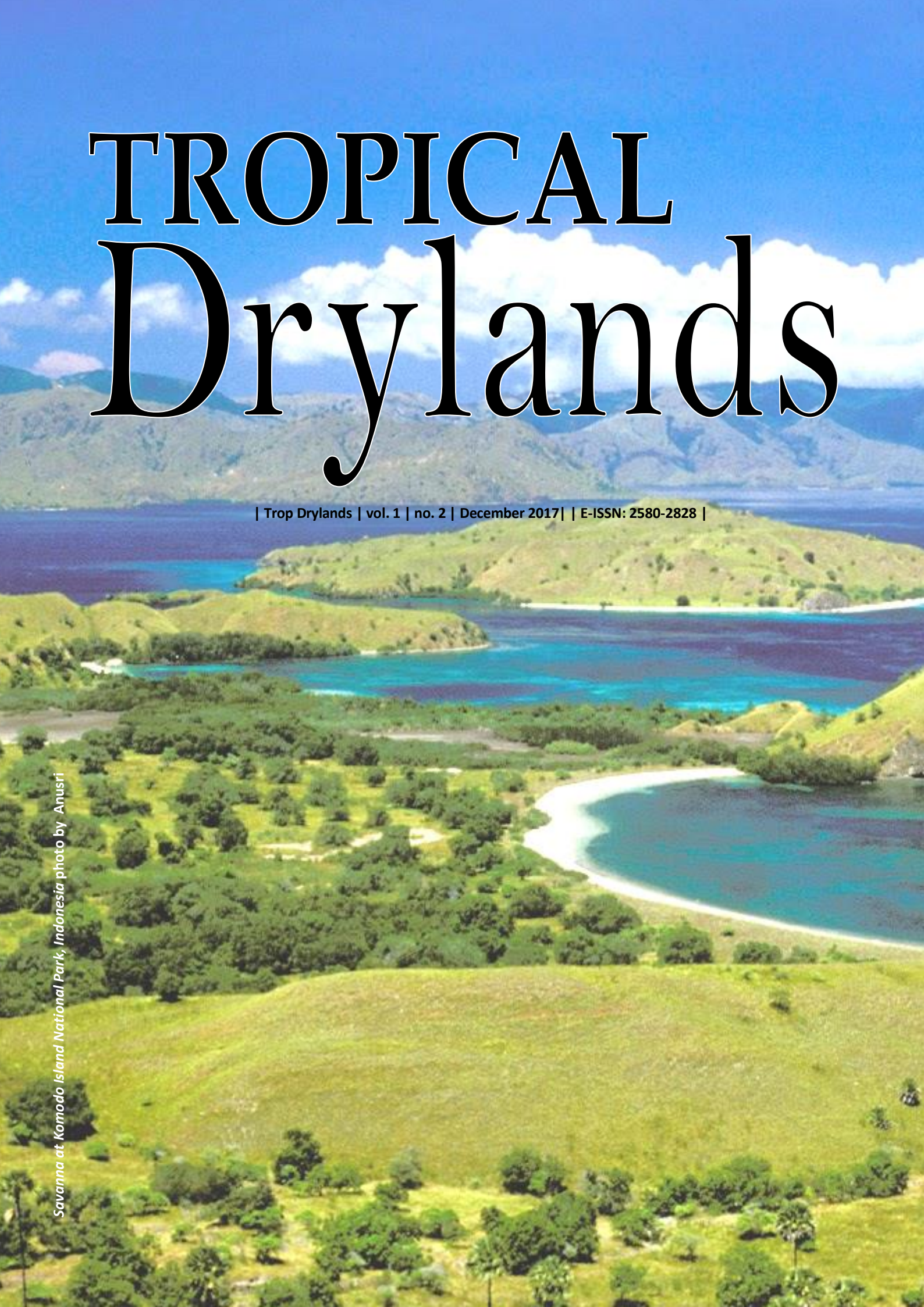
TROPICAL Drylands

| Trop Drylands | vol. 1 | no. 2 | December 2017| | E-ISSN: 2580-2828 |



Savanna at Komodo Island National Park, Indonesia photo by Anusri

Tropical Drylands

| Trop Drylands | vol. 1 | no. 2 | December 2017 | E-ISSN: 2580-2828 |

Published semiannually **PRINTED IN INDONESIA**

E-ISSN: 2580-2828

9 772580 282022

Tropical Drylands

| Trop Drylands | vol. 1 | no. 2 | December 2017 |

ONLINE
http://smujo.id/td

e-ISSN
2580-2828

PUBLISHER
Society for Indonesian Biodiversity

CO-PUBLISHER
Universitas Nusa Cendana, Kupang, Indonesia

OFFICE ADDRESS
Archipelagic Dryland Center of Excellence, Universitas Nusa Cendana.
Jl. Adisucipto Penfui, Kupang 85001, East Nusa Tenggara, Indonesia. Tel.: +62-380-881580, Fax.: +62-380-881674, email: td@smujo.id, tropdrylands@gmail.com

PERIOD OF ISSUANCE
June, December

Society for Indonesian Biodiversity

Universitas Nusa Cendana Kupang, Indonesia

Published by Smujo International for The Society for Indonesian Biodiversity and Universitas Nusa Cendana Kupang, Indonesia

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Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta***.** 50th Annual Symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.) Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

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Information from internet:

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TROPICAL DRYLANDS
Volume 1, Number 2, December 2017 E-ISSN: 2580-2828
Pages: 65-68 DOI: 10.13057/tropdrylands/t010201

Short Communication: Seasonal occurrence of the tree locust *Anacridium melanorhodon melanorhodon* on *Acacia senegal* in North Kordofan State, Sudan

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Manuscript received: 19 July 2017. Revision accepted: 28 August 2017.

Abstract. *Rahama ORM, Ahmed MOB, Yassin MM. 2017. Seasonal occurrence of the tree locust* Anacridium melanorhodon melanorhodon *on* Acacia senegal *in North Kordofan State, Sudan. Trop Drylands 1: 65-68.* The tree locust, *Anacridium melanorhodon melanorhodon* (Walker, 1870) (Acrididae: Orthoptera) causes sporadic damage mainly to trees. In Sudan, it is called night wanderer because of its nocturnal activity. It is commonly found on the Sudanese western sand plains, causing considerable damage to the gum Arabic producing trees *Acacia senegal*. The objectives of the study were to investigate the seasonal pattern of the occurrence of tree locusts on *A. senegal* and factors that influence the tree locust population movements and distribution. Fieldwork was made at an *Acacia senegal* plantation of the Acacia Project (El Rahad) site, North Kordofan State, during August 2007 and September 2008. The results showed that adults of the tree locust appeared in the field in May and high populations were recorded during the period from June to September reaching the peak (25.00±3.08 per tree) in November. Then the population decreased gradually and disappeared at the end of February. Sexual maturation began during May /June with the first rains and lasted for about four weeks. Oviposition period was during June and July and hoppers, which have six stages, appeared between July and October and their development lasted 1-2 months. The hoppers density was at its peak during September (27.00±5.15 per tree). Rainfall and relative humidity coincide with the development of hoppers, while adults were encountered during periods of low rainfall and relative humidity.

Keywords: Tree locust, occurrence, North Kordofan, Sudan

INTRODUCTION

Anacridium melanorhodon melanorhodon (Walker, 1870) (Acrididae: Orthoptera), generally known as Sahelian tree locust, is a pest that causes sporadic damage mainly to trees (COPR 1982). There are twelve species causing the same type of damage in varying degrees to crops, particularly trees (Dirsh and Uvarov 1953). Popov (1989) assumed that *A. m. melanorhodon* is a mesophilous species that lives primarily in moderately humid habitats, and it is also xerophilous which can live in dry habitats of open forest with thorny trees and shrubs. It is widely distributed in Cape Verde Island, Morocco, Mauritania, Senegal, Mali, Niger, Chad, Nigeria, Ethiopia, Eritrea and Sudan (Uvarov 1923; Johnston 1924, 1932; Tigani 1965; Popov and Ratcliffe 1968). In Sudan, it is called Sahelian tree locust, Sudan tree locust and night wanderer (Popov 1978; FAO 2007). It is distributed in large areas forming a continuous belt from the east to the west spreading over Khartoum, Kassala, White Nile, Blue Nile, Kordofan, Darfur and Northern States (Abdalla 1990; Bashir 1997).

The tree locust is more common in the Sudanese western sand plains and commonly attracts *Acacia mellifera* and *Acacia senegal*. Other host plants include trees of the genus *Acacia*, *Balanites aegyptiaca*, and *Zizyphus spina-christi*. Besides the trees of such species, tree locusts also attack the flowers and leaves of fruit trees (e.g. mango, citrus, date palm and guavas). They also feed on vegetables and cause harm to crops such as cotton and sorghum (Schmutterer 1969; SEA 1990) as well as tobacco, maize and millet. It is a serious pest of natural and planted forests (FAO 2007).

The host plants of *A. m. melanorhodon* are scattered in the gum Arabic belt which lies between latitudes 10° and 15° N of semi-arid land across sub-Saharan Africa and receives annual rainfall between 280- 450 mm. The infestation of tree locust on *A. senegal* is devastating since this tree produces Gum Arabic which is the principal source of income in these areas. In addition to gum production, *A. senegal* tree is used for sand dunes stabilization, microclimate improvement, soil amelioration through nitrogen fixation and a source of firewood and fodder for animals. The economic consequence of the tree locust infestation has been progressively more recognized in many countries, particularly in countries like Sudan, where a great deal of damage was caused by defoliation of *A. senegal* (El Amin et al. 2008; Eisa et al. 2008). According to (Wewester et al. 1993), *A. senegal* suffers from the attack of tree locusts especially during years of outbreak. The tree locust feeds on *A. senegal* leaves leading to low gum productivity. In Sudan, El Zian (1994) mentioned that the loss in gum production caused by tree

locusts in seasons 1991 and 1992 was estimated at 86.5% of the total production. Furthermore, (Ballal et al. 2005) recorded that gum Arabic production in Sudan declined due to many factors; including defoliation of trees by tree locust, especially in Kordofan State.

Controlling tree locusts may potentially restore incomes from gum Arabic, boosts foreign exchange earnings, and assist the livestock, forestry, and horticultural industries (SEA 1990). Very few studies have been done on tree locusts in Sudan. It is not known what factors trigger the upsurge of locust population, or whether natural control agents will ultimately reduce the population back to recession levels. This is a potentially valuable area for research (SEA 1990). The objectives of the study are to investigate the seasonal pattern of tree locusts on *Acacia senegal* in North Kordofan State, Sudan, and factors that influence the tree locust population movements and distribution. This will delineate the period and areas of control, hence avoiding widespread use of pesticides. It also saves effort, time and cost.

MATERIALS AND METHODS

Study site

This study was carried out in Al Rahad, 57 km southeast El Obeid, Sheikan Locality, Northern Kordofan State, during August 2007 – September 2008 in a plantation of *A. senegal* trees with extent of 10.50 ha. Regular surveys of the plantation were conducted twice a week to record tree locust populations during the period from May to October, as well as rainfall and % relative humidity were regularly recorded.

Data collection of hoppers and adults

The first hopper stages were counted in the morning between 08:30 and 10:30 h, a period of minimum locust activity, in ten replications of one-meter square each (Luong-Skovmand 2005) and converted to total number per hectare. The second to the sixth instar hoppers were counted in each marked tree using a plastic cup which was placed under a branch, and a stick was used to push the hoppers into the cup. The number of hoppers per tree and the number per hectare were thus determined at each site. Counting of adults was done similarly and was carried out in the morning between 08:30 and 10:30 h. The destructive sampling method was used according to Leather (2005). Fifty trees were selected for adult and hopper counting twice a week.

RESULTS AND DISCUSSION

Field distribution of adults and hoppers

Figure 1 shows that *A.m. melanorhodon* adults appeared in the field in May, which is the beginning of the rainy season. High population density was recorded during June, at which time females gathered at egg laying sites. In July hoppers appeared in reasonable number reaching the peak in September (27.00±5.15 per tree). The adults generated from these nymphs appeared on the field in September reaching the peak in November (25.00±3.08 per tree), but their density decreased gradually, and they finally migrate at the end of February.

Distribution of the different hopper stages

First hopper stage appeared at the beginning of July and prevailed until mid-August. The second hopper stage appeared in mid-July. There was overlapping between other hopper stages, but the sixth hopper stage appeared during September and October (Figure 2).

Relationship between rainfall and population density of adults and hoppers

Figure 3 shows that the number of hoppers increased between July and August due to hatching while that of adults decrease because of death after oviposition. In September and October hoppers transform into fledglings adults then the number decreased. Therefore, the number of hoppers increased during the rainy season, but the number of adults decreased.

Figure 4 shows that the mean number of hoppers per tree increased with the increase of RH%, and the mean number of adults per tree decreased with the increase of RH.

Discussion

The tree locust, *A. m. melanorhodon* adults in North Kordofan State appeared in the field in May, and high population density was recorded during June and increased in September reaching the peak in November. Then their density decreased gradually, and they finally disappeared at the end of February. This could be due to the beginning of the rainy season and the accessibility of food throughout these months because all acacia trees completed their greenness, and adult locusts possibly migrated to the other alternative hosts after February. The results agreed with Meinzingen (1993) who reported that the Sahelian tree locust, *A.m. melanorhodon*, lays eggs during June-July, hoppers develop in August and September, and adults emerge at the end of the rainy season and the onset of the dry season (October and November).

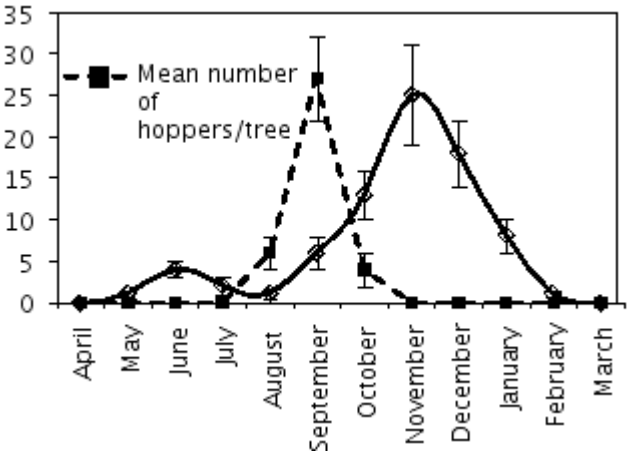

Figure 1. Mean number of the tree locust (adults and hoppers) per tree in the field during seasons from August 2007 to September 2008.

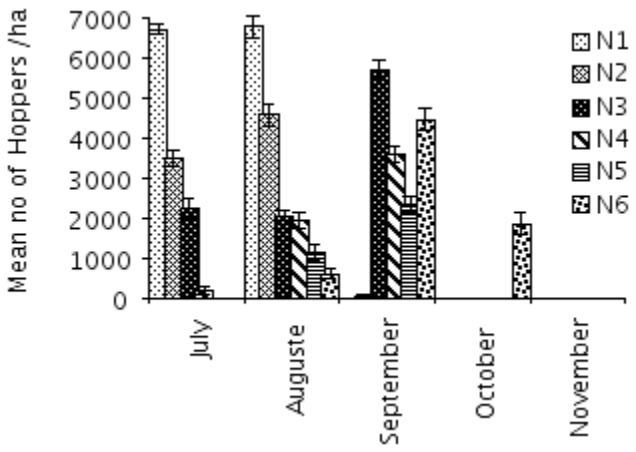

Figure 2. Mean number of the tree locust hopper instars in the field during seasons 2007/08 and 2008/09. N= Hopper nymph stage.

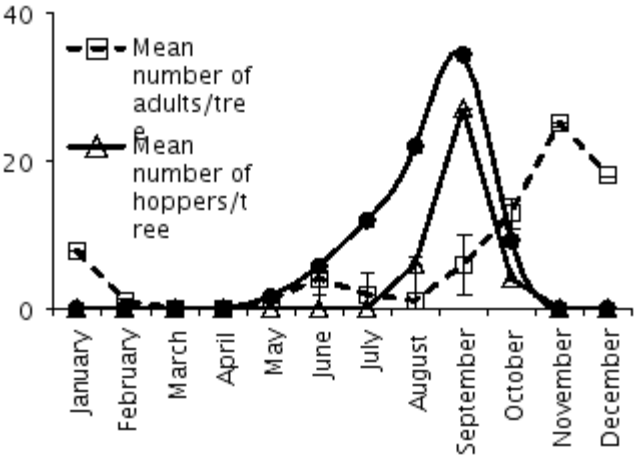

Figure 3. Mean number of the tree locust adults and hoppers per tree in the field in relation to rainfall (seasons 2007/2008 and 2008/2009)

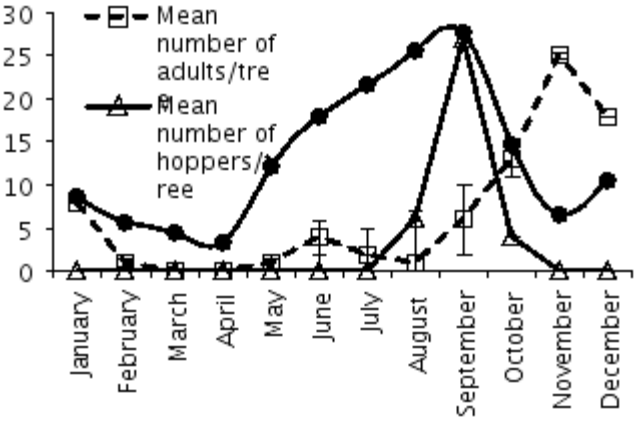

Figure 4. Mean number of the tree locust adults and hoppers per tree in relation to relative humidity (seasons 2007/2008 and 2008/2009)

There were six hopper stages. The first hopper stage appeared at the beginning of July and prevailed until mid-August. The second hopper stage appeared at the mid of July. There was overlapping between other hopper stages, but the sixth hopper stage appeared during September and October. This is because the favorable condition initiates females to lay eggs at that period. These results agreed with Luong and Popov (1997) who reported that imagoes remain in a resting maturation stage until the first rain of the following year in May- June. They took four weeks before copulation, and then females lay eggs and hoppers hatched during the period from July to October.

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TROPICAL DRYLANDS
Volume 2, Number 1, June 2018
Pages: 5-11

E-ISSN: 2580-2828
DOI: 10.13057/tropdrylands/t020102

Resistance response of fifteen sweet potato genotypes to scab disease (*Sphaceloma batatas*) in two growing sites in East Nusa Tenggara, Indonesia

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Faculty of Agriculture, Universitas Nusa Cendana. Jl. Adisucipto, Penfui, Kupang 85001, East Nusa Tenggara, Indonesia, Tel./fax.: +62-380-881085, email: yosepmau@yahoo.com

Manuscript Received: 5 April 2018. Revision Accepted: 13 May 2018.

Abstract. *Mau YS. 2018. Resistance response of fifteen sweet potato genotypes to scab disease (*Sphaceloma batatas*) in two growing sites in East Nusa Tenggara, Indonesia. Trop Drylands 2: 5-11.* Scab disease is one of most prevalent problems of agricultural crops, including sweet potato, in tropical and sub-tropical regions. This study aimed to evaluate and determine the scab resistance levels of local sweet potato genotypes from Nusa Tenggara Timur (NTT) Province, Indonesia, and to identify sweet potato genotypes with good resistance levels to scab disease. Field experiments were carried out in two growing locations involving potential sweet potato clones from NTT Province. The experiment was carried out in the fields employing a Randomized Block Design with a mono-factorial treatment design in each location. The treatment assigned was sweet potato genotype, each consisting of two replicates. The variables observed were disease severity that was assessed at 2, 4, 6, and 8 weeks after inoculation (WAI), which then was used to calculate the Area Under the Disease Progress Curve (AUDPC) of the disease severity. The ANOVA of AUDPC was used to determine the treatment effect, and the disease severity at 8 WAI was used to assess scab resistance level of the sweet potato genotypes tested. The study results showed highly significant differences in disease severities among the tested sweet potato genotypes within each trial location. The majority of the genotypes tested were classified Resistant or Moderately Resistant to scab disease, except the check clone SLM-01 and KRA-01 that were, respectively, Susceptible and Moderately Susceptible to scab disease. The majority of sweet potato genotypes evaluated were consistent in their resistance performance in the two trial locations.

Keywords: Sweet potato, genotype, scab disease, resistance

INTRODUCTION

Scab disease is one of the most destructive diseases of sweet potatoes in the sub-tropical and tropical regions of the world. Scab disease has been reported to cause yield loss of sweet potato of about 30-65% in Indonesia (Saleh and Rahayuningsih 2013; Rista et al. 2017) and 60% in Papua New Guinea (Jackson and McKenzie 1991). In Indonesia, the disease has been recorded to be widespread in sweet potato productions centers, such as Papua, Bali, Jawa, and Nusa Tenggara (Saleh and Rahayuningsih 2013; BPS Indonesia 2015).

Scab disease in sweet potato is caused by the fungus *Sphaceloma batatas* Saw. (Anamorph) or *Elsinoe batatas* (Teleomorph) (Jackson and McKenzie 1991). This pathogen infects leaves and stems with early symptoms of tiny, circular to elliptical or elongate, brown spots or lesions. In favorable weather conditions, the symptoms may reach the top leaves, and the buds become twisted (Nayga and Gapasin 1986; Clark and Moyer 1988; Sumartini et al. 2006). High disease intensity may slow down the development of the leaves so that the leaves become curly and distorted, the petioles become shorter and twisted, and the stems grow wrinkled. Severe disease infection may result in low tuber production or total plant loss (Nayga and Gapasin 1986; Moyer et al. 1989; Ames et al. 1997).

The use of fungicide has been so far the primary control measure of sweet potato scab disease (Jackson and McKenzie 1991) as this method is known to be more comfortable in its application and the effect is immediately seen. This chemical control method, however, is, in many cases, neither affordable by the poor farmers and nor environmentally friendly. Therefore, the use of scab-resistant sweet potatoes varieties is considered more efficient and economically visible in controlling the disease. Nevertheless, scab resistant superior varieties are now limitedly available and hardly affordable by the farmers. The production of scab-resistant varieties in sweet potato can be initiated through the selection of local germplasm as a source of scab resistance, which then is further employed for generation of superior scab-resistant varieties through cross-breeding program.

Several local sweet potato genotypes from East Nusa Tenggara (Nusa Tenggara Timur; NTT) Province of Indonesia have been identified and selected for several traits. A few of this local germplasm were found to be drought-tolerant (Mau et al. 2008; Mau 2012), resistant or moderately resistant to sweet potato weevil *Cylas formicarius* (Mau et al. 2011), and also high yielding and stable across environments (Mau et al. 2009; 2013). This local germplasm with such superior traits is invaluable genetic resource that can be used as parental sources for generation of more superior varieties and can also be directly registered as superior local varieties for germplasm

conservation and the property rights of the local community represented by the local government.

In addition to the above-mentioned superior variety traits, resistance to scab disease is another important trait that needs to be possessed by the sweet potato genotypes from NTT Province. The scab disease is one of the many factors that caused the low sweet potato productivity in NTT (6.98 t ha^{-1}) (BPS NTT 2015) that is much lower than the national level (16.05 t ha^{-1}) (BPS Indonesia 2015). Local sweet potato clones with good scab resistance will enable them to be used to increase the sweet potato productivity and production and also more suitable to be used as superior parental sources as well as registration of superior local varieties. To date, information on scab resistance level of local sweet potato clones/genotypes from NTT is lacking. This study was carried out with the following objectives: (i) to evaluate and determine the scab resistance levels of local sweet potato genotypes from NTT, (ii) to identify sweet potato genotypes with good resistance level to scab disease.

MATERIALS AND METHODS

Research location

The present study was carried out in two sites in East Nusa Tenggara (NTT) Province, Indonesia, i.e., Detubapa Village (630 m asl), Detusoko Sub-District, Ende District and Kesetnana Village (810 m asl), Mollo Selatan Sub-District, Timor Tengah Selatan (TTS) District. *S. batatas* inoculum was obtained from the infected plants in the field and prepared in the Plant Pathology Laboratory, Faculty of Agriculture, Universitas Nusa Cendana, Kupang, Indonesia for inoculations of the plants in the fields. The study was conducted for five months during April-August, 2011.

Research design and materials

This study employed a Randomized Block Design in each of the two growing locations. The assigned treatments were sweet potato genotype consisting of 13 local clones from East Nusa Tenggara Province and two check varieties. The check varieties were Kidal (the scab-resistant variety) kindly provided by Indonesian Legumes and Tuber Crops Research Institute (*Balai Penelitian Tanaman Aneka Kacang dan Umbi*; Balitkabi), Malang, East Java, Indonesia, and SLM-01 (the scab-susceptible clone) collected from Sumber Arum Village, Sleman District, Yogyakarta, Indonesia. In total, 15 genotypes were evaluated in each location; i.e., Detubapa Village, Ende District, and Kesetnana Village, TTS District. A total of 60 experimental units were evaluated in two trial locations.

Research procedures

In each location, the experimental field was previously cultivated with maize plant. The field was first cleared from the plant debris and plowed at 30-40 cm depth to allow easy preparation of the planting plots. The planting field in each location was divided into two blocks as replicates, and each block was further sub-divided into single row planting plots of 3 m x 1 m size as the experimental unit. The number of planting plots prepared in each block/replicate was 15 to fit the number of sweet potato genotypes evaluated. The distance between blocks was 100 cm while that between plots within a block was 50 cm. Placement of treatments within each block was carried out randomly.

The planting materials were prepared from the sweet potato shoot cuttings of 25-30 cm in length or consisted of 3-4 stem internodes. Five sweet potato cuttings were planted in each plot with a planting space of 50 cm within the plot. Basal fertilizers containing 30 g Urea $plot^{-1}$ (100 kg Urea ha^{-1}), 30 g TSP $plot^{-1}$ (100 kg TSP ha^{-1}), and 45 g KCl^{-1} (150 kg KCl ha^{-1}) were applied at the time of planting.

Scab resistance evaluation was carried out by artificially inoculating the tested plants in the field. *S. batatas* conidia were obtained from the field-infected plants. The infected plant parts were cultured in a PDA medium in the laboratory to get a pure culture of *S. batatas*. Fourteen days old *S. batatas* pure culture was then used to prepare the inoculum for artificial inoculation using a conidial concentration of $2x10^6$ conidia mL^{-1}. The inoculum was prepared in a hand sprayer of 1000 mL size and was applied by spraying the sweet potato plants six weeks after sowing. Each sample plant was sprayed using the prepared inoculum until all the leaves and stems were thoroughly wet.

Observation and data analysis

The main variable observed in the present study was the disease severity, which was recorded four times during the study, i.e., at 2, 4, 6, and 8 weeks after inoculation (WAI) or at 8, 10, 12, and 14 weeks after planting (WAP). The observation was done on ten upper leaves of the main stem of each plant in each plot (five plants per plot). The scab disease severity was calculated using the following formula:

$$I = \frac{\sum(nxv)}{ZxN} x100\%,$$

Where: I = disease severity, n = number of leaves in each disease category/score, v = disease score, Z = the highest disease score, N = total number of leaves observed in each plant. The mean disease severity of each plot was obtained from the average of all individual plant disease severities within each plot.

The disease score was determined following the method of Zuraida et al. (1992) as follows: 0: healthy, no apparent infection; 1: visible scabs on leaves, petioles, and stems > 0-20%; 2: scabs on leaves, petioles, and stems > 20-40%; 3: scabs on leaves, petioles, and stems > 40-60%; 4: scabs on leaves, petioles, and stems > 60-80%, and 5: scabs on leaves, petioles, and stems > 80%.

Disease severity at the last assessment (8 WAI) was used to classify the scab resistance level of the tested sweet potato genotypes. Classification of sweet potato scab resistance was performed based on the range of disease severity as the followings: 0-10% = "Resistant" (R), 11-20% = "Moderately Resistant" (MR), 21-30% =

"Moderately Susceptible" (MS), >30% = "Susceptible" (S) (Mukelar et al. 1994).

Meanwhile, disease severities during the study, i.e., at 2, 4, 6, and 8 WAI were used to calculate the Area Under the Disease Progress Curve (AUDPC) following the formula by Campbell and Madden (1990):

$$AUDPC = \sum_{i}^{n-1} \left(\frac{Y_i + Y_{i+1}}{2} \right) (t_{i+1} - t_i)$$

Where: Yi = disease severity at the i^{th} observation, n = the last disease assessment (number of assessment), t = period of assessment

RESULTS AND DISCUSSION

Isolation and identification of *S. batatas*

The scab-infected plant leaves from the field were brought to the laboratory and were cultured in PDA medium to obtain pure culture for isolation and identification of the pathogen. The pure culture of *S. batatas* (Figure 1.A) shows white hyphae while the fungal conidia are elliptical (Figure 1.B). This observed morphological pure culture characteristics of *S. batatas* were similar to the results of the previous study by Martanto (2010). We then concluded that the scab-infected plant leaves taken from the field were caused by the fungus *S. batatas*. Thus, the pure culture was then used to produce *S. batatas* inoculum for evaluation of scab resistance in sweet potato genotypes from NTT Province.

The observed symptoms of scab disease

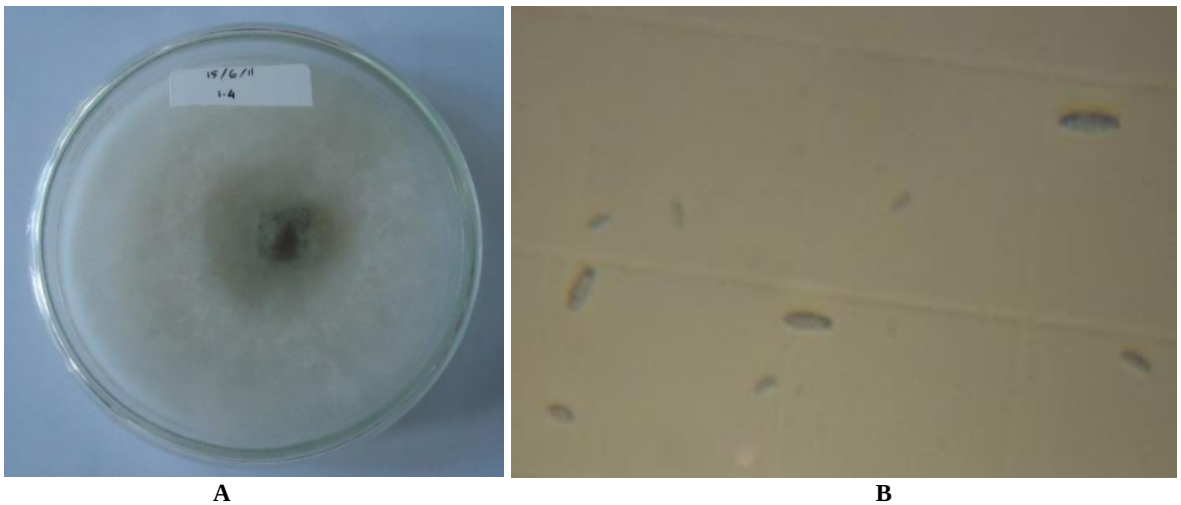
The tested plants showed early signs of reddish-brown spots/pustules on the stems and petioles, which then ruptured to form scabies symptoms. Rupture of the spots caused exfoliation of the epidermis which later resulted in a sunken scab symptom. In severe infections, the scab disease caused leaves in the young shoots to become curly and distorted; even no new leaves/stalks were produced at all. Most of the scabies symptoms were found in stems and petioles with varying lesion severities which depends on the sweet potato genotypes.

In mild disease infection, only a few scabies spots were observed on the affected plant parts, but in severe disease infection, the leaves appeared curly and dwarfed. The susceptible check clone SLM-01 exhibited severe scab symptoms on the stems, petioles, and young shoots while the resistant check variety Kidal suffered only a mild infection. Almost all local sweet potato clones from NTT Province generally showed just mild scab disease symptoms.

The observed scab symptoms in the present study were nearly similar to those observed in the previous studies (Nayga and Gapasin 1986; Clark and Moyer 1988; Moyer et al. 1989; Ames et al. 1997). These similar symptoms indicate the successful artificial inoculation in the field, even though the disease evaluation was carried out during the dry season, where the environmental conditions in NTT Province were, in general, not favorable for scab disease development. The two growing locations that are located at a medium altitude (about 600-800 m asl) might have been quite favorable to allow the artificial scab inoculation in the field was successful.

The progress of scab disease during the experiment

The development of scab disease severity during the observation period is presented in Table 1. At two weeks after inoculation (WAI), the observed disease severity was still below 10% except for the susceptible check SLM-01 that suffered 18.55% infection in Kesetnana and 13.50% in Detubapa. Consistently, the susceptible check SLM-01 demonstrated high disease severities in each of the two locations. Disease severity of the tested sweet potato genotypes tended to increase along with the increase in time after inoculation or along with the rise in the plant's age.



A **B**

Figure 1. Pure culture and microscopic characteristics of the fungus *S. batatas*. A. Pure culture appearance at seven days after culture, B. Shape of *S. batatas* conidia isolated from the pure culture

Table 1. The progress of disease severity (%) at two growing sites: Kasetnana village in Timor Tengah Selatan District and Detubapa village in Ende District

Sweet potato genotype	Growing site							
	Kesetnana				Detubapa			
	2 WAI	4 WAI	6 WAI	8 WAI	2 WAI	4 WAI	6 WAI	8 WAI
EBS-01	0.42	0.50	1.70	2.00	0.00	0.33	0.50	0.67
HK-02	0.11	0.09	0.78	1.00	0.00	3.50	5.67	6.33
KIDAL	3.30	4.73	8.25	11.00	0.33	1.50	2.17	3.00
KRA-01	2.64	2.86	8.36	11.00	5.83	9.50	13.00	18.33
LB-01	2.50	2.40	9.00	10.00	0.50	3.83	6.17	7.17
NBN-01	0.18	0.18	0.95	1.00	0.33	1.00	1.83	2.67
NLK-01	4.05	4.32	7.29	9.00	0.00	3.00	4.00	5.17
NPL-01	0.24	0.28	1.60	2.00	0.33	2.33	3.17	3.67
ON-02	0.72	0.80	2,96	4.00	2.83	5.83	6.83	7.67
ON-06	1.75	2.75	4.05	5.00	0.50	0.50	2.00	3.00
ON-07	0.80	0.95	4.50	5.00	0.17	1.67	2.33	2.83
ORM-02	0.81	0.72	2.22	3.00	0.67	0.83	1.33	1.83
SEO-01	3.60	4.08	5.46	6.00	0.00	1.67	3.00	4.00
SLM-01	18.55	19.25	31.15	35.00	13.50	17.33	20.83	23.83
SOE-02	0.47	0.49	0.89	1.0	1.17	4.00	5.00	5.50

Note: WAI = Week After Inoculation, 2 WAI (8 Weeks After Planting/WAP), 4 WAI (10 WAP), 6 WAI (12 WAP), 8 WAI (14 WAP)

Table 1 shows that the disease severity development varied considerably according to sweet potato genotypes as well as the growing locations. In Kesetnana, the highest disease severity was observed in the susceptible check SLM-01 while the lowest severity was shown by local clones NBN-01, HK-02, and SOE-02. The SLM-01 consistently exhibited high disease severity in Detubapa, followed by KRA-1, ON-02, and LB-01. The lowest disease severity in Detubapa was observed in EBS-01, followed by ORM-02 and NBN-01.

Overall, we did observe substantial differences in disease resistance reactions of the evaluated sweet potato genotypes. Even though the growing locations significantly affected the disease severity of the tested sweet potato genotypes; we did observe a tendency that most of the genotypes consistently showed almost similar disease severity at the two different sites except for Kidal, KRA-01, NLK-01, and ON-02. The SLM-01 susceptible check consistently demonstrated higher disease severities in both test sites. As with SLM-01, KRA also showed high disease severities in both locations, much higher than most local genotypes. Meanwhile, the resistant check variety Kidal showed much higher disease severity in Kesetnana as compared to the local clones, except for KRA-01 NLK-01 and LB-01, while in Detubapa, Kidal showed a lower disease severity than those of most of the local clones tested.

Observed differences in disease severity at different locations might have been caused by variations in environmental conditions, especially temperature, humidity and sunlight intensity that profoundly influenced the disease development and intensity. Also, other factors that might have affected the observed disease severity differences in the fields were the presence of wind, water droplets, and insects that can facilitate the spread of the pathogens among plants in the field. The existence of these factors may assist the spread of the fungus inoculum from one leaf to the others, most notably to the newly grown leaves, which overall affected the disease intensity as well as the disease progression rate.

AUDPC of scab disease

Area under the disease progress curve (AUDPC) analysis is an approach used to calculate the severity of the disease that is repeatedly observed over time, and thus the AUDPC data can be subjected to ANOVA to see the effect of the treatment on the observed variables (Campbell and Madden 1990). ANOVA results revealed a significant effect of sweet potato genotypes ($P < 0.01$) on AUDPC of scab disease severities during the observation period in each of the two locations. In Kesetnana, the highest AUDPC of disease severity was observed in the susceptible check SLM-01 (1086.75%.day), followed by KRA-01, LB-01, Kidal and ON-07, while the lowest AUDPC was shown by local clone NBN-01 (12.04%.day), which was not significantly different from that of other local clones such as HK-01, SOE-02, NPL-02, NLK-01, and ORM-02 (Table 2).

Table 2. Mean AUDPC of scab disease severity (%.day) of sweet potato genotypes evaluated in two growing sites.

Sweet potato genotype	Growing Site			
	Kesetnana		Detubapa	
EBS-01	156.35	bcd	16.33	a
HK-02	29.30	ab	172.67	cde
KIDAL	206.19	cde	74.67	ab
KRA-01	261.52	e	484.17	f
LB-01	235.06	de	193.67	de
NBN-01	12.04	a	60.67	ab
NLK-01	70.91	abc	134.17	bcd
NPL-02	41.72	ab	105.00	abc
ON-02	95.34	abc	250.83	e
ON-06	155.65	bcd	59.50	ab
ON-07	164.92	bcde	77.00	ab
ORM-02	68.46	abc	47.83	ab
SEO-01	117.50	abcd	93.33	ab
SLM-01	1086.72	f	795.67	g
SOE-02	29.79	ab	172.67	cde

Note: Means within the same column followed by the same letter (s) are not significantly different at $\alpha = 0.05$ DMRT

When grown in Detubapa (630 m asl), the susceptible check SLM-01 also showed the highest AUDPC of disease severity (795.67%.day), which then followed by KRA-01, ON-02 and LB-01 at the second, the third and the fourth place, respectively; meanwhile the local clone EBS-01 demonstrated the lowest AUDPC (16.33%.day), which did not statistically differ from other local clones such as NBN-01, Left, ON-06, ON-07, ORM-02, and SEO-01.

Higher disease severity AUDPC of the susceptible check SLM-01 indicated a higher disease progress rate in this check genotype as compared to other genotypes evaluated in the present study. Thus, SLM-01 produced a higher accumulated disease severity than other genotypes. In contrast, genotypes with lower disease severity AUDPC exhibited lower disease progress rates and also lower accumulated disease severity during the observation period. Levels/values of the disease severity AUDPC indicate the performance response of the tested sweet potato genotypes concerning their ability to resist/reduce the development and the progress rate of the disease (Campbell and Madden 1990).

In general, data in Table 2 demonstrate a considerable variability of the AUDPC of disease severity, both among the tested sweet potato genotypes in the same growing location and also between the same genotype at different test sites. These variations did occur, presumably, due to differences in the response of the tested genotypes under changing environmental conditions. However, in general, we observed consistency in the disease severity AUDPC rank among the tested genotypes within the two growing locations, where the susceptible check SLM-01 consistently accumulated the highest AUDPC, whereas the local clones ORM-02, NBN-01, and the resistant check Kidal consistently exhibited the lowest AUDPC. Thus, we can deduce from the present study results that variability in disease severity accumulation shown by the tested sweet potato genotypes during the two months observation period was mainly due to the genetic factor, although the effect of the environmental factor, i.e., growing sites, was also apparent.

Scab disease resistance level

Scab resistance level of tested sweet potato genotypes was determined based on disease severity assessment carried out eight weeks after inoculation or 14 weeks after planting. Scab resistance classification (Table 3) shows that the majority of local sweet potato genotypes were Resistant to scab disease when grown in Kesetnana location. Meanwhile, KRA-01 and the resistant check Kidal were Moderately Resistant whereas the susceptible check SLM-01 was Susceptible in the same location. These findings indicated that in Kesetnana growing location, the resistant check Kidal was slightly less resistant than its genetic potential as described in the varietal description while SLM-01 consistently showed a Susceptible reaction as it was supposed to be. Almost similar to the study results in Kesetnana growing location, almost all sweet potato genotypes that were grown in Detubapa location were also classified Resistant, except KRA-01 that was Moderately Resistant and SLM-01 that was Moderately Susceptible to scab disease.

Table 3. Scab resistance levels of tested sweet potato genotypes based on disease severity assessment at eight weeks after inoculation

Sweet Potato Genotype	Growing Site			
	Kesetnana		Detubapa	
	Severity (%)	Resistance Level	Severity (%)	Resistance Level
EBS-01	2.00	R	0.67	R
HK-02	1.00	R	6.33	R
KIDAL	11.00	MR	3.00	R
KRA-01	11.00	MR	18.33	MR
LB-01	10.00	R	7.17	R
NBN-01	1.00	R	2.67	R
NLK-01	9.00	R	5.17	R
NPL-02	2.00	R	3.67	R
ON-02	4.00	R	7.67	R
ON-06	5.00	R	3.00	R
ON-07	5.00	R	2.83	R
ORM-02	3.00	R	1.83	R
SEO-01	6.00	R	4.00	R
SLM-01	35.00	S	23.83	MS
SOE-02	1.00	R	5.50	R

Note: R = "Resistant", MR = "Moderately Resistant", MS = "Moderately Susceptible", S = "Susceptible".

Data in Table 3 demonstrate that most of the tested sweet potato genotypes exhibited consistent scab resistant reactions in two growing locations. However, the resistance responses of the two check genotypes were slightly deviated along with the change of growing locations. The resistant check, Kidal, was Resistant in Detubapa location but was Moderately Resistant in Kesetnana. Meanwhile, the susceptible check clone, SLM-01, was Susceptible in Kesetnana location but was Moderately Susceptible in Detubapa location. Slight differences in resistance responses observed in the two check genotypes may indicate the presence of genotype by environment interaction effect on the scab resistance phenotype.

Environmental conditions in the field such as temperature and humidity are highly dependent on the local climatic conditions of the growing locations. Although the scab resistance evaluation was done during the dry season, the scab infections in the fields did occur as expected. This might have happened because the growing locations were located at a medium altitude of above 800 m asl in Kesetnana and above 600 m asl in Detubapa, where the temperature and humidity were still in the optimal ranges for scab infection. Thus, the scab resistance performance of the tested sweet potato genotypes in the field did very much reflect their genetic potency regarding resistance to scab disease.

Overall, the results showed that 12 out of 13 local genotypes of NTT Province exhibited scab resistant reactions in the fields. This local sweet potato genotype's resistance performance was much higher than that found by Sumartini et al. (2006). By employing the same resistance classification method, Sumartini et al. (2006) observed only one genotype (Genjah Rante) of 14 sweet potato genotypes evaluated that showed Moderately Susceptible reaction while other genotypes were Susceptible to scab. In

addition to genetic factors, the higher scab susceptibility reactions shown by sweet potato genotypes assessed by Sumartini et al. (2006), presumably, might have been caused by the more favorable growing environmental conditions for scab infection since the evaluation was done during the rainy season.

This is in line with Lenne (1994) who found that the fungus *S. batatas* caused more severe scab infection on sweet potato during wet months (rainy season) as compared to that in the dry season. Additionally, the differences in the virulence levels of *S. batatas* isolates employed could have contributed to the observed variability in the scab resistance levels in the present study and that of Sumartini et al. (2006). Furthermore, in another scab resistance evaluation carried out during dry season by Martanto (2003) in Solo, Central Java, only one of four sweet potato clones evaluated was Resistant to scab, i.e., Muara Takus variety, while the three clones/varieties were, respectively, Moderately Susceptible and Susceptible to scab. In a laboratory experiment, Martanto (2010) also found only one Papuan local clone (Halake), out of four local clones of Papua and the check variety Bogor, that showed scab disease severity of <10%. Meanwhile, other clones/varieties tested in the same study suffered scab disease severity within the range of 12-22%, which, according to Mukelar (1994) classification, were classified as, respectively, Moderately Resistant and Moderately Susceptible to scab. Using another scab resistance classification according to Ramsey et al. (1988), Widiantini et al. (2015) found about 50% of 600 sweet potato genotypes of F1, parental and check populations that showed resistant reaction to scab disease during the dry season 2013 in Sumedang, West Java, Indonesia.

Based on the present study results, it can be said that variability in scab resistance levels of the tested sweet potato genotypes was mainly due to the genetic factor, while the influence of environmental factors, i.e., growing sites, was also apparent. The high scab resistance responses observed in the local sweet potato clones from NTT could be attributed to their genetic background. The fact that most of the local genotypes were resistant to scab might have also occurred due to the limited virulence level of *S. batatas* race used in this study. The local sweet potato clones with good resistance identified in the present study are invaluable genetic resources for future sweet potato breeding programs. Some of these clones had also been determined to be high yielding and stable across environments (Mau et al. 2009; 2013), drought-tolerant (Mau et al. 2008; Mau 2012) and resistant to sweet potato weevil (Mau et al. 2011). All these good traits will enable the selected clones to be used as the parental sources for the development of more superior varieties or can be directly released as superior local varieties.

In conclusion, we find in the present study that scab disease severities and AUDPC among sweet potato genotypes evaluated in two sites varied considerably. Almost all tested sweet potato genotypes exhibited scab resistant reaction except KRA-01 that was moderately susceptible, and SLM-01 that was susceptible in Kesetnana and moderately susceptible in Detubapa. The majority of sweet potato genotypes consistently demonstrated similar resistance responses between the two locations. Scab-resistant local sweet potato genotypes observed in the present study are invaluable genetic resources that can be used to generate scab-resistant superior varieties adaptable to the dryland and semi-arid agroecosystem conditions of NTT Province.

ACKNOWLEDGEMENTS

This research was funded by DP2M DIKTI of Indonesian Ministry of Education and Culture through National Strategic Research Scheme 2011. The author would like to thank A.S.S. Nidwa, Dr. I G.B. Adwita Arsa, and Julinda B. Henuk, for valuable discussions during the research and writing of this article. Special thanks are also extended to Dewi Pattinasarany, Septiani Kahali, Mercy Ndoen, dan Ansel Parera for technical assistance provided during the pathogen inoculum preparation in the laboratory and disease assessments in the fields.

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TROPICAL DRYLANDS
Volume 1, Number 2, December 2017 E-ISSN: 2580-2828
Pages: 78-82 DOI: 10.13057/tropdrylands/t010203

Effect of processing methods on nutrient and tannin content of tamarind seeds

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Manuscript received: 4 May 2017. Revision accepted: 2 November 2017.

Abstract. *Ly J, Sjofjan O, Djunaidi IH, Suyadi.2017. Effect of processing methods on nutrient and tannin content of tamarind seeds. Trop Drylands 1: 78-82.* The seeds of tamarind (*Tamarindus indicus*) are abundant in semi-arid region of Indonesia and have the potential to be utilized as animal feed sources. Yet, the seeds contain tannin which might have adverse effects on the animals, implying that processing seeds are necessary to reduce the tannin content. The study aimed to evaluate the nutrient content of tamarind seeds collected from Kupang, East Nusa Tenggara, Indonesia and to examine the effect of physical processing methods on nutrient and tannin content. Four treatments using a completely randomized design were trialed: sun-dried seeds (T0); dry fried/roasted seeds (T1); moistening seeds 12 hours after dry fried/roasted (T2); and moistening seeds 24 hours after dry fried/roasted (T3). Dry frying increased significantly ($P<0.05$) crude protein (CP), essential amino acids (EAA), and non-essential amino acids (NEAA) but reduced ($P<0.05$) crude fiber (CF), free fatty acids (FFA), SAFA, UFA and tannin contents of sun-dried tamarind seeds. Moistening 12-24 hours improved significantly ($P<0.5$) CP, SAFA, UFA; reduced ($P<0.5$) CF, FFA, EAA, NEAA; and released 7-8.5% additional tannin contents of ground dry fried seeds kernel. The study highlighted that Indonesia's semiarid region tamarind seeds contain comprehensive nutrients and tannin compounds. Dry frying, dehusked tamarind seeds and grinding followed by moistening the ground dry fried seed's kernel could reduce tannin compound and improve the nutrient content.

Keywords: Dry-fried, moistening, processing, tamarind, tannin

INTRODUCTION

Some regions in Indonesia have semi-arid areas including islands in East Nusa Tenggara Province. While these regions generally have low floristic diversity due to low rainfall and hot temperature, they are endowed with local grains and seeds which have the potentials as feed sources. Tamarind seeds produced from *Tamarindus indicus* are one of the potential wild plant seeds that can be produced in the range of 3000-5000 tons annually in East Nusa Tenggara Province (Statistics of Indonesia 2014). However, 99% of this production is wasted (East Nusa Tenggara Central Statistical Bureau 2014), and only 1% were traditionally used for pigs feeding due to astringent taste, inaccessible processing method and unavailable comprehensive nutrient content data (Ly 2016).

Vadivel and Pugalenthi (2010) reported that raw tamarind seeds contain 675.0±0.12 mg/100 g tannin compound of which about 90% are stored in the seed's husk, and such tannin is responsible for the astringent taste in tamarind seeds. Tannin compound is dangerous for monogastric animals, such as pigs, as it inhibits nutrient digestion and absorption, causing constipation and inducing digestive tract disorders (Pugalenthi et al. 2004; De Caluwé et al. 2010). On the other hand, raw tamarind seeds contain 23% crude protein (CP) (Vadivel and Pugalenthi 2010) which have the potential as protein source. Nonetheless, knowledge regarding nutrient and tannin content in Indonesian tamarin seeds, and proper processing method to remove tannin compounds in tamarind seeds are not available. Therefore, comprehensive information on nutrient content and method for eliminating tannin compounds are important to optimize tamarind seeds utilization for animals.

The tannin compound in the tamarind seed's husk is technically hard to be removed. Dehusking by heating the seeds has been suggested as the initial step to remove the tannin (Pugalenthi et al. 2004; Vadivel and Pugalenthi 2010), but 10% of tannin content remain in the seed's kernel. Grinding seed's kernel continued with moistening them with water are assumed to ameliorate the remaining tannin content without destroying the essential nutrients in the tamarind seed's kernel. It is because tannin is a water-soluble compound (Khanbabaee and van Ree 2001). But tamarind seed kernel is hard, and grinding it is the easiest way to facilitate water penetration into the hard tamarind seed's kernel. Reliable attempts to find out the proper way in processing tamarind seeds are rarely studied. The present study aimed to evaluate the nutrient content in tamarind seeds collected from Kupang District, East Nusa Tenggara Province, Indonesia, and to examine the effect of drying and moistening treatments of seed kernel on nutrient and tannin content.

MATERIALS AND METHODS

Material preparation

Thirty kg of raw sun-dried tamarind seeds were collected from several tamarind center areas in Kupang District, East Nusa Tenggara Province, Indonesia. The seeds were cleaned and sun-dried for two days. Eight kg of those seeds were then randomly sampled for study purposes. The samples seeds were treated with four different processing methods. Crude protein (CP), fat, crude fiber (CF), and energy as well as amino acids, fatty acids, and tannin contents were analyzed by the Integrated Laboratory in Bogor Agricultural University (IPB), Bogor, West Java, Indonesia.

Experimental design and treatments

Sun-dried tamarind seeds were randomly allotted to the following treatments in a completely randomized design consisting of 4 treatments with 5 replicates: (i) T0: sun-drying the seed kernels, (ii) T1: dry-fried the seed kernel, (iii) T2: moistening 12 hours the dry-fried seed kernel, (iv) T3: moistening 24 hours the dry-fried seed kernel.

Physical processing procedure

Eight kg of sun-dried tamarind seeds samples were divided into two groups of 2 kg for T0 and 6 kg for T1, T2, and T3. Two kg of the T0 seeds group were dehusked with a low-speed peeling machine to separate the husk from the seed kernel. The clean seed kernels were then ground into 0.6-1 mm particle size. As much as 500 g ground sun-dried seed's kernel was sampled for T0 then divided into five replicates of 100 g of each. Six kg of T1, T2 and T3 treatments were dry fried in an iron wok at ± 60°C for 15 minutes. The fried seeds were immediately taken out from the hot wok as soon as the color of the seeds turned into dark brown and fissures around the husk followed with peanut aromatic appeared from the fried seeds. The fried seeds were cooled in open air for 15 minutes and dehusked as for T0 seeds group. Clean fried seeds' kernels were then ground into 0.6-1 mm particle size and 500 g of them were sampled for T1 which was divided into five replicated of 100 g of each. Ten sample units consisting of five replicates of T0 and T1 each were analyzed in the laboratory to evaluate the crude protein, fat, crude fiber, Ca, P, amino acids, fatty acids and tannin contents.

Moistening ground dry fried seeds kernel with water

One kg of ground dry-fried seed kernels was divided into two groups of 500 g. The first 500 g groups were randomly allotted to T2, and the remaining 500 g were allotted to T2. Each group was divided into 5 replicates with 100 g each. As much as 600 mL distilled water was prepared and equally divided into the ten replicates with 60 mL each. Each replicate (100 g) of T2 and T3 was mixed with each 60 mL of prepared distilled water to perform a moist mixture of ground dry-fried tamarind seeds' kernel. The ratio of 100 g ground seed kernels: 60 mL distilled water was considered as the optimal mixing ratio to gain the best moist mixture as prescribed by Zamindar et al. (2013). Each replicate of T2 and T3 was stored in a 100 g aluminum bowl with the T2 bowls were opened after 12 hours and T3 bowls after 24 hours incubation. Before being analyzed in the laboratory, the units of T2 and T3 were weighed and immediately put into a 60 °C oven for one hour to halt the moistening process, dry and well separate the mixture particles. The moistening stages are briefly shown in Figure 1.

Variables studied

Variables studied consisted of: (i) Nutrient content: crude protein, fat, crude fiber, and gross energy were analyzed using proximate analysis (AOC); amino acids and fatty acids content were analyzed using Chromatographic; (ii) Tannin content was analyzed using Spectrophotometric method (AOC).

Statistical analysis

Proximate and tannin content were analyzed using one-way Analysis of Variance (ANOVA) to test the significance of the treatments, and Duncan's multiple range test was used to compare differences between treatment means ($P<0.05$) according to Steel and Torrie (1997) using SPSS v. 19.0. AA and FA data were descriptively analyzed.

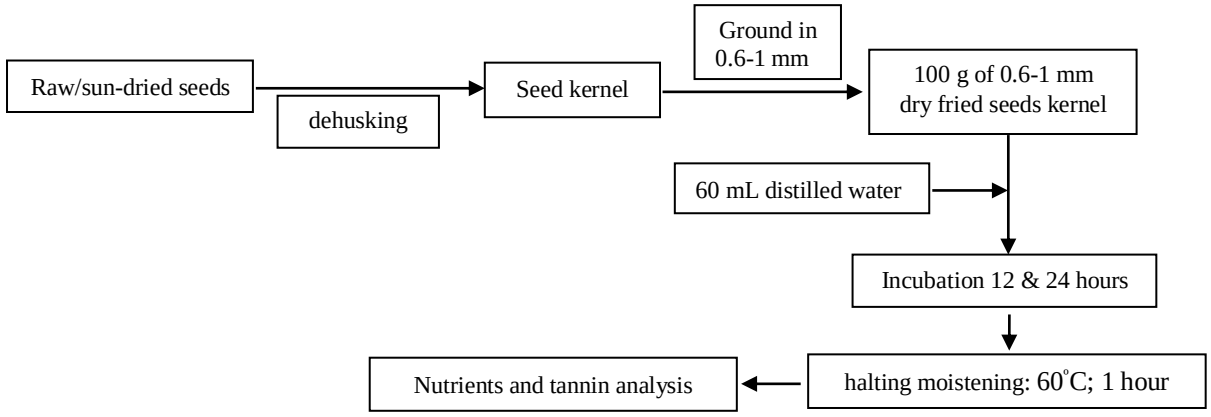

Figure 1. Diagram of processing stages of tamarind seeds adopted from van Der Stege et al. (2011)

RESULTS AND DISCUSSION

Nutrients and tannin contents

The results of proximate analysis and tannin content are shown in Table 1. Amino acids and fatty acids compositions are shown in Table 2 and Table 3, respectively.

Dry frying treatment increased 7.83% DM content, but moistening 12 and 24 hours reduced 27% DM content of ground tamarind seed's kernel. Dry frying increased 1.9% CP content of sun-dried seed kernels; moistening 12 and 24 hours respectively increased 1.1% and 1.4% CP content ($P<0.05$). Fat content decreased 45.5% ($P<0.01$) by the dry frying process, but moistening 12 and 24 hours respectively improved 9.9% and 8.8% ($P<0.05$) fat content. CF content was reduced 52% ($P<0.01$) by dry fried, and moistening 12 and 24 hours reduced CF content 5.5% and 2.7%, respectively ($P<0.05$).

Tannin content was high (92.3%) in the husk and low (7.7%) in the kernel of seeds. Dry frying reduced 23.5% tannin content in the husk and 10% tannin in the kernel. Moistening 12 hours reduced 1.5%, but moistening 24 hours released 7% additional tannin content. Statistical analysis shows that effect of treatment is significant at $P<0.05$ on DM, CP and tannin; and highly significant at ($P<0.01$) on fat and CF contents (Table 1).

Amino acids (AA) composition

Amino acids compositions were measured in 3 groups: total (AA), essential (EAA) and non-essential (NEAA) amino acids of the seeds. Sun-dried (raw) tamarind seed's kernel contained 13.34 mg/100 g CP, consisting of comprehensive EAA (6.06 mg/100 g CP) and NEAA (7.28 mg/100 g CP). Dry frying increased 7.2% of total AA, 4% of EAA and 11% NEAA contents. Moistening 12 and 24 hours reduced 6.2% and 7.1% of total AA, 6.8% and 7.5% of EAA, and 6.3% and 7.6% of NEAA contents, respectively. Total AA, EAA and NEAA contents of moistening results were similar to raw seeds' kernel contents. The change is EAA/NEAA ratio had similar range (1/1.2 to 1/1.3) between dry frying and moistening processes (Table 2).

Free fatty acids (FFA) compositions

FFA compositions were divided into three main categories: total FFA, SAFA and UFA contents. Sun-dried tamarind seed's kernel contained 74.1 mg FFA/100 g fat, consisting of 19.5 mg SAFA and 54.6 mg UFA/ 100 g fat. Dry frying reduced 55.7% total FFA, 2.6% SAFA and 74.2% UFA. Moistening 12 and 24 hours, respectively, improved 47.2% and 67.3% total FFA, 26.8% SAFA and 55% UFA (Table 3). The data show that UFA group has higher reduction than SAFA by all processing methods. Heat during dry frying might have a high impact on both fatty acids fractions which UFA fractions are more sensitive to heating since they have a lower melting point (-49.5-13.4°C) compared to SAFA fractions (44.2-86°C). It seems that moistening could not recover all the part of those fatty fractions that were melted during dry frying.

Table 1. The results of proximate analysis and tannin contents of tamarind seed

Contents	Sun-dried seeds (T0)		Dry fried seed (T1)		Moistening	
	husk	kernel	husk	kernel	T2	T3
DM (%)	na	91.5^{b}	na	98.7^{b}	71.2^{a}	71.6^{a}
OM (%)				97.0^{a}	97.0^{a}	97.1^{a}
CP (%)		16.2^{a}		18.1^{b}	19.2^{b}	19.5^{b}
Fat (%)		7.06^{c}		3.85^{a}	4.23^{b}	4.19^{ab}
CF %		7.7^{b}		3.7^{a}	3.5^{a}	3.6^{a}
Ca %		0.72^{a}		0.75^{a}	0.72^{a}	0.72^{a}
P %		0.30^{a}		0.37^{a}	0.31^{a}	0.31^{a}
GE (MJ/kg)		18.0^{a}		19.0^{a}	19.1^{a}	19.3^{a}
Tannin (mg/100 g)	3620	300^{b}	2760	270^{ab}	266^{ab}	289.3^{b}

Note: ^{abc} Means in the same row without similar letter are different at $P<0.05$. na: not analyzed

Table 2. Amino composition of tamarind seeds

Amino acids (mg/100 g CP)	T0	T_1	T_2	T_3
Aspartic acid	1.59	2.0	1.88	1.83
Glutamic acid	2.40	2.8	2.69	2.57
Serine	0.78	0.91	0.86	0.84
Histidine	0.33	0.32	0.30	0.28
Glycine	0.82	0.58	0.52	0.62
Threonine	0.46	0.50	0.47	0.49
Arginine	1.04	1.03	0.97	0.96
Alanine	0.61	0.68	0.63	0.63
Tyrosine	0.58	0.63	0.61	0.60
Methionine	0.15	0.16	0.18	0.11
Valine	0.69	0.73	0.68	0.66
Phenylalanine	0.75	0.85	0.78	0.78
Iso-leucine	0.74	0.80	0.73	0.76
Leucine	1.18	1.32	1.24	1.26
Lysine	1.18	0.99	0.88	0.89
Total amino acids	***13.34***	**14.30**	**13.42**	**13.28**
EAA	*6.06*	*6.30*	*5.87*	*5.83*
NEAA	*7.28*	*8.06*	*7.55*	*7.45*
EAA/NEAARatio	*1/1.2*	*1/1.3*	*1/1.3*	*1/1.3*

Table 3. FFA composition of tamarind seeds

Fatty acids composition (mg/100 g fat)	T_0	T_1	T_2	T_3
Total fat %	7.06	3.85	4.23	4.19
Caprilic. C8:0	0.05	0.14	0.11	0.20
Lauric. C12:0	0.48	0.02	0.02	0.31
Myristic. C14:0	0.36	0.10	0.09	0.33
Pentadecanoic. C15:0	0.03	0.05	0.05	0.07
Palmitic. C16:0	5.72	6.31	7.11	10.34
Palmitoleic. C16:1 (1)	***0.03***	***0.03***	***0.03***	***0.19***
Heptadecanoic. C17:0	0.08	0.10	0.12	0.17
Stearic. C18:0	3.56	3.53	4.64	4.84
Oleic. C18:1n9c (2)	***18.00***	***7.91***	***10.41***	***13.20***
Elaidic. C18:1n9t	0.03	0.03	0.04	0.09
Linoleic.C18:2n9c (3)	**35.89**	**5.83**	**13.77**	**10.89**
Linolenic. C18:3n3 (n3) (4)	*nd*	*0.04*	*0.04*	*0.09*
Arachidic. C20:0	1.79	1.69	2.41	2.60
Eicosenoic. C20:1	0.82	0.33	0.53	0.55
Eicosenoic. C20:2 (5)	**0.13**	**0.03**	**0.07**	**0.08**
Eicosapentaenoic. C20:5n3 (6)	*0.05*	*nd*	*0.04*	*0.05*
Heneicosanoic. C21:0	0.03	0.06	0.08	0.08
Behenic. C22:0	2.38	2.73	3.72	3.96
Erucic. C22:1n9	nd	nd	0.02	0.02
Decosahexaenoic. C22:6n3 (n3) (7)	*nd*	*0.05*	*0.06*	*0.06*
Decosenoic. C22:2 (8)	**nd**	**0.02**	**0.02**	**Nd**
Tricosanoic. C23:0	0.12	0.18	0.20	0.23
Lignoceric. C24:0	4.55	3.63	4.73	5.05
Total FFA	*74.1*	*32.8*	48.29	54.88
Saturated fatty acids (SAFA)	19.50	19.00	24.10	29.50
Unsaturated fatty acids (UFA)	54.60	13.91	24.42	24.57
Mono unsaturated Fatty acids (MUFA) (1+2)	***18.03***	***7.94***	***10.44***	***13.39***
Poly unsaturated fatty acids (PUFA) (n3+n6) (1+5+8)	**36.07**	**5.97**	**13.98**	**11.18**
UFA/SAFARatio	2.77/1	1/0.73	1/1.01	0.83/1
MUFA/PUFARatio	1/2	1/0.75	1/1.34	1/0.83
n-3 PUFA (4+6+7)	***0.05***	***0.09***	***0.14***	***0.20***
n-6 PUFA (3+5+8)	**36.02**	**5.88**	**13.84**	**10.98**
n-3/n-6Rasto	**1/720**	**1/65.3**	**1/98.9**	**1/55**

Note: [abc] Means in the same row without similar letters are different at P <0.05. na: not analyzed; nd: not determined; MUFA: oleic+palmitoleic; PUFA (poly-unsaturated fatty acids): linoleic and linolenic.

Discussion

CP content of sun-dried (raw), dry fried and both moistening processes of seed's kernel in this study are lower than those in India as reported by either Pugalenthi et al. (2004) (sun-drying and roasting) or Vadivel and Pugalenthi (2007, 2010) (roasting and soaking 12 hours in the water). Increasing CP content by moistening could be a way to release bound protein from other binding protein molecules such as carbohydrates groups and tannin compounds. It could occur because there are some protein fractions bound to carbohydrate fractions such as sugar and fiber (Sooriyaarachchi 2010) and tannin compound (Frutos et al. 2004).

Total fat of raw seeds in this study is lower than in Indian tamarind raw seeds reported by Pugalenthi et al. (2004) or Vadivel and Pugalenthi (2010). The following two factors might have contributed to the difference: seed moisture content and chemical soil properties. Total fat content was found to decrease highly significantly by dry frying process, which then was improved slightly by moistening. These results are similar to the results of roasting process reported by Vadivel and Pugalenthi (2010) in Indian tamarind seeds. Melting cases could occur by heat in dry frying the seeds that resulted in fat content reduction in the kernel; then they were condensed by moistening (Steane 2016). The heat broke bonds between the fat molecules and converted the solid state into a liquid state. In moistening projecting-H atoms of water were linked to fat molecules projecting-OH groups to produce unoriginal water (H_2O) (Steane 2016), resulting in losing water and performing condensed state of fat.

Tannin content of whole tamarind seeds in this study is lower than tannin content of whole seeds of Indian tamarind seeds reported by Pugalenthi et al. (2004) but slightly higher than that of Nigerian raw tamarind seeds reported by Yusuf et al. (2007). Dry frying result of this study is lower than that of roasted result of Pugalenthi et al. (2004) study. Moistening results of this study are lower than soaked results of Pugalenthi et al. (2004) study in Indian tamarind seeds. Dry fried reduced tannin content in both the husk and kernel of the seeds. It may be because heat reduced water content and broke down bonds among tannin molecules resulting in reducing water-soluble tannin fractions for tannin is naturally a water-soluble compound (Khanbabaee and van Ree 2001). Moistening the seeds in 12 hours reduced tannin content in the ground seed kernels but moistening 24 hours increased the tannin slightly.

Total AA of raw tamarind seeds of this study is in the range of two studies reported by De Caluwé et al. (2010). Dry fried increased total AA, EAA and NEAA contents in tamarind seeds but moistening reduced them. Increasing AA may relate to the increase in total DM content, resulting in higher AA content in CP and AA contents. Reducing total AA, EAA and NEAA contents by moistening is not aligned with the increasing of proximately CP content. It can be assumed that the increase of CP content is only because of increasing non-protein nitrogen (NPN) group as a result of protein denaturation to yield NPN group. It may occur since longer moistening damaged more building protein amino acids or built more NPN than building protein nitrogen group. Overheating in dry frying is the most suspicious influencing factor damaging protein structure in protein duration to yield NPN group (Whittemore and Kyrizakis 2006).

UFA contents were reduced by drying then increased 41-63.6% after moistening. It shows that moistening achieved 20% and fermentation performed 11-23% improvement. The 12 hours moistening had the highest UFA enhancement (23%) from dry frying, yet these all are still lower than raw seed contents.

The data show that UFA group had higher reduction than SAFA in all processing methods. It may be because molecules bonds among UFA are looser, resulting in more sensitivity to heat (frying) compared to SAFA molecules. UFA is the group of fat with low melting point meaning

that it is easily melted and reduced by heat. UFA molecule bonds could be easily loosened and more sensitive to heat (frying) because they are built-in branching carbon chain that easily reacts with O_2 in oxidation process (Lehninger 1982).

Total FFA, UFA and SAFA contents of raw seeds were reduced by dry frying but those of ground kernel was improved by moistening, and these figures aligned with the figure of total fat content. It is shown that UFA content reductions were higher than that of SAFA groups. The difference in melting point between those two FFA groups could be the primary influencing factor. Tannin and nutrient contents presented in Tables 1-3 show that dry frying is better in eliminating tannin but not in maintaining nutrient content. Moistening is better in improving nutrient content with a slight increase of tannin content.

In conclusion, the study highlighted that Indonesian semiarid region tamarind seeds contain comprehensive nutrients and low tannin compounds. Dry frying, dehusking tamarind seeds and grinding continued with moistening the ground dry fried seed kernels as presented in this study could optimally eliminate tannin compound and maintain essential nutrients of tamarind seed kernels in this study. A study using other processing methods is required to find out the best way to eliminate tannin and maintain nutrient content of tamarind seeds.

ACKNOWLEDGEMENTS

The authors are grateful to the Nusa Cendana University, Kupang, Indonesia and Brawijaya University, Malang for supporting his study. We thank the Integrated Laboratory of Bogor Agricultural University, Bogor and the Chemical Laboratory of Faculty of Animal Husbandry, Nusa Cendana University, Kupang for feed analysis. We also thanks to the farmers and students for their supports in raw material collection, preparation, and processing of tamarind seeds.

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TROPICAL DRYLANDS
Volume 3, Number 2, December 2019 E-ISSN: 2580-2828
Pages: 56-59 DOI: 10.13057/tropdrylands/t030204

The effect of cattle manure and mineral fertilizers on soil chemical properties and tuber yield of purple-fleshed sweet potato in the dryland region of East Nusa Tenggara, Indonesia

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Manuscript received: 27 August 2019. Revision accepted: 7 December 2019.

Abstract. *Nur MSM, Arsa IGBA, Malaipada Y. 2019. The effect of cattle manure and mineral fertilizers on soil chemical properties and tuber yield of purple-fleshed sweet potato in the dryland region of East Nusa Tenggara, Indonesia. Trop Drylands 3: 56-59.* Sweet potato is potential crop developed in dryland regions, yet the yield is deemed low due to poor soil conditions. Thus, fertilizers are often needed to improve soil quality, leading to increasing tuber yield. A field experiment was carried out to study the effect of combination of cattle manure and mineral fertilizer on the soil chemical properties and yield of purple sweet potato. The experiment was arranged in a Randomized Block Design, with six treatments and four replicates. The assigned treatments were P0 = without manure and without mineral fertilizer, P_1 = 100% recommended dosage of manure (20 tons ha^{-1}), P_2 = 75% recommended dosage of manure (15 tons ha^{-1}) + 25% recommended dosage of mineral fertilizer (25 kg urea ha^{-1}, 25 kg SP-36 ha^{-1} and 37.5 kg KCl ha^{-1}), P_3 = 50% recommended dosage of manure (10 tons ha^{-1}) + 50% recommended dosage of mineral fertilizer (50 kg urea ha^{-1}, 50 kg SP-36 ha^{-1} and 75 kg KCl ha^{-1}), P_4 = 25% recommended dosage of manure (5 tons ha^{-1}) + 75% recommended dosage of mineral fertilizer (75 kg urea ha^{-1}, 75 kg SP-36 ha^{-1} and 112.5 kg KCl ha^{-1}), and P^5 = 100% recommended dosage of mineral fertilizer (100 kg urea ha^{-1}, 100 kg SP-36 ha^{-1}, 150 kg KCl ha^{-1}). The results showed that P_1 and P_2 treatments produced the highest contents of organic-C, total-N, available-P, exchangeable-K and soil Cation Exchange Capacity. However, the highest tuber weight was obtained in treatment P_3. These results indicated that the combination of 50% recommended manure dosage (10 tons ha^{-1}) + 50% recommended mineral fertilizer dosage (50 kg urea ha^{-1}, 50 kg SP-36 ha^{-1} and 75 kg KCl ha^{-1}) could provide a balanced nutrient content in sufficient quantities that meet the sweet potato requirements from the early growth stage to the tuber formation stage, and create soil physical conditions that support the sweet potato tuber development.

Keywords: Purple fleshed sweet potato, soil chemistry

INTRODUCTION

Sweet potato (*Ipomoea batatas* L. (Lam) is one of the potential food crops that can be used as the main staple food – other than rice and corn – since the sweet potato tuber contains high carbohydrates (± 28%). In Indonesia, the average national sweet potato productivity is about 16 t ha^{-1}, which is still far below the potential yield of superior varieties of sweet potatoes which can reach 25-40 t ha^{-1} (BP 2015). The low productivity of sweet potato in Indonesia, particularly in the dryland region such as East Nusa Tenggara (NTT) Province, is caused by many factors, including poor soils and crop management, especially fertilizer application. In general, farmers do not apply fertilizers for sweet potato crop, although there are many sources of fertilizer, such as cattle manure that is abundantly available in the vicinity of agricultural areas and settlements.

The nutrient requirement in sweet potato cultivation can be met through a combination of organic and inorganic/chemical fertilizers. The use of organic fertilizer can improve soil structure, and eventually provide better root growth. Furthermore, inorganic fertilization can fulfill the high nutritional needs of sweet potatoes. This high nutrient requirement can not be met only by providing organic fertilization, except if it is provided in a high dosage which often cannot be afforded by the farmers. The combination of inorganic/chemical fertilizers and organic fertilizers is an ideal alternative as these fertilizers combinations are able to meet the needs of the crop and also can maintain sustainable production and soil fertility.

The effect of a combination of inorganic and organic fertilizers on sweet potatoes has been reported by many studies. Salawu and Muktar (2008) recommended the use of 5 to 10 t ha^{-1} cattle manure combined with NPK inorganic fertilizer. Meanwhile, the combination of NPK (15:15:15) at rates of 300 kg ha^{-1} with 3.2 t ha^{-1} of chicken manure produced the highest sweet potato yield in Ultisols (Omenka et al. 2012). This study also recommended the application of a combination of moderate rates of inorganic fertilizers (150-300 kg NPK ha^{-1}) with 2-3 t ha^{-1} of manure for sweet potato cultivation in Ultisols with low to moderate soil fertility.

In Indonesia, in general, the recommended inorganic fertilizer rate for sweet potato fertilization is 100-150 kg of

Urea + 100 kg SP-36 + 150 kg KCl – ha^{-1} (Saleh et al. 2008). However, the application of such fertilizers is also recommended to be applied in combination with organic fertilizers, such as manure, with rates of 3-5 t ha^{-1}. Many studies have also been carried out under proportional combination of organic and inorganic fertilizers on sweet potatoes. However, study on the effect of these fertilizers combination on a specific variety of purple sweet potato particularly in the dryland region with alkaline soils such as in East Nusa Tenggara Province, Indonesia is limited. The present study was aimed to (i) evaluate the effect of a combination of organic (cattle manure) and inorganic fertilization on the soil physical and chemical properties and the yield of purple sweet potato, and (ii) identify the best fertilizer combination for purple sweet potato grown on alkaline soils.

MATERIALS AND METHODS

Research location and materials

The experiment was conducted in the Integrated Field Laboratory of Archipelagic Dryland Center of Excellence, Universitas Nusa Cendana, Kupang, East Nusa Tenggara, Indonesia (10°09"15.34" S and 123°4012.47" E), commencing from November 2017 to March 2018. The average annual rainfall was 1,539 mm with the wet season occurring for three months from December to March/April. Average daily air temperature was 31°C and relative humidity was 82%. The soil type is classified as a Typic Ustropept (Soil Survey Staff 1998) containing 34% clay. Materials used in this study were a purple sweet potato variety, cattle manure, and inorganic/mineral (NPK) fertilizer.

Experimental design

The experiment was arranged in a Randomized Block Design with six treatments and four replicates. The assigned treatments were P_0 = without manure and without mineral fertilizer (Control), P_1 = 100% recommended dosage of manure (20 tons ha^{-1}), P_2 = 75% recommended dosage of manure (15 tons ha^{-1}) + 25% recommended dosage of mineral fertilizer (25 kg urea ha^{-1}, 25 kg SP-36 ha^{-1} and 37.5 kg KCl ha^{-1}), P_3 = 50% recommended dosage of manure (10 tons ha^{-1}) + 50% recommended dosage of mineral fertilizer (50 kg urea ha^{-1}, 50 kg SP-36 ha^{-1} and 75 kg KCl ha^{-1}), P_4 = 25% recommended dosage of manure (5 tons ha^{-1}) + 75% recommended dosage of mineral fertilizer (75 kg urea ha^{-1}, 75 kg SP-36 ha^{-1} and 112.5 kg KCl ha^{-1}), and P_5 = 100% recommended dosage of mineral fertilizer (100 kg urea ha^{-1}, 100 kg SP-36 ha^{-1}, 150 kg KCl ha^{-1}). Each treatment had four replicates, thus, 24 experimental units were evaluated.

Research procedures

Field preparation and plant cultivation

The planting field was cleared from weeds, plowed as deep as 30 - 40 cm, and then grazed. Twenty-four single row planting plots, each measuring 3 m x 1 m with a 30 cm deep, were made. Space between blocks was 100 cm while between plot spacing was 70 cm. At two weeks before planting, cattle manure was applied to each planting plot according to the treatment. The NPK fertilizers (16:16:16) were applied at early planting time with rates according to the treatment assigned.

Sweet potato stems were cut into 25-30 cm in length with 4-5 nodes each was used in the experiment. The cutting stems were produced from two months old purple sweet potato plant. Each plot was planted with 5 cuttings with a spacing of 50 cm within the plot. Each planting hole was planted with one cutting. One-third or 1-2 nodes of lower part of the cutting were inserted into the planting hole, and the remaining two-thirds of the cutting was left above the ground. Irrigation was done twice a day to reach a field capacity level. Weeding was carried out manually using hand or knife. Harvesting was done four months after planting.

Soil sampling and laboratory analysis

Sampling of soil for chemical analysis was done before planting and after harvesting period. Chemical property analysis of cattle manure was done before planting sweet potato. Soil samples were taken from each planting plot.

Soil samples and cattle manure were sieved (1.0 mm). pH-H_2O (1:10 w/v) was measured using a pH meter (Jenway 3305), C-organic was determined based on the Walkley and Black method (Association of Official Agriculture Chemists 2002), total nitrogen was determined – using the Kjeldahl method (American Society of Agronomy and Soil, 1982), Available-P was determined using Olsen method and measured by using a spectrometer (Spectronic 21 D), K was extracted based on the basic oxidation method with HNO_3 and $HClO_4$ (Association Official Agriculture Chemists 2002) and measured by using an AAS

Variables and data analysis

Observed data included chemical properties of soil before planting and at harvest, nutrients content (N, P, K) of cattle manure, and fresh tuber yield of sweet potato. Fresh tuber yield was harvested from each planting plot and weighed. Only the marketable tuber yield (≥200 g each) was included in the measurement of tuber yield. Observed data were subjected to Analysis of Variance (ANOVA) according to the assigned treatment following the procedure in Gasperz (1992). A Duncan Test (DMRT) (5% significance level) was used to separate the treatment means.

RESULTS AND DISCUSSION

Chemical properties of soil and cattle manure (before experiment)

Chemical properties of the soils and cattle manure are presented in Table 1. This table shows that before planting, the soil pH (H_2O) was 7.7, C-organic content was 0.26%, available P (Olsen) was 9.28 ppm, CEC was 31.67 cmol kg^{-1} and K content was 0.87 cmol kg^{-1}. The chemical properties of cattle manure used were pH (H_2O) 7.8, organic-C content was 30.9%, total-N was 1.66%, available

P was 0.22%, CEC was 113.33 cmol kg^{-1} and exchanged K was 110%. The chemical characteristics of soil and cattle manure are presented in Table 1.

Chemical properties of soil at harvest and sweet potato yield

The effect of combination of cattle manure and NPK mineral fertilizer treatment on soil chemical properties and sweet potato tuber yield is presented in Table 2. ANOVA results showed that cattle manure and mineral NPK fertilizer significantly or highly significantly affected both soil chemical properties at harvest as well as purple sweet potato tuber yield.

The experimental results presented in Table 2 show that the application of cattle manure and inorganic fertilizer into the soil increased the content of organic-C, total N, available P, exchanged-K contents as well as soil Cation Exchange Capacity (CEC). The highest content of C, N, P, K, and CEC was observed in the treatment of P_1 (20 t ha^{-1} cattle manure) and P_2 (15 t ha^{-1} cattle manure + 25 kg urea ha^{-1}, 25 kg SP-36 ha^{-1} and 37.5 kg KCl ha^{-1}).

The organic-C content of manure used was 30.86%, so the application of cattle manure at a dosage of 20 t ha^{-1} was equivalent to 6,172 kg org-C ha^{-1}, while the dose of 15 t ha^{-1} of manure was equivalent to 4,629 kg org-C ha^{-1}. Decomposition of organic matter is a fundamental process that occurs when the material is immersed in the soil. Some of the immersed organic material will be utilized by soil microorganisms as an energy source; some are oxidized and produce CO_2 emissions into the atmosphere, some of the organic matter, altogether with microorganisms, will die and become residues left in the soil. In line with the decomposition process of manure occurs in the soil, Nur et al. (2014) reported that decomposed cattle manure lost about 1.42 ln(t)% organic-C per day, and after 120 days, the loss of organic-C reached 36.5%, meaning that 63.5% of organic-C are still stored in compost material. Therefore, manure that is immersed in the soil will undergo a gradual decomposition, and after 120 days, it will leave a residue thereby increasing the soil's organic-C content.

The data in Table 2 also shows that the use of manure as a soil conditioner affects the soil total N content. The highest soil total N content was observed in treatments P_1 and P_2 (application of cattle manure at a dosage of 20 t ha^{-1} and 15 t ha^{-1}). This is because the nitrogen content of cattle manure is 1.66% so that a dosage of 20 t ha^{-1} is equivalent to 332 kg N ha^{-1} or similar to 738 kg urea ha^{-1}. Meanwhile, cattle manure at a dose of 15 tons ha^{-1} is equivalent to administering 249 kg N ha^{-1} or 554 kg urea ha^{-1}. Manure applied to the soil will undergo decomposition, some of the Nitrogen is used by microorganisms for its growth, some will be absorbed by plant roots, some will be washed away with drainage water and some others will experience volatilization into the atmosphere in the form of NH_3. According to Tiquia and Tam (2000), initial C:N ratio of composted material below 20:1 contributed significantly to Nitrogen loss through NH_3 volatilization. (C: N ratio of manure used was 18.59). When soil organisms die, together with N residues from existing manure will contribute to soil total N. In line with the process of decomposition of manure that occurs in the soil, Nur et al. (2014) reported that decomposed manure experienced a total N-loss of 39.1% during 120 days of decomposition, implying that 60.9% of total N was still stored in compost material. Manure that is immersed in the soil, therefore, will undergo a gradual decomposition, and after 120 days, it will leave a residue, thus, increases the soil's total-N content.

Table 1. Chemical properties of soil (before planting) and cattle manure

Chemical property	Soil	Cattle manure
Organic- C (%)	1.30	30.86
Total N (%)	0.26	1.66
C/N ratio	5.00	18.59
P-available (Olsen) (ppm)	9.28	-
(%)	-	0.22
Exchangeable-K (cmol kg^{-1})	0.87	-
(%)	-	1.10
CEC (cmol kg-1)	31.67	113.33
pH (H_2O)	7.75	7.8

Table 2. Effect of combined treatment of cattle manure and NPK mineral fertilizer on soil chemical properties and tuber yield of purple sweet potato

Treatment	Org-C (%)	Total-N (%)	Available-P (ppm)	Exch-K (cmol kg^{-1})	CEC (cmol kg^{-1})	Tuber yield (kg per plant)
P_0	1.25 a	0.14 a	20.95 a	0.68 a	33.67 a	0.85 a
P_1	1.67 b	0.29 c	33.96 d	1.16 d	41.76 b	0.95 a
P_2	1.60 b	0.28 c	32.16 cd	1.15 cd	41.38 b	0.93 a
P_3	1.53 b	0.26 bc	29.25 c	1.11 b	38.99 a	1.36 b
P_4	1.46 ab	0.22 b	25.89 b	0.99 b	35.71 a	0.94 a
P_5	1.22 a	0.16 a	22.53 a	0.74 a	33.51 a	1.06 a

Note: Numbers within the same column followed by the same letter(s) are not significantly different at 0.05 DMRT. P_0 : without manure and without mineral fertilizer. P_1 : 100% recommended dosage of manure (20 tons ha^{-1}). P_2 : 75% recommended dosage of manure (15 tons ha^{-1}) + 25% recommended dosage of mineral fertilizer (25 kg urea ha^{-1}, 25 kg SP-36 ha^{-1} and 37.5 kg KCl ha^{-1}). P_3 : 50% recommended dosage of manure (10 tons ha^{-1}) + 50% recommended dosage of mineral fertilizer (50 kg urea ha^{-1}, 50 kg SP-36 ha^{-1} and 75 kg KCl ha^{-1}). P_4 : 25% recommended dosage of manure (5 tons ha^{-1}) + 75% recommended dosage of mineral fertilizer (75 kg urea ha^{-1}, 75 kg SP-36 ha^{-1} and 112.5 kg KCl ha^{-1}). P_5: 100% recommended dosage of mineral fertilizer (100 kg urea ha^{-1}, 100 kg SP-36 ha^{-1}, 150 kg KCl ha^{-1})

The application of manure also increased the available P content of the soil (Table 2), and the highest increase in available P occurred in treatments P_1 and P_2 (application of cattle manure at a dosage of 20 t ha^{-1} and 15 t ha^{-1}, respectively). The phosphorus content in manure was 0.22%, thus, a dose of 20 t ha^{-1} is equivalent to 44 kg P ha^{-1} or 140 kg SP-36 ha^{-1}. Whereas, a dose of 15 t manure ha^{-1} is equivalent to 33 kg P ha^{-1} or 105 kg SP-36 ha^{-1}. The soil of the experiment site was calcareous with a very high total P content (417.28 ppm). Although the total P content of the soil was very high, the available P was very low (9.28 ppm) or only about 2.2% of the total P (Nur 2014, 2015). Manure applied to the soil during decomposition will produce humic acid and fulvic acid, which can chelate calcium in the soil so that the P sorption by Ca decreases and, hence, the availability of P increases. Nur et al. (2014) reported that the P content available in calcareous soil could be increased by 43.6% by applying cattle manure compost.

Data in Table 2 also shows that the use of manure as soil ameliorant affected soil exchangeable K content. The highest soil exch.-K content was observed in P_1 and P_2 treatments (application of cattle manure at a dosage of 20 t ha^{-1} and 15 t ha^{-1}, respectively). High exch-K content in these two treatments did occur because the potassium content of manure was 1.10%, thus, a dose of 20 tons ha^{-1} is equivalent to application of 220 kg K ha^{-1} or 530 kg KCl ha^{-1}. A manure dose of 15 t ha^{-1} is equivalent to application of 165 kg K ha^{-1} or 398 kg SP-36 ha^{-1}.

The application of manure also increased soil CEC content (Table 2). The highest increase in CEC occurred in treatments P_1 and P_2 (application of cattle manure at a dosage of 20 t ha^{-1} and 15 t ha^{-1}, respectively). The increase in CEC of soil fed with manure is thought to originate from oxidation of the carboxyl, phenolic and alcoholic groups possessed by humic and fulvic acids produced in the decomposition process of the manure. According to Stevenson (1994), humic acid and fulvic acid have a chemical structure similar to the same OH-phenolic acidity (310 cmol kg^{-1}), however, fulvic acid has higher OH-alcoholic acidity (500 cmol kg^{-1}) than humic acid (260 cmol kg^{-1}).

Although the improvement in soil chemical properties (increase in content of C, N, P, K and CEC) occurred the best in P_1 and P_2 treatments (application of cattle manure at a dosage of 20 t ha^{-1} and 15 t ha^{-1}, respectively), data in Table 2 shows that the highest purple sweet potato tuber yield was produced not in P_1 and P_2 treatments but in P_3 treatment (application of 50% manure or 10 tons ha^{-1} + 50 kg Urea ha^{-1}, 50 kg SP-36 ha^{-1} and 75 kg KCl ha^{-1}). These results indicate that a combination of 50% recommended dosage of manure + 50% recommended dosage of mineral fertilizer was able to provide a nutrient balance in an adequate amount of sweet potato requirements from the early growth to the formation of tubers, and created a physical condition of the soil that supports tuber development. In the early period of sweet potato growth, the cattle manure was just started to decompose (mineralization), thus, it has not been able to provide sufficient quantity of nutrients to support optimum plant growth; the role of manure as a nutrient source is carried out by inorganic fertilizers or mineral fertilizers. In this circumstance, the role of fertilizer as nutrient provider can be prepared through a combination of organic fertilizer and inorganic fertilizer throughout the vegetative growth phase until tuber formation and enlargement phases.

In conclusion, based on the present study results and discussion, it can be concluded that the treatments of P_1 (20 tons ha^{-1}) and P_2 (15 tons manure ha^{-1} + 25 kg urea ha^{-1} + 25 kg SP-36 ha^{-1} + 37.5 kg KCl ha^{-1}) produced the highest C-organic, total N, available P, and exch-K and CEC. However, the highest tuber yield was obtained at P_3 treatment (10 tons manure ha^{-1} + 50 kg urea ha^{-1} + 50 kg SP-36 ha^{-1} + 75 kg KCl ha^{-1}). A combination of 50% recommended rates of manure (10 t ha^{-1}) + 50% recommended rates of mineral fertilizer (50 kg Urea ha^{-1}, 50 kg SP-36 ha^{-1} and 75 kg KCl ha^{-1}) was able to provide nutrient balance in a sufficient amount of purple-fleshed sweet potato requirements from the initial growth period to the tuber formation period, and created soil physical conditions that support the tuber development.

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TROPICAL DRYLANDS
Volume 1, Number 2, December 2017 E-ISSN: 2580-2828
Pages: 90-99 DOI: 10.13057/tropdrylands/t010205

Production system, population and productivity of exotic versus indigenous chickens in selected districts of North Western Amhara, Ethiopia

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Manuscript received: 11 April 2017. Revision accepted: 27 November 2017.

Abstract. *Sisay T, Alemayehu K, Wuletaw Z. 2017. Production system, population and productivity of exotic versus indigenous chickens in selected districts of North Western Amhara, Ethiopia. Trop Drylands 1: 90-99.* Chicken in Ethiopia contributes to 98.5% and 99.2% of the national egg and chicken meat production, respectively. The total chicken population is estimated to be 56.87 million of which 95.86, 2.79 and 1.35% are indigenous, crossbred and exotic breeds, respectively. The objectives of this paper were to investigate the production systems, population and performance of exotic versus indigenous chicken populations in the selected districts of northwestern Amhara, Ethiopia. Banja and Burie districts and six Kebeles were purposively selected. A total of 180 respondents were selected by systematic and simple random sampling techniques for the survey. On the other hand, a total of 90 exotic chicken owners were purposively selected for monitoring and evaluation. GLM procedure of SAS (2002) was used to quantify the fixed effects of agroecology and breeds on egg production performance. The results revealed that the majority (91.12%) of distributed exotic chickens were kept in traditional/backyard production system. The overall mean egg production for exotic chickens (141.58±11.5) was too low. Significantly, the mean number of clutch per year per hen of Bovans Brown chicken was higher (4.51±0.11 days) than Bovans white breeds (3.5±0.10 days). Shortage at first egg was attained from midland of Koekoek chicken breed (5.38±0.24 months) than from highland (6.54±0.10 months) in Bovans Brown chicken. A highly significant difference in mortality was observed between Bovans Brown (89%) and Koekoek breed (32.4%), respectively due to traditional farmers' management practice. Distribution of different exotic chicken genotypes in the region is increasing from time to time for the upgrading of local chicken ecotypes but, the survival, productivity and population size of exotic and their crosses were too low. On the other hand, the population size of the indigenous chicken and its productivity remain almost constant. Causes of chick mortality in the study area were disease and predator which need to be considered in the development plan of the districts. This is due to the inappropriate production system, genotype, and management. Therefore, production and productivity will be increased through the selection of indigenous chicken ecotypes and crossbreed or upgrading by introducing exotic cocks, pullets, and/or fertile eggs of high egg producing strains with an appropriate production system and management in respective production system.

Keywords: Genotypes, performance, production system, population dynamics, dissemination trend

INTRODUCTION

Ethiopia ranks first in Africa and tenth in the world in livestock production; and this sector plays important socio-economic roles for rural poor (Salam 2005; Fessiha et al. 2010). Among the livestock species, chicken is widespread and important source of income for rural families (Tadelle et al. 2003; Fessiha et al. 2010). The total chicken population in the country was estimated at about 56.87 million (CSA 2015/16). Approximately 99% of these chicken populations are maintained under the traditional production systems. Rural poultry system is dominated by indigenous chickens (Alders and Pym 2009) which are well adapted to harsh environmental conditions (Ajayi 2011). These indigenous chickens vary in body size, feather distribution, plumage color, comb type, shank color, poor production, and productivity. These variations, according to Tadelle et al. (2003) and Halima et al. (2006) are caused by their adaptive nature in different production environments (Gueye 1998; Nigussie et al. 2010). Therefore, many efforts have been done to improve village chicken production and distribution through introduction of exotic chickens (Alemu and Tadelle 1997). Nevertheless, despite the large distribution of exotic chicken, its contribution to the improvement of local chicken is very low (Hailemariam et al. 2006). Even though more than 50 million local chickens in the country were reported (CSA 2011), their productive and reproductive performance is very poor than exotic chickens.

In Amhara region, the total chicken population is about 18 million. The current production system, however, according to Hailemariam et al. (2006) is lack of knowledge on chicken husbandry, lack of complementary inputs, high disease prevalence and predation, lack of strong extension follow up, unavailability of credit services and market are the limiting factors. Distribution of pullets, day-old chicken and fertile eggs, cockerels, layers, and duals breeds, has been one of the poultry extension packages accomplished by the Regional Office of Agriculture, for the last 20 years with the objective to

improve chicken production and productivity. Even though governments and NGOs distributed a large number of different exotic breeds to farmers in Amhara region, the contribution (adoption rate) of improved chicken in the current production system of the area is very low, mainly due to the high mortality rate of chicks (Hailemariam et al. 2006). The objectives of this work were to investigate the production systems, population and performance of exotic versus indigenous chicken population in the selected districts of northwestern Amhara, Ethiopia

MATERIALS AND METHODS

Study area

Banja District

Banja District is one of the administrative districts of Awi zone in Amhara regional state of Ethiopia. The district is 122 km far from the regional city Bahir Dar to the south and 447 km north to Addis Ababa. This district is characterized by a predominantly mountainous location with geographical coordinates of 10°57′N 36°56′E bordered in the south by Ankesha and Gougusa Shikudad woreda, in the west by Guangua woreda, in the north by Fagta Lakeoma woreda and in the east by Sekele woreda. The area is part of the north-western part of Ethiopian highlands where 80% of the area is highland and 20% is midland (BDARDO 2007). It has unimodal rainfall distribution pattern. The rainy season for the area starts in May and extends to the end of October. The average elevation of the district is 2560 m above sea level (BDARDO 2007). The district has a total of 26 Kebeles. As with parts of the country, agriculture is the main economic activity and livestock supports crop production. The district is classified into one agro-climatic zone, which is highland with wet and cool weather conditions (BDARDO 2007).

Bure District

Bure District is located in the northern part of Ethiopia. The district has a total of 27 administrative Kebeles which five are urban, and 22 are rural. Burie administrative and commercial center of the district is located 420 km from Addis Ababa and 148 km from Bahir Dar. The district has a total land area of 2207.2 km, and, the district has three agro-climatic zones, i.e. 80% w/Dega, 10% Dega and 10% kola, respectively (BDARDO 2007).

Sampling methods

The two districts as mentioned before (i.e. Banja for highland and Burie for midland) were purposively selected; six Kebeles that have been participating in the improvement of poultry extension package were also chosen purposively. The selection was done with the help of experts from agriculture livestock offices of the two districts based on high potentiality of exotic chicken distribution from high and midland agro-ecologies. As many as 180 exotic chicken farmers were selected from household package beneficiary's registration book of each selected Kebeles using systematic and simple random sampling techniques. Finally, a total of 90 exotic chicken farmers who have three different chicken breeds were selected purposively for monitoring activities.

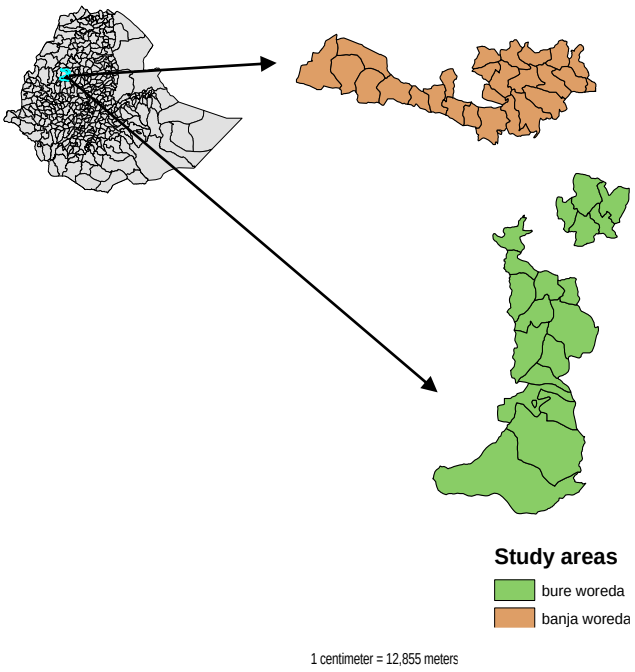

Figure 1. Map of the study districts are indicated by arrows, i.e. Banja (*above*) and Burie (*bottom*) of Ethiopia

Table 1. Environmental characteristics, and human and chicken populations in the studied areas

District	Altitude	Annual rainfall	Mean annual temp.	Human population	Total chicken population	Indigenous chicken	Exotic chicken
Banja	1900-2700 m. asl	2,200-2400 mm	12°-25°C	111,975	97497	78,054	9,443
Burie	700-2750 Masl	713-2832 mm	17-27°C	281,310	203079	183,307	19,772

Source: BBDARDO 2007

For the interview, a semi-structured questionnaire was prepared, pretested on two non-random sampled households from each study site during the rapid field survey. The interview was carried out with the head of the household. Enumerators were selected among the development agents of the agricultural office of the administration. Personal observations and informal discussions with the experts and key informants were carried out. Also, the semi-structured questionnaire survey, focus group discussion (FGD), and monitoring work was employed to collect the required data. Experts from agriculture and rural development agents, extension staff, district administrators in both districts at Kebeles also participate in the group discussions. Continuous supervision was considered to reduce errors during data collection.

Data collection procedures

Questionnaire survey and group discussion

The questionnaire survey was conducted on different aspects of the backyard poultry production systems and pre-tested before the actual data collection. Qualitative data (the type of management systems and husbandry practices) were the core points considered in the process. Quantitative data like production and reproduction performance were collected through predesigned questionnaires from farmers involved in chicken production.

Group discussions were performed with focus group established from each Kebeles with a group comprising of 5 to 7 members. The focus group members include people believed to be aware of past and present social and economic status of the area, community elders, women, and extension agents. Discussions were focused on basic data on the type of management system of chicken, chicken husbandry, season of extra feeds offer, feed shortage season, production and reproduction performance. Also, the average number of eggs was taken from farmers (estimation of eggs laid/hen/year), cause and rate of mortality, season of chicken mortality, occurrence, and severity of disease outbreak. Other vital aspects in chicken production were collected through group discussion.

Monitoring activities

Functional traits were collected from 90 purposively selected exotic chicken owners (45 per agroecology and 15 households for each breed) and regularly monitored with ten days interval for three months. A total of 900 eggs of three exotic breeds (450 eggs per agroecology and 150 eggs for each breed) were collected for monitoring to determine fertility and hatchability using local broody (mother hen) using natural incubation method. Eggs were candled to identify and remove infertile eggs. On the 21st day, the numbers of hatched chicks including the normal, weak, abnormal chicks and dead chicks after hatched were recorded. During monitoring, chick survival rate, cause (diseases or predators) and percentage of chick mortality parameters were recorded through monitoring. Moreover; fertility and hatchability were also calculated during the candling using the following formula.

$$\text{Percent fertility} = \frac{\text{(Total fertile eggs during candling)} \times 100}{\text{Total number of egg set}}$$

Percent hatchability from two points of view:

$$\%\ \text{hatchability on fertile egg basis} = \frac{\text{(number of chicks hatched)} \times 100}{\text{Total number of fertile egg}}$$

$$\%\ \text{hatchability on total eggs set basis} = \frac{\text{(number of chicks hatched)} \times 100}{\text{Total number of egg set}}$$

Data management and statistical analysis

Data were managed both in hard and soft copies. All collected data were entered into Microsoft Excel computer program. The qualitative data were analyzed using descriptive statistics of frequency procedures and cross-tabulation of SPSS version 16 (2008) to observe frequency, percentage and mean used to calculate survey data like husbandry practices, mortality. GLM procedure (SAS 9.0 ver. 2002) was used to analyze the effect of agroecology on the productive and reproductive performance of exotic chickens. ANOVA model was used to investigate the effect of breeds on different response variables and for continuous data type (productive and reproductive) performances like sexual maturity.

An observation on fertility, hatchability, chick survival and mortality was analyzed using the frequency procedure of chi-square for monitoring data. Tests were considered significant at $p<0.05$. Therefore, GLM procedure (SAS 9.0.ver.2002) was used with the fixed effects of agroecology and breeds on the egg production performances

The following model was used to calculate the production and reproduction performances by considering them as the fixed effects of agroecology and breeds.

Statistical model: $Yik = \mu + A_{i+}Ck_{+} (AC)\ ik_{+}e_{ik}$

Where:

Y_{ik} = the production and reproduction performance (i.e. evaluated parameters of exotic chickens).

μ = Overall mean

A_i = Fixed effect of i^{th} breed (i = 4, Bovans white, Bovans Brown, Koekoek and indigenous)

Ck=the fixed effect Of agroecology of k^{th} (k=2, highland, and midland)

$(AC)_{ik}$ = The fixed effect interaction k^{th} of agroecology with i^{th} of breed

ei_k = random residual error

RESULTS AND DISCUSSION

Chicken production system

Management system

About 91.12% of respondents used backyard chicken management systems in both study areas, whereas 8.89% of farmers kept their chicken by the semi-intensive management system (Table 2). According to the result obtained from group discussion, the majority of the farmers managed exotic chickens extensively under traditional

production systems. The reason might be created by poor awareness of farmers due to lack of strong extension service. This result is higher than that reported by Ahmedin (2014) in Gorogutu District in which extensive management practices was 74.4%. The previous report in the other parts of the study areas is similar to Simegnew et al. (2015) in northwestern Amhara Region and Addis and Malede (2014) who stated that almost all interviewed farmers in the north Gondar zone practiced extensive production system.

Feed and feeding practices

About 72.77% of the respondents managed their exotic chickens under a free scavenging system with no additional feed supplements (Table 2). The remaining 27.22% of the exotic chickens are managed under free scavenging with supplementary feed (Table 2). This result is not in line with reports in East Shewa zone by Desalew (2012) in which 2.2% and 97.8% the managed exotic chickens were scavenging with no additional feed supplements and scavenging with additional supplements for exotic chicken respectively. In Gorogutu District 4.4% of the chickens were scavenging alone and 95.6% were scavenging with supplements (Ahmedin; 2014).

The cumulative feeding frequency was 67.78% of the respondents feed evening and morning, whereas morning, evening and afternoon (4.44%), afternoon only (12.22%), morning only (8.34%) and 7.22% were no feeding practices in both agro-ecologies. Whereas, 82.78% and 17.22% of the respondents throw on the ground and feeding troughs were the major feeding practices in the study areas.

About 90% of the respondents stated that the season of serious feed shortage was in rainy season in both agro-ecologies. Almost 100% of the respondents elicited that season of extra feed was from June to September (long-rainy) in both agro-ecologies, as well as supplementation was mainly in long wet seasons. This report is in line with a report by Leulseged (2005) who reported that more scarcity of feed was in wet season.

Chicken house and watering practices of farmers

About 8.88% of the respondents were cleaning daily, while 21.11% of the respondents were reported cleaning weekly as well as 65.56% of the respondents were cleaning monthly and 13.33% of the respondents did not do cleaning practices frequently in highland agro-ecologies. Whereas 12.22% of respondents were cleaning daily, 33.33% of the respondents reported cleaning weekly as well as about 43.33% of the respondents were cleaning monthly, and 11.11% of the respondents did not do cleaning practices frequently in high and midland agroecology (Table 2). This result indicated that lack of frequent cleaning of chicken shelters could easily cause infectious disease and increase mortality rate.

From the total respondents, 16.11% of them kept their chicken at night at a separate shelter in both agro-ecologies. About 43.89% of the respondents shelter the chickens in the family house and the remaining (25%) in a separate house with other animals and in bamboo cage in both agro-ecologies (Table 2). This result is not in line with finding of Desalew (2012) in East Shewa zone, where 95.6% of the respondents constructed a separate house at village production system, and in Gorogutu district where 36.7%, 40% and 23.3% of the respondents sheltering the chickens in a separate house, different shelter during night and share the same room with family, respectively (Ahmedin, 2014). Similar research result was reported from the northwestern part of Ethiopia (Halima 2007) and from Fogera (Bogale 2008) that revealed 50.77% and 59.7% of farmers kept their chicken outside the house, respectively. The main reason for not constructing separate chicken houses in both agro-ecologies was lack of awareness and risk of predators.

Water plays an important role in feed digestion and metabolic activity of chickens. About 85.56% from high land and 88.89% from midland agro-ecologies respondents provide water once/day at any time. Whereas, 14.44 % from highland and 11.11% from midland agro-ecologies provided water twice/day. This result is not in line with the result of Desalew (2012) in East Shewa zone where 95.6% of the respondents have free access under improved management system, and with Ahmedin (2014) in which 20% of the respondents in Gorogutu district, eastern Hararghe have the overall watering frequency twice/day and once/day.

Exotic chicken breed dissemination trend in Amhara

Introduction of exotic breeds of chicken into the northwestern part of Amhara Region has been conducted over the last two decades, and the trend is increasing in the region (Figure 2). Such massive introduction of exotic genotypes was performed via distribution of fertile eggs, day-old chickens, crossbred pullets, and exotic cockerels. However, neither the exotic chicken breed/crossbred increased in sizes nor the egg production in the areas distributed (Figure 2).

Accordingly, the Bureau of the Amhara National Regional State of Agriculture and Rural Development (BoARD) schemed poultry development strategy starting from 2010 (Figure 2). The main purpose of the strategy was to enable farmers to generate income through rearing day-old chickens of three exotic breeds, Bovans-Brown (BB), Potchefstroom Koekoek (PK) and Bovans white breeds (BW) which were hatched and distributed from poultry multiplication centers located at Andassa, Kombolcha, and Ethio-chick. During the periods of 2010 to 2016, over 32,134,426 (31,319,335 day-old chickens, 642378 two month pullets and cockerels and 172713 fertile eggs) were distributed in the region (Figure 2).

Distribution of pullets, cockerels, day-old chickens and fertile eggs, layers and duals purpose breeds is one of the poultry extension packages accomplished by the Regional Office of Agriculture aiming at improving chicken production and productivity. The highest chicken population of the region (206 200, 513705 and 17311216 exotic, hybrid and indigenous, respectively) is found in Amhara region (CSA 2015/16) (Figure 3).

Table 2. Chicken management systems, feed and feeding practices in the study areas

Parameters	Agroecology		
Management practices (%)	Highland % (N)	Midland % (N)	Cumulative % (N)
Backyard	95.56 (86)	86.67 (78)	91.12 (164)
Semi-intensive	4.44 (4)	13.33 (12)	8.89 (16)
Frequency of feeding (%)			
Morning, evening and afternoon	7.78 (7)	1.11 (1)	4.44 (8)
Morning and evening	66.67 (60)	68.89 (62)	67.78 (122)
Afternoon only	13.33 (12)	11.11 (10)	12.22 (22)
Morning only	12.22 (11)	18.89 (17)	15.56 (28)
Overall	100 (90)	100 (90)	100 (180)
Feeding practice (%)			
Throw on the ground	95.56 (86)	70 (63)	82.78 (149)
On feeding trough	4.44 (4)	30 (27)	17.22 (31)
Feed resources (%)			
From the house	94.44 (85)	87.78 (79)	91.11 (164)
Purchased	5.56 (5)	12.22 (11)	8.89 (16)
Type of feeding system (%)			
Only scavenging	72.22 (65)	73.33 (66)	72.77 (131)
Scavenging with additional feed	27.78 (25)	26.67 (24)	27.22 (49)
Season of extra feed (%)			
Long-rainy(Jun-Sep)	100 (90)	100 (90)	100 (180)
Short –rainy (Apr-Jun)	NA	NA	NA
Season of feed shortage severe (%)			
Rainy season (Jun-Aug)	100 (90)	95.56 (86)	90 (176)
Dry season (Feb.-May)	NA	NA	NA
Hygiene status (%)			
Cleaning Daily	8.88 (8)	12.22 (11)	10.55 (19)
Cleaning Weekly	21.11 (11)	33.33 (30)	22.77 (41)
Cleaning Monthly	65.56 (59)	43.33 (39)	54.44 (98)
No cleaning practices	13.33 (12)	11.11 (10)	12.22 (22)
Housing type (%)			
In bamboo cage	26.67 (24)	23.33 (21)	25 (45)
In the family house	47.78 (43)	40 (36)	43.89 (83)
Night separate shelter	4.44 (4)	27.78 (25)	16.11 (29)
Separate house with other animals	21.11 (19)	8.89 (8)	15 (27)
Watering practices (%)			
Once a day at any time	85.56 (77)	88.89 (80)	87.22 (157)
Twice/ day	14.44 (13)	11.11 (10)	12.77 (23)

Note: NA: Not available

The exotic versus indigenous chicken population in Ethiopia

According to the CSA (2015/16), the total chicken population in Ethiopia is about 56.87 million, of which 95.86, 2.79 and 1.35 % are indigenous, crossbred and exotic breeds, respectively. However, the survival, productivity and population size of either exotic (1.35 %) or crossbred (2.79 %) is too low to consider (Figure 4).

Productive and reproductive performances aspect of exotic chickens

Mean number of clutches per year per hen of Bovans Brown chicken breed (4.51±0.11 days) was significantly higher than Bovans white breeds (3.5±0.10 days) in high and midland, respectively (Table 3). This result is not in line with the result of Alem (2014) in central Tigray (3.3 days) rural poultry of RIR exotic breed. According to the key informants during group discussion and the farmers, Bovans Brown, Bovans white, and Koekoek exotic breed hen didn't show broody nature but having clutch nature when they are out of production due to poor management practices (during feed shortage) because of commercial layer (BB and BW) are sensitive for feed shortage.

Clutch length among breeds was significantly longer ($P<0.05$) in Bovans white breed (43.77±7.31 days) than Koekoek breed (33.63±7.94 days) in highland agroecology (Table 3). This result is not in line with the finding by Alem (2014) who reported an average clutch length of 46.6 days for RIR. As explained by the key informants in the group discussion, clutch number and clutch length of exotic breed hens were hardly identified by the farmers because it was very difficult for the farmers to know whether the interruption of egg production is due to nature of the hen or shortage of feed because exotic breeds are sensitive to feed shortage. Significantly higher average number of eggs laid per clutch among breeds was obtained in Bovans white

breed (41.2±1.33) than Bovans Brown (29.60±1.47) in highland agroecology. This result is lower than that of the finding of Alem (2014) in central Tigray for RIR breed (46.3). However, it is greater than that reported by Ahmedin (2014) in Gorogutu district (33.28) for exotic chicken and reported by Matewos et al. (2013) in Nolekobba woreda (26.14) for exotic breeds.

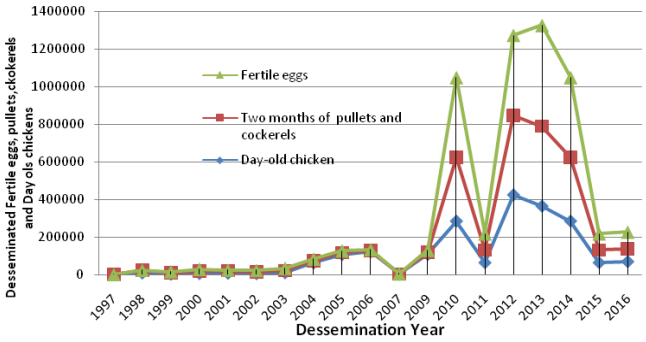

Figure 2. Trends of exotic chicken distribution in Amhara region

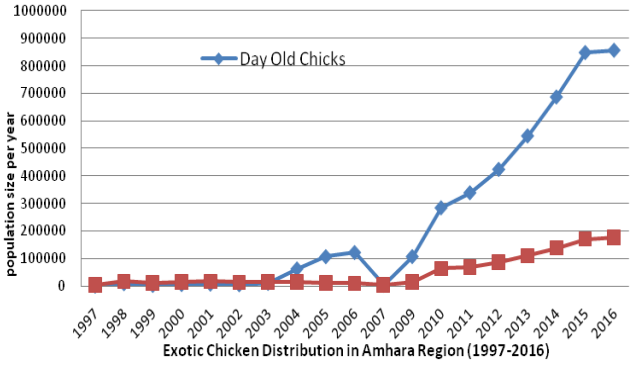

Figure 3. Trends of exotic Chicken distribution in Amhara region (1997-2016).

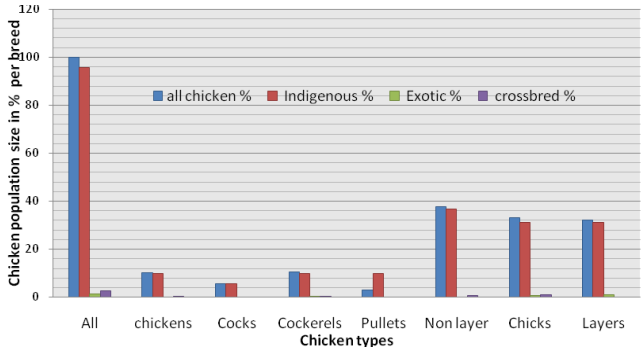

Figure 4. Indigenous, exotic and crossbred chicken population size in Ethiopia

Significantly higher mean annual egg production was observed in commercial layer (Bovans White) breed (156.56±8.13) than dual purpose (Koekoek) breed (130.46±4.01) in highland agroecology (Table 3). According to the respondents' point of view, the current weak performance difference could be created in genetic variation and management (lack of supplementary feed, water intake and parasite infection, diseases and poor health care) of farmers to their chickens. As the key informants explained during group discussion, commercial types mainly Bovans Brown chicken require more feed and balanced diet to sustain maximum egg production over time. This result is significantly lower than the finding of Desalew (2012) mean egg production/hen/year (276.1, 266.32, and 187.04) of Isa Brown, Bovans Brown and Koekoek exotic breeds, respectively, in East Shewa zone under village production system with additional feed supplementation. In addition, the current study was lower than other exotic chickens reported by Abraham and Yayneshet (2010) in North Ethiopia for White leghorn (173), Rhode Island Red (185) chicken under village household condition, the maximum number of eggs/year under Oromia agricultural research institute (156) and (176), Alganesh et al. (2003) in Ethiopia (250), FAO (2007) and Halima et al. (2007a) found at research farm, breeding center and commercial farms (197.40, 200 and 230), respectively. However, the current result is higher than the result of Solomom (2007) who reported 82 eggs/hen for WLH based on evaluation under rural household conditions with additional supplements. This finding is almost similar to that reported by Ahmedin (2014) from Gorogutu district, i.e. 150.2 for exotic chickens, 144 in Fayoumi breed as reported by Abraham and Yayneshet (2010) in North Ethiopia under village household condition and Alem (2014) who reported average egg production of 150.3 for RIR breed in Tigray. According to Mwalusanya et al. (2004), the low productivity of chickens in Tanzania is due partly to the prevailing inadequate management practices, especially the lack of proper health care, poor nutrition and housing.

This study revealed that shortage at first egg was attained from midland of Koekoek chicken breed (5.38±0.24) than from midland (6.5±0.45 months) for Bovans white breed and from highland (6.54±0.10) in Bovans Brown chicken breeds, respectively (Table 3). However, the current result is higher than the finding of Desalew (2012) mean egg production (5.35, 5.52 and 5.11 months) of Isa Brown, Bovans Brown and Koekoek breeds (Figure 5.A), respectively, in East Shewa zone under village production system, and also higher as compared to other exotic chickens reported by FAO (2007) and Halima et al. (2007a) found at research farm, breeding center and commercial farm (4.98 months), (5 months) and (4.83 months), respectively. According to the result obtained from different key informants during group discussion and interviewed farmers, the differences in reaching age at first egg among breeds might be due to poor management practices (feeding and disease) and variation of genotype.

Table 3. Performance aspect of exotic chickens in Banja and Burie districts (Mean±SD)

Parameters	Highland Exotic chicken breeds			Midland Exotic chicken breeds			Overall mean	P-value
	Bovans Brown	Koekoek	Bovans White	Bovans Brown	Koekoek	Bovans White		
Aaffsm (month)	6.54±0.10[a]	5.5±0.00[a]	6.04±0.30[a]	6.49±0.11[a]	5.38±0.24[b]	6.5±0.45[a]	6.07±0.14	(0.0001)**
Aafmsm(month)	NA	4.8±0.33[a]	5.64±0.52[a]	NA	5.12±0.24[a]	6.36±0.13[a]	5.48±0.16	(0.0001) **
Egg no per year	133.49±7.03[a]	130.46±4.01[a]	156.56±8.13[a]	135.42±5.7[a]	141.44±9.14[a]	152.13±6.93[a]	141.58±11.5	(0.0001) **
Clutch /year (day)	4.51±0.11[a]	3.95±0.06[a]	3.8±0.05[a]	4.12±0.08[a]	3.93±0.08[a]	3.9±0.10[a]	4.03±0.83	(0.0001) **
Egg/clutch/hen	29.60±1.47[a]	33.03±1.31[a]	41.2±1.33[a]	32.87±1.97[a]	35.99±1.03[a]	39.01±1.32[a]	35.28±1.27	(0.0001) **
Clutch length (day)	30.26±5.4[a]	33.63±7.94[a]	43.77±7.31[a]	33.66±2.43[a]	35.71±6.55[a]	41.13±5.52[a]	36.36±4.21	(0.0001) **

Note: Aafmsm = age at first male sexual maturity, Aaffsm = age at first female sexual maturity, means with different superscripts within a row are significantly different (P < 0.01), SD=Standard Deviation, NA=Not available

Figure 5. A. Bovans Brown, Bovans White (commercial layers) and Potchefstroom Koekoek (dual purpose). B. Ethiopian local chicken type (female)

Performance of Indigenous chickens

Results of this study indicated that the indigenous chicken production and reproductive traits performance are varied and expressed as low production and reproductive performance (Table 4 and Figure 5.B). The mean result of age at first egg (156.2 days) was recorded for indigenous chicken ecotypes in the study areas. The current result is similar to Bogale (2008) in Fogera district.

Fertility and hatchability of exotic chickens

The monitoring result of fertility, hatchability on fertile egg basis and total egg basis is presented in Table 5. The highest egg fertility on the 18th day of handling was observed in Koekoek breed (75.83%) from highland, whereas, the lowest was recorded in Bovans Brown chicken (34.16%) from midland. This variation might be due to genetic variation among breeds. This result is almost similar to the report of Ahmedin (2014) in Gorogutu district (66.67%). However, this is not in line with Halima et al. (2007a), and FAO (2007) found at research farms, breeding centers and commercial farms (94%, 80%, and 80%, respectively). Similarly, the present result is not in line with result of Shiferaw et al. (2011) at Debre Zeit agricultural research center (90.10%). The fertility of eggs and their hatchability depends on various factors such as breed, season, pre-incubation holding period and temperature, care of hatching eggs, moisture (Silversides and Scott 2001).

The higher hatchability on fertile egg basis was observed in Koekoek breed in monitoring result (87.5%) than Bovans Brown (41.46%) in high and midland, respectively (Table 5). This result is almost in line with the result reported by Halima et al.(2007a), and FAO (2007) found at breeding center (65%) and commercial farm (90%), Ahmedin (2014) in Gorogutu district (76.98%) and in exotic breeds (51.11%), Shiferaw et al. (2011) at Debre Zeit agricultural research center (71.30% and 64.30%), Malese et al. (2013) in Beresa watershed district (67.9% and 54.7%) RIR-crossbreed, Abraham and Yayneshet (2010)in Northern Ethiopia (74.1%) in WLH and Alem (2014) in central Tigray (84.2%). This finding is in line with the report of King'ori (2011) who reported that egg parameters that mostly influence hatchability are: weight, shell thickness and porosity, and the consistency of the contents. The current result is higher than that of a study report based on the five years average of fertility and

hatchability of RIR chickens of the poultry breeding and multiplication centers (88% and 69% at Nazareth, 86.6% and 54.4% at Kombolcha and 82.89% and 62.36% at Andassa, respectively). These figures are below the recommended levels. Bruzual et al. (2000) indicated that the fertility and hatchability percentage of commercial layers are recommended to be around 97% and 90%, respectively. Most previous studies were conducted under intensive management conditions where the housing, feeding, disease and other environmental factors are controlled. In the current study, distributed exotic chickens are only scavenging, and other factors were not controlled which possibly could affect the full genetic expression of chickens.

Chicks performance (survival rate) of exotic chickens

There was significant variation ($P<0.05$) in survival rate between Koekoek (70.3%) and Bovans Brown (35.7%) breeds to reach eight weeks age (Table 5). This could be due to disease prevalence rate, poor management practice of the farmers in the study area. This result is almost higher as reported by Alem (2014) in lowland and midland agro-ecological zones of Tigray mean (65.8).

Mortality rate of exotic chickens

There was a substantially significant difference ($p<0.05$) in mortality rates among breeds. There was highly significant difference ($p<0.05$) in mortality rates of chick in three months between Bovans Brown (89%) and (32.4%) Koekoek breed in highland and midland, respectively (Table 5). This difference could be attributed to high prevalence of disease and poor management practices of the farmer's mainly poor hygienic status and housing system which were quickly exposed to disease and predators attacks. This might be attributed to the difference in management systems like housing and cleaning rate of chicken house. This result is higher than that reported by Abraham and Yayneshet (2010) in Tigray region in mean survival rate of Fayoumi (67.9), WLH (48.8), and also that reported by Alem (2014) in central Tigray (16.14%), Fassil et al. (2010) in sub-tropical environment in Ethiopia (19%), Hailu et al. (2012) in the Northwestern Amhara region (45.0%) and reported by Halima et al. (2007a) in traditional production system, and commercial farms (40%) and (5-10%), respectively.

The result from monitoring data for chick mortality due to predator and disease is described in Table 5. Higher mortality (66.7%) observed in Bovans white breeds due to predators (mainly by wild cat and eagle) is higher than from Koekoek (47%) in highland and midland agroecology, respectively. As farmers stated that, the reason might be poor management practices (lack of house) and white feather color of Bovans; white breeds might be easily exposed to predator. Zemene (2011) from Amhara region indicated that predators are the major constraints in village chicken and by Alem (2014)in central Tigray (42.5%). Among breeds, higher mortality rate due to diseases was observed in for Bovans Brown breed (72.4%) (Table 5). However, this result is not in line with that reported by Alem (2014) in central Tigray (90%). According to the farmers, seasonal disease outbreak was the major cause of chick loss during growth period in both agro-ecologies. Farmers responded similarly to symptoms (head and wing dropping and look sleeping and sometimes diarrhea) and name of disease occurrence in the area. This result indicated that the disease might probably be Newcastle disease (local name: "kofis" or Wararshe (Fengel). The reason might be lack of pre-vaccination given to chicks before the time of occurrence of disease due to lack of vaccine availability in the study areas.

Table 4. Mean productive and reproductive performances of indigenous chickens

Parameters	Min.	Max.	Mean	SD
Average egg weight(g)	35	50.73	51.7	9.13
Mean laying period/ hen (days)	20	240	175	104.08
Eggs/hen per year	56	63	171.9	76.02
Chick mortality (%)	5.5	40	13.3	18.09
Fertility (%)	75	94	82.3	8.18
Hatchability (%)	65	90	77.5	11.90
Age at first egg (days)	158	190	156.2	16.05

Table 5. Fertility, hatchability, chick survival and mortality rate collected through monitoring

Parameters	Highland			Midland		
	Exotic breeds			Exotic breeds		
	Bovans Brown	Koekoek	Bovans White	Bovans Brown	Koekoek	Bovans White
Eggs incubated (no)	150	150	150	150	150	150
Fertility %	40	75.83	60	34.16	71.66	54.16
Hatchability on fertile egg %	43.75	87.85	71.95	41.46	72.91	66.15
Hatchability on total egg %	14	62.66	39.33	11.33	46.66	28.66
Chick mortality /3 month %	89	47	38	63.2	32.4	48.5
Disease cause for mortality %	72.4	61.3	33.3	57.5	53	44.9
Predator cause for mortality %	27.6	38.7	66.7	42.5	47	55.1
Chicks survival to 8 week %	35.7	70.3	49.5	43.02	67.8	38.6

From this study, it was possible to conclude that though chicken production in the rural area reach up to 98.5% and 99.2% of the national egg and chicken meat production, respectively, the production and productivity of chicken remains low. The government of Amhara region has implemented strategies to boost production and productivity through introduction of exotic breeds since 1997. However, the population size of exotic genotypes remains under 5% as compared to the indigenous chicken ecotypes. On the other hand, with increased population size, the production and reproductive traits performance of the local chicken ecotypes are varied and expressed as low production and reproductive performance. The massive introduction of exotic genotypes via distribution of fertile eggs, day-old chickens, crossbred pullets and exotic cockerels (Bovans White, Bovans Brown and Potchefstroom Koekoek) were distributed in Amhara region but still the mean egg production, productivity and survival rate was very low. The main challenges revealed were poorly designed production system and management as per the urban, pre-urban and rural chicken production and indiscriminate introduction of exotic chicken genotypes which could not match with prevailing production system. These challenges could be overcome by selection of indigenous chicken ecotypes and crossbreeding or upgrading by introduction of cocks, pullets and fertile eggs of high egg producing strains. Designing appropriate production systems and management in respective urban, pre-urban, and rural areas could help to increase production and productivity

ACKNOWLEDGEMENTS

The authors would like to thank the farmers found in the study area for their cooperation during data collection. We would like to thank also Sustainable Land Management Organization (SLM) /GIZ for funding this research.

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TROPICAL DRYLANDS
Volume 1, Number 2, December 2017 E-ISSN: 2580-2828
Pages: 100-104 DOI: 10.13057/tropdrylands/t010206

Effect of growth stage on fodder yield and nutrient qualities of dual purpose sorghum

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Manuscript received: 4 November 2017. Revision accepted: 23 December 2017.

Abstract. *Mwangi PG, Gachuiri CK, Mbugua PN. 2017. Effect of growth stage on fodder yield and* nutrient qualities *of dual purpose sorghum. Trop Drylands 1: 100-104.* The reduction of land for dairy and fodder production necessitates dual purpose crops that fulfill the needs for livestock feed and cereals for human consumption. This study aimed to investigate the yield and nutrient qualities of Improved Dual Purpose Sorghum (IDPS) (*Sorghum bicolor*-Var Ikinyaruka) at six physiological growth stages. Six treatments based on sorghum growth's physiological stage were randomly administered to the plot in a block and replicated three times. The treatments were IDPS yielded at bloom stage (PS1), soft dough stage (PS2), hard dough stage (PS3), physiological maturity stage (stalks with grains), (PS4), physiological maturity stage (stalks without grains) (PS5), and 1 month post grain reap (PS6). The parameters monitored were Dry Matter (DM) crop, Crude Protein (CP), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL), In vitro Dry Matter Digestibility (IVDMD) and shoot count. The highest DM crop (18.0 ton/ha) was achieved at PS4 secernated with 8.69, 12.75, 16.27 17.04 and 13.04 ton/ha for PS1, PS2, PS3, PS5 and PS6, respectively. CP reduced with maturity from 8.6 at PS1 to 7.98, 7.96, 7.61, and 6.77 to 6.72 at PS2, PS3, PS4, PS5 and PS6, respectively. NDF and ADF at PS1, PS2, PS3, PS4, PS5 and PS6 were 54.4, 60.8, 65.71, 65.93, 66.73 70.3 and 27.93, 35.96, 41.98, 41.97, 42.04, 46.05, respectively. ADL was 3.44, 5.03, 7.38, 7.39, 7.42, and 8.3 for PS1, PS2, PS3, PS4, PS5 and PS6, respectively. Highest fodder IVDMD of 60.72 was at PS1 secernated with 60.12, 54.73, 53.82, 53.56 and 45.75 achieved at PS2, PS3, PS4, PS5 and PS6, respectively. The PS3 growth stage yielded fodder material with highest nutritive value while highest fodder yields were achieved at PS4. Reaping at PS5 supplied both fodder and grains for livestock and human consumption respectively. It was proven that crop and quality of IDPS were affected by age at reaping time.

Keywords: Dual purpose, fodder, growth stage, sorghum

INTRODUCTION

Grasslands and fodder are the main feed source for dairy cattle production in sub-Saharan Africa. Their availability is highly dependent on rain, which is sufficient during the rainy season but is inadequate during the dry season (KMDP 2013). Accordingly, milk production follows a similar seasonal pattern in response to feeding availability (Le Van 2003). Unfortunately, small-scale farmers rarely stock feed sources for dry-season feeding, due to limited knowledge of conservation technologies and reduced land size for overproduction of livestock feed (KMDP 2013).

In Kenya, dairying work is mainly performed in medium and high potential areas in which increasing population pressure has reduced the average farm size to below 1.2 acres (Nandwa et al. 2013). This indicates that the areas for fodder production are gradually replaced by cultivation of food crops in response to population growth (Shem et al. 2001). Commercial crops, such as coffee and tea, also compete in the same space with fodder so the availability of human food and animal feedstock is a problem for the majority of farming families (KMDP 2013). To overcome this problem, there is a need to identify dual purpose crops with high production per unit area of feed for livestock rearing and cereals for human consumption.

Improved dual purpose sorghum (IDPS) variety *Ikinyaruka* matches with such requirements because it is able to supply grain and sufficient feed throughout the year when reaped at different growth stages (Gachuki et al. 2007). However, the yield and quality of feed at this stage of crop are unknown. Hence, to measure the effect of growth stage at reaping time of IDPS on DM crops and the nutritive value of the feed was the main objective of this study.

MATERIALS AND METHODS

The study was performed at Kenya Agricultural and Livestock Research Organization (KALRO) station in Lanet, Nakuru County, Kenya. The station is situated at altitude of 1920 m above sea level (m asl). The area is located in ecological zone 1V with long rains being received from the month of March to June and short rains in the months of October, November and December. Annual rainfall is often below 800 mm and unreliable both in quantity and distribution. Temperatures range between 8 to 30°C. Soils are deep sandy loam with good water holding capability and a pH range of 5.5 to 6.5.

The experimental field was plowed and hallowed prior to the onset of the rains. Large clods of soil were broken into finer particles using hoes and rakes to attain a fine tilth. Dual purpose sorghum seeds (*Ikinyaruka)* were sown in a three block experimental plot containing eighteen plots using a completely randomized block design. Each block would have six plots in 5 x 4.8 meters measurement.

Treatments were bloom stage (PS1), soft dough stage (PS2), hard dough stage (PS3), physiological maturity stage (stalks with grains), (PS4), physiological maturity stage (stalks without grains) (PS5), and 1month post grain reap (PS6). Shallow rows with a space of 60cm were dug and Di-Ammonium Phosphate (DAP) fertilizer was applied at a rate of 80 kg/ha and mixed with the soil thoroughly. Certified seeds were drilled in the rows at a rate of 6-8 kg/ha and covered with a thin layer of soil. Thinning was done when the crop was 20 cm aboveground to achieve inter plant spacing of 20 cm. After thinning, top dressing was done using CAN fertilizer at a rate of 80 kg/ha. Weed control was done manually during the growth period. Pesticides were used to control pests and diseases.

Before reaping, the growth stage is carefully observed and the number of days after sowing is carefully noted. PS1 was reaped at 87 days after sowing at the time it is estimated that half the plants in the net plot had panicles carrying about 50% of flowers. PS2 at 115 days at the time panicles had 50% of soft milky grains, PS3 at 142 days at the time panicles had 50% of hard grains. PS4 at 169 days at the time panicles had 50% of mature grains. PS5 was reaped 169 days after removal of panicles, while PS6 was reaped 1 month after the grain reap. Reaping and sampling were performed on whole plant except at PS5 and PS6 where main stalk panicles had been cut for grain reaping. A net plot of 3.0 x 4.0 meters was assessed within the six middle rows of each plot leaving 0.5 meters on either side of the row to cushion the border effect.

Calibrated measuring iron bar was used to measure height of all plants in the plot while shoots were counted physically. Stalks within the plots were reaped (cut) at height of 3 inches above the ground for each growth stage and their fresh weight was noted. Reaped stalks were then chopped using a machete into small irregular pieces of about 2-3 cm in size and mixed thoroughly on a plastic sheet spread on the ground. Approximately 1kg sample of the chopped material was placed in an air-dry oven for 3 days at a temperature of 60^0C for fresh fodder dry matter (DM) specification. After reaping at PS1, farmyard manure was applied to reaped plot and ratoon crop was allowed to grow. The ratoon crop was later reaped at bloom stage and subjected to similar sampling and data collection procedures. Grains reaped at PS5 were sun-dried to a moisture value of approximately 12.5% and their dry weight was recorded. Samples of dried fresh stalk were ground in the Wiley Mill to pass a 1 mm screen for subsequent DM and nutrient analysis.

Fresh fodder yield was achieved by weighing freshly reaped material from each plot and the yield was stated in t ha^{-1}. Similarly, dry matter (DM) and grain from each plot were stated in t ha^{-1}. Dry matter value of forage was specified by placing an air dried sample in an oven at 105^0C overnight, cooled in a desiccator and weight recorded. Nitrogen concentrations were specified by the Kjeldahl procedure (AOAC 1990). NDF, ADF and ADL were analyzed according to the sequential method of Van Soest et al. (1991). IVDMD was specified in accordance with the two-stage fermentation technique of Tilley and Terry (Tilley and Terry 1963). Analysis of variance was done using the GLM procedure of SAS Statistical Software Version 9.1. Effects were considered significant in all statistical calculations if the P-values were < 0.05. Means were separated using Fisher's Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

The number of shoots, dry matter value and yields accrued (P <0.05) with advancing age of the plant (Table 1). Mean shoot counts per plant were 2.60, 2.76, 3.86, 3.87, 3.89 and 3.92 for PS1, PS2, PS3, PS4, PS5 and PS6, respectively. The dry matter values were 21.00 25.30, 27.30, 29.91, 28.90 and 26.19 for PS1, PS2, PS3, PS4, PS5 and PS6, respectively. DM value was lowest at PS1, accrued significantly at PS2 and was highest and similar at PS3, PS4 and PS5. The DM yields for PS1, PS2, PS3, PS4, PS5 and PS6 stages were 8.69, 12.75, 16.27, 18.01, 17.04, and 13.05 t/ ha, respectively. Highest DM yields of 16.27, 18.01 and 17.04 t/ ha^{-1} were achieved at PS3, PS4 and PS5 growth stages, respectively and coincided with the highest DM value of the crop.

The crude protein NDF, ADF, ADL, Ash and IVDMD of forage were significantly (P<0.05) affected by stage at reap (Table 2). CP value was 8.60, 7.98, 7.96, 7.61, 6.77 and 6.72 for PS1, PS2, PS3, PS4, PS5 and PS6, respectively, reducing with the advancing age of the crop. Highest CP value of 8.60 was achieved at PS1 then reduced to less than 7 after grain reap.

NDF values were, 54.4, 60.8, 65.71, 65.93, 66.73 and 70.3 for PS1, PS2, PS3, PS4, PS5 and PS6, respectively. ADF values were, 27.93, 35.96, 41.98, 41.97, 42.04 and 46.05 for PS1, PS2, PS3, PS4, PS5 and PS6, respectively while ADL was 3.44, 5.03, 7.38, 7.39, 7.42, and 8.3 for PS1, PS2, PS3, PS4, PS5 and PS6, respectively.

Table 1. Shoot count and yields of IDPS at six different physiological growth stages

Growth stage	Shoots/ plant	DM value	DM yield (t/ha^{-1})
Bloom stage (PS1)	2.60^a	21.00^a	8.69^a
Soft dough (PS2)	2.76^a	25.03^b	12.75^b
Hard dough stage (PS3)	3.86^b	27.30^c	16.27^c
Physiological grain maturity (stalks with grains) (PS4)	3.87^b	29.91^c	18.01^c
Physiological grain maturity (stalks without grains) (PS5)	3.89^b	28.90^c	17.04^c
1 month post grain reap (PS6)	3.92^b	26.19^b	13.05^b
SEM	0.849	0.63	0.001
Stage effect	*	*	*

Note: ^{a,b,c},: Means within the same column with different superscripts differ significantly (P< 0.05). *= Significant effect (P < 0.05). SEM = standar error of the mean

Table 2: Nutrient composition of IDPS reaped at different growth stages

Growth stages	% DM					
	CP	NDF	ADF	ADL	ASH	IVDMD
Bloom stage (PSI)	8.60[d]	54.40[a]	27.93[a]	3.44[a]	8.52[d]	60.72[c]
Soft dough (PS2)	7.98[c]	60.80[b]	35.96[b]	5.03[b]	8.50[d]	60.12[c]
Hard dough (PS3)	7.96[c]	65.71[c]	41.98[c]	7.38[c]	7.90[c]	54.73[b]
Physiological grain maturity (stalks with grains) (PS4)	7.61[b]	65.93[c]	41.97[c]	7.39[c]	7.09[c]	53.82[b]
Physiological grain maturity (stalks without grains) (PS5)	6.77[a]	66.73[c]	42.04[c]	7.42[c]	6.48[b]	53.56[b]
1 month post grain reap (PS6)	6.72[a]	70.30[d]	46.05[d]	8.30[d]	6.21[a]	45.75[a]
SEM	0.31	1.42	1.22	0.32	0.24	0.66
Stage effect	*	*	*	*	*	*

Note: a,b,c,d: Means in the same column followed by different superscripts differ significantly at $P < 0.05$. *= Significant effect (at $P < 0.05$) of growth stage. NS = Lack of significant effect of growth stage, at $P < 0.05$. SEM = standard error of the mean.

Table 4. Growth parameters and yields of ratoon crop secernate with parent crop at PS1 growth stage

Growth stages	Plant height (cm)	Shoots/ plant	DM%	DM yield (t/ha^{-1})
PS1-Ratoon crop	100. 78[a]	5.18[b]	24.21[b]	9.54[b]
PS1-Parent crop	130.36[b]	2.60[a]	21.00[a]	9.10[a]
SEM	3.980	0.142	0.117	0.114
Stage effect	*	*	*	*

Note: a,b: Means in the same column followed by different superscripts differ significantly at $P < 0.05$. *= Significant effect (at $P < 0.05$) of growth stage. SEM = standard error of the mean

Table 5. Nutrient composition of IDPS ratoon crop at PS1 growth stage

Growth stages	% DM					
	CP	NDF	ADF	ADL	ASH	IVDMD
(PS1) Ratoon	8.48	53.95	27.90	3.33	8.98	60.69
(PS1) parent crop	8.60	54.40	27.93	3.44	8.52	60.72
SEM	0.209	0.741	0.598	0.035	0.035	0.209
Ratoon effect	NS	NS	NS	NS	NS	NS

Note: NS = Lack of significant effect, SEM = standard error of the mean

Ash values for PS1, PS2, PS3, PS4, PS5 and PS6 stages were 8.52, 8.5, 7.9, 7.09, 6.48 and 6.21 for PS1, PS2, PS3, PS4, PS5 and PS6, respectively. *In vitro* dry matter digestibility values were 60.72, 60.12, 54.73, 53.82, 53.56 and 45.75 for PS1, PS2, PS3, PS4, PS5 and PS6, respectively, and reduced with plant age.

Plant height (cm), shoots count, forage and DM yield (t/ha^{-1}) of ratoon secernated with parent crop is shown in Table 4. Parent crop was taller ($P<0.05$) than the ratoon crop while the latter had more shoots. Ratoon crop had higher DM yield than parent crop in agreement with Irungu et al. (1993).

Nutrient composition of ratoon crop and parent crop (PS1) is shown in Table 5. There was no difference ($p > 0.05$) in nutrient composition between the two crops.

Discussion

The shoot count in this study was in agreement with Yoseph and Sorsa (2014) who reported counts of 3, 2.8, and 2.7 for three improved sorghum varieties at flowering growth stage. There was a significant accretion in the number of shoots from PS2 to PS3 with no significant accretion thereafter. Dual purpose sorghum varieties have inherent shoot emerging ability and the number of shoots has been reported to accrue with maturity (Gachuki et al. 2007). Number of shoots did not accrue after soft dough stage (PS2) and this might have been associated with non-production or dormancy of shooting buds as more energy could have been diverted to grain formation and filling.

Dry matter (DM) yield accrued as the crop got older. Accrued DM value and yield at PS3, PS4 and PS5 growth stages could be ascribed to accrue in composition of plant organs as the plant got mature. There are accrued proportions of stems, leaves, panicles and shoots and accrued grain fraction. Accrued number of shoots as the plant matures results in accrued foliage DM fraction. IDPS has inherent ability of shoot emerging and this could be associated with its accrual of DM as it matures (Ouma et al. 2013). Ability of forage crops to amass sufficient DM value is extremely important for both fresh forage feeding and ensiling (Carmi et al. 2005). Shoot emerging is an important genetic trait that affects grain yield and biomass production (Kuraparthy et al. 2008; Hammer et al. 2006). Shoot emerging in sorghum is associated with genetics, carbon supply demand (S/D) balance of the plant, or an intrinsic propensity to tiller (PTT) (Hae et al. 2010).

Reduced DM value at PS5 might be ascribed to removal of DM fraction contained in grains after their reaping. PS6 coincided with dry spell and moisture stress yielded to stunted growth of shoots and thus a decline in DM accrual. Prolonged reaping of PS6 yielded to emergency of large proportion young shoots as the parent stalks degenerated. During reaping at PS6, the young shoots had not amassed much DM as the parent materials at PS5 and this could have contributed to reduced DM yields which were noticed at this growth stage

Reduction of CP with plant age in sorghum was in agreement with several other researchers. Ibrahim et al. (2012) reported a reduction from 9.2 from panicle emergence to 5.7 at physiological maturity growth stage. Similarly, Khan et al. (2011) reported a reduction from 7.00 to 6.00 from heading to milk growth stages respectively. Reduced CP percentages with advancing maturity might be ascribed to a reduced proportion of leaves to stem. Leaves contain high amount of CP and are the main contributor of protein in the forage (Cakmakci et al. 1999). Lower CP between PS and PS5 could be ascribed to loss of some of the protein contained in grains prior to reaping. The crude protein value of the forage at all growth stages was below 8%, the minimum required to keep sufficient microbial growth in the rumen (Gregory and Felker, 1992). Addition of protein rich fodder crops, legumes and some agro-by products is recommended for sorghum basal diets in agreement with Jumaa et al. (2012). Addition induces ingestion of the forage resulting in high energy intake (Gregory & Felker, 1992).

Accretion in NDF value with plant age was in agreement with Khan et al. (2011) who reported an accretion from 68.40, 69.01 to 71.70 of forage sorghum from pre-heading, boot and milk growth stages respectively. Ibrahim et al. (2012) reported an accretion in ADF value from 339 to 353 g/kg-^{1} for sorghum cultivar *Nes* from panicle emergence to milk growth stage and ADL value from 39.2 to 44.2 g/kg^{-1} for sorghum cultivar *Nes* from panicle emergence to milk growth stage respectively. Ashiono et al. (2005) reported ADF of 43.7 while Heuze et al. (2012) reported ADL of 7.4 at physiological maturity growth stages. Synthesis and accrual of fiber value as plants mature could be ascribed to formation and thickening of secondary cell walls and could also be as a result of accretion in cell wall value, lignification of stem and leaves as cellulose increases more than hemicellulose value (Ibrahim et al. 2012). NDF, ADF and ADL value at PS3, PS4 and PS5 were similar. This might be ascribed to the emergence of shoots which ameliorated the fiber value even with accretion in age through the three growth phases.

The highest ash value was in PS1, PS2 and PS3 and can be associated with rapid mineral consumption during the early stages of growth. Warrick et al. (2011) stated that about 80% of the mineral consumption by plants occurs at the flowering stage and beyond this stage its absorption is reduced drastically. Stored minerals are utilized at afterward stages of growth for various physiological processes occurring within the plant, such as grain formation. This may explicate the reduction in ash levels at afterward stages of plant growth.

Heuve et al. (2012) reported that 60.30 and 55.00 in milk and dough growth stages were comparable with IVDMD in PS2 and PS3 of 60.1 and 54.7 in this study. The decrease in IVDMD as crop senesced from PS1 to PS6 can be ascribed to leaf and stalk lignification with raised cell wall value. The increment in proportion of stems and consequently a reduction in the proportion of leaves with maturity may also lead to a reduction in IVDMD. Dissoluble solids rapidly decline and lignin and xylan augment shortly after physiological maturation (Chaudhary et al. 2012). High protein value at early growth stage can raise rumen microbial activity and thereby raise IVDMD. The resemblances in IVDMD in PS3, PS4 and PS5 can be ascribed to the resemblances of their chicks that are at the same growth stage (soft and hard dough stages). The levels of IVDMD found at all stages of growth (PS1 to PS6) were above 45% reported by Youngquist et al. (1990) for received levels to keep the weight of bovine in the tropics.

At the same growth stage, the ratoon crop system produced a higher DM result than the parent crop system. Accrued DM yields were associated with accretion in sapling after the first cutting. Cutting off the main stem stimulates the emergence of the basal node (Ashiono et al. 2005) while the application of manure after cutting increases the sapling emergence of the basal node (Gachuki et al. 2007). The nutritional value of ratoon plants and parent plants was similar and this can be ascribed to similar morphological changes in growth between ratoon and parent plants. Ratoon crop reaped in bloom stage (PS1) amassed no DM and nutrients and should be allowed to grow beyond this growth stage and might be reaped in hard dough stages to make a balance in DM yield and quality.

In conclusion, DM harvests of IDPS accrued with the increase of reaping age while forage quality decreases with increasing age. The balance between quality and quantity is gained at reaping time within 142 to 169 days. It is recommended that the optimal time for the use of IDPS as animal feed should be inside the time of hard dough to physiological grain maturity growth stage. Protein supplementation was needed since CP value in IDPS was low. The ratoon crop of IDPS produced a higher DM than the mother crop and farmers should be encouraged to allow for ratooning.

ACKNOWLEDGEMENTS

We thank Kenya Agricultural and Livestock Research Organization (KALRO) for financing the study, Animal Nutrition Laboratories at KALRO Lanet, KALRO Naivasha and the University of Nairobi, Kenya for preliminary samplings and consequent feed analysis, Peter Gachuki and Dr. Samuel Mbuku for sharing some knowledge on sorghum and livestock production respectively, and James Kinyua of Chuka University, Ndagani, Kenya for his guidance in statistical data analysis

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