Forage Res., **42** (3) : pp. 143-148 (2016) **http://forageresearch.in**

DETERMINATION OF APPROPRIATE TIME AND EFFICIENT METHOD OF SEED HARVESTING FROM *ANDROPOGONGAYANUS* AT BENISHANGUL-GUMUZ, WESTERN ETHIOPIA

ALEMAYEHU ABEBE*,[1], MULISA FAJI[1] AND SOLOMON MENGISTU[2]

[1]Ethiopian Institute of Agricultural Research,
Assosa Agricultural Research Center, P. O. Box 265
(e-mail : alabe_2008@yahoo.com)
(Received : 19 October 2016; Accepted : 15 December 2016)

SUMMARY

This study was done to determine efficient method and appropriate time of harvesting seed from *Andropogongayanus* thereby delivering the information and knowledge to private and public forage seed producers.The study was conducted in research field of Assosa Agricultural Research Center for three consecutive years with treatment set up of factorial combinations of four harvesting methods and four harvesting times with four replications. The harvesting methods were hand plucking/mowing of ripened panicle, shaking the panicle at harvesting, allowing the ripe seeds to fall in nylon net collecting bags attached to stems, sweeping of fallen seeds from the ground after previously cutting of the dry stems and mowing of panicle with half-mature seed and sweating it in a shade. Time of harvest schedule defined by number of days after peak anthesis; and the treatments were 14th, 21st, 28th and 35th days. Data were analyzed by SPSS computer software using GLM procedures. The overall mean seed yield and germinable seed yield (kg/ha) recorded in the study were 561.3 and 309.9, respectively. Highly significant ($P<0.001$) yield differences were recorded for germinable seed among harvesting methods and time of harvesting. The interaction of harvesting method and harvesting time was also significant ($P<0.05$).The most efficient method and appropriate time that maximum germinable seed yield attained was sweating on 28th day followed by mowing on 21st day; and the least germinable seed yield was attained by sweeping on 14th day. Thus, we recommend farmers and seed producers growing *Andropogongayanus* in Benishangul-Gumuz and in similar agro-ecologies to harvest seed by sweating on 28th day after peak anthesis.

Key words : Benishangul-Gumuz, germination, seed maturity, shattering, tropical grasses

Forage grasses are the most important sources of feed in ruminant farm animals in the world. They provide livestock with most palatable high quality pasture and hay at a low cost. Moreover, grasses are capable of growing in a wide range of soil and climate. *Andropogongayanus* is one of the grasses native to tropics and it is drought resistant, tufted and leafy perennial grass. It is tolerant to low pH, low soil fertility, seasonal flooding and quite palatable with 6-12 per cent protein.

Feed shortages and poor quality of available feeds are among the major constraints to increased livestock productivity in sub-Saharan Africa. To improve this situation, sowing a new pasture or improving an existing natural pasture is important, but it requires a reliable source of seed or vegetative materials of species that are well adapted for the area (HSU, 1994). However, pasture seeds are not readily available in developing countries, especially in arid and semi-arid areas (Hanson,1994). In Ethiopia, no public or private institution is involved in forage seed production due to technical skill limitation, weak and unreliable seed demand and lack of market information.

Some of more productive grass species like *Andropogongayanus* tend to be troublesome in practical seed production operations in relation to lack of uniformity in maturation; loss of seed due to shattering even before maturity and loss of immature seed due to pest attack.Thus, identifying an appropriate time and efficient method of seed harvest is critical in order to avoid seed losses and improve seed quality since this information is lacking for this particular grass species.

[2]Ethiopian Institute of Agricultural Research, Debrezeit Agricultural Research Center.

Generally, the husbandry of forage seed crops depends firstly on the particular species, especially its growth habit and seed structure, the synchrony of crop development and relative amounts of standing and fallen seed; secondly, it depends on the availability of machinery or hand labour and finally, on previous experience (Pizarro *et al*., 2010).

Several methods are commonly used for harvesting forage grass seed ranging from plucking of seed heads by hand to mechanized harvest by specialized forage combine harvesters. But, as to our knowledge, so far no effort has been made to determine efficient method and an appropriate time for harvesting elite tropical pasture crops at Benishangul-Gumuz condition. Information on seed quality and yield of *Andropogongayanus* using different harvesting techniques and time of harvesting is scarce in tropics, in general, and in Ethiopia, in particular.Thus, the objective of this study was to determine efficient method and appropriate time of seed harvesting from *Andropogongayanus* and finally deliver the information and knowledge to scientific community, private and public forage seed producers.

MATERIALS AND METHODS

Area Description

The study was conducted in three consecutive rainy seasons from 2013 to 2015 in the experimental field of Assosa Agricultural Research Center. Assosa Agricultural Research Center is located $10^{0}30'$N latitude and $034^{0}20'$E longitude, at an altitude of 1565 m above sea level. The pattern of rain was uni-modal with mean annual rainfall of 1275 mm. The minimum temperature varied between 14^{0}C and 20^{0}C, and the maximum temperature ranged from 25^{0}C to 39^{0}C. The soil type was reddish brown nitsols (AsARC, 2006).

Experimental Design and Cultural Practices

The treatment set-up was a factorial combination of four harvesting methods and four harvesting times with four replications. The harvesting methods were hand plucking/mowing of ripened panicle, shaking the panicle once daily allowing the ripe seeds to fall in nylon net collecting bags attached to stems, sweeping of fallen seeds from the ground after previously cutting of the dry stems and mowing of panicle with half-mature seed and sweating it in the shade. Nylon bags were attached at peak anthesis period and remained until sampling period for all methods except sweeping. Time of harvest schedule was defined by number of days after peak heading stage (100% anthesis); and the treatments were 14^{th}, 21^{st}, 28^{th} and 35^{th} days.

Plot size was 12 m^2, 3 m wide and 4 m long. The planting was done in the rainy season of first year of experimental period. The space between rows was 10 cm; the seeding rate was 15 kg/ha. Basal fertilizer (46 kg/ha P as triple superphosphate) was applied at planting and N (100 kg/ha/year) was applied as urea in equal applications at planting and before flowering. In the subsequent years, grass was cut at the start of rainy season and fertilizers were applied in the same form and amount as to initial year.

Data Collection Procedures

The number of inflorescence which is the individual plant emerged from seed above the ground was counted from meter square in each plot. Number of raceme per inflorescence was recorded on six randomly selected plants in each plot (within the sampling area) and spikelet number per raceme was recorded from 20 inflorescences in each plot (Phaikaew *et al*., 2002) at harvest.

Seed yield was recorded from 1 m^2 of each plot for each season and then 1000-seed weight was recorded. After cleaning, seed was stored in paper bag at room temperature and germination test (over 21 days) was done after seven months of post-harvest. Germinable seed yield was calculated by multiplying total pure seed yield by germination percentage. Seed moisture content, 1000-seed weight and seed germination were determined using the seed-test methods of the International Seed Testing Association. Total seed yield, germinable seed yield and 1000-seed weight were recorded adjusting to 10 per cent moisture content.

Data Analysis

Data were entered to SPSS computer software and appropriate data management techniques were applied prior to analysis. Descriptive, correlation and ANOVA techniques were used to data analysis. General linear model was employed to understand the effects of year, harvesting method and harvesting time on seed yield and seed yield components of *Andropogongayanus.*

Year had no effect so it was excluded from the analysis. The model is indicated below :

$$Yijk=\mu+Mi+Tj+Mtij+ +eijk$$

Where,

Yijk is dependent variable, μ is the overall mean, *Mi* is the fixed effect of harvesting method i, i=mowing, shaking, sweating and sweeping; Tj is the fixed effect of harvesting time j, j=14th day, 21st day, 28th day and 35th day; MTij is the interaction of harvesting method i and time of harvesting j; and eijkis a is a random error.

The square root transformation was applied for data sets having values from 0 to 20 per cent or 80-100 per cent and arcsine transformation was used for percentages that do not follow the ranges specified (William *et al.*, 1990). The square root transformation was done by computing $\sqrt{x+1/2}$ and the arcsine $\sqrt{X}$ transformation was carried out by computing arcsine x, where, X is the original datum (William *et al.*,1990).

RESULTS AND DISCUSSION

The Number of Inflorescence, Racemes and Spikelet

The number of inflorescence per m^2, racemes per inflorescence and spikelet per racemes for *Andropogongayanus* is indicated in Table 1. The results are pooled from the three consecutive years of experimental period.

TABLE 1
Number of inflorescence per m^2, racemes per inflorescence and spikelets per raceme for *Andropogongayanus* at Assosa Agricultural Research Center

Parameters	N	Mean	SD	Minimum	Maximum
Inflorescence	192	147.32	35.58	70.0	246.00
Racemes	192	9.21	8.17	2.67	32.67
Spikelet	176	10.42	1.25	7.33	14.00

Total Seed Yield, Germinable Seed Yield and Germination Percentage

The effect of harvesting methods and harvesting times on total seed yield, germinable seed yield and germination percentage of *Andropogongayanus* is indicated in Table 2. The overall mean seed yield and germinable seed yield (kg/ha) recorded in the study were 561.3 and 309.9, respectively. Total seed yield was significantly affected by harvesting method ($P<0.001$) and time of harvesting ($P<0.01$). The interaction of harvesting method and time of harvesting was non-significant ($P>0.05$). Total seed yield in sweating method was significantly higher than mowing, shaking and sweeping methods. In the same manner, mowing had significantly higher seed yield than shaking and sweeping; and shaking method yielded significantly higher than sweeping. Concerning harvesting time, collecting seed on 14th day after peak anthesis had significantly lower total seed yield than collecting on 21st, 28th and 35th days. No significant differences

TABLE 2
Mean seed yield (kg/ha) of total, germinable seed and germination percentage of *Andropogongayanus* in different methods and time of harvesting

Harvesting method	N	Total	SE	Germinable seed	SE	Germination (%)	SE
Shaking	44	555.8c	35.02	334.2	21.88	60.9	1.71
Mowing	43	650.2b	35.02	337.0	21.88	49.6	1.71
Sweating	36	771.4a	38.33	435.8	23.94	58.0	1.71
Sweeping	44	336.5d	34.67	169.5	21.66	51.8	1.71
Significance		***		***		***	
Harvesting time							
14th day	45	457.9b	34.02	211.2	21.25	46.2	1.71
21st day	45	609.1a	34.02	355.0	21.25	58.6	1.71
28th day	43	619.0a	34.73	367.8	21.69	61.1	1.71
35th day	34	628.0a	40.03	342.4	25.01	54.4	1.71
Significance		**		***		***	
Harvesting method x Harvesting time		NS		*		***	

*P<0.05, **P<0.01 and ***P<0.001. NS–Not Significant.

(P>0.05) were recorded on total seed yield among 21st, 28th and 35th days.

Seed germination percentage was significantly affected by both harvesting method and harvesting time (P<0.001) with significant interaction effect (P<0.001). The overall trend showed that germination percentage increased with increasing number of days to harvesting and declined on 35th day. The maximum seed germination percentage (68%) was recorded by shaking on 28th day after peak anthesis followed by sweating on 35th day and mowing on 21st day (63% each). In contrary, the least germination percentage (35%) was recorded for harvesting by mowing on 14th day after peak anthesis (Fig. 1).

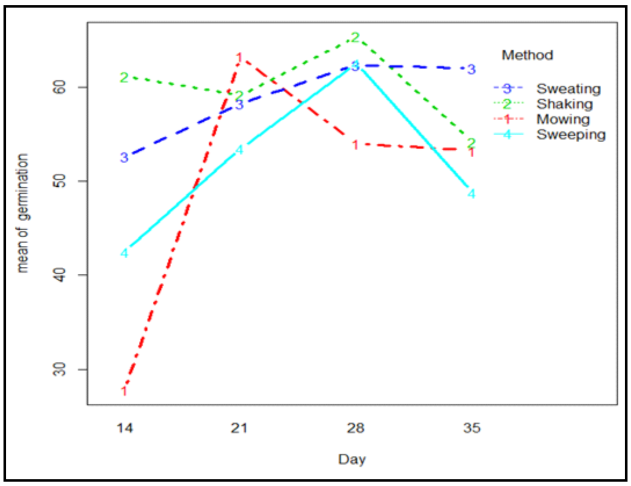

Fig. 1. Seed germination percentage of *Andropogongayanus* in different harvesting methods across the harvesting days.

Highly significant (P<0.001) yield differences were recorded for germinable seed among harvesting methods and harvesting times. The interaction of harvesting method and harvesting time was also significant (P<0.05). The interaction of method and time of seed harvesting on germinable seed yield is indicated in Table 3. The most efficient method and appropriate time that maximum total seed yield attained was sweating on 28th day followed by sweating on 21st day after peak anthesis. In contrary, the least total seed yield was attained by sweeping on 14th day followed by sweeping on 21st day. In the same manner, the most efficient method and appropriate time that maximum germinable seed yield attained was sweating on 28th day followed by mowing on 21st day; and the least germinable seed yield was attained by sweeping on 14th day.

TABLE 3
Mean germinable seed yield (kg/ha) of *Andropogongayanus* in interaction of different methods and time of harvesting

Harvesting method	Harvesting time (days)				SE
	14	21	28	35	
Shaking	271.4	331.7	388.9	344.8	21.88
Mowing	120.6	478.8	384.6	359.7	21.88
Sweating	367.4	447.4	480.8	447.4	23.94
Sweeping	85.4	158.1	216.9	217.8	21.66

1000-Seed Weight

Harvesting method and harvesting time did not significantly (P>0.05) affect 1000-seed weight. The maximum 1000-seed weight was attained by shaking on 35th day, whereas the least 1000-seed weight by sweeping on 14th day of peak anthesis (Table 4).

TABLE 4
Thousand seed weight (g) of *Andropogongayanus* in different methods and time of harvesting

Harvesting method	Harvesting time (days)				SE
	14	21	28	35	
Shaking	4.3	4.6	4.6	5.1	0.34
Mowing	4.5	4.3	4.1	4.2	0.34
Sweating	4.5	4.2	4.6	4.5	0.34
Sweeping	3.8	3.9	4.2	4.5	0.42

Correlations among Seed Yield and Seed Yield Components

The correlation analysis of various variables is indicated in Table 5. Number of inflorescence was negatively correlated (P<0.001) with number of raceme, but it was positively correlated (P<0.001) with seed yield. Seed yield did not correlate (P>0.05) with number of raceme and spikelet.

TABLE 5
Correlation among variables

	Inflorescence	Raceme	Spikelet	Seed yield
Inflorescence				
Raceme	-.394***			
Spikelet	-.068	.041		
Seed yield	.324***	-.095	-.058	

Inflorescence, racemes and spikelet are important components that could determine seed yield of *Andropogongayanus*. As Elgersma (1991) indicated that seed yield was the result of the product of seeds per unit area and individual seed weight; and seed number depended on number of inflorescence per area, racemes per inflorescence and spikelet per raceme. Thus, maximizing these components could result in higher seed yield from *Andropogongayanus*. The number of inflorescences per unit area in this experiment (147) was higher than that reported by Gobius *et al*. (2001) (58) for the same grass species in India.

The mean seed yield from this experiment was higher than reported by Nobius *et al.* (2001) both in India and Thailand. The higher yield might be attributed to higher inflorescence density and better soil fertility. The significant difference in total seed yield of *Andropogongayanus* among different harvesting methods and time of harvesting in this study indicated that seed yield losses could be minimized by choosing efficient harvesting method at appropriate time. The highest seed yield attained by sweating over other harvesting methods could be due to allowance of this method for better abscission of all spikelets than other methods. It was indicated that sweating generally gave about twice the yield of direct-heading for various tropical grasses (HSU, 1994). It was also indicated that seed obtained by sweating was of very high quality because maturation could be completed in moist conditions inside the stack; and sweated seed was also stored very well (HSU, 1994).

The least seed yield was recorded in sweeping method compared to others; this could be associated with loss of seeds by wind and small insects before harvesting. In this experiment, it was realized that fallen seeds of *Andropogongayanus* were collected and taken away by small ants (personal observation). This harvesting method was also found to be tiresome and labour intensive than others; and, in general, a mechanical means was required if large amount of *Andropogongayanus* seed to be harvested.

The lowest yield attained on 14th day after peak anthesis compared to other days of harvesting was probably due to immaturity of seeds. This implies that seeds of *Andropogongayanus* will not attain maximum dry weight within 14 days after peak anthesis and immaturity is likely to be more important as a source of seed loss. Simon *et al.* (1997) reported that for most forage species, the number of days from peak anthesis to maximum seed dry weight was around 30 days.

In this experiment, seed quality (germination %) depended on both harvesting method and harvesting time. The better germination percentage attained in shaking and sweating indicated the appropriateness of these methods for better germination capacity. The lowest germination percentage attained on 14th day harvest after peak anthesis was possibly attributed to seed immaturity. As reported by Simon *et al*. (1997), immature seeds had higher initial seed moisture content, less developed, lighter, and as a result less viable than mature seeds. Threshing viable seed too early can also reduce germination due to physical damage to the seed. Hill and Johnstone (1984) also pointed out that low germination was an indication of seed lot deterioration excluding seed dormancy and hard seed coat; due to production of abnormal seedlings and presence of dead seed. The abnormal seedlings included harvesting of immature seed, harvesting seed at high-moisture content and insect damage, but as the same authors Hill and Johnstone (1984) indicated, in forage grasses, low germination was often associated with dead seeds than abnormal seedlings. The significant interaction of harvesting method and harvesting time on germination percentage indicated that harvesting methods responded differently to different harvesting times.

Germinable seed yield is a product of seed yield and associated seed germination; and thus determining the optimal harvesting method and time that provides the highest yield of quality seed has been the main interest of this experiment. The significant interaction of harvesting method and harvesting time indicated that harvesting methods responded differently to different harvesting times. However, due to lack of standard method and time of seed harvesting developed so far for this grass in Ethiopia or elsewhere in tropics, it is not possible to quantify seed losses of each harvesting method and in each harvesting period.

Nordestgaard and Andersen (1991) indicated that number of inflorescence was the first and most decisive component governing seed yield potential in forage grasses and legumes, and it was confirmed from this study by the strong positive correlation between inflorescence number and seed yield. Absence of correlation between seed yield and number of spikelets indicated that seed yield was not influenced by the number of spikelets per raceme. This could be due to constant number of spikelets per raceme within *Andropogongayanus*. This finding is in agreement with that of Elgersma (1990) as she reported that the number of spikelets per tiller was not correlated with the seed yield of nine perennial rye grass cultivars grown in different environments.

CONCLUSION

This study was dealt with determination of efficient method and appropriate time for harvesting of quality seed from *Andropogongayanus* at Benishangul-Gumuz condition. The study indicated that seed yield and germination percentages of *Andropogongayanus* were affected by harvesting method and time of harvesting. The maximum quality seed yield was attained from seed harvested by sweating on 28th day after peak anthesis; and the least quality seed yield was attained by sweeping on 14th day. Thus, we recommend farmers and seed producers growing of *Andropogongayanus* in similar agro-ecology with Benishangul-Gumuz to harvest seed by sweating on 28th day after peak anthesis. In general, with high seed yield and good germination, Benishangul-Gumuz region of Ethiopia has a great potential for *Andropogongayanus* seed production either for smallholders or for commercial farms. But, as pasture seed production is new for the region, training on seed production is required for producers to attain maximum and high quality seed. Finally, findings of this study are applicable to manual harvesting and labour requirements of man hours per hectare should be further studied to identify harvesting method that yields not only the highest quality seed but also cost effective.

ACKNOWLEDGEMENT

This study was sponsored by Ethiopian Institute of Agricultural Research. The authors thank Kedija Ahmed, Diribi Mijana and Ali Mohammed for their technical assistance.

REFERENCES

AsARC (Assosa Agricultural Research Center). 2006 : Results of farming system survey of Benishangul Gumuz Regional State. Ethiopian Institute of Agricultural Research, Assosa Agricultural Research Center, Assosa (unpublished).

Elgersma, A. 1990 : Genetic variation for seed yield in perennial rye grass (*Lolium perenne* L.). *Plant Breed.*, **105** : 117-125.

Elgersma, A. 1991 : Floret site utilization in perennial rye grass (*Lolium perenne* L.). *J. Appl. Seed Prod.* (Supp.), **9** : 38-43.

Hanson, J. 1994 : Seed production by smallholder farmers. Proc. ILCA/ICARDA Research Planning Workshop held at Addis Ababa, Ethiopia, 13-15 June 1994. ILCA (International Livestock Research Institute), A. A. Ethiopia.

Hill, M. J., and C. R. Johnstone. 1984 : Post-harvest seed quality assessment. *Proc. New Zealands Grassland Assoc.*, **45** : 243-246.

HSU (Herbage Seed Unit). 1994 : *Forage Seed Production, ILCA Training Manual*. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 70 pp.

Nobius, N. R., C. Phaikaew, P. Pholsen, O. Rodchompoo, and W. Susena. 2001 : Seed yield and its components of *Brachiaria decumbens* cv. Basilisk, Digitariamilanjiana cv. Jarra and Andropogongayanus cv. Kent in north-east Thailand under different rates of nitrogen application. *Trop. Grassl.*, **35** : 26-33.

Nordestgaard, A., and S. Andersen. 1991 : Stability of high production efficiency in perennial herbage crops. *J. Appl. Seed Prod* (Supp.), **9** : 27-32.

Phaikaew, C., G. Nakamanee, S. Intarit, S. Tudsri, Y. Ishii, H. Numaguchi, and E. Tsuzuki. 2002 : Effect of soil fertility and fertilizer nitrogen rate on seed yield and seed quality of *Paspalumatrtum* in Thailand. *Trop. Grassl.* **36** : 138-149.

Pizarro, E. A., M. D. Hare, J. H. Antezana, R. R. Rojas, I. G. Ramón, A. Miranda, C. Chávez, A. Balbuena1, J. W. Miles, and P. Grupo (2010). Harvest methods and seed yield potential in *Brachiaria* hybrids. *Proc.*, **7** : 33-37.

Simon, U., M. D. Hare, B. Kjaersgaard, P. T. Clifford, J. G. Hampton, and M. J. Hill. 1997 : Harvest and post-harvest management of forage seed crops : Forage production/edited by D. T. Fairey and J. G. Hampton. Cab International, UK.

Kiyothong, K., C. Satjipanon, and P. Pholsen. 2002 : Effect of cutting height and time on seed yield and seed quality of *Stylosanthes anensis* CIAT 184. *Songklanakarin J. Sci. Technol.*, **24** : 587-593.

William, H. A., J. C. Darrel, and B. Girish. 1990 : Use of arcsine and square root transformation for subjectively determined percentage data. *Weed Sci.*, **38** : 452-458.