@yahoo.com

heavily depends on the speed with which the current subsistence oriented production system is transformed into a market orientated production system (Berhanu et al., 2006). Currently, transforming agriculture from its current subsistence orientation into market oriented production system forms the basis of the agricultural development strategy of the Government. However, producing for the market requires re- orientation of the production system and development of a knowledge base and responsive institutional support services.

The agricultural extension service is one of the institutional support services that have a central role to play in the transformation process (Berhanu et al., 2006). Ethiopia's long history of extension services has been documented by a number of researchers (Belay, 2003; Habtemariam, 2004; Berhanu et al., 2006). The current extension service for small holders farmers in Ethiopia is almost exclusively funded and provided by the government with Nongovernmental actors operating in limited and dispersed areas. It is critically commented that extension system of the country lacks pluralistic framework and should reform itself to respond to the changing nature of the country's agricultural situation (Berhanu et al., 2006).

As is very evident from different studies (Wilson, 1991; Rivera et al., 2009; Shekara, 2005; Anderson, 2007), there are no models or external prescriptions that are entirely appropriate or applicable to the particular needs of individual countries or geographical locations within the country. Each case is different and the most crucial factor in assuring progress in services reform, including privatization measures, and development of successful partnership between the public and private sectors is the preparedness of all actors to engage in open experiential learning processes and foster the self-confidence and local leadership necessary for their own lessons and capacities to bring about the outcomes and ends they require.

According to Rivera et al. (2009) commercialization of extension services is only possible if farmers are willing to pay for these services and where extension services have previously been provided free of charge, assessment should be made to understand commercial demand for agricultural information. However, information on farmer valuation of current extension benefits, willingness to pay for extension services, types of services they are willing to pay for, and opportunities and obstacles to commercialization of extension is very scanty in the country. There is little or no effort to scrutinize alternative delivery extension mechanism. Ethiopian experiences need to be documented, analyzed and disseminated for a better understanding and implementation of commercial extension concept and how to achieve collaborative efforts in Ethiopian context in general and Haramaya district in particular. Consequently, this study was initiated to explore the willingness of farmers to pay for advisory services and empirically identify which characteristics make farmers more or less favorable towards paying for extension services.

Objectives of the study

The general objective of this study was to assess the need for and the implications for the development of commercial extension as an alternative to existing public extension support systems in Eastern Ethiopia. The specific objectives of this study were:

1. To assess farmers' willingness to pay for extension services, and
2. To identify factors determining willingness of farmers to pay for agricultural extension services.

METHODOLOGY

Study area

The study was carried out in the Eastern districts of Ethiopia. The district was selected purposively because of its long history in agricultural extension service provision. It was the place where the first Extension program was launched in Ethiopia. Haramaya is one of the sixteen Districts in Eastern Hararghe Zone with an estimated size of 52,163 ha. It is situated in the semi-arid tropical belt of eastern Ethiopia and characterized by a sub-humid climate with an average annual rainfall of about 790 mm, annual mean temperatures of 17°C with mean minimum and maximum temperatures of 9.4 and 24°C, respectively. The area experiences biannual type of rainfall classified as short and long rainy seasons. The short rainy season usually occurs from end of February to mid May and the long rainy seasons occur from July to end of September (District Agriculture office, 2009). Its altitude ranges from 1600 to 2100 m above sea level. The livelihood of the farmers is based on a mixed type of agriculture that is subsistence in nature. Sorghum, maize and chat are the most important agriculture crops in the area and dominantly consumed by rural community. Farmers intercrop sorghum and maize with chat and produce varieties of vegetable crops for export to Djibouti and Somalia and mostly using irrigation water.

Data sources and sampling technique

To achieve the objectives of the study, a combination of suitable qualitative and quantitative data were collected using both primary and secondary data. Primary data were collected from sample respondents through structured and pre-tested interview schedule. Four villages were purposively selected due to their high level of participation in terms of extension services, commercial orientation, access to transportation and market infrastructure, and access to irrigation facilities. Simple random sampling techniques were employed to select sample household heads from the four villages. The sample household percentage proportions to be selected per each sample village were calculated by using probability proportional to size technique. In all, a total 140 households were sampled for the study. Information gathered from farmers include: Questions related to socioeconomic, demographic and institutional characteristics of the households, current sources of information, the nature and extent of contact between the farmers and public

extension agents, and farmer willingness to pay (WTP) for extension services. Secondary data were also collected from annual reports and other published documents from various sources including district offices of agriculture and village administrative centers. Finally, qualitative data were also collected through focused group discussions, key informants interview.

Data analysis

In this particular study both descriptive statistics including percentages, mean, standard deviation, frequency of appearance and econometric models including Logit model, Chi-square test, t-test were used to analyze the data obtained from the field.
The specification of the logit model is as follow:

$$\frac{1}{1+e^{-z(i)}} \quad (1)$$

Where Pi denotes the probability that the i^{th} farmer will fall in the group of farmers who are willing to pay (yi=1) and (Zi) stand for function of n explanatory variables (Xi), and expressed as:

$$Zi = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + \text{--------} + \beta_n\chi_n \quad (2)$$

Where β0 is the intercept and β_i are the slope parameters in the model. The slope tells how the log-odds in favor of being willing to pay for extension services change as independent variables change. Since the conditional distribution of the outcome variable follows a binomial distribution with a probability given by the conditional mean P_i, interpretation of the coefficient will be understandable if the logistic model can be rewritten in terms of the odds and log of the odds (Gujarati, 1995). The odds to be used can be defined as the ratio of the probability that a farmer will practice (P_i) to the probability that he/she will not ($1-P_i$).

$$1 - Pi = \frac{1}{1+e^{zi}} \quad (3)$$

Therefore,

$$\left[\frac{pi}{1-pi}\right] = \frac{1+e^{z(i)}}{1+e^{-z(i)}} \quad (4)$$

And,

$$\frac{p(i)}{1-p(i)} = \frac{1+e^{z(i)}}{1+e^{-z(i)}} = e^{\beta 0 + \sum_{i=1}^{n} \beta ixi} \quad (5)$$

Taking the natural logarithms of the odds ratio of Equation (5) will result in what is known as the logit model as indicated here:

$$\ln\left[\frac{p(i)}{1-p(i)}\right] = \ln\left[e^{\beta 0} + e\sum_{i=1}^{n}\beta ixi\right] = z(i) \quad (6)$$

If the disturbance term U ($_i$) is taken into account the logit model becomes:

$$Z(i) = \beta_0 + \sum \beta ixi + Ui \quad (7)$$

In reality, the significant explanatory variables do not all have the same level of impact on the willingness of farmers to pay for extension services. Therefore, the impact of each significant variable on the probability of willingness to pay (WTP) will be calculated by keeping the continuous variables at their mean values and the dummy variables at their most frequent values (0 or 1).

Dependent variable of the model

In this investigation, willingness to pay for extension services (WTP) was treated as a dichotomous dependent variable, that is, it took the value 1 if the farmer is willing to pay and 0 otherwise. Accordingly, for understanding the determinants of the willingness to pay, the binary responses were analyzed within the logit regression framework.

Independent/explanatory variables of the study

Different empirical studies conducted elsewhere on factors influencing farmers' willingness to pay for extension services indicate the role of many social and economic factors in determining farmers' willingness to pay. The choice of explanatory variables was based on these studies and the characteristics found among the respondents. The a priori expectations of the variables are also specified in Table 1.

Summarizing, the independent variables of the study those which were hypothesized to have association with the willingness to pay for agricultural extension services were presented independently here under.

RESULTS

Willingness to pay

The data obtained from the survey depict that only 10.5% of sampled farmers agreed to pay for current extension service provided by development agents in their village. The remaining 89.5% of the respondents were not willing to pay for the current services. As can be seen from the above 60% of the willing respondents agreed to pay between 100 - 250 birr annually followed by 20% willing to pay between 300 - 450 birr per year.

Conditions for willingness to pay by farmers

In first scenario, no suggestion was made about any improvement in service quality. Thus, the resulting estimates are contingent on the current quality of the public extension services. In the second scenario, the improvement of the service quality was proposed. Majority (38.4%) of the willing respondents would have WTP between 350 and 550 birr annually. 27.9% would have WTP between 500 and 750 birr; and 18.6% agreed to pay between 800 and 950 birr per year. The remaining 8.1 and 6.9% of the willing respondents would have WTP greater than 1000 birr and less than 350 birr per year respectively. The farmers were also asked conditions under which they could make payments; accordingly majority of respondents (about 90%) among unwilling farmers, show willingness to pay under the condition of profit guaranteed specific advices for their farm, if payment made after production. Qualitative data analysis indicates that large proportions of the household were

Table 1. Definition of explanatory variables and their expected effect on willingness to pay.

Codes	Variables definition	Expected effect
SEX	Sex of household head, 0 = female, 1 = male	+
AGEHH	Age of household head in years	-
EDULHH	No of years of formal schooling	+
FXPHH	Farm experience of Household head in years	-/+
LDSH	Leadership involvement of the household head, 0= no 1= yes	+
FAMS	Family size of household	-/+
FARMS	Farm size of household in hectares	+
IRRIG	Whether a farmer use irrigation or not 0= no, 1= yes	+
INCOME	Total income of the household in Birr	+
TTLU	Livestock ownership in TLU	+
CREDIT	Credit use, 0= no, 1= yes	+
EXCTACT	Frequency of extension visit per year	+
LSTR	Radio ownership & listening 0=no, 1= yes	+

Table 2. Types of information / services for which farmers were ready to make payment.

Advice on marketing opportunities	40	46.5
Advice on improved seeds of crops	26	32.2
Advice on improved varieties of vegetables	50	58.1
Advice on crop protection	32	37.2
Animal health	8	9.3
Dairy development	27	31.3
Irrigation facilities	56	65.1
Agricultural implements and machineries	42	48.8
Arrangement of input supply	38	44.2
Liaison with credit services	17	19.8
Advice on micro enterprise and nonfarm activities	9	10.5
Advice to solve specific problems	10	11.6

* indicates, the percentage do not add up to 100 because of multiple counting.

willing to pay for the services. Concerning the amount of money, if the service can satisfy their needs, they can pay even a lot depending on the improvement on their farm income. Farmers were also asked to indicate whether they prefer in group or individual to make payment. Large proportion (92%) of the respondents preferred to pay in group/cooperative. The rest 8% respondents indicated that they want to pay individually.

Types of information / services for which farmers were ready to make payment

Farmers who had expressed their willingness to pay for agricultural information were asked to indicate the types of services for which they would be willing to pay. The top services indicated that farmers are preferring to pay for includes irrigation facilities (65.1%), providing information on improved varieties of vegetables (58.1%), advice on agricultural implements and machineries (48.8%), information on marketing opportunities (46.5%), advice on crop protection (37.2%), arrangement of input supply (44.2%), information on new varieties of crops (32.2%), dairy development (31.3%), and liaison with credit services (19.8%) (Table 2).

Econometric results for the binary logistic regression model

Before using the logit model for hypothesized variables, it is necessary to test the problem of multicollinearity or association among the potential independent variables. There are two measures that are often suggested to test the existence of multicolinearity. These are: Variance Inflation Factor (VIF) for association among the

Table 3. The maximum likelihood estimates of the logit model.

Variables	Coefficient	Wald - statistics	Sig. level	Odds ratio
	Constant		1.691	
AGEHH	-0.139	3.399	0.065*	0.870
EDHH	-0.056	0.273	0.601	0.945
SEX	-0.508	0.155	0.693	0.602
FAMSIZE	-0.235	3.307	0.069*	0.790
EXCTACT	0.030	1.575	0.210	1.031
TTLU	0.270	1.105	0.293	1.310
FXPHH	0.48	0.415	0.520	1.050
FARMSIZE	1.406	4.586	0.032**	4.078
INCOME	0.087	3.836	0.050**	1.091
LDSHP	-0.526	0 .745	0.388	0.591
IRRIG	0.381	0.345	0.557	1.464
LSTR	-2.559	9.529	0.002***	0.077
CREDIT	0.949	0.559	0 .455	2.583
Model- chi-square value	38.980***			
-2 log likelihood	80.750			
Correctly predicted (%)	80.6			
Sensitivity	82			
Specificity	78.1			

continuous explanatory variables and contingency coefficients for dummy variables. VIF shows how the variance of an estimator is inflated by the presence of multicolinearity (Gujarati, 2003).

As a rule of thumb continuous variable having variance inflation factor of less than 10 are believed to have no multicollinearity and those with VIF of above 10 are subjected to the problem were excluded from the model. Similarly, the contingency coefficient, which measures the association between various discrete variables based on the Chi-square, were computed in order to check the degree of association among the discrete explanatory variables to detect multicollinarity problem.

Contingency coefficient value ranged between 0 and 1, and as rule of thumb variables with contingency coefficient below 0.75 shows weak association and value above it indicates strong association of variables. The contingency coefficient for the dummy variables included in the model was less than 0.75 that didn't suggest multicollinearity to be a serious concern In total, 13 independent variables were used to estimate the determinants of willingness to pay for agricultural extension services, among hypothesized explanatory variables that are supposed to have influence on households. Using a statistical package known as SPSS version 18. These are education, family size, farming experience, farm size, tropical livestock unit, credit access, sex, age of household head, leadership status, income, irrigation availability, frequency of extension visit, and listening to the radio. These variables were selected on the bases of theoretical explanation and the results of various empirical studies. Moreover, they were selected by testing significant differences of the mean using t-test and $\chi 2$ and testing the existence of muliticollinearity using Variance Inflation Factors (VIF) and contingency coefficients.

The various goodness of fit measures were checked and validate that the model fits the data. The likelihood ratio test statistics exceeds the Chi-square critical value at less than 1% probability level. This implies that the hypothesis, which says all coefficients except the intercept is zero, was rejected. The value of Pearson Chi-square test shows the overall goodness of fit of the model at less than 1% probability level. Another measure of goodness of fit of the model was based on a scheme that classifies the predicted value of events as one if the estimated probability of an event is equal or greater than 0.5 and 0 otherwise. From all sample farmers, 80.6% were correctly predicted into willing and non-willing categories by the model. The correctly predicted willing and correctly predicted non-willing of the model were 82 and 78.1%, respectively. The estimated model, thus, groups willing and non-willing sampled respondents accurately. The maximum likelihood estimate of the parameters and the effect of independent variables on probability of WTP were analyzed and presented (Table 3)

DISCUSSION

As indicated earlier, thirteen key characteristics of farmers which are hypothesized to have influence on WTP for agricultural extension services/advisory services in the study area were included in the model. These variables include: Sex of household head (SEX), age of household head (AGE), education level of household head (EDULHH), farming experience of household heads (FXPHH), leadership position of the household head (LDSHP), family size (FAMS), farm size FARMS), total income of household (INCOME), total tropical livestock holding (TTLU), credit access (CREDIT), frequency of extension contact (EXCTACT), irrigation availability (IRRIG), and listening to the radio/mass media (LSTR) .

Five of the variables were found to be statistically significant at different levels of significance. Result from the logit model shows that listening to the radio/mass media (LSTR) was found significant at less than one percent probability level. Farm size (FARMS) and household income (INCOME) were significant at less than 5% significance level. The other two variables, age of household head (AGE) and family size (FAMS) were significant at less than ten percent probability level. The remaining eight variables, namely sex of household head (SEX), education level household heads (EDUHH), farming experience of household heads (FXPHH), frequency of extension contact (EXCTACT), irrigation use (IRRIG) and total livestock holding (TTLU) were not statistically significant. As expected, the coefficient on frequency of extension contact (EXCTACT), total livestock holding (TTLU), farm size (FARMSIZE), household income (INCOME), irrigation use (IRRIG) were positive. This indicates that an increase in any of these variables will lead to an increase in the probability of willingness to pay for extension services. The more farmers are frequently visited by extension agents, the more they hold large number of livestock, the more they use irrigation, the more they earn farm income and the more they hold large farm sizes the higher the probability of the willingness to pay for extension services. The coefficient on the age of household head (AGEHH) was also statistically significant and conforms to *a priori* expectations. The variable of listening to the radio (LSTR) significantly influenced the attitude of respondents towards payment for extension services but negatively. Contrary to *a priori* expectations, other variables, such as education level (EDUHH), leadership position (LDSHP), sex (SEX), and family size (FAMS), were found negatively related to WTP. The negative signs indicate that these variables were inversely related to farmers' willingness to pay for extension services.

CONCLUSION AND RECOMMENDATIONS

The study indicated that, 89.5% of the respondents were not satisfied with the extension services provided while only a small proportion of the respondents (10.5%) were satisfied by the current extension services. However, the findings in this study clearly show that there is a great opportunity to commercialize agricultural extension services. Majority of respondents (64.2%) were favorably disposed to paying for extension services if the service is satisfying them and could earn more profit than what they are now getting. The results imply that there exists significant demand by farmers for extension information services, making it potentially attractive for commercialization or privatization if high-quality extension services can be provided. These findings suggest that cost recovery mechanisms might be able to enhance the funding of extension delivery systems that farmers indicate they find useful and important. One can also easily deduce from the results of this survey that there is great opportunity for graduates of agricultural sciences to be organized and establish consultancy firms to serve farmers through providing quality information useful to farmers to make good decision. This can have two fold advantages. The result of the econometric analysis that age have an inverse and significant relationship with willingness to pay for extension services should be properly considered. To ensure financial sustainability of extension service young farmers should be targeted. Household income, farm size and household size are critical to how much farmers will be willing to spend on extension services. By targeting farmers, with high level of incomes, large farm sizes and small household sizes, the commercialization of extension services could be enhanced. However care should be taken to equally address poor, household with large families as well as household with small land holdings.

Conflict of Interest

The authors have not declared any conflict of interest.

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Economic viability of the agricultural recycling of sewage sludge in Brazil

Mônica Kristina Foltran Marcon[1]*, Elisandro Pires Frigo[2], Carlos Eduardo Camargo Nogueira[1], Helton José Alves[2], Leandro Paiola Albrecht[2] and Juliana Pires Frigo[3]

[1]Universidade Estadual do Oeste do Paraná (UNIOESTE), Programa de Pós-Graduação, Mestrado em Engenharia de Energia na Agricultura. Rua Universitária, 2069, CEP 85819-130, Cascavel, Paraná, Brazil.
[2]Universidade Federal do Paraná (UFPR), Câmpus Palotina - Rua Pioneiro, 2153, CEP 85950-000, Palotina, Paraná, Brazil.
[3]Universidade Federal da Integração Latino-Americana (UNILA). Avenida Silvio Américo Sasdelli, 1842, CEP 85866-000, Foz do Iguaçu, Paraná, Brazil.

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The sewage sludge can be used for agricultural recycling as biosolids, since all the legal requirements are fulfilled, in plantations whose edible part does not have contact with the ground, thus its use is not allowed with the oleraceous, tubers, roots and flooded cultures. Considering that, from data collected by the Sanitation Company of Paraná (SANEPAR), the agronomic analysis reports of 10 lots of biosolids processed at Ouro Verde Sludge Management Unit, in the city of Foz do Iguaçu, Brazilian state of Paraná, were checked, relating the concentration of nutrients N, P, K, Ca and Mg. Assuming the biosolids are given to farmers, responsible for transportation costs, the material becomes attractive only when equivalent to mineral fertilizers cost. By determining the price of fertilizers by the lot of biosolids, the distance that justifies its utilization was established. The main results found allow the conclusion that biosolids have from R$30.83 to R$167.32 of fertilizers per ton, considering the worst and best case scenario, respectively. The compensatory distance has exceeded 1500 km, increasing the possible use by producers from other cities or states. The reduction of the humidity content in the material is directly proportional to economy granted to the producer.

Key words: Biosolids, fertilizer, cost.

INTRODUCTION

The investments in the sector of sanitation increased significantly, mainly after the announcement of the Plan of Growth Acceleration, which fulfilled the gap in the sanitary treatment in the Brazilian scenario. Data of the federal government show that in the year of 2012 the volume of sewage collected exceeded 5 trillion meter cube for the volume of sewage treated around 3.5 trillion meter cube, with the addition of 8.9 and 10.5%, respectively, compared to the year of 2011 (Brasil, 2014). Consequently, the concern about the residue generated by this process becomes significant, taking into account the environmental impact that can still be created, even

*Corresponding author. E-mail: monicakfm@yahoo.com.br, Tel: (55) 45 99233428.

with the proper destination. The agricultural use, the destination to places of residue elimination, the recuperation and restoration of blighted áreas, and the incineration, stand out among others (Fytili and Zabaniotou, 2008).

In general, in Brazil, the effluent treatment plants (ETEs) are designed to remove settleable solids and carbonaceous organic matter, with deficiency to remove the nitrogen and phosphorus, which cause the deterioration of the water resources and accelerators of eutrophication of the bodies of water which are recipient from the effluents (Lamego Neto and Costa, 2011).

The biosolids, originating from the sewage sludge, is the organic product of the sewage treatment system, rich in organic matter and nutrients, especially nitrogen and phosphorus, with agricultural potential for isolated use or in combination with mineral compost (Lemainski and Silva, 2006a). Thus, the agricultural recycling of biosolids is a viable alternative for the final destination, since besides the acknowledged presence of several nutrients in its composition; there is equivalence of performance when substituting the chemical fertilizers (Backes et al., 2009; Adair et al., 2014). Studies show that biossolid aplication on no-till dryland agroecosystem is an efficient method of recycling for this source of nutrients (Barbarick et al., 2012). However, the availability of potentially toxic metals, several times, restrains its use (Singh and Agrawal, 2008), when the limits required by law are not.

In a long-term study, the application of sewage sludge for agricultural lands changed the physical properties of the soil (Maria et al., 2010); the same happened on experiments in vases (Song and Lee, 2010). Besides, there are reports of increase of productivity from certain cultures, such as the sunflower, when used instead of the mineral fertilizer (Lamb et al., 2012; Figueiredo and Grassi Filho, 2007).

Teixeira et. al. (2005) estimated the average energy added to the nitrogen-based fertilizer at 59.46 $MJkg^{-1}$, for the phosphate at 11.96 $MJkg^{-1}$ and for the potassium at 5.89 $MJkg^{-1}$. This demonstrates that the acquisition of mineral or industrialized fertilizers, available at the market, is strongly dependent on fossil fuel. According to Pracucho et al. (2007), when the energy balance of corn plantation is analyzed, the part regarding the energy consumption of fertilizers stands out from the other variables.

The Brazilian regulation defines, through the Resolution number 375/2006 of the National Environmental Council (Conama, 2006), the criteria for the agricultural recycling of biosolids, considering the macronutrients and other variables of agronomic interest existent in each lot of the product. The document also defines the cultures able to use biosolids, whose edible part doesn't have contact with the soil, thus it is not allowed to be used with the oleraceous, tubers, roots and flooded cultures. In spite of that, some producers are still afraid of the use of biosolids in the food production. One alternative that eliminates the drawback in the possibility of food chain contamination is its use as indirect alternative energy, such as the energetic cultures, for the production of biogas, bioethanol and biodiesel, or in cultures of fibers as the combustion feedstock (Wang et al., 2008).

Independent on the culture that will be planted, the attractiveness for the rural producers opting for the biosolids is increased when the cost-effect relationship is considered favorable.

This way, this work aims to relate, from a historical series of data, the agronomic parameters of ten lots of biosolids processed in a Sludge Management Unit (UGL), determining the quantity and the correspondent price of nitrogen, phosphorus, potassium, calcium and magnesium inserted in the biosolids, as well as the distance of economic viability that justifies the substitution of chemical fertilizers by the use of biosolids, considering that the cargo dues will be paid by the farmer.

MATERIALS AND METHODS

The study was based on data from the Sludge Management Unit (UGL) Ouro Verde, located on Idalina Correa Gradela Street, no address number, in the city of Foz do Iguaçu, in the Brazilian State of Paraná, with geographic coordinates S 25°33'36" W 54° 34'48", kept by the Sanitation Company of Paraná (SANEPAR). The sludge processed is predominantly domestic, originating from the sewage treatment system in the region, which use the process of anaerobic digestion. The dewatering of the material was obtained through natural bed dryers; the sanitation was done through extended alkaline stabilization for 30 days, with addition of lime to 30% of the total solids according to procedures standardized by SANEPAR.

After the period of stabilization, the lots were sampled in order to characterize the agronomic features determined by Conama (2006). However, for the periods prior to 2006, there is not a standardization of methodology, due to the lack of regulation. In spite of that, the techniques used were considered adequate for the aimed study, since all the lots were allocated to agricultural recycling, with the authorization from the responsible environmental agencies.

From the analysis history, 10 (ten) lots were considered within the period from 2002 to 2012, from which the agronomic parameters of the biosolids on dry basis referred to the concentrations of nitrogen, phosphorus, potassium, calcium and magnesium.

For the data shown in this study, from the original reports of chemical characterization, it was performed the calculation adjustment of nitrogen available for the plants, considering the fraction of mineralization (FM) determined by Conama (2006). The other parameters, which refer to the the concentrations of phosphorus, potassium, calcium and magnesium, did not need calculation adjustment, taking into account the initial analysis' values. The Kolmogorov-Smirnov method was used for the normality statistical test.

From the concentration of nutrients contained in the biosolids, it was possible to establish the equivalence of chemical fertilizers NPK and of limestone, due to the presence of Ca and Mg, inserted individually in each lot, considering, at first, the dry basis, in order to establish the best and the worst case scenario.

Nevertheless, the influence of humidity in the lots of biosolids was considered, since it alters the concentration of nutrients, besides affecting directly the cost of transport and capability of cargo in the vehicle , regarding volume and mass. Hence, the

Table 1. Concentration of nitrogen, phosphorus, potassium, calcium and magnesium per lot of biosolids on dry basis (mg kg^{-1}).

Lot	Date	N	P	K	Ca	Mg
I	jul/02	1820	4400	450	63000	226700
II	apr/03	3000	2300	400	31030	48000
II	feb/05	3040	6900	626	77600	85100
IV	sep/05	2740	6900	2400	46000	2300
V	may/06	3420	2100	280	37241	1800
VI	mar/07	3220	7800	612	120700	1600
VII	mar/09	2432	5728	755	168600	4798
VIII	aug/10	4666	4526	410	161700	12075
IX	jul/11	8220	5298	940	168300	1450
X	apr/12	4873	2276	1600	72000	1250
Average		5048	4823	847	94617	38507

Source: report analyses SANEPAR (2002 - 2012).

concentration of nutrients in the lots of biosolids in the wet basis was recalculated, according to the indication of the samples collected, which is the valid condition for transport.

The costs were extracted from the site of the National Supply Company (Conab, 2013), regarding the average price of industrialized fertilizers charged within the period from November 2012 to October 2013, in the State of Paraná, namely: Ammonium nitrate, simple superphosphate and potassium chloride. Regarding the calcium content, under direct comparison, dolomite lime was chosen over the calcium lime, due to a bigger concentration of Mg, identified in the analysis of the biosolids.

Relating the values about the costs of chemical fertilizers by the concentration of nutrients contained in the lots analyzed, the costs of nutrients inserted in a ton of biosolids on dry basis were obtained.

Assuming that there are some advantages for the use by the farmer when the total value of the nutrients contained in a definite mass of the material is equal or above the cargo dues, the maximum efficient distance of transport of the sewage sludge was calculated according to the methodology presented by Silva et al. (2002), in Equation 1.

$$d \leq \frac{CN}{CT} \quad (1)$$

Where: d, distance in kilometers (km); CN, cost of nutrients inserted in 1 ton of biosolids (R$ t^{-1}); CT, cost of transport per ton - kilometer (R$ $t^{-1}km^{-1}$).

The CT was obtained in the System of Cargo Information (Sifreca, 2013), and the maximum distance with economic viability for the use of biosolids was determined, simulated for the scenarios of nutrient concentration in each lot.

RESULTS AND DISCUSSION

The concentration of nutrients for 10 lots of biosolids on dry basis is related on Table 1. The concentration of nitrogen was adjusted, from the original data, for the nitrogen available for the plants in the superficial application.

The data showed normality, as $p_{value} > 0.05$, for the Kolmogorov-Smirnov test. However, it is perceptible the large variability in the chemical composition among the lots of biosolids, meeting the data behavior from Martins et al. (2003), which reported difficulties conducting long term experiments. The same way, Silva et al. (2002), reported the occurrence of daily variations in the nutrient composition of the sludge. Thus, it was not possible to establish a tendency in the concentration of different nutrients of the biosolids. Other attributes must also be observed, as in other heavy metals and other composts, which also have variation in their concentration, due to the places, time and seasonality (García-Delgado et al., 2007). This way, it is necessary to adjust the calculation for the quantities of the material in every application, of the individualized evaluation per lot or according to the monitoring time based on the quantity of sludge processed at UGL, in order to elaborate the agronomic project, as defined by Conama (2006).

For Vesilind and Hsu (1997), the water in the sewage sludge can be presented in four ways: free, adsorbed, capillary and cellular. For the first form, the portion can be separated by simple gravity process. For the rest, there is a need of mechanical forces or a change in the physical state of water sample evaporation or freezing.

In the samples analyzed, the humidity to 0% occurred only under lab conditions, due to the greenhouse drying process for determining the dry mass. Under environmental conditions the data demonstrate great humidity variation in the sludge obtained after draining in natural bed. This implicates that for each ton of humid biosolids transported, from 122.20 to 461.40 kg of water are included. By contrast, the concentration of nutrients per ton of biosolids decreases, as observed on Table 2.

The cost of industrialized fertilizers according to Conab (2013), are shown on Table 3, with the adjustment for the nutrient content.

Relating Tables 2 and 3, the total cost of nutrients inserted in a ton of biosolids was obtained, under the conditions of dry and humid basis, resulting in Table 4.

Table 2. Concentration of nutrients NPK, Ca e Mg per ton biosolids on humid basis.

Lot	Humidity %	Biosolids dry basis (kg)	N (mg kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
I	26.32	736.80	1341	3242	332	46418	167033
II	25.18	748.20	2245	1721	299	23217	35914
II	13.70	863.00	2624	5955	540	66969	73441
IV	21.60	784.00	2148	5410	1882	36064	1803
V	16.06	839.40	2871	1763	235	31260	1511
VI	23.80	762.00	2454	5944	466	91973	1219
VII	38.50	615.00	1496	3523	464	103689	2951
VIII	46.14	538.60	2513	2438	221	87092	6504
IX	32.46	675.40	5552	3578	635	113670	979
X	12.22	877.80	4278	1998	1404	63202	1097
Average	25.60	744.02	2752	3557	648	66355	29245

Table 3. Average cost of nutrient adjusted by R$ t^{-1} of nitrogenous, phosphate, potassic and dolomite lime, in the Brazilian State of Paraná, within November/2012 and October/2013.

Product	Average cost of product (R$ t^{-1})	Nutrient content (%)	Adjusted cost nutrient (R$ t^{-1})
Ammonium nitrate	1075.58	34.00	3163.47
Simple superphosphate	916.77	18.00	5093.18
Potassium chloride	1399.24	60.00	2332.06
Dolomitic limestone	111.37		
CaO		30.00	366.36
MgO		21.95	507.39

It is possible to observe that there are from R$ 30.83 to R$ 167.32 of nutrients inserted in a ton of biosolids, considering the worst and the best scenario, respectively. The difference on dry and humid basis was up to R$ 48.05, which demonstrates the considerable advantage in the reduction of humidity. Silva et al. (2002), says that one of the possibilities to increase the area range for the use of biosolids is to remove the excess of water.

According to Sifreca (2013), the average cost of national bulk cargo for the transport of fertilizers was R$ 0.1091 t^{-1} km^{-1}. Applying the Equation (1), the maximum distance of economic viability for the use of biosolids was simulated on Table 5.

The lower the water content is, the bigger the compensatory distance for the farmer to use biosolids, reaching 1521.12 km. Even for the worst case scenario, the distance was 280.24 km. The average distance was between 841.66 and 613.47 km, for dry and humid basis, respectively. The last column shows the proportion of increased attractiveness of the product distance for dry basis, which we can observe the significant difference for lot VIII.

As mentioned by Quintana et al. (2012), considering only the substitution of NPK, the added value to sewage sludge was R$ 102.47 per ton. For the distance of 25 km, the cargo cost R$ 11.84, almost 10 (ten) times less than the price of fertilizers, therefore, compensating. When compared to other possible destinations, the agricultural application of sewage sludge has the lowest cost (Lundin et al., 2004), which highlights the economic advantage of its utilization.

For Kimberley et al. (2004), the application of biosolids can increase significantly the economic benefit and compensate its transportation and application costs. It demonstrates that, the less distant from the UGL the rural property is, the bigger the profit for the farmer, who could use the resources which would be used to purchase industrialized fertilizers on other investments on their property.

Lemainski and Silva (2006b), in an experiment on the production of corn, biosolids were on average 21% more efficient than mineral fertilizers. Considering the transport distance of 100 km, the best cost-benefit ratio in productivity (1.90) was obtained with the application of 30 t ha^{-1} of humid biosolids.

The use of sewage sludge as fertilizer may be the best option from an economic and environmental point of view, it has the lowest cost for final disposal, allowing a

Table 4. Comparison of total cost of nutrients per ton of biosolids on dry and humid basis (R$ t^{-1}).

Lot	Dry basis	Humid basis	Difference
I	167.32	123.28	44.04
II	57.86	43.29	14.57
II	117.83	101.69	16.14
IV	67.43	52.86	14.56
V	36.72	30.83	5.90
VI	96.37	73.44	22.94
VII	102.83	63.24	39.59
VIII	104.14	56.09	48.05
IX	117.57	79.41	38.16
X	57.75	50.69	7.06
Average	92.58	67.48	25.10

Table 5. Maximum distance (km) of economic viability for the use of biosolids at UGL Ouro Verde.

Lot	Distance (km) dry basis	Distance (km) humid basis	Difference (%)
I	1521.12	1120.76	35.72
II	526.00	393.56	33.65
II	1071.17	924.42	15.87
IV	612.98	480.57	27.55
V	333.86	280.24	19.13
VI	876.11	667.59	31.23
VII	934.82	574.91	62.60
VIII	946.69	509.89	85.67
IX	1068.86	721.91	48.06
X	525.02	460.86	13.92
Average	841.66	613.47	37.20

reduction in the use of mineral fertilizers and recycling of organic matter, with essential nutrients to plants (Santos et al., 2011). This demonstrates its importance in agricultural recycling, especially when considering the scarcity of mineral resources in certain regions.

Conclusion

The biosolids processed at UGL Ouro Verde showed economic viability for agricultural use. In a ton of biosolids at UGL Ouro Verde there are from R$ 30.83 to R$ 167.32 of fertilizers, considering the worst and best case scenario, respectively, at a distance of viability that reaches 1500 km. This way, the use of biosolids is not restrained to rural producers close to the UGL, whereas it is also viable to make the material available to producers from other cities, and even other states, considering the geographic localization. The humidity content in the biosolids is directly proportional to the transportation cost for the producer. Thus, the economy generated is related to the decreased humidity, since this way more nutrients are transported. So, future studies about technology aimed at the reduction of humidity are advisable, from which it is possible to highlight the use of thermal energy from biogas produced in the sewage treatment plant.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Comparative efficacy of brown, red and green seaweed extracts on low vigour sunflower (*Helianthus annus* L.) var. TN (SUF) 7 seeds

K. Sujatha*, V. Vijayalakshmai and A. Suganthi

Department of Seed Science and Technology, Agricultural College and Research Institute, Madurai, Tamil Nadu, India.

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Extracts of the brown seaweeds (*Sargassum myricocystum*) red seaweed (*Gracilaria edulis*) and green seaweed (*Caulerpa racemosa*) have been used as a biostimulant to promote seedling emergence and vigour. The two different concentrations (1 and 5%) and soaking durations of (1:1 seed t solution ratio) were used. Results of the present study suggest that the sunflower seed soaked in 5% *C. racemosa* seaweed extract for 8 h performed significantly in all estimated characters (72% Germination; 15.95 cm Shoot length; 13.60 cm Root length; 0.399 OD Dehydrogenase activity; 0.277 dSm^{-1} electrical conductivity and lowest abnormal seedlings production 3%) can be recommended as a mid storage seed treatment for improving the vigour and viability of aged seeds.

Key words: Seaweed extracts, sunflower seeds and vigour.

INTRODUCTION

Seaweeds are one of the most important marine resources of the world. Seaweed extract is a new generation of natural organic fertilizers containing highly effective nutritious and promotes faster germination of seeds. Unlike, chemical fertilizers extracts derived from seaweeds are bio – degradable, non toxic, non – polluting and non – hazardous to humans, animals and birds (Dhargalkar and Untawale, 1983). Seaweeds are known to contain appreciable concentrations of plant growth regulators (Mooney and Van Staden, 1985), cytokinin (Smith and Van Staden, 1984). IAA (Abe et al., 1972), gibberellins and gibberellins like substabces (Bentley, 1960; Sekar and others, 1995).

Quality seed is the key for successful and sustainable agriculture. Tropical countries like India, due to prevalence of high temperature and relative humidity may greatly accelerate seed ageing. Loss of physiological quality during ageing leads to deterioration of seeds. Any treatment given to seeds at the time of packing for maintaining physiological stamina and germination will be advantageous. Use of organics (or) naturally occurring biological materials like seaweeds is a new approach for seed preservation. With this background the present study was undertaken to explore the possibility of utilizing

*Corresponding author. E-mail: sujathakvk@gmail.com

seaweed extracts in sunflower seeds.

MATERIALS AND METHODS

Seed material

Naturally aged seeds of Sunflower (*Helianthus annus* L.) cv. TN (SUF) 7 with 58% germination were used for this study.

Collection of seaweeds

The seaweeds *Sargassum myricocystum* (Brown algae); *Gracilaria edulis* (red algae) and *Caulerpa racemosa* (green algae) were collected from Mandapam coast, Tamil Nadu, India were washed with seawater initially to remove macroscopic epiphytes and sand particles, finally with fresh water to remove adhering salt.

Preparation of seaweed extracts

Seaweeds were shade dried for 4 to 5 days followed by oven drying at 45°C for 24 h and powdered from which 100 g powder was taken and 100 ml of alcohol was added then kept it for overnight with intermittent stirring and extracted through rotary evaporator and extract collected and stored in air tight container. This constitutes 100% extract.

Seed treatment

Graded seeds of low vigour sunflower treated with *S. myricocystum*, *G. edulis* and *C. racemosa* extracts with different concentrations of 1 and 5% for 8 h with 1:1 ratio (seed to solution) along with water and dry seeds as control.

Experiment

Treated seeds were subjected to germination test in paper medium in quadruplicate using 100 seeds for each treatment with four sub replicates of 25 seeds (ISTA, 1999) and kept in a germination room maintained at 25 ± 1°C and RH 96 ± 2% with diffused light (Approx. 10 h) during the day. Final count on normal seedlings was recorded on 10^{th} day and percentage germination, shoot and root length was computed.

Biochemical analysis

The electrical conductivity was measured by soaking 50 seeds in 50 ml of deionised water for 24 h (Presley, 1958) and dehydrogenase activity (Kittock and Law, 1968) was assessed using embryos from seeds soaked with water for 12 h.

Statistical analysis

The experiments were arranged in a factorial completely randomized design (FCRD) with four replicates. An analysis of variance (ANOVA) was made using SAS software. Correlation was assessed by using Microsoft Excel software. Significance of mean difference of the variable means was separated using LSD at P = 0.05.

RESULTS

Sunflower seed emergence and seedling growth studies

Sunflower seeds treated with *C. racemosa* 5% aqueous solution of seaweed extract showed significantly higher percent emergence, shoot length and root length over control and water. Higher germination of (72%), shoot length (15.53 cm) and root length (11.60 cm) was observed and it was on par with 5% seaweed extract of *S. myricocystum.* when compared to control seeds (51%, 11.17 cm and 9.9 cm for germination, shoot length and root length). The percent increase over control was 21, 39 and 18 for germination, shoot and root length (cm) (Figure 1 and Plate 1a). This suggested that the positive response of *Caulerpa* extract and its organic fractions were the maximum effect on seed emergence and seedling vigour.

Effect of seaweed extracts on biochemical attributes

Dehydrogeanse activity in sunflower seeds was significantly higher than that of the untreated control. When compared to control *Caulerpa* 5% extract showed higher dehydrogenase activity (0.399 OD value). These results suggest that the bio–active compounds that induce the dehydrogenase activity in sunflower are organic compounds that can be readily extracted into organic solvents. Generally the electrical conductivity of seed leachate values are related to membrane integrity and physiological quality of seed. In the present study *Caulerpa* 5% treated seeds showed lower electrical conductivity (0.277 d Sm^{-1}). EC values differed with the treatments owing to their differential influence of membrane integrity. The lower EC values recorded with these seeds treated with seaweed extract and the beneficial effect of prevention of lipid auto oxidation by antioxidants.

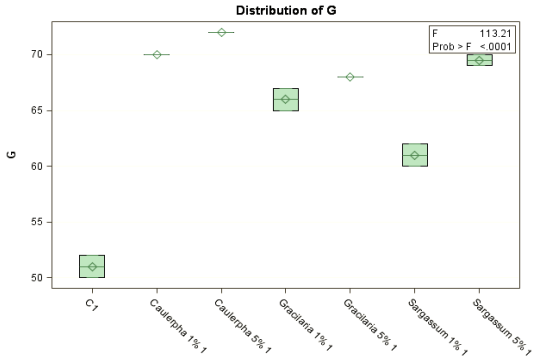
Abnormal seedling percentage

Abnormal seedling percentage differed significantly due to seaweed extracts. However, these abnormal seedlings percentage increased in control seeds (14) compared to other seaweed extracts *S. myricocystum* (7), *G. edulis* (8) and *C. racemosa* (5). Significantly lower abnormal seedling percentage (3%) was observed in seeds treated with *C. racemosa* 5% extract (Plate 1b).

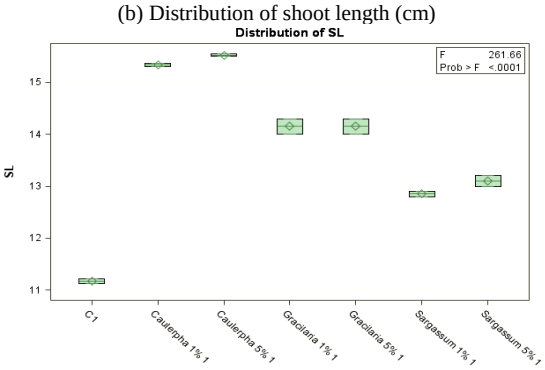
DISCUSSION

The beneficial effect of seaweed has attempted in many crops (Venkataraman et al., 1993) in blackgram and green gram;Gandhiappan and Perumal (2001) in sesame

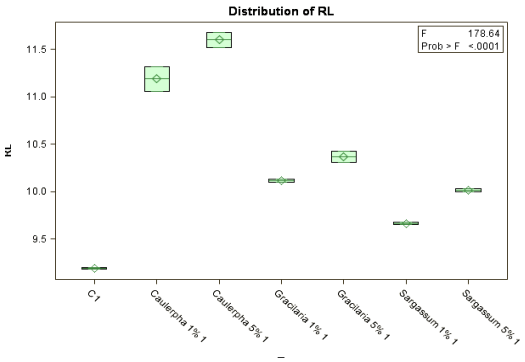
(a) Distribution og Germination %



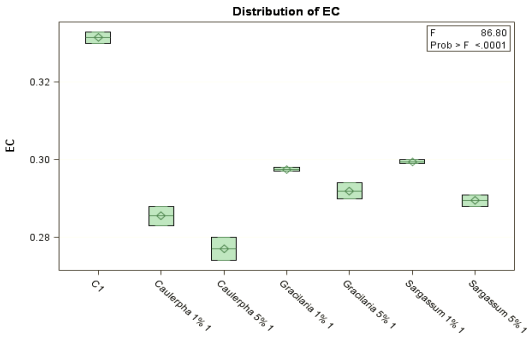
(b) Distribution of shoot length (cm)



(c) Distribution of root length (cm)



(d) Distribution of Electircal conductivity (dSm^{-1})



(e) Distribution of Dehydrogenase (OD value)

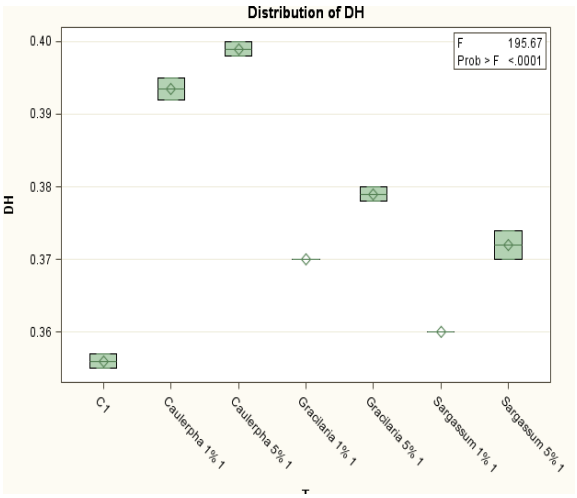


Figure 1. Effect of seaweed extract on low vigour sunflower seeds.

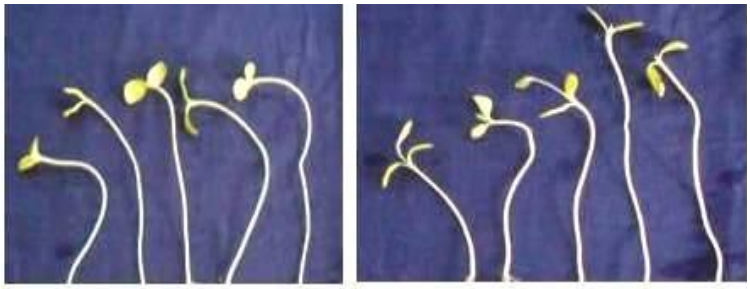
and Veeragurunathan et al., 2011 in capsicum). Being a cheap and abundant source of nutrients, minerals and natural antioxidants seaweeds will be beneficial in improving seedling emergence and vigour.

In the present study, among the seaweeds *C. racemosa* 5% extract shown to increase the seedling emergence and vigour over control. This enhanced growth effect is thought to be due to various organic compounds present in the seaweed extract. More specifically it is thought to be due to presence of phyto hormones mainly cytokinins in the seaweed extracts (Wrightman and Thimann, 1980; Steveni et al., 1992;

(a) Seed germination and seedling vigour

Control Treated seeds

Earliness in leaf formation



Control Treated seeds

(b) Abnormal seedlings

Control Treated seeds

Plate 1. *C. racemosa* (5%) seaweed extract on low vigour sunflower. (a) Seed germination and seedling vigour,(b) Abnormal seedlings.

Rayorath et al., 2008). They had observed that root growth – promoting effects of cytokinin in *Maxicrop triple* and *Ascophyllum nodosum* and these extracts improved root and shoot growth over control seeds. Early seed emergence and increased seedling vigour have a large effect on seedling establishment.

High enzyme activities were observed in seaweed treated seeds compared to water soaking and control and also lower abnormal seedling and EC values. The effect of seaweed extract particularly *Caulerpa* followed by *Gracilaria* and *Sargassum* would have contributed for antioxidant role in quenching of free radicals minimising peroxidant changes. The seaweeds *Caulerpa* have natural sources of vitamins A, C and E (Ratana – arporn and Chiropart,2006; Sivasankari et al., 1999; Matanjun et al., 2009; Sarojini et al., 2011). The promotional impact

Table 1. Correlations between various vigor parameters of treated sunflower seedling.

Parameter	G %	RL (cm)	SL (cm)	EC	DH	Abnormal (%)
G %	1.000					
RL (cm)	0.892**	1.000				
SL (cm)	0.851**	0.911**	1.000			
EC	-0.947**	-0.801**	-0.811**	1.000		
DH	0.843**	0.709*	0.864**	-0.805**	1.000	
Abnormal (%)	-0.903**	-0.948**	-0.974**	0.888**	-0.824*	1.000

*Significant at 5% (P = 0.05) level; **Significant at 1% level (P =0.01) - : Negatively correlated, G % - Germination %, RL – Root Length (cm), SL – Shoot length (cm), EC – Electrical Conductivity (dSm^{-1}), DH – Dehydrogenase activity(OD), Abnormal (%) – Abnormal seedlings %.

was more pronounced in the case of alcohol aqueous method. This may be due to growth promoting ingredients soluble either in alcohol or water getting completely isolated in the seaweed extracts (Sylvia et al., 2005; Vethanayagi et al., 2009; Jeba et al., 2010).

Correlation studies also shown that percentage of germination increase was positively correlated with shoot, root and dehydroenase activity and negatively correlated with electrical conductivity and abnormal seedling percentage (Table 1). It could be concluded that low vigour sunflower seeds treated with 5% *C. racemosa* seaweed extract obtained through rotary evaporator can be recommended for mid - storage seed treatment for improving seed vigour and viability.

Conflict of Interest

The authors have not declared any conflict of interest.

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African Journal of Agricultural Research

Full Length Research Paper

Gross antibodies, chemical composition of bovine milk and its influence by thermal stability

K. M. El-Zahar[1,3]*, M. M. El-Loly[2] and Azza S. Abdel-Ghany[1]

[1]Food Science Department, Faculty of Agriculture, Zagazig University, Egypt.
[2]Dairy Science Department, National Research Centre, Dokki, Giza, Egypt.
[3]University of La Rochelle, Laboratory of Transfer Phenomena and Instantaneity in Agro-Industry and Building, Pôle Science and Technology. Av. Michel Crépeau 17042 La Rochelle Cedex01, France.

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Immunoglobulin G (IgG), chemical composition contents of bovine milk during the first week of postpartum and the effect of heat treatments on bovine colostrum IgG contents were evaluated. Individual milk samples were collected from five cows at 0 to 0.5, 1, 2, 3, 4, 5, 6 and 7 days postpartum. The obtained results showed that the total solids, total protein, fat and ash contents decreased irregular with time after parturition, while the lactose content had an opposite trend. IgG concentrations were higher significantly during 0 to 0.5 and 1st days than those of other days postpartum, where the mean±SD of IgG concentrations were 122.60±5.24 and 118.44±5.90 g/L during 0-0.5 and 1st days postpartum, respectively. However, IgG concentrations dropped markedly with time progress of lactation at the end of the first week (7th day); it was 55.16±17.30 g/L that had dropped ratio of 55.01% when compared with its concentrations at 0 to 0.5 day. The IgG concentrations of thermally treated colostrum were decreased to 28.24, 30.27 and 30.18% at 63°C/30 min as well as 57.33, 73.54 and 95.1% at 72°C/15 s during 1, 2 and 3 days postpartum, respectively. On the other hand, the most thermal influence on IgG was at 100°C/10 min, where the percentage losses were 95.72% at 1st and 100% at 2 and 3 days postpartum. The total amino acids values of bovine milk immunoglobulins (IgS) were highest at 0 to 0.5 day and dropped markedly with time progress of lactation.

Key words: Bovine milk, colostrum, immunoglobulin G (IgG), heat treatments, amino acids.

INTRODUCTION

Colostrum is very important part of milk and lays down the immune system and confers growth factors and other protective factors for the young ones in mammals. Also, it is a unique food created by nature to sustain and protect the new born mammal. It is a pre-milk made available by the mother to the newborn in the first few days after birth has taken place. Colostrum contains high levels of immunoglobulins, the self-defense mechanism by which the body fights infection as well as valuable growth factors to nourish the newborn (Radu Dragomirescu, 2013). Vetter et al. (2013) mentioned that the provision of quality colostrum with a high concentration of immunoglobulin S is critical for newborn calf health, because first colostrum may be low in overall

*Corresponding author. E-mail: k.elzahar@yahoo.com

concentration to effectively reduce the risk of newborn infections.

The nutritional and physiological needs of the neonate during this period of very early life are typically quite specialized. The composition of the maternal colostrum is tailored to meet these unique requirements (Tsioulpas et al., 2007; Chistiansen et al., 2010; Abd El-Fattah et al., 2012). The colostrum composition and its quality are influenced by a variety of factors, including maternal age, parity, breed, nutritional status, season, premature parturition, premature lactation, colostral handling factors, induction of parturition and health status. During transition from colostrum to normal milk, gradual or sometimes sudden changes may occur in composition and properties (Gulliksen et al., 2008; Abd El-Fattah et al., 2012; Morrill et al., 2012).

Colostrum is not only a source of nutrients such as proteins, carbohydrates, fat, vitamins and minerals, but it also contains several biologically active molecules that are essential for specific functions. Most of the biologically active substances in complete bovine colostrum that can convey significant health benefits are proteins (Pakkanen and Aalto, 1997).

In recent years, bovine colostrum has become popular as a product for human consumption, because it is an excellent source of bioactive proteins. The latter would have the ability to prevent bacteria and viruses as well as to improve the gastrointestinal and body condition. Really, the exploitation of the beneficial properties of colostrum is not a new concept (Conte and Scarantino, 2013). The immunoglobulins S (IgS), or antibodies, found in colostrum or milk are the same as those found in the blood or mucosal secretions. They are used by the immune system to identify and neutralize foreign objects, such as bacteria and viruses. For cattle, IgS are grouped into four isotypes, IgG (IgG_1 and IgG_2), IgM, IgA, and IgE, based on the heavy chain they possess (Korhonen et al., 2000a, b; Gapper et al., 2007). IgG, IgM and IgA are present in high levels in milk, especially in colostrum. The IgG is dominant in colostrum, milk and blood (about 80 to 90%, 60 to 70% and 90% of total IgS, respectively) (Mix et al., 2006; Zhao et al., 2010).

IgG concentrations change throughout the first six milking's postpartum. The relatively high levels of IgG in early bovine colostrum thus provide an essential source of this nutrient to the calf immediately following parturition and until it can establish immunosufficiency. IgG antibodies express multifunctional activities, including complement activation, bacterial opsonisation and agglutination as well as act by binding to specific sites on the surfaces of most infectious agents or products, either inactivating them or reducing infection (Lilius and Marnila, 2001; Gapper et al., 2007).

Interest has arisen on the effect of heat treatments on different Ig classes. Detectable IgG in colostrum or colostral whey are reduced by heat treatment at a slower rate than the isolated IgG. Thermal Protestants such as sugars or glycerol can increase the stability of isolated IgG to heat treatment (Chen et al., 2000; Zagorska and Ciprovica, 2012). According to Chen and Chang (1998) IgS are thermo labile. Exposure to temperatures of 75°C/5 min can reduce detectable isolated bovine IgG by 40%, and by 100% at 95°C/15 s. The explanation of it is conformational changes in the IgG molecule caused by heat exposure (Calmettes et al., 1991). Donahue et al. (2012) demonstrates that batch heat treatment of colostrum at 60°C/60 min can be successfully conducted on commercial dairy farms by farm staff to decrease colostrum microbial counts while maintaining colostrum IgG concentrations. Also, Gelsinger et al. (2014) reported that heat treatment significantly reduced all types of bacteria and IgG concentration in colostrum at 60°C/30 min.

The aim of the current study was to analyze gross IgS, chemical composition of bovine milk during the first week postpartum and evaluate the effect of heat treatments on bovine milk IgG content.

MATERIALS AND METHODS

Sample collection

This study was conducted from February 2010 till December 2012 aiming at estimation of the concentrations of total protein and IgG in bovine milk during the first week postpartum.

Individual milk samples were collected from five Frisian cows of El-Sadeen village, Menia Al-kamh Center, Sharkia Governorate, Egypt. Milk samples were obtained at 0 to 0.5, 1, 2, 3, 4, 5, 6 and 7 days postpartum. Samples were collected in sterilized bottles by supervised manual expression at the end of the milking and transported to the laboratory in an ice box. All samples were stored at -20°C immediately on arrival and kept frozen till analysed.

Determination of gross chemical composition

The total solids (TS), total protein (TP) and fat contents, lactose and ash contents were determined according to AOAC (2000).

Determination of immunoglobulins in bovine milk

Samples preparation

Bovine milk samples were defatted by centrifugation at 4000 rpm/3 min. Milk whey was prepared from the skim milk by adjusting pH to 4.6 using 1 *N* HCl solution and centrifuging at 10000 rpm/15 min to remove casein precipitate. Total IgS were prepared from whey samples by using saturated ammonium sulphate solution according to the method described by Hebert (1974). The ammonium sulphate extract was dialysed against distilled water for 24 h, at refrigerator with several changes of distilled water during this period. The dialysed extract was kept at -20°C until analysed.

Immunoglobulin quantification by single radial immunodiffusion (SRID)

The immunoglobulin G (IgG) content was quantified using Single Radial Immuno Diffusion Technique (SRID) as described by Fahey and Mckelvey (1965). SRID plates containing antibodies to IgG

Table 1. Gross chemical composition content (%) with means±SD* of bovine milk (N=5) during the first week postpartum.

Lactation period (days)	TS	TP	Fat	Lactose	Ash
0-0.5	19.83±2.12^{a}	10.65±1.71^{a}	5.68±0.72^{a}	2.50±0.45^{e}	1.01±0.09^{a}
1	17.55±1.65^{b}	9.26±1.32^{b}	4.76±0.89^{b}	2.59±0.34^{e}	0.94±0.07^{b}
2	15.33±0.96^{c}	7.36±0.53^{c}	4.26±0.86^{bc}	2.83±0.38^{de}	0.88±0.04^{bc}
3	14.63±0.68^{cd}	6.67±0.13^{cd}	3.90±0.64^{cde}	3.22±0.24^{cd}	0.85±0.02^{cd}
4	13.76±0.80^{de}	5.77±0.36^{de}	3.70±0.56^{cdef}	3.49±0.15^{bc}	0.81±0.02^{def}
5	13.18±0.80^{de}	5.18±0.74^{ef}	3.30±0.48^{def}	3.90±0.35^{ab}	0.79±0.02^{def}
6	12.81±0.70^{e}	5.00±0.56^{ef}	3.10±0.46^{ef}	3.94±0.44^{a}	0.77±0.04^{ef}
7	12.22±0.78^{e}	4.48±0.63^{f}	2.94±0.50^{f}	4.04±0.29^{a}	0.75±0.03^{f}
LSD**	1.45	1.11	0.82	0.42	0.60

SD*: Standard deviation; LSD**: The least significant difference. Means with different superscript within the same column are significantly different.

and IgM (Cat. No. RL 200.3, RN 278.3, the Binding Site LTTDR, UK) were used.

Heat treatments

To investigate the effect of heating methods on the IgG content of bovine milk, the milk samples were collected from individual cow's milk during the first three days of postpartum (colostrum) and defatted, the skim milk was heat treated as follows: Heating was carried out at 63˚C / 30 min, 72˚C / 15 s and 100˚C / 10 min; then followed by rapid cooling to 37˚C for all samples.

Amino acids analysis

Amino acids content were determined as described by Folkertsma and Fox (1992). The analysis was performed in Central Service Unit, National Research Centre, Egypt, using LC3000 amino acid analyzer (Eppendorf-Biotronik, Germany). The technique was based on the separation of the amino acids using strong cation exchange chromatography followed by the ninhydrine color reaction and photometric detection at 570 nm. Samples were hydrolysed with 6 *N* HCl at 110˚C in Teflon capped vials for 24 h. After vacuum removal of HCl, the residues were dissolved in a lithium citrate buffer, pH 2.2. 20 µl of the solution were loaded on to the cation exchange column (pre-equilibrated with the same buffer), then four lithium citrate buffers with pH values of 2.2, 2.8, 3.3 and 3.7 respectively, were successively applied to the column at flow rate 0.2 ml/min. The ninhydrine flow rate was 0.2 ml/min and pressure of 0 to 150 bar. The pressure of buffer was from 0 to 50 bars and reaction temperature was 130ºC.

Statistical analysis

Statistical analysis for the obtained data was carried out using SPSS version 20 computer program (Dominick and Derrick, 2001). All data were expressed by means and standard deviations of 3 replicates and were compared using One- way ANOVAs and least significant difference (LSD). Values with different letters within the same column differ significantly at p<0.01 to 0.05.

RESULTS AND DISCUSSION

Gross chemical composition of bovine milk

It was noticed that the mean±SD concentration of TS was 19.83±2.12% during 0 to 0.5 day postpartum. TS Total solids content decreased to reach a mean±SD 17.55±1.65% at 1st day postpartum. While gradual decreases of TS could be noticed on the following days at 2, 3, 4, 5, 6 and 7 postpartum, respectively. The mean concentrations of TS were higher significantly during 0 to 0.5 day than other days postpartum. But no significant differences were found between 3, 4 and 5 days. No significant differences were found between 4, 5, 6 and 7 days postpartum, in the same order (Table 1). Similar results have been reported by Abd El-Fattah et al. (2012) who observed that the TS contents decreased irregularly with time after parturition. TS content at 1st day postpartum in the present study was higher than those reported by Kleinsmith (2011). Bar et al. (2010) found that the mean of TS contents in bovine colostrum were 27.6 and 23.6% with ranges 18.3 to 43.3 and 21.6 to 29.15%, respectively, while in mature milk (0.0.5H) were 12.7 and 12.9%; Walstra et al. (2006) and Kleinsmith (2011) found that the TS contents in bovine colostrum were 27, 20.5, 14.5, 12.8, 12.2 and 11.5% at 0, 6, 12, 24, 36 and 48 h postpartum, respectively. Also, Abd El-Fattah et al. (2012) stated that the mean of TS content in bovine colostrum at calving was 24.2%. TP concentration of bovine milk was higher significantly during 0 to 0.5 day postpartum (10.7±1.7%) than other days, followed by 1st day postpartum (9.3±1.3%). No significant differences were found between the mean±SD concentrations of TP at 2nd day (7.4±0.5%) and 3rd day (6.7±1.1%), but significant differences were found between 2nd (7.4±0.5%) and 4th days (5.8±0.4%). However, no significant differences were found between the mean±SD concentrations of TP at 5 (5.2±0.7%), 6 (5.00±0.6%) and 7 (4.5±0.6%) days postpartum (Table 1). These results are in agreement with those found by Tsioulpas et al. (2007); Kleinsmith (2011) and Abd El-Fattah et al. (2012) who found that the protein content decreases gradually with time after parturition. Protein content at 1st day postpartum in this study was higher than those reported by Klimes et al. (1986) and lower than those reported by Tsioulpas et al. (2007). The mean of TP content in bovine

colostrum was 14.92% with range 7.1 to 22.6% within 4 h of calving (Kehoe et al., 2007); 9.5% with range 6.6 to 11.7% at first milked after calving (Bar et al., 2010); 13.45% at calving (Abd El-Fattah et al., 2012) and 12.2% with range 8.9 to 21.9% after 2 to 3 days postpartum (Conte and Scarantino, 2013), while in mature milk, the protein contents were 3.4% (Gopal and Gill, 2000), 2.9% (Fox and McSweeney, 2003) and 3.3% (Walstra et al., 2006).

The mean ± SD concentration of fat was 5.7 ± 0.7% during 0 to 0.5 day postpartum and dropped to a mean ± SD 4.8 ± 0.9% at 1st day postpartum. Thereafter, a gradually decreasing could be noticed on the following days, where the means ± SD of fat concentrations were 4.3 ± 0.9, 3.9 ± 0.6, 3.7 ± 0.6, 3.3 ± 0.5, 3.1 ± 0.5 and 3 ± 0.5% at 2, 3, 4, 5, 6 and 7 days postpartum, respectively (Table 1). These results indicate that a significant difference was found between the fat content during 0 to 0.5 day and other days, but no significant differences were found between 1 and 2; 2, 3 and 4 and 4, 5, 6 and 7 days postpartum. Also, the results are in quite agreement with those of Abd El-Fattah et al. (2012) who observed that the fat content decrease with time after parturition, but in contrast with the study of Tsioulpas et al. (2007) and Kleinsmith (2011). Fat content at 1st day postpartum in the present study was higher than those reported by Tsioulpas et al. (2007). Fat content of the first milking colostrum varies over a wide range and was reflected in values for TS (Elfstrand, et al., 2002). The mean of fat contents in bovine colostrum were 6.7% with range 2.0 to 26.5% within 4 h of calving (Kehoe et al., 2007), 3.5 (4.6 to 5.8%) of first milked after calving (Bar et al., 2010), 8.0% at calving (Abd El-Fattah et al., 2012) and 7.9 (2.6 to 16.1%) after 2 to 3 days postpartum (Conte and Scarantino, 2013), while in mature milk, it was 3.7% (Jensen, 1995), 4.6% (Gopal and Gill, 2000), 4.5% (Fox and McSweeney, 2003) and 4.0% (Walstra et al., 2006).

It is evident from Table 1 that the mean ± SD of lactose concentrations at 0 to 0.5, 1st and 2nd days were 2.50±0.45, 2.59±0.34 and 2.83±0.38%, respectively without significant differences between the first two days of lactation. The lactose content increased to a mean ± SD 3.2±0.2% at 3rd day, 3.5±0.2% at 4th day and 3.90±0.3% at 5th day. On the other hand, the mean ± SD concentrations of lactose at 6 and 7 days were 3.9±00.4and 4.04±0.3%, respectively without significant differences between them. Our results are closely similar with those of Kleinsmith (2011) and Abd El-Fattah et al. (2012) who observed that the lactose content increase with time after parturition. This difference is an advantage because lactose can induce the young to scour (diarrhea) with subsequent death or unthiftiness (Roy, 1970). In contrast with the study of Elfstrand et al. (2002) who found that the lactose contents were 3.0, 2.9, 3.5, 3.2, 3.5, 3.5 and 3.8% during 0 to 6, 7 to 10, 11 to 20, 21 to 30, 31 to 40, 41 to 50 and 51 to 80 h, respectively.

Changes in lactose content of colostrum showed the opposite trend than the corresponding values in the mature milk, probably due to the knowledge of the mechanisms of lactose synthesis. Kuhn (1983) suggested that the lower availability of plasma glucose and colostral Lactalbumin is a possible cause of the lower percentage of lactose in colostrum immediately after parturition. Lactose contents in the present study were lower than those reported by Tsioulpas et al. (2007) at 1st to 5th day; Kleinsmith (2011) at 1st and 2nd days; Klimes et al. (1986) at 3rd and 5th days postpartum. But, it was higher than those reported by Klimes et al. (1986) at 1st day postpartum. Bar et al. (2010) and Conte and Scarantino (2013) showed that the mean of lactose contents in bovine colostrum were 2.49, 3.5 and 2.04% with ranges 1.2 to 5.2, 3.37 to 3.94 and 1.46 to 3.19%, in the same order, while in mature milk, it were 4.1 and 4.6% (Walstra et al., 2006).

The mean ± SD concentrations of ash were higher significantly during 0 to 0.5 day (1.0 ± 0.1%) than those of other days postpartum, then dropped to range from 0.8 to 1.0% at 1st day postpartum with a mean ± SD 0.9±0.1%, while at 2nd day postpartum had a mean ± SD 0.9 ± 0.04%, without significant differences between 1st and 2nd day. A gradual decrease could be observed on the following days namely, 0.9±0.02, 0.8±0.02, 0.8±0.02, 0.8±0.04 and 0.75 ± 0.03% at 3, 4, 5, 6 and 7 days postpartum, in order. There were significant differences between ash content at 2nd and 4th days postpartum, but insignificant variations were found between 4, 5, 6 and 7 days postpartum (Table 1). These results are in agreement with the previous reports by Klimes et al. (1986), Tsioulpas et al. (2007) and Abd El-Fattah et al. (2012) who observed that the ash content decrease with time after parturition. This may be attributed to increase of mineral in colostrum compared to mature milk. However, in colostrum, high protein and salt, low sugar content are ideal for the neonate's immature digestive system (Hamosh, 1996). Bar et al. (2010) showed that the mean values of ash content in bovine colostrum were 0.05 and 1.5% with ranges 0.02 to 0.1 and 1.10 to 1.3%, respectively, while in mature milk were 0.7 and 0.8% (Fox and McSweeney, 2003).

IgG concentrations of bovine milk during the first week postpartum

Individual milk samples were taken from five cows within 7 days postpartum. The IgG concentrations of bovine milk samples were quantified by the SRID technique at 0 to 0.5, 1, 2, 3, 4 and 7 days postpartum. The relation between the IgS concentrations and the diameter of the precipitated antigen-antibody reaction are found in Figures 1, 2, 3, 4 and 5 (wells No. 1 and 2). It is clear that the IgG concentrations were highest in colostrum, which falls drastically with the first few days of lactation. The IgG concentrations were higher significantly during 0 to 0.5

Figure 1. Single radial immunodiffusion analysis of IgG for individual bovine milk samples during the first week postpartum. Wells No: 1, 2, 3, 4, 5 and 6 represent samples of cow number 1 at 0-0.5, 1, 2, 3, 4 and 7 days postpartum. Wells No: 7, 8, 9, 10, 11 and 12 represent samples of cow number 2 at 0-0.5, 1, 2, 3, 4 and 7 days postpartum. Wells No: 13 and 14 represent samples of cow number 3 at 0-0.5 and 1 day postpartum.

Figure 2. Single radial immuno diffusion analysis of IgG for individual bovine milk samples during the first week postpartum. Wells No: 1, 2, 3 and 4 represent samples of cow number 3 at 2, 3, 4 and 7 days postpartum. Wells No: 5, 6, 7, 8, 9 and 10 represent samples of cow number 4 at 0-0.5, 1, 2, 3, 4 and 7 days postpartum. Wells No: 11, 12, 13 and 14 represent samples of cow number 5 at 0-0.5, 1, 2 and 3 days postpartum.

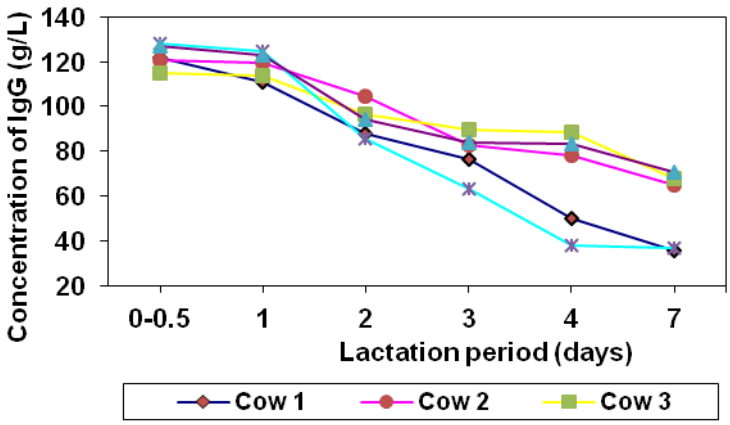

Figure 3. IgG concentrations of individual bovine milk samples during the first week postpartum.

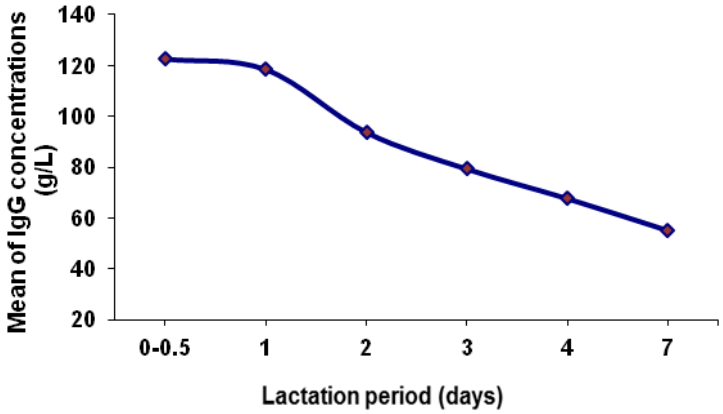

Figure 4. Mean IgG concentrations of bovine milk samples during the first week postpartum.

Figure 5. Single radial immunodiffusion analysis of IgG for bovine milk samples affected by different heat treatments. Wells No: 1 and 2 represent samples of cow number 5 at 4 and 7 days postpartum. Wells No: 3, 4, 5 and 6 represent control, 63°C/30 min; 72°C/15 s and 100°C/10 min at 1st day postpartum. Wells No: 7, 8, 9 and 10 represent control, 63°C/30 min., 72°C/15 s and 100°C/10 min at 2nd day postpartum. Wells No: 11, 12, 13 and 14 represent control, 63°C/30 min., 72°C/15 s and 100°C/10 min at 3rd day postpartum.

and 1st days than those of other days postpartum, where the mean±SD of IgG concentrations were 122.6±5.2 and 118.4±5.9 g/L during 0 to 0.5 and 1st days postpartum, respectively (Table 2). However, IgG concentrations dropped markedly with time progress of lactation. At 2nd, 3rd and 4th days, the mean ± SD values of IgG were 93.7±7.6, 79.3 ± 10.0 and 67.7±22.4 g/L, respectively, which had dropped ratios of 23.5, 35.3 and 44.8%, in order. At the end of the first week (7th day), the mean ± SD of IgG concentration was 55.2±17.3 g/L that had dropped ratio 55.0% when compared with its concentrations at 0 to 0.5 day. This change in IgG content indicates that the significance of colostrum for the health of the newborn calf where the absorption of IgG during the first 24 h, after birth was reported occur excessively (Butler, 1971). These results are in good agreement with those of Saucedo-Quintero and Avendano-Reyes (2004) and Abd El-Fattah et al. (2012). Elfstrand et al. (2002) stated that the major IgS present in bovine milk are IgG with 85% ratio, among which 95% belong to the sub classes IgG_1 and 5% to the IgG_2. The mean concentrations of IgG (IgG_1+IgG_2) were 92.8, 80.9, 66.8, 25.1, 31.5, 17.7 and 12.2 g/L during 0 to 6, 7 to 10, 11 to 20, 21 to 30, 31 to 40, 41 to 50 and 51 to 80 h, respectively. Similar results were reported by Bar et al. (2010), Morrill et al . (2012) and Quigley et al. (2013),

Table 2. IgG concentrations of bovine milk during the first week postpartum.

Lactation period (days)	Concentration of IgG (g/L)					Mean±SD*	% of decrease
	Cows						
	1	2	3	4	5		
0-0.5	122.00	120.80	115.10	128.20	126.90	122.60±5.24[a]	-
1	110.80	119.70	114.00	124.50	123.20	118.44±5.90[a]	3.39
2	88.07	104.70	96.50	85.42	94.00	93.74±7.57[b]	23.54
3	76.60	83.00	89.50	63.40	84.18	79.34±10.02[bc]	35.29
4	50.00	78.20	88.80	38.00	83.58	67.72±22.38[cd]	44.77
7	35.80	64.80	67.70	36.90	70.60	55.16±17.30[d]	55.01
LSD**	**16.986**						

SD*: Standard deviation; LSD**: The least significant difference. Means with different superscript within the same column are significantly different.

Table 3. Effect of heat treatments on bovine colostrum IgG concentrations (g/l).

Lactation period (days)	Control	Heat treatment					
		63°C/30min	%Loss	72°C/15 s	%Loss	100°C/10 min	%Loss
1	125.70	90.20	28.24	66.20	47.33	5.38	95.72
2	107.70	75.10	30.27	28.50	73.54	-	100
3	84.79	59.20	30.18	4.23	95.01	-	100

while in mature milk, it was 0.72 and 0.556 mg/ml (Zagorska and Ciprovica, 2012).

Effect of heat treatments on bovine colostrum IgG

It could be noticed that the concentrations of IgG during thermal treatments were reduced from 125.7, 107.7 and 84.8 g/L in control individual milk samples at 1, 2 and 3 days postpartum to 90.2, 75.1 and 59.20 g/L in thermally treated milk at 63°C/30 min, in order, it were decrease to 28.2, 30.3 and 30.2%, respectively (Table 3). Increasing temperature to 72°C/15 s, the IgG concentrations of heated individual milk samples were reduced to 66.2, 28.5 and 4.2 g/L, it were decreased by 52.7, 26.5 and 5% at 1, 2 and 3 days postpartum, respectively. On the other hand, the most influence on IgG content at 100°C/10 min, where the percentage losses were 95.7% at 1st and 100% at 2 and 3 days postpartum. It could be concluded that the stability of IgG in bovine milk was influenced by thermal treatments. These results are in accordance with those reported by El-Loly (1996) and Zagorska and Ciprovica (2012). While Mainer et al. (1997) had different research results, HTST pasteurization (72°C/15 s) led to 25 to 40% loss of IgG concentration.

Amino acids composition of bovine milk IgS during the first week postpartum

The essential and non-essential amino acids composition of bovine milk IgS from parturition to 7th day postpartum are presented in Table (4) Threonine, leucine, phenylalanine, histidine, aspartic, glutamic, glycine and tyrosine concentrations were gradually decreased during the first week of lactation, values being 0.9 to 0.4, 2.4 to 1.0, 1.4 to 0.6, 0.9 to 0.3, 1.6 to 0.7, 3.25 to 1.3, 0.25 to 0.1 and 1.0 to 0.5 mg/100 ml at 0-0.5 and 7 days postpartum, respectively. Whereas, valine, methionine, isoleucine, lysine, serine, alanine, cystine, arginine and proline concentrations were the highest at 0 to 0.5 day that then decreased at 7th day postpartum, but these decreases were progressively. These values at 0 to 0.5 and 7th days postpartum were valine (1.1 and 0.5), methionine (0.6 and 0.2), isoleucine (0.7 and 0.3), lysine (1.5 and 0.6), serine (1.15 and 0.54), alanine (1.2 and 0.5), cystine (01.0 and 0.4), arginine (1.04 and 0.5) and proline (2.2 and 0.8) mg/100 ml, respectively. From the obtained data, it is evident that the generally total of amino acids values were highest at 0 to 0.5 day and gradually decreased at the following days, these values were 22.2, 19.6, 19.1, 16.6, 13.65, 12.4, 10.7 and 9.2 mg/100 ml at 0 to 0.5, 1, 2, 3, 4, 5, 6 and 7 days postpartum, respectively.

Furthermore, it is very clear that glutamic acid (non-essential) was found in the largest amount of bovine milk IgS in amount 2.2 mg/100 ml of the generally total amino acids with a ratio 14.25% of them. While in the essential amino acids, the leucine acid was presented in the highest content with ratio 10.2% of the generally total in a mean 1.6 mg/100 ml. These results are in contrast with

Table 4. Amino acids composition (mg/100 ml) of bovine milk IgS during the first week postpartum.

Amino acids		Lactation period (days)							
		0-0.5	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Valine	1.08	0.98	1.02	1.08	0.71	0.68	0.47	0.47
	Leucine	2.42	1.91	1.81	1.68	1.24	1.24	1.31	1.00
	Isoleucine	0.72	0.57	0.45	0.49	0.38	0.35	ND	0.30
	Threonine	0.89	0.87	.0.81	0.70	0.56	0.48	0.42	0.3.8
Essential	Methionine	0.61	0.43	0.48	0.23	0.29	0.23	0.31	0.19
	Phenylalanine	1.37	1.17	1.16	1.13	0.85	0.80	0.79	0.60
	Histidine	0.93	0.78	0.68	0.67	0.53	0.51	0.40	0.33
	Lysine	1.52	1.40	1.25	1.24	0.85	0.81	0.61	0.60
	Total	9.54	8.11	7.65	7.22	5.41	5.11	4.31	3.87
	Aspartic	1.59	1.54	1.07	1.31	0.90	0.89	0.75	0.69
	Serine	1.15	1.19	1.12	1.30	0.85	0.69	0.59	0.54
	Glutamic acid	3.25	2.84	2.74	2.29	1.90	1.68	1.63	1.29
	Glycine	0.25	0.24	0.23	0.21	0.20	0.18	0.12	0.12
Non-essential	Alanine	1.23	1.07	1.05	0.74	0.78	0.64	0.65	0.53
	Cystine	0.98	0.84	1.37	0.02	0.72	0.75	0.70	0.42
	Tyrosine	1.01	0.93	0.91	0.90	0.73	0.60	0.46	0.47
	Arginine	1.04	0.96	1.06	1.29	0.78	0.70	0.55	0.48
	Proline	2.21	1.85	1.88	1.31	1.37	1.20	1.00	0.76
	Total	12.70	11.46	11.44	9.39	8.23	7.33	6.43	5.30
Overall total		22.24	19.57	19.09	16.61	13.65	12.44	10.74	9.18

ND: Not detected.

those reported by El-Loly (1996) who observed that buffalo's milk IgS at the first 12 h postpartum contained higher values of all essential amino acids except leucine and lysine.

Effect of some heat treatments on amino acids contents of bovine colostrum IgS

Composite colostrum samples collected throughout the first milking (1, 2 and 3 days) after calving in dairy cows. Heating was carried out at 63˚C /30 min, 72˚C / 15 s and 100˚C /10 min., and then followed by rapid cooling to 37˚C for all samples. As known, milk is a heat labile material and the thermal treatments of milk are to improve quality. Therefore, it is very important to understand the changes happening in the amino acids composition of milk IgS during the applied thermal treatments. It could be noticed that the values of all essential amino acids were reduced in thermal treated milk samples at 63°C/30 min, 72°C/15 s and 100°C/10 min. compared to control sample except histidine value at 63°C/30 min. Non-essential amino acids values were decreased in thermal treated milk samples at 63°C/30 min., 72°C/15 s and 100°C/10 min. compared to control sample except proline value at 72°C/15 s. On the other hand, the highest influence on all amino acids values was at 100°C/10 min. because this protein is sensitive to heating. The effect of heat treatment at 72°C/15 s on values of aspartic, glutamic and glycine were lower than that effect of heated samples at 63°C/30 min. (Table 5). El-Loly (1996) observed that the lysine concentration of the IgS content of buffalo's milk was decreased at sterilization treatment (130ºC/15 s), while aspartic and glutamic values were increased at the boiling and sterilization methods. Isoleucine, leucine and phenylalanine values were increased, but glycine and alanine were decreased from control to sterilized milk samples.

Conclusion

Immunoglobulins an important component of the immunological activity found in colostrum and milk. They are central to the immunological link that occurs when the mother transfers passive immunity to the offspring. Cattle provide a readily available immune rich colostrum and milk in large quantities, making those secretions important potential sources of immune products that may benefit humans.

Table 5. Effect of heat treatments on amino acids composition (mg /100 ml) of bovine milk IgS.

Amino acids		Control	Heat treatment		
			63°C/30 min	72°C/15 s	100°C/10 min
Essential	Valine	0.66	0.58	0.44	0.18
	Leucine	1.09	0.94	0.88	0.42
	Isoleucine	0.33	0.30	0.25	0.16
	Threonine	0.52	0.41	0.35	0.26
	Methionine	0.27	0.27	0.24	0.19
	Phenylalanine	0.70	0.64	0.56	0.30
	Histidine	0.42	0.52	0.35	0.21
	Lysine	0.81	0.62	0.60	0.30
	Total	**4.80**	**4.28**	**3.67**	**2.02**
Non-essential	Aspartic	0.82	0.63	0.73	0.48
	Serine	0.80	0.59	0.57	0.29
	Glutamic acid	1.67	1.28	1.50	0.91
	Glycine	0.20	0.15	0.15	0.05
	Alanine	0.68	0.56	0.51	0.17
	Cystine	0.58	0.41	0.10	0.10
	Tyrosine	0.72	0.58	0.45	0.17
	Arginine	0.71	0.45	0.39	0.21
	Proline	1.01	0.99	1.17	0.25
	Total	**7.20**	**5.64**	**5.58**	**2.62**
Overall total		**12.00**	**9.92**	**9.25**	**4.63**

ND: Not detected.

Conflict of Interest

The authors have not declared any conflict of interest.

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Determinants of technical, allocative and economic efficiencies among onion producing farmers in irrigated agriculture: Empirical evidence from Kobo district, Amhara region, Ethiopia

Berhan Tegegne Haile

Socio-Economics and Agricultural Extension Research Directorate, Sirinka Agricultural Research Centre. P. O. Box 74, Woldiya, Ethiopia.

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This study investigated the determinants of technical, allocative and economic efficiencies among small-scale onion farmers in North Wollo zone of Amhara National Regional State, Ethiopia. Structured questionnaires were used to collect data from 200 respondents randomly selected from designated locations in the study area. A stochastic production frontier function was fitted to the sample households. The findings revealed that land related factors such as land distance, ownership, and fragmentation explained much of the technical inefficiencies in addition to other socio-economic characteristics of farm households (age, market access, training access, years of experience in onion production, farm income, responsibility and field visit) were found to be significant at different levels of significance for technical efficiency. The variables that explained allocative efficiency were plot distance, market access, sources of irrigation water, extension visit, farm income and field visit. Major determinants for economic efficiency were age of the household, plot distance, fertility, source of irrigation water, extension visit, experience in onion production, land fragmentation and farm income. It is therefore suggested that any development intervention program through irrigation should consider the aforementioned socioeconomic characteristics and determinants of efficiency for success. Tenure insecurity and land fragmentation also play significant role for farmers to adopt the available technologies and maximize production on irrigated farms. Likewise, it has shown positive effect on production inefficiency, calling for the need to think about policies targeting land consolidation at least with in farms, improving institutional services (extension, market, training, attitude change on credit utilization), soil management options and increased investment in irrigation services could jointly contribute to the improvement in efficiency of onion farmers in the study area.

Key words: Efficiency, inefficiency, irrigation, Amhara region, Kobo, Ethiopia.

INTRODUCTION

Ethiopia is an agrarian country where around 95% of the country's agricultural output is produced by smallholder

E-mail: hberhantegegne@yahoo.com

farmers (MoA, 2010). Agriculture contributes about 41% of the country's GDP, employs 83% of total labour force and contributes 90% of exports (EEA, 2012).Ethiopian agricultural sector has always been an important component of the country's economy. A sectoral analysis in 2011 of the real GDP indicated that the agricultural sector contributed about 41.1% of the GDP, with crop, livestock, forestry and fishery accounting for 27.5, 10.6, 2.9, and 0.2% respectively (CSA, 2012). This implies that the crop sub-sector contributed 66.9% of agriculture GDP.

Though agriculture remains the most important sector of the Ethiopian economy, its performance has been disappointing and food production has been lagging behind population growth (Demeke, 2008). Kobo district is among the north eastern area endowed with ground and surface water sources and substantial quantities of vegetables are grown under irrigation during dry season (KGVDP, 2005).

Despite its potential, kobo district productivity increase is said to be declining (CSA, 2012). Similarly, productive efficiency for most crops still falls under 60% (Haji, 2008). These shortfalls are attributed to inefficiencies in production. Therefore, the need for the efficient allocation of productive resources cannot be overemphasized. Presently, there are very few firm-level studies of efficiency in the developing economies, particularly in Ethiopia.

As far as the researcher knows, no specific investigation into farm level productive efficiency involving onion production is carried out in the study area, as most of these studies focus on only the resource use efficiency (Belay et al., 2010).

The total irrigable land potential in Ethiopia is 5.3 million hectares assuming use of existing technologies, including 1.6 million hectares through Rain Water Harvesting (RWH) and ground water. There are 12 river basins that provide an estimated annual run-off of 125 billion m^3 per year, with total irrigating potential of 3,731,222 ha from surface water.

The potential available estimates for RWH range from 40,000 to 800,000 ha. The area under irrigation development to-date is estimated to be 640,000 ha for the entire country which is 5% of the potential irrigable (Awulachew et al., 2010). Irrigation benefits the poor through higher production, higher yields, lower risk of crop failure, and higher and year-round farm and non-farm employment. Irrigation enables smallholders to adopt more diversified cropping patterns, and to switch from low value staple production to high-value market-oriented production. Increased production makes food available and affordable for the poor (Asayehegn et al., 2011).

In the light of the foregoing, this study examined farm household' technical, allocative and economic efficiencies of smallholder drip and furrow irrigated farm production in Kobo district of Amhara National Regional State Ethiopia.

METHODOLOGY

Study area

The study was carried out in Kobo district. It is located in the North Eastern part of Amhara National Regional State, North Wollo zone, Ethiopia, lying between 11° 54' 04" and 12° 20' 56" N latitude and between 39° 25' 56" and 39° 49' 04" E longitude (Figure 1). The district has an altitude that ranges from 1400 to 3100 m above sea level. The district capital town, Kobo is about 570 km away from Addis Ababa on the way to Mekele (CSA, 2011; WOA, 2010). According to the North Wollo Zone Agricultural Office (2010), Kobo district shares 43.74% of the total 47,292.7 ha of irrigable land of North Wollo, which is equivalent to 5.5% of the total irrigable land of the region (BoWME, 2005).

Kobo district has total human population of 239,504 of which 120,383 (50.26%) are male and 119,121 (49.74%) are female. Out of the total population, 20.15% are urban dwellers. Kobo has a population density of 119.7 people per square kilometer, which is less than the zonal average of 132.3 per km^2. The district has a total area of 2001.57 km^2. With regard to land use pattern of the district, cultivable land comprises the highest (29%) followed by degraded land (26.5%) (CSA, 2011).

According to WOA report, (2009), the agro climatic feature of the district is tropical as 7.9, 37.2 and 54.9% are Dega, Weyina dega and Kola respectively. As described by the report of WOA, 65% is plain while the rest 20, 6, 5 and 4% are mountainous, rugged, gorges and swampy. Kobo is characterized by low and erratic rainfall with mean annual rainfall of 670 mm that ranges from 500 mm to 850 mm. The temperature varies from a minimum of 19°C to a maximum of 33°C annually. Compared to other districts of the zone, Kobo district has relatively hot climate and it has mean annual temperature of 23.1°C.

The total land area under cultivation in the Kobo District is 58,045 ha, of which 90% is rain fed. Average land holding in the District is 0.75 ha, whereas average holding under irrigation is 0.15 ha. Main types of crops grown during rainy season are Teff, Sorghum, Maize and Chickpea in their order of area coverage. In the district, production of vegetables and root crops under rain fed condition is virtually impossible unless the seasonal rainfall is supplemented with irrigation water. Thus their production is limited to those households who have access to irrigation water.

In most irrigable lands of kobo, horticultural crops in general and onion in particular, play an important role in contributing to the household food security. Some of the vegetables and root crops produced using irrigation includes onion, tomato and pepper. Among the vegetables and root crops, onion takes the highest share.

Due to this, more than 75% of irrigated area, which is 4000 ha, was allocated for production of onion in the district that could generate income for the poor households (WOA, 2010).

Sampling procedure and sample size

The target population for this study was onion farmers in the study area. Since onion is produced in virtually all the areas of the district and in order to have a representative sample in achieving the stated objectives, the sampling procedure covered all the areas equally. Accordingly, a two-stage sampling procedure was employed in selecting the sample for this study. The first stage involved the random selection of six villages in different irrigation scheme. The second stage was the random selection of 100 farming households in each of the already selected group of scheme based on proportionate probabilistic sampling techniques. Accordingly, a sample of two hundred farming households was collected and subsequently analyzed for the study. The sampling distribution of the respondents is shown in Table 1.

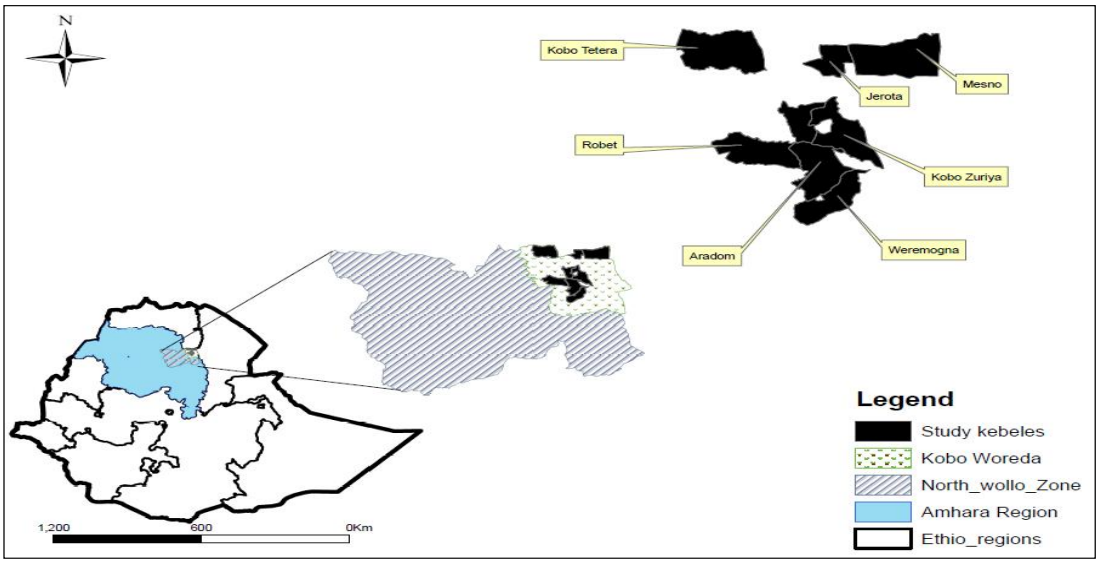

Figure 1. Location of the study area

Table 1. Sampling distribution in the study area.

Kebele	Area (ha)	Total households			Onion producer households			Sample households		
		Total	Male	Female	Total	Male	Female	Total	Male	Female
Furrow User	490	1592	1145	447	404	371	33	100	92	8
Aradom	400	1372	962	410	236	215	21	60	55	5
Robit	52	157	137	20	85	81	4	20	19	1
Jarota	38	63	46	17	83	75	8	20	18	2
Drip User	148	383	251	132	383	359	24	100	94	6
Kobo K4	50	129	91	38	129	121	8	30	28	2
Kobo K6	48	140	86	54	140	130	12	35	32	3
Kobo K7	48	114	74	40	114	110	4	35	34	1
Total	638	1975	1396	579	787	730	57	200	186	14

Source: Author Survey (2013).

Analytical techniques

Descriptive statistics and Cobb–Douglas stochastic production frontier approach was used to estimate the production function and the determinants of technical, allocative and economic efficiencies among onion farmers in the area. The stochastic function assumes the presence of technical inefficiency of production.

The specification involves a function specified for cross-sectional data, which has an error term, with two components, one to account for technical inefficiency. Hence, the function is defined by:

$$Y_i=X_i\beta + (V_i-U_i), i=1,...,N, \quad (1)$$

Where:

Y is the monetary value of onion crop per farm
X is a kx1 vector of (transformations of the) input quantities of the i-thfirm;
B is a vector of unknown parameters to be estimated;
Vi are random variables, two-sided ($-\infty<vi<\infty$) normally distributed random error.

$N\sim(0,\delta_v^2)$, which are assumed to be independent of the U_i that captures the stochastic effects outside the farmer's control (for example, weather, natural disasters, and luck ,measurement errors in production, and other statistical noise). The two components v and u are also assumed to be independent of each other.

Thus, to estimate Cobb-Douglas production function, we must log all the input and output data before the data is analyzed (Coelli, 1995). The estimating equation for the stochastic function is given as:

$$\ln Y=B_0 +B_1\ln X_1+B_2\ln X_2 +B_3\ln X_3+B_4\ln X_4 +B_5\ln X_5+ B\ln X+V-U \quad (2)$$

In the area farming, land, labour, seeds, fertilizers, agro-chemical and irrigation water are generally regarded as inputs. On the basis

of this, land (X_1) in hectare, labour (X_2) in person day, planting materials or seeds (X_3) in kg, fertilizer in kg (X_4), agro-chemical in liters (X_5), irrigation frequency in days (X_6) and irrigation methods (X_7) dummy D=1 when drip and 0 otherwise were included in the stochastic frontier models.

Technical efficiency of an individual firm is defined in terms of the ratio of the observed output (Y) to the corresponding frontier output (Y*), given the available technology, conditional on the levels of input used by the firm.

$$TE_i = \frac{y_i}{y^*} = \frac{\exp(x_i\beta + v_i - u_i)}{\exp(x_i\beta + v_i)} \quad (3)$$

$$TE_i = \exp(-u_i)$$

That is technical efficiency which is obtainable by the use of Frontier 4.1 (Coelli, 1996). Based on the individual farm's technical efficiency, the mean technical efficiency for the sample is obtained (Rahji, 2005).

Assuming that the production function in Equation (1) is self-dual (e.g., Cobb-Douglas), the dual cost frontier is derived algebraically and written in the following form:

$$C_i = C(W_i, Y_i^*, \alpha) \quad (4)$$

Where
C_i is the minimum cost of the i^{th} farm associated with the adjusted yield of output
Y_i^* and α is a vector of parameters to be estimated.
The economically efficient input vector of the i^{th} farm,

X_{ie} is derived by applying Shepard's Lemma and substituting the firm's input prices and adjusted yield of output level into the resulting system of input demand equations

$$\partial C_i / \partial W_k = X_{ke}(W_i, Y_i^*, \psi) \quad (5)$$

Where k represents the total number of inputs used. The observed, technically and economically efficient costs of production of the i^{th} farm are then equal to $W_i' X_i$, $W_i' X_{it}$ and $W_i' X_{ie}$, respectively. According to Sharma et al. (1999) these cost measures are used to compute technical efficiency (TE),

$$TE_i = W_i' X_{it} / W_i' X_i \quad (6)$$

Economic efficiency (EE),

$$EE_i = W_i' X_{ie} / W_i' X_i \quad (7)$$

Following Farrel (1957) allocative efficiency (AE) can be derived from equation (6) and (7) as,

$$AE_i = W_i' X_{ie} / W_i' X_{it} \quad (8)$$

indices of the i^{th} farm. The production frontier was estimated using frontier model whereas the cost frontier is derived analytically from production assuming self-dual. The determinants of technical, allocative and economic inefficiencies are explained by:

$$U_i = \delta o + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \ldots + \delta_n Z_{ni} + W_i \quad (9)$$

Where: for farm i, z is a vector of observable explanatory variables and δ is a vector of unknown parameters. Thus, the parameters of the frontier production function are simultaneously estimated with those of an inefficiency model, in which the inefficiency effects are specified as a function of other variables. U represents inefficiency effects; δ_o represents the intercept.

After a thorough review of previous studies and the prevailing situation in the study area, socio economic and institutional factors (Z_i's) that would affect efficiency were hypothesized as follows:

Age of the household head (Agehh): The age of the household head is hypothesized to reflect the experience of the farmer.

Education level of the household head (Edeuclvl): Farmers are expected to acquire the ability of better management through education and can be used as a proxy variable for managerial ability.

Family size (Famsize): Family is an important source of labour supply in rural areas. It is expected that households with many family members have better advantage of being able to use labor resources at the right time, particularly during peak cultivation periods.

Total cultivated land (Totcultlnd): This refers to the size of (own, shared or rented in) all land the household managed during 2012 production season.

Land fragmentation (Fragment): This is defined as the total number of plots that the farmer has managed during the 2012 production season. Plots in the area are highly fragmented and scattered over many places that would make difficult to perform farming activities on time and effectively. Increased land fragmentation leads to inefficiency by creating shortage of family labour, costing time and other resources that should have been available at the same time.

Number of livestock (Livstock): This is the total number of livestock in terms of Tropical Livestock Unit (TLU).

Distance of household's residence (Distress): Distance between farmer's residence and onion plot is assumed to have negative impact on efficiency.

Farm income (Totfincom): This includes all income from on farm and off farm activities of the household. It is a continuous variable measured in the amount of income (birr) the household head and/or other members get per year.

Land ownership (Lndowner): This is a dummy variable measured as 1 if the farm for production of onion is on sharecropping basis and 0 otherwise.

Experience in onion production (Experio): the number of years of experience is directly related to the farmers know how on onion production.

Off-farm/non-farm income (Offincome): Dummy variable having a value of 1 if the farmer is involved in off-farm/non- farm activities, 0 otherwise.

Access to credit (Acscdt): is a dummy variable which indicates accessibility of credit which is 1 if the farmer can access credit, 0 otherwise.

Extension service use (Extserv): Extension service given to farmers was measured as how much farmers implement the advice

Table 2. Socio-economic characteristics of the households' heads in the study area.

Variable description	Minimum	Maximum	Mean	Std. deviation
Age	25	78	46.59	10.78
Family size	1	12	6.02	1.84
Adult equivalent	1	10	5.02	1.59

Variable description	Category	Frequency	%	χ^2 value
Education	Illiterate	86	43	3.92**
	Literate	114	57	
Sex	Male	182	91	
	Female	18	9	

and techniques given by the extension agent during the production season and was defined using a dummy variable 1 for service user 0 for nonuser.

Access to market (Accmkt): It is dummy 1 for those who have access to market otherwise 0.

Field visit (Fieldvis): In the study area, field visit program is adjusted for farmers at their locality and nearby districts in the region. It is dummy 1 for those who have access to field visit otherwise 0.

Access to training (Acctrain): Training is an important tool in building the managerial capacity of the farmer. It is dummy 1 for those who have access to training otherwise 0.

Responsibility (Responsi): Responsibility in different social and committee leadership give the farmers opportunity of sharing information on improved production techniques by interacting with other farmers and experts thereby improve efficiency. It is dummy variable taking the value of 1 if the household has different responsibility in the kebele and 0 otherwise.

RESULTS AND DISCUSSION

The mean age of the respondents is 46.59 years and the modal age is 41 to 50 years, which constituted about one-third of the total respondents (Table 2). The age of the farmer according to Adewumi and Omotesho (2002) is expected to affect his labor productivity and output. This agrees with findings of former studies Tsoho (2004). The study revealed that more than 90% of the respondents were married, while the remaining were either single or widow(ers), respectively.

The mean family size was 6.02 persons per respondent and it ranged from 1 to 12. The study also revealed that 57% have attained between primary and tertiary education. More than two-third of the respondents have had religious education. The farmer's years of experience ranged from 5 to 45 with an average of 23.21 years. Farmers experience is expected to have a considerable effect on farmer's productive efficiency. Almost all the respondents have inherited farming as an occupation, while the others were introduced to farming by either friends or relatives. About 90% of the respondents have farming as their main occupation and only 10% adopts farming as their secondary occupation.

Efficiency analysis

The expected parameters and the related statistical test results obtained from the analysis of the maximum likelihood estimates (MLE) of the Cobb-Douglas based stochastic frontier production function parameters for irrigated season vegetable farmers are presented in Tables 3 and 4.

The variance parameters of the production function represented by Sigma-squared (σ^2) and Gamma (γ) are all significant even at 1%. The Lambda is greater than one (λ = 8.41). The statistical significance of Lambda showed that there exits sufficient evidence to suggest that technical inefficiencies are present in the data. Theoretically, this implies a good fit for the estimated model and correctness of the distributional assumptions for the Ui and Vi. The statistical significance of the sigma-squared also indicated a good fit for the model. The estimated gamma (0.89) shows the amount of the variation in onion outputs which results from technical efficiency of the sampled farmers (Berhan et al., 2014).

The results of the estimated parameters revealed that all the coefficients of the physical variables except quantity of seeds used, conform to a priori expectation of a positive signs. The positive coefficient of land, labour, fertilizer, agro-chemical and irrigation implies that as each of these variables is increased, *ceteris paribus*, vegetable output increased. The negative sign of the seeds suggest a situation of excessive (and, hence, inefficient) use of planting material in the production of vegetable in the area.

The coefficient of the variable associated with land although positive, is statistically not significant even at 10% level of significance. The coefficients of the three physical variables: labor, fertilizer and irrigation water are all significant even at 1% level of significance. Therefore,

Table 3. Estimated stochastic production frontier function.

Variables	OLS estimate		ML estimate	
	Coefficient	Standard error	Coefficient	Standard error
Intercept	2.799***	0.443	3.398***	0.305
lnLand	-0.124	0.077	-0.187***	0.043
lnSeed	-0.079	0.072	0.011	0.045
lnLabour	0.174*	0.100	0.149**	0.075
lnOxenday	0.220**	0.087	0.198***	0.071
lnUrea	0.0224***	0.0064	0.019***	0.005
lnDAP	0.003	0.006	0.002	0.004
lnCHEM	0.013*	0.008	0.012**	0.006
IRRMTD	0.208***	0.075	0.260***	0.062
R^2	0.3816		∑β=0.464	
F statistics	14.73***			
$\sigma^2 = \sigma_v^2 + \sigma_u^2$			0.275***	
$\lambda = \sigma_u / \sigma_v$	-		8.714***	
γ (gamma)	-		0.987***	
LLR	-		-72.81	

*, ** and *** significant at 10, 5 and 1% significance level, respectively. Source: Author computation (2013).

Table 4. Estimated stochastic cost frontier function.

Variables	Maximum Likelihood estimate	
	Coefficient	Standard error
Intercept	1.566***	0.256
lnLandcost	0.639***	0.036
lnSeedcost	0.529***	0.022
lnLaborcost	0.120***	0.031
lnOxencost	-0.001	0.002
lnchemcost	0.0003	0.002
lnfertcost	0.232***	0.023
lnoutput	0.011***	0.003
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.033***	
$\lambda = \sigma_u / \sigma_v$	1.522***	0.040
LLR	118.81	

*, ** and *** significant at 10, 5 and 1% significance level, respectively. Source: Author computation (2013).

these are the major factors explaining onion production under irrigation condition in the area. The finding agrees with those of Tsoho et al. (2013) Ajibefun et al. (2002) and Onyenweaku and Effiong (2005).

The returns to scale (RTS)

The return to scale (RTS) analysis, which serves as a measure of total resource productivity, is given in Table 5. The maximum likelihood estimates (MLE) of the Cobb-Douglas based stochastic production function parameter of 0.464 is obtained from the summation of the coefficients of the estimated inputs (elasticties). It indicates that onion production in study area was in the stage II of the production surface which is decreasing positions of return to scale where resources and production were believed to be efficient.

Determinants of technical, allocative and economic efficiencies in onion production

Multiple regression analysis (OLS)

Based on the literature on previous studies; nine

Table 5. Elasticities and returns to scale of the parameters of stochastic frontier production function.

Variables	Elasticities
lnLand	-0.187
lnSeed	0.011
lnLabour	0.149
lnOxendays	0.198
lnUrea	0.019
lnDAP	0.002
lnChem	0.012
IRRMTD	0.260
Returns to scale	**0.464**

Source: Author computation (2013).

Table 6. Relationship between transformed efficiency indices and farm-farmer characteristics.

Variables	TE		AE		EE	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Constant	0.440***	0.145	0.858***	0.165	0.349***	0.098
Land size	-0.017	0.021	-0.009	0.024	-0.006	0.014
Age	-0.003***	0.001	0.000	0.001	-0.002**	0.0009
Education	-0.034	0.027	0.012	0.031	-0.013	0.018
Family size	-0.009	0.010	0.016	0.011	-0.000	0.007
Plot distance	-0.008	0.007	0.024***	0.007	0.011***	0.004
Fragment	0.065***	0.005	0.002	0.059	0.058***	0.015
Fertility	0.095	0.066	0.006	0.074	0.080*	0.044
Off farm income	0.026	0.033	0.004	0.038	0.002	0.022
Credit use	0.005	0.027	0.002	0.030	0.003	0.018
Market access	0.169***	0.069	-0.195***	0.079	-0.001	0.047
Source of water	0.023	0.028	0.090***	0.037	0.072***	0.022
Access to training	0.056**	0.028	-0.052	0.032	-0.013	0.019
Extension	0.072***	0.004	0.089**	0.049	0.08***	0.029
TLU	0.002	0.007	-0.003	0.008	-0.002	0.005
Exp. in onion	0.011***	0.005	0.004	0.006	0.011***	0.004
Ownership	-0.003	0.034	0.017	0.039	0.003	0.023
Farm income	2.97***	1.87	-3.21***	0.694	-1.44***	0.411
Responsibility	-0.058***	0.026	0.075**	0.030	0.019	0.018
Field visit	0.102***	0.033	-0.066*	0.037	-0.016	0.022

*, ** and *** significant at 10, 5 and 1% significance level, respectively. Source: Author computation (2013).

characteristics are chosen as indicators of the farmer's socio-economic environment and are subsequently used as explanatory variables in the analysis of productive efficiency for onion production under irrigation in the study area. The Technical, allocative and economic efficiency estimates derived from SFA will be regressed, using a censored Tobit model on the following farm-specific explanatory variables that might explain variations in production efficiencies across farms.

Estimation with OLS regression of the efficiency scores would lead to biased parameter estimates since OLS assumes normal and homoscedastic distribution of the disturbance and the dependent variable (Greene, 2003). As the distribution of the estimated efficiencies are censored from above at the value one, Tobit regression (Tobin, 1958) is specified as

$$E_i^* = \sum_i \beta_i X_i + V_i$$
$$E_i = 1 ....if .... E_i^* \geq 1$$
$$E_i = E_i^* ....if .... E_i^* < 1 \quad (10)$$

Where E_i is an efficiency score, and $V \sim N(0, \sigma^2)$ and β_j

are the parameters of interest.

The results of the analysis of the relationship between the farmer's characteristics and efficiency indices are presented in Table 6.

The results indicated that, overall, the explanatory ability of the variables included in the analysis is limited (R^2 values are generally low) and not all regressions or parameters are significant. This result agrees with the findings of several researchers who have generally obtained an R^2 value of less than 0.5 in their secondary analysis similar to this study. For example, Xu and Jeffrey (1997) obtained an R^2 value of 0.21, 0.31 and 0.19, respectively.

The variables fragment, ownership, total farm income, training and participation in field day visit affect efficiency positively while responsibility and age of the household head affect technical efficiency negatively. Households who have got the chance to participate in field visit and field days are more efficient than their counter parts. Because it improves the technical knowhow and skill of the farmers thereby exchange of experience will improve the efficiency. The result shows that access to field visit is found to have positive and significant effect (at 5% level of significance) on farmers' technical efficiency in production.

The result shows that households having better farm income would devote their time and effort in day to day farming activities and able to use improved technologies thereby production efficiency improved. Thus the result is found to have positive and significant effect on farmers' technical efficiency in production.

Experience in onion production is a proxy measure of managerial and technical knowhow. The result shows that experience is found to have positive and significant effect on farmers' technical efficiency in production. This result is in conformity with the finding of Abdukadir (2010).

Extension contact and training has a positive sign and is statistically significant in technical efficiency and negative sign in allocative efficiency indices. The positive and statistically robust relationship between extension and efficiency supports the notion, which implies that farmers who had more extension visits/teachings are likely to be more successful in gathering information and understanding new practices and the use of modern inputs which in turn will improve their EE through higher levels of TE and AE respectively. These results are consistent with the findings of Onyenweaku and Nwaru (2004) and Rahji (2005). Contrarily, the study disagreed with findings of those of Parikh et al. (1995) that have found extension to be negatively and statistically related to efficiency indices.

Source of irrigation water has positive and statistically significant coefficients for AE and EE. But, the opposite is true for the TE as its relationship is negative and non-significant. The positive coefficient suggests that farmers who use underground water to irrigate their onion are allocatively and economically more efficient than those who use surface water. Interestingly, these same categories of farmers are however, technically less efficient. This finding is consistent with Baba and Wando (1998) that the there is a positive and significant relationship between the source of water and the efficiency of the farmers.

The coefficients of family size, farm size, education status, off farm income, credit use, TLU, and land ownership systems are not important in explaining the variation in TE, AE and EE of farmers in the study area.

Conclusion

The study aimed at finding out the determinants of technical, allocative and economic efficiency levels of onion farmers at the Kobo Girana Valley Development Irrigation Project in the Eastern Amhara Region of Ethiopia.

In terms of methodology, the Cobb-Douglas specification of the model performed better than the translog specification. Therefore, the Cobb-Douglas stochastic frontier production was estimated, from which TE and EE extracted. The study indicated that 82.6 and 76.8% were the mean levels of TE, under drip and furrow irrigated, respectively. This in turn implies that farmers can increase their farm production on average by 17.4 and 23.2% respectively when they were technically efficient. Similarly, the EE of drip and furrow were 51.49 and 44% respectively. In the second step of the analysis, relationships between efficiency indices (TE, AE and EE) and variables expected to have effect on farm efficiency were examined. This was relied on maximum likelihood estimation of frontier model of inefficiency effect, where inefficiency, expressed as functions of 19 independent variables. Among them, age, plot distance, fragment, source of water, experience in onion production, farm income, fertility status and extension visit were found to be statistically significant to affect the level of production efficiency.

The inputs that were important in determining output were fertilizer, labour, oxen power and seed cost were statistically significant as well as most of them maintaining their expected signs. The results indicated that the extension contact, source of water, and crop diversification exhibited higher levels of positive significant impact on TE and EE, the location of the farm exerts a negative significant impact on TE. In addition, farm location has a statistically positive association with AE. In all, extension contact exerts a uniform impact on all the efficiency indices. Thus, the results of the study give information to policy makers and extension workers on how to better aim efforts to improve farm efficiency as the level and specific determinant for production efficiency. These findings

stresses the need for appropriate policy formulation and implementation to enable farmers reduce their inefficiency in production as this is expected to have multiplier effects ranging from farm productivity growth to economic growth and poverty reduction at macro level.

In the study area, field visit promotes technical efficiency of irrigated onion production. This indicates that the existing training and field visit experience sharing services should be continued and promoted in improving the technical efficiency and thereby the performance of farmers. Therefore, it is recommend that government should have a prime responsibility to improve the performance of farmers training center much more in these areas and others so that farmers can use the available inputs more efficiently under the existing technology. Therefore extension services has to keep on aiming to provide information and practical farming knowledge for all farmers particularly those involving in irrigation to improve resource utilization and reduce cost of production in irrigated agriculture. The analysis also indicated that participation in collective action like crop protection is vital in improving the efficiency.

The result also revealed that land related factors such as land size, land ownership, and land fragmentation explain much of the technical inefficiencies in addition to other socio-economic characteristics of farm households. Total land size is inversely related to the technical efficiency. We also observed that land size has negative effect on onion yield, which signifies the theory of inverse relationship between farm size and productivity in onion production. All these imply that labor market is still imperfect that causes households' to relay on family labor. Farmers are more efficient on owned plots than leased in (in the form of sharecropping and fixed rent) plots. Tenure insecurity play significant role for farmers to adopt the available technologies and maximize production on irrigated farms. Likewise, land fragmentation has showed positive effect on technical inefficiency, calling for the need to think about land consolidation at least within farms. Hence, it can be concluded that onion production can further be increased by introducing improved water application technologies like drip and sprinkler suitable for small farmers with appropriate policies aimed at creating tenure security, perfecting labor market and consolidating fragmented plots.

Conflict of Interest

The authors have not declared any conflict of interest.

RECOMMENDATIONS

Given the limited resources in the study areas, efforts to strengthen the efficiency of smallholder farmers who are the largest segment in agricultural production are indispensable. Policy makers should foster the development and provision of qualitative extension services, development of irrigation infrastructures and soil fertility management options to the farmers, while promoting the wide adoption of pumps and drip lines use by the farmers. In the study area, field visit promotes TE and AE of irrigated onion production. This indicates that the existing training and field visit experience sharing services should be continued and promoted in improving the technical efficiency and thereby the performance of farmers. Therefore, it is recommended that government should have a prime responsibility to improve the performance of farmers training center much more in these areas and others so that farmers can use the available inputs more efficiently under the existing technology. More importantly, practical training should be planned to be comprehensive in considering issues like efficient resource use (land, labour, fertilizer and seed), cost reduction, profit maximization objectives so that farmers could be benefited from accelerated increase in income from onion production.

Above all, the attention of policy makers should not be only to the introduction and dissemination of yield enhancing externally supplied inputs to mitigate the existing level of food deficiency and poverty more importantly the working culture and perception on improved technologies in that area should be improved. Besides, researchers and development practitioners should give due attention towards improving the existing level of efficiency and marketing problems through providing labour saving farm implements, appropriate enterprise choice for the study area, efficient water application techniques, construction of modern river diversion canals , providing advice and training to use the recommended fertilizer and seed rate, providing credit with reasonable interest rate and market related studies are vital. Finally, it is recommended that a panel study is carried out to better understand the long term implications of the determinants of efficiency in the study area.

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