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Effects of two harvesting methods on seed physical quality and cultural value of three *Panicum maximum* (Jacq.) ecotypes in Togo

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Abstract

The objective of this study is to evaluate the quality of Panicum maximum seeds harvested using two methods: direct harvesting and bag harvesting. The experimental design is a Fischer block comprising three blocks, each containing all ecotypes arranged randomly. The seeds were harvested, threshed, dried and winnowed. Quality attributes such as Thousand Seed Weight (TSW), Purity percentage (P), Germination Percentage (GP) and Pure Germinated Seed Yield (PGSY) were evaluated. The Cultural Value (CV), Sowing Rate (SR) for each ecotype and the Area Corresponding (AC) to the yields of the different ecotypes were determined. Purity was influenced by the harvesting method ($p < 0.05$). A very significant ($p < 0.01$) and highly significant ($p < 0.001$) difference was obtained for TSW and TGSY. The CV of the seeds was highly influenced ($p < 0.001$) by the harvesting method. Sowing 1ha of land requires approximately 15 kg and 5 kg of seeds of each ecotype for direct harvesting and bag harvesting, respectively. The areas to be covered with such yields (direct harvesting vs. bagging) are 10 ha vs 53 ha; 13 ha vs 82 ha and 27 ha vs 94 ha for ecotypes E1, E2 and E3 respectively. Bag harvesting is the best method for obtaining high quality seeds.

Key words: *Panicum maximum, Harvesting method, Seed quality, Togo*

1. Introduction

Most forage plots based on forage grasses in Togo are established using root cuttings. *Panicum maximum* is one of the most widely used forage grasses for livestock feed in Togo. However, the problem of seed quality for this species is an obstacle to its propagation. The production of high-quality seeds of tropical forage grasses such as *Panicum maximum* Jacq is influenced by a number of factors. The harvesting method is one of the most important factors influencing the quality of *Panicum maximum* seeds. This observation that the method of harvesting forage grass seeds influences their quality has been noted in several studies (Noirot, 1981; Phaikaew *et al.*, 1995; Mandret and Noirot, 1999; Souza, 1999; Hare *et al.*, 2007; Melo *et al.*, 2016). In Togo, there are several ecotypes of *Panicum maximum*, some of which are being tested at stations for their seed production potential.

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However, the seed quality attributes of these different ecotypes of *Panicum maximum* have never been evaluated. This information is crucial in order to determine the cultural value and use of the seeds of these different ecotypes of *Panicum maximum*. The hypothesis underlying this study is that the physical quality of seeds differs according to the harvesting method and the different ecotypes. The objective of this study is to evaluate the physical quality of *Panicum maximum* seeds harvested by two methods: (i) direct cutting of panicles; and (ii) harvesting by bagging panicles.

2. Materials and methods

2.1. Experimental site

This study was conducted at the Avétonou zootechnical and veterinary research station situated in the "region des plateau" in southern of Togo. This station was established in 1964 as part of German-Togolese cooperation under the name "Centre de Recherche et d'Elevage d'Avétonou-Togo" (CREAT). It was then handed over to the Togolese government in 1988 and finally attached to the "Institut Togolais de Recheche Agronomique" in 1998 specifically the "Direction du Centre de Recherche Agronomique zone forestière/ station d'Avétonou". This region enjoys a sub-equatorial climate characterised by two rainy seasons from March to June and September to October, and two dry seasons from November to February and July to August. The average temperature varies between 20° and 35 °C, and annual rainfall over the last five years has ranged between 1,100 mm and 1,600 mm (CREAT rainfall station). The vegetation consists of a series of wooded savannahs interspersed with gallery forests (Seme, 2017). The tree and shrub species found include: *Gmelina arborea, Daniella olivieri, Vitex doniana, Antiaris africana, Triplochiton cleroxylon, Lonchocarpus sericeus, Nauclea latifolia, Securinega vrosa, Terminalia avicenoides, Vitellaria paradoxa* (Koumessi *et al.*, 2019). *The herbaceous layer consists mainly of Panicum maximum, Pennisetum purpureum, Pennisetum violaceum, Hyparrhenia sp, Andropogon gayanus, Setaria spacelata, Cenchrus ciliaris, Brachiaria brizantha, Cynodon dactylon, Centrosema pubescens, Calopogonium mucunoides,* and *Crotalaria retusa* (Koumessi *et al.*, 2019).

2.2. Plant material

The plant material consists of three ecotypes of *Panicum maximum* namely: Ecotype E1 of variety C1, ecotype E2 of variety T58 and ecotype E3 of the local variety.

2.3. Experimental design and treatments

The experimental design is a Fischer block comprising three blocks, each containing all ecotypes arranged following a randomized design. The cuttings were transplanted in rows on 16 m² plots with a spacing of 0.5 m x 0.5 m. A1 m border was observed between rows and around plots.

2.4. Measurement of parameters

The parameters evaluated included Total Seed Yield (TSY) and quality attributes such as Thousand Seed Weight (TSW), Purity percentage (P), Pure Seed Yield (PSY); Germination Percentage (GP) and Pure Germinated Seed Yield (PGSY).

In addition, the cultural value and seed utilisation (cultural value, sowing rate, area covered) were determined.

Seed production: To evaluate seed production, two harvesting methods were applied: (i) direct cutting of panicles; and (ii) bagging of panicles (Mandret and Noirot, 1999). To this end, twenty (20) clumps were randomly identified on each elementary plot for seed production assessment. Each method was applied to ten (10) clumps. The clumps were chosen so as to spare the outer rows. The bags were placed one week after peak flowering and harvested three weeks later (Mandret and Noirot, 1999). The panicles were then threshed, the seeds purified and dried in the shade. They were winnowed before being weighed and stored.

The Total Seed Yield (TSY) of the plot was assessed as follows:

$$TSY = \frac{(\text{Average production of one clump} \times \text{total number of clumps in the plot})}{16} \text{x} 10000 \quad ...(1)$$

16 = area (in m²) of the elementary plot

10000 = area (in m²) of one hectare

2.5. Germination Percentage (GP)

The germination test was carried out after one year of storage. It was performed in accordance with ISTA (1993) ('International Seed Testing Association) guidelines. The germination tests were carried out in the laboratory in four replicates. Two subsamples of seeds were tested: (i) the subsample of seeds obtained by direct harvesting; and (ii) the subsample of seeds obtained by bag harvesting. For this purpose, 100 seeds from each subsample were randomly placed in a Petri dish containing a substrate of soil mixed with sand. The seeds to be tested were placed evenly in the dishes and moistened every two days. During germination, the seedlings were counted every 3 to 4 days, removing any seeds that had germinated. The germination test lasted fifteen (15) days. The number of seeds that germinated out of the 100 seeds placed in germination constitutes the germination percentage. The average germination percentage for each sub-sample is obtained by calculating the average of the germination percentages obtained for the four boxes.

Purity percentage (P): Purity analysis consists of separating the sample into three components: "pure seeds", "seeds from other plants" and "inert matter". This separation is done by manual sorting and observation of each element that makes up the sample. It was determined using two 8 g subsamples, which were weighed on a precision balance (0.001 g) (Brasil, 2009). Impurities consist of residual racemes, empty spikelets, inert matter and other seeds in each sample. Empty spikelets were detected using a magnifying glass. Cleaning and separation were carried out manually to obtain pure seeds, with the results expressed as a percentage.

$$P = \frac{\text{weight of pures seed} \times 100}{\text{Total weight of the sample}} \quad ...(2)$$

Pure Seed Yield (PSY): Was calculated as follows

$$PSY = \frac{TSYxP}{100} \quad ...(3)$$

Pure Germinated Seed Yield (PGSY): Was calculated as follows

$$PGSY = \frac{PSYxGP}{100} \quad ...(4)$$

Thousand seed weight: Determined using eight subsamples of 100 seeds, removed from the pure portion and weighed in precision scale (0.001 g), with results expressed in gram (Brasil, 2009).

The Cultural Value (CV): Was calculated as follows:

$$CV = \frac{PxGP}{100} \quad ...(5)$$

Sowing Rate (SR): For seeds to germinate at 100%, a maximum of 4 kg of Panicum seeds per hectare is required. The sowing rate (SR) was assessed according to the expression:

$$SR = \frac{100x4}{CV} \quad ...(6)$$

2.5. Statistical analysis of data

The data collected was entered into an Excel spreadsheet. R software was used to perform analysis of variance (ANOVA) on the various quality parameters (TSY, P, PSY, GP, PGSY and TSW), cultural value and seed utilization (CV, SR, SC). The arithmetic means of the different treatments were discriminated and compared using Duncan's test at a 5% threshold when a significant difference was found for the ANOVA test.

3. Results

Total Seed Yield (TSY), Pure Seed Yield (PSY) and Germination Percentage (GP) will not be discussed in this study.

Tables 1, 2, 3, and 4 show the effects of harvesting methods on the seed quality of different ecotypes, as well as their cultural and utilization values.

3.1. Effect of two harvesting methods on the seeds physical quality of different Panicum maximum ecotypes

Purity percentage (P): Purity percentage was influenced by the harvesting method ($p < 0.05$). The values obtained for direct harvesting were 97 ± 0.95; 97.49 ± 0.69; 96.85 ± 0.38 compared to 98.73 ± 0.36; 98.39 ± 0.24; 98.13 ± 0.15 for bag harvesting, respectively for ecotypes E1, E2, and E3. The different ecotypes did not show significant differences in purity regardless of the harvesting method ($p > 0.05$) (Table 2).

Table 1: Effect of harvesting methods on seeds physical quality of different *Panicum maximum* ecotypes

Methods	Ecotype	TSY	P (%)	PSY (Kg/ha)	TSW (g)	GP (%)	TGSY (Kg)
DH	E1	149.75 ± 31.71^{c}	97 ± 0.95	146.72 ± 30.87^{c}	1.073 ± 0.038^{c}	27.33 ± 0.58	40.1 ± 8.44^{c}
	E2	193 ± 45.92^{b}	97.49 ± 0.69	188.98 ± 44.83^{b}	1.254 ± 0.044a^{b}	28.33 ± 0.58	53.54 ± 12.7^{b}
	E3	379.15 ± 63.35^{a}	96.85 ± 0.38	367.33 ± 62.52^{a}	1.349 ± 0.054^{a}	29 ± 1	106.52 ± 18.13^{a}
	P-value	0.00262**	0.543^{ns}	0.00293**	0.0009***		0.00228**
BH	E1	290.48 ± 34.88^{c}	98.73 ± 0.36	286.88 ± 35.45^{c}	1.225 ± 0.055^{b}	74 ± 1	212.29 ± 26.24^{c}
	E2	437.50 ± 28.63^{b}	98.39 ± 0.24	430.50 ± 28.98^{b}	1.391 ± 0.014^{a}	76 ± 2.65	327.18 ± 22.02^{b}
	E3	510.16 ± 89.59^{a}	98.13 ± 0.15	500.66 ± 88.30^{a}	1.398 ± 0.009^{a}	75 ± 4.36	375.49 ± 66.20^{a}
	P-value	0.00942**	0.0794^{ns}	0.0103*	0.0011**		0.00907**

Note: ns: non significant ($P > 0.05$); *: significant ($p < 0.05$); **: very significant ($p < 0.01$); ***: highly significant ($p < 0.001$); DH: Direct harvesting; BH: Bag harvesting; TSY: Total seed yield; P: Purity percentage; PSY: Pure seed yield; TSW: Thousand seed weight; GP: Germination percentage; TGSY: Total germinated seed yield. $^{a,\ b}$ and ^{c} mean values with different superscript letters within the same year on the same column differ significantly ($p < 0.05$).

Table 2: The seed quality attributes of different ecotypes of *P. maximum* (DH vs. BH)

Ecotype	Methods	TSY (Kg/ha)	P (%)	PSY (Kg/ha)	TSW (g)	GP (%)	TGSY (Kg)
E1	DH	149.75 ± 31.71	97 ± 0.95	146.72 ± 30.87	1.073 ± 0.038	27.33 ± 0.58	40.1 ± 8.44
E1	BH	290.48 ± 34.88	98.73 ± 0.36	286.88 ± 35.45	1.225 ± 0.055	74 ± 1	212.29 ± 26.24
P-value		0.00665**	0.0413*	0.00668**	0.0171*		0.000414***
E2	DH	193 ± 45.92	97.49 ± 0.69	188.98 ± 44.83	1.254 ± 0.044	28.33 ± 0.58	53.54 ± 12.7
E2	BH	437.50 ± 28.63	98.39 ± 0.24	430.50 ± 28.98	1.391 ± 0.014	76 ± 2.65	327.18 ± 22.02
P-value		0.00144**	0.0324*	0.00143**	0.00695**		0.0000487***
E3	DH	379.15 ± 63.35	96.85 ± 0.38	367.33 ± 62.52	1.349 ± 0.054	29 ± 0.58	106.52 ± 18.13
E3	BH	510.16 ± 89.59	98.13 ± 0.15	500.66 ± 88.30	1.398 ± 0.009	75 ± 1	375.49 ± 66.20
P-value		0.107^{ns}	0.00559***	0.0997^{ns}	0.201^{ns}		0.00246**

Note: ns: non significant ($P > 0.05$); *: significant ($p < 0.05$); **: very significant ($p < 0.01$); ***: highly significant ($p < 0.001$); DH: Direct harvesting; BH: Bag harvesting; TSY: Total seed yield; P: Purity; PSY: Pure seed yield; TSW: Thousand seed weight; GP: Germination percentage; TGSY: Total germinated seed yield.

Thousand Seed Weight (TSW): The TSW of seeds obtained by the direct method was 1.073 ± 0.038 g; 1.254 ± 0.044 g; 1.349 ± 0.054 g for E1, E2 and E3 respectively, with a very significant difference ($p < 0.01$). The values obtained for bagging were 1.225 ± 0.055 g; 1.391 ± 0.014 g; 1.398 ± 0.009 g for E1, E2, and E3, respectively, with a highly significant difference ($p < 0.001$). Within each ecotype, the harvesting method (DH vs. BH) showed a significant ($p < 0.05$), highly significant ($p < 0.01$), and non-significant difference for E1, E2, and E3, respectively (Table 2).

The Pure Germinated Seed Yield (PGSY): A very significant difference ($p < 0.01$) was observed between the different ecotypes for direct harvesting and harvesting by bagging the panicles.

The PGSY (direct harvesting vs. bag harvesting) is 40.1 ± 8.44 vs 212.29 ± 26.24; 53.54 ± 12.7 vs 327.18 ± 22.02; 106.52 ± 18.13 vs 375.49 ± 66.20 respectively for ecotypes E1, E2, and E3 (Table 1). The total germinated seed yield is low for direct harvesting.

Table 3: Effect of harvesting method on the seed cultural and utilization values of the different ecotypes of *P. maximum*

Methods	Ecotype	CV (%)	SR (Kg/ha)	AC (ha)
DH	E1	26.51 ± 0.26^{c}	15.09 ± 0.15^{a}	10.02 ± 2.10^{b}
	E2	27.61 ± 0.19^{b}	14.48 ± 0.10^{b}	13.38 ± 3.17^{b}
	E3	28.08 ± 0.11^{a}	14.24 ± 0.06^{c}	26.63 ± 4.53^{a}
	P-value	0.000179***	0.000201***	0.00228**
BH	E1	73.06 ± 0.26^{b}	5.47 ± 0.02^{a}	53.07 ± 6.56^{c}
	E2	74.78 ± 0.18^{a}	5.35 ± 0.013^{b}	81.79 ± 5.51^{b}
	E3	73.5 ± 0.11^{b}	5.43 ± 0.0082^{a}	93.87 ± 16.55^{a}
	P-value	0.00011***	0.00011***	0.00907**

Note: *: significant ($p < 0.05$); **: very significant ($p < 0.01$); ***: highly significant ($p < 0.001$); DH: Direct harvesting; BH: Bag harvesting; CV: Cultural value; SR: Sowing rate; AC: Area covered. $^{a, b}$ and ^{c} mean values with different superscript letters within the same year on the same column differ significantly ($p < 0.05$).

Table 4: Cultural and utilization values of the different ecotypes seed (DH vs. BH)

Ecotype	Methods	CV (%)	SR (Kg/ha)	AC (ha)
E1	DH	26.51 ± 0.26	15.09 ± 0.15	10.02 ± 2.10
E1	BH	73.06 ± 0.26	5.47 ± 0.02	53.07 ± 6.56
P-value		0.00000000266***	0.0000000388***	0.000414***
E2	DH	27.61 ± 0.19	14.48 ± 0.10	13.38 ± 3.17
E2	BH	74.78 ± 0.18	5.35 ± 0.013	81.79 ± 5.51
P-value		1.53e-10***	8.37e-12***	0.0000487***
E3	DH	28.08 ± 0.11	14.24 ± 0.06	26.63 ± 4.53
E3	BH	73.5 ± 0.11	5.43 ± 0.0082	93.87 ± 16.55
P-value		9.45e-11***	0.00000000116***	0.00246**

Note: *: significant ($p < 0.05$); **: very significant ($p < 0.01$); ***: highly significant ($p < 0.001$); DH: Direct harvesting; BH: Bag harvesting; CV: Cultural value; SR: Sowing rate; AC: Area covered.

3.2. Effect of two harvesting methods on the seeds cultural and utilization value of different Panicum maximum ecotypes

Cultural value: The cultural values of seeds obtained by direct harvesting are 26.51 ± 0.26; 27.61 ± 0.19 and 28.08 ± 0.11 for E1, E2 and E3 respectively, compared to 73.06 ± 0.26; 74.78 ± 0.18 and 73.5 ± 0.11 for the bagging method, with a highly significant difference ($p < 0.001$) between ecotypes (Table 3).

Sowing rate: To sow 1 ha, approximately 15 kg of seeds from each ecotype must be used if they are obtained by direct harvesting. However, the sowing rate is approximately 5 kg/ha for seeds obtained by bag harvesting, regardless of the ecotype.

Area covered: The areas to be covered with such yields obtained by direct harvesting are 10 ha, 13 ha, and 27 ha for ecotypes E1, E2, and E3, respectively. The areas to be sown are 53 ha, 82 ha and 94 ha using seeds from E1, E2, and E3 obtained by bag harvesting, respectively.

4. Discussion

4.1. Effect of two harvesting methods on the seeds physical quality of different Panicum maximum ecotypes

Most seed quality attributes were influenced by the harvesting method.

Purity percentage (P): A very significant difference was observed for the harvesting method. However, the difference between ecotypes was not significant. This result shows that seed purity does not depend on the ecotype but rather on the harvesting method.

Bag harvesting resulted in higher purity than direct harvesting. This may be due to seeds falling during direct harvesting, with the presence of a large number of empty spikelets and immature seeds. The results observed are higher than those reported by Melo *et al.* (2016), who observed purity levels ranging from 2.4 to 95.5% for *Panicum maximum* (Jacq.) cv Tanzanian and from 0 to 71.3% for *Panicum maximum* (Jacq.) cv Mombaça. Imura *et al.* (2024) observed purities ranging from 98.75 to 99.82% for two varieties of *Urochloa ruziziensis* (cv. 'OKI-1' and cv. 'Br-203').

Purity percentage varies according to the harvesting method and technical procedures. It can be influenced by the cleaning technique and equipment. In our work, we recorded fewer impurities than in the work of Melo *et al.* (2016) because this author used the ground sweeping method, which results in a lot of clods of earth, stones, straw, and weed seeds in the batch. This sweeping method has been found to result in more impurities in forage grass seeds (Souza, 1999; Hare *et al.*, 2007; Nery *et al.*, 2009; Hessel *et al.*, 2012; Melo *et al.*, 2016).

In our trial, seed winnowing was done manually and was easier due to the small quantity of seeds. We did not find any weed seeds because the plot was well maintained.

The seeds obtained by both harvesting methods have a purity higher than the minimum purity standard for the marketing of certified seeds for *Panicum maximum*, which is 50% (Brasil, 2008). However, we cannot say that these seeds are marketable internationally, as there are other considerations to take into account, such as seed germination percentages. On the other hand, these seeds can be used locally for the establishment of forage plots. The seed purification process determines the weight of a thousand seeds.

Thousand Seed Weight (TSW): Seeds obtained by direct harvesting have a lower TSW than seeds obtained by bagging panicles. In addition, ecotype E3 has a higher TSW than the others. The factors that may explain this difference are physiological, as the seeds obtained by direct harvesting are mostly immature and therefore lighter after drying than seeds that have completed their maturation. The results observed for E1 and E2 are lower than those obtained by Kamphayae *et al.* (2013). This author observed a thousand-grain weight of 1.352 g for seeds of Panicum maximum cv. 'Umaku' obtained by bagging panicles, a value comparable to that observed for ecotype E3. Phaikaew *et al.* (1995) observed PMGs of 1.398 g for *Panicum maximum* TD.58 using the inflorescence bagging method and 1.327 g using the flowering stem shaking method. Hare (2014) found average grain weights of 1.54 g for *Panicum maximum* cv. Mombaça and 1.20 g for Panicum maximum cv. Tanzanian among smallholder farmers.

Melo *et al.* (2016) observed average grain weights ranging from 0.36 to 1.27 g for Panicum maximum cv. Tanzanien and 0.93 to 1.53 for *Panicum maximum* cv. Mombaça

Factors that may explain this difference with other authors include: variety, fertilization, sowing pattern, harvesting method, and seed moisture content. The ecotypes used in this study do not have the same morphological characteristics as the ecotypes used by other authors. In addition, the technical procedures are not the same (sowing pattern, fertilization, harvesting methods, drying and separation of seeds into homogeneous batches, etc.). The technical procedures (sowing pattern and fertilization) affect the vigor of the plants and, in turn, the quality of the seeds.

The influence of sowing patterns on the quality attributes of forage seeds has been noted by Phaikaew *et al.* (2001), Kumar *et al.* (2005) and Juntasin *et al.* (2019). Furthermore, seed purification operations in other trials were carried out using appropriate equipment and supplemented by manual sorting. In the work of Melo *et al.* (2016), for example, seed purification was carried out using appropriate equipment that allowed the seeds to be separated into more or less homogeneous batches, whereas in our trial, sorting was carried out manually without taking seed size into account. The thousand-seed weight is an indicator of seed viability.

The Pure Germinated Seed Yield (PGSY): Seed viability is influenced by the harvesting method. The bagging method results in significantly higher seed viability. This variability in seed quality can be attributed to the low germination percentage of seeds obtained by direct harvesting. Data on germination percentages (Table 1) indicated that bag harvesting was superior to direct harvesting. Mature seeds (threshed from the panicle) predominate in bagging harvesting, while the direct method results in a significant proportion of immature and non-viable seeds. Our observations corroborate those of Hare (2014), Hessel *et al.* (2012) and Maschietto *et al.* (2003), according to which the harvesting method influences seed quality.

4.2. Effect of two harvesting methods on the seed cultural and utilization value of different Panicum maximum ecotypes

4.2.1. Cultural value, seeding rate, and area covered

The seeding rate depends on seed quality in relation to purity and germination percentage. Observing the correct seeding rate is important for successful establishment. Seed production is generally delicate and requires a relatively large workforce (Hare *et al.*, 2007). It is therefore important to rationalize seed use for economic reasons. The seeding rate is higher for seeds from direct harvesting. These seeds are of poor quality and have relatively low germination percentages. On the other hand, seeds obtained by bagging panicles are of good quality and have a relatively low seeding rate. This seeding rate obtained with bagging corresponds to that reported by Messager (1984), who recommended a rate ranging from 2.5 to 3.5 kg per hectare for row sowing and 4.0 to 5.0 kg per hectare for broadcast sowing. Buldgen and Dieng (1997) recommend seeding rates for *Andropogon gayanus* ranging from 4 to 5 kg/ha for a germination percentage of 35% or a seeding rate of 400 to 600 g for dehusked Andropogon caryopses with a germination percentage of 80 to 90%.

With the yields obtained during our work on the two harvesting methods (DH vs. BH), it is possible to cover an area (in ha) of 10 vs. 53; 13 vs. 81; 27 vs. 94 respectively for ecotypes E1, E2, and E3.

Ecotype E3 covers a larger area than the others due to the high seed yield observed for this ecotype.

5. Conclusion

The harvesting method has an influence on the quality of seeds from different ecotypes of *P. maximum*. The method of bagging panicles produces better quality seeds than direct harvesting. It allows a larger area to be covered due to its higher cultural value. It is very important that whenever seeds are acquired, their quality attributes (purity and germination percentage) are checked before use. Seed treatment is one of the stages of production aimed at improving seed quality. This stage requires the existence of a seed purification unit (purification machines such as a gravity table and an Air and Sieve Machine (ASM)) to facilitate the work of seed purification for large-scale production. The effect of other harvesting methods (shaking flowering stems, sweeping the ground, etc.) on the physical quality of seeds from different ecotypes of *P. maximum* in Togo should be studied.

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