INTERNATIONAL JOURNAL of OIL PALM

Volume 6, Number 1, 2023
Page 1–8
DOI: 10.35876/ijop.v6i1.85

ISSN: 2599-3496 print
ISSN: 2614-2376 online

New Nonwoven Fabrics for Pollination Control Bags for Oil Palm

Marnie E. Light[1], Daljit Singh Virk[2*], Hannah Senior[3]

[1]Dami Oil Palm Research Station, Kimbe, Papua New Guinea
[2]Bangor University, Bangor LL57 2UW, United Kingdom
[3]PBS International, Scarborough YO11 3UP, United Kingdom

ABSTRACT

Oil palm hybridisation requires the isolation of inflorescences with pollination control bags (PCBs) for which polyester duraweb® PCBs are used at the Dami Oil Palm Research Station in Papua New Guinea. This work demands strong pollination bag material, but increasing strength affects other properties that may impact performance. This study compared the performance of duraweb® PCBs against three new types of nonwoven fabrics designed to have greater strength characteristics. Nine-year-old clonal palms in one of the Dami SUPERFAMILY® seed gardens were used. The station experiences a humid climate and received weekly total rainfall ranging from 53 to 228 mm (total rainfall 1035 mm) during the reproductive phase in March and April 2020, when the trial was conducted. Analyses of variance of various traits - including time taken to install the bags, bag intactness, spine damage, bunch weight, total seed number and weight, seed health score, and 100-seed weight - were all non-significant. The average number of healthy seeds per bunch was 1120 seeds with mean weight of 376 g per 100 seeds. Blank pollinations showed equal pollen-proofing ability among all bags without any noticeable insect entry. This study demonstrated that increasing the strength of the novel nonwoven fabric PCBs did not improve performance over the control duraweb® bags for most of the important seed traits. These results pertain only to the materials and the bags under investigation. It is concluded that a range of properties of the materials and the bag must be considered in combination, and trialled in practice, when selecting appropriate pollination control.

Keywords: controlled pollination, nonwoven polyester, oil palm breeding, seed production, seed yield

INTRODUCTION

Commercial seed production and breeding programmes of African oil palm (*Elaeis guineensis* Jacq.) rely on isolating male and female inflorescences with pollination control bags (PCBs) for pollen collection and controlled hybridisation to ensure the genetic integrity of the crosses. According to Bonneau et al. (2017), a good PCB should: (i) exclude the oil palm

*Corresponding author:
School of Natural Sciences, Bangor University, BangorLL57 2UW, UK
Correspondence Address: C/O PBS International, Salter Road, Scarborough YO11 3UP,
UKE-mail: dsvirk2012@gmail.com; Tel: +44 7 799 057 846

pollinating weevil, *Elaeidobius kamerunicus,* which is strongly attracted to the scent of the anthesising infloresceces inside bag (Corley and Tinker 2016) so that no contamination occurs from foreign pollen; (ii) be strong enough not to collapse over the inflorescence when wet; and (iii) allow gas exchange without allowing water to accumulate inside the bag which can lead to inflorescence abortion. Recent research in the advancement of PCBs has focused on developing novel nonwoven fabrics with all therefore mentioned properties (Gharaei and Russell 2022), and such PCBs are being increasingly used in breeding of many crops, e.g, Gitz *et al*. (2015) in sorghum, Clifton Brown *et al*. (2018) in sugar beet, wheat, Arabidopsis, and Miscanthus; Vogel *et al*. (2014), Adhikari *et al*. (2015) and Trammell *et al*. (2020) in grasses.

PCBs used specifically for oil palm should be able to withstand tearing or damage from the sharp spines of inflorescences. In the Dami Oil Palm Research Station (OPRS) seed production programme, nonwoven duraweb® bags have been used for many years for their good features, as compared to canvas bags or Tyvek-style high density polyethylene (HDPE), which may become contaminated with insects, accumulate water after rain, and sag onto the inflorescence (Bonneau *et al.* 2017). However, even duraweb® bags have, under some circum stances been known to be pierced by the spiky bracts on the oil palm inflorescence as it grows during the bagging period.

For this study, novel variations on duraweb® were developed to test whether changes to the strength related parameters, such as tensile strength, density, or thickness, could improve PCB performance by reducing the incidence of the foresaid type of damage. In nonwoven materials, however, changing one property typically influences other properties or performance characteristic, e.g, increasing strength may decrease air permeability. Thus, the null hypothesis was that these novel nonwoven polyester fabrics are equally suitable as material for PCBs for oil palm seed production and have performance on par with the standard (H0). Any deviation from the standard for any trait would reject null hypothesis in favour of alternative hypothesis (H1).

MATERIALS AND METHODS

Three new materials, named DWB26, DWB27, and DWB28 were tested along with the standard duraweb® material (DWB01). Properties of the different materials are given in Table 1.

Table 1 Material properties of the nonwoven fabrics used for the pollination control bags (PCBs) tested in the study.

Bag type	Density (gm^{2-1})	Thickness (mm)	Tensile strength (MD; Ns^{-1} cm)	Air permeability (l m^{2-1} s^{-1})
DWB01	100	0.18	170	80
DWB26	100	0.18	256	90
DWB27	100	0.25	305	90
DWB28	102	0.14	368	*

*Data not available; MD=Machine directional; N=Newton; g=gram; l=litre; m=metre; s=second.

Twenty bags per type were used for random allocations. The experiment was conducted at the Dami OPRS seed garden having clonal *dura* palms which are utilised for SUPERFAMILY® seed production. The palms are all of same age and planted in close proximity to each other (field planted in November 2012; Figure 1), thereby reducing any effect of genetic and soil heterogeneity in the study. Five pollination workers were each assigned to carry out 16 isolations (i.e bagging), and were allocated four bag types in four replications using a randomised plan. A total of 80 bunches were isolated for evaluation of seed production (5 workers x 4 replicates x 4 bag types = 80).

Palms in the seed garden were surveyed on a daily basis to select female inflorescences at a suitable developmental stage (about 10 days before the receptive stage) for isolation with the pollination bags. The isolations were started on March 5th, 2020 and ended on March 19th, 2020. All pollinations (real or blank; see below), were completed by April 11th, 2020.

Figure 1 Clonal seed garden of 9 year old *dura* palms at Dami OPRS used for the study.

All inflorescence isolations and pollinations (including blank pollinations) were carried out on 84 of the same age clonal dura palms within a 0.89 ha area. Of these, 16 of the palms were used twice, two female inflorescences at the appropriate developmental stage were found, isolated and pollinated on the same palm which ensured contiguity of palms toreduce field heterogeneity. In such cases, however, a different bag type was used for the second isolation. All isolations were allocated randomly, depending on when the inflorescences were at a suitable stage for bagging. Of the 80 isolations done as part of the trial, two were excluded from data collection as a result of one inflorescence snapping prior to pollination, and another inflorescence where the bag was not correctly secured around the peduce. Thus, one bag was missing for each bag type of DWB01 and DWB26, and a total of 78 inflorescences were pollinated and the bunches harvested for seed processing. For assessment of pollen proofing, each worker bagged one inflorescence with each type of bag as a blank pollination. When the female flowers became receptive, pollination was done with pure talcum powder. The pollinating workers were unaware of which the blank pollinations were. A total of 20 additional isolations and blank pollinations were carried out (5 workers x 4 bag types = 20).

Daily rainfall data were obtained from the Dami OPRS Weather Station, approximately 1.3 km away from the seed garden. A total rainfall of 1035 mm was recorded over March 2020 and April 2020 during time of isolations and pollinations. There were 10 days of no rainfall, 13 days with 1–5 mm rainfall, 38 days of >5 mm rainfall, and 4 days with >50 mm rainfall during this period. The two heaviest rainfalls of 75 mm and 70 mm were recorded on March 11th, 2020 and April 3rd, 2020, respectively with a mean of 26 mm for rainfall events >5 mm. Weekly totals from the start of the first isolations on May 5th, 2020 ranged from 53 to 228 mm. This pattern of rainfall is quite typical of the weather observed towards the end of the 'rainy season' at Dami OPRS, Kimbe, although the rainfall in 2020 was 18% higher than the long-term average.

Following pollinations (real or blank), bags were retained on inflorescences for about three weeks before being removed and the bunches being allowed to mature normally. The bags were periodically checked over the whole period for the presence of any insects (1= no insects in bag, 2= insects in bag with count), intactness (1= collapsed on inflorescence, 2= shrinks touches^{-1} on inflorescence, 3= fully intact without touching inflorescence) or bag damage (1= no holles or tears, 2= shreds or traces of holes, 3= complete holes) and were scored accordingly. Water resistance of bags was scored as 1 to 3 over the whole period when bags remained on inflorescences; 1= no moisture inside bag; 2=

bag is moist; 3= water collects in the bag.

During each isolation event, each worker was timed in how long it took to bag the inflorescence. The timing commenced the moment the worker started to unfurl the pollination bag (Figure 2, shows how bags were prepared for the isolation process), and was stopped once the worker had covered the exposed inflorescence and properly tied the bag around the peduncle (i.e the base of the inflorescence). Timing did not take into account the time taken to prepare the inflorescence for bag placement (i.e removal of the spathe, clearing the base, and spraying the inflorescence lightly with an aerosol insecticide).

Figure 2 Pollination control bag types as prepared (i.e, carefully folded, rolled, and tied) prior to isolation of female inflorescences of oil palm.

The blank bunches were evaluated 12 weeks after false pollination with talcum powder for any seed set with count of the number of seeds (if any). The total number of flowers on the inflorescence was estimated by recording the number of spikelets on the inflorescence, and then counting the number of flowers on 60 spikelets (20 from the top, middle and bottom of the inflorescence) to calculate an average number of flowers per spikelet. From this, percentage of fruit set per bunch was calculated. The pollinated seed bunches were harvested at around 150 days after pollination. Bunch weight was recorded, and seeds were processed and sorted after the fleshy mesocarp was removed and seeds cleaned. For each seed lot (one bunch), the weight and the number of normal and healthy seeds was recorded, as well as the weight and number of abnormal seeds (discoloured, damaged, abnormal shape etc.). Each seed lot was scored for an overall seed health, where 1= majority of seeds in the bunch looked shrunk and small; 2= majority of the seeds were of medium size (i.e smaller than normal); and 3= majority of the seeds appeared to be healthy and fully developed.

Analysis of variance was performed for all traits using MINITAB 17 software. Pairwise grouping of mean values for bag types was performed by using unprotected Fisher's Least Significant Difference (LSD). Grouping following unprotected LSD is performed regardless of significance of the main effect in the analysis of variance.

RESULTS AND DISCUSSION

Pollen Proofing

Inspection of the 20 blank pollinated inflorescences (five for each bag type), around 12 weeks after pollination with talcum powder, revealed that four of the bunches had developed between 2–4 fruit. From an approximation of the number of flowers per inflorescence, this resulted in an estimated fruit set of 0.1% for these four bunches, whereas the other 16 inflorescences did not from any fruits on the bunch (i.e 0% fruit set). Furthermore, these bunches were not associated with any particular worker or bag type. Importantly, no insects were found inside the bags at any stage (for the blank pollinations, or for the other pollinations carried out). Thus, all bag types resulted in secure isolation of the inflorescences with extremely low levels of blank fruit set.

Statistical Analysis

For all traits given in Tables 2 and 3,

no significant differences (P > 0.05) were observed among bag types. Only thetime taken for tying of bag to female inflorescence was significantly different between workers (Table 2). This worker effect is confounded with block effects in our design and shows that testing was done in wider conditions in the trial and that the mean values for all the traits were closer to their true values.

Bag Traits

The three bag traits recorded were time taken for installation of bag, intactness and water retention. Analysis of variance for time taken to bagging showed that bag types did not differ significantly (P > 0.05). All bag types fell in one group and the overall average time taken for bagging by all bag types was 3.83 min (Table 2). Three PCBs DWB 01, DWB27 and DWB28 showed an average time of 3.8 min, whereas DWB26 showed 3.95 min. Apparently, fabrics of new PCBs have no additional handling limitations while tying. The intactness of bags on 1 to 3 scores showed mean values from 2.6 to 2.7 which was close to score 3 for all nonwoven PCBs with nonsignificant differrence. However, there were some bag observations with a score of 2 since they were touching the inflorescence due to which the overall bag means were reduced. The overall mean value of about 3 showed that all synthetic PCBs were sufficiently strong to remain intact (Table 2). Despite the fairly wet conditions as shown by the weather data, very little collection of water was observed at the base of the bags. Although there was some condensation visible through the windows of all the bag types, this did not appear to accumulate inside at the base of the bags to any extent that could adversely affect the development of seeds in the inflorescence during rainy days (Table 2).

Of all, only six bags showed some form of damage: four of DWB26 and two of DWB27. The damage in all cases was caused by the sharp spine bracts of the female inflorescences resulting in small holes of size 1–2 mm (Figure 3). Furthermore, evidence of piercing through the window weld of at least one bag demonstrates just how formidable the task of withstanding damage by the bracts is. Importantly, however, no insects were observed inside any of these bags. Whilst there is perhaps some indication that the DWB26 and DWB27 bag types are prone to damage by the spiny inflorescences of oil palm, DWB28, which represent the bag types with the lowest and greatest tensile strength,

Table 2 Mean values with standard errors for four bag types for different traits; N=20(five workers and 4 replications of each bag type).

Bag type	Time to install (min)	Intact-ness (score, 1 to3)α	Water (score, 1to 3)β	Bunch weight (kg)	No. of abnormal seeds (1st sort)*	Weight (g) of abnormal seeds (1st sort)*	No. of discard seeds (2nd sort)	Weight (g) of discard seeds (2nd sort)	No. of healthy seeds (2nd sort)
DWB01	3.80±0.22	2.62±0.07	1±0	32.21±1.60	342±50ab	778±137ab	92±16	242±40	1143±118
DWB26	3.95±0.22	2.61±0.07	1±0	31.42±1.60	292±50b	599±137b	73±16	203±40	1047±118
DWB27	3.78±0.22	2.68±0.07	1±0	33.85±1.56	448±49a	990±134a	101±15	268±39	1197±115
DWB28	3.79±0.22	2.65±0.07	1±0	31.35±1.56	378±49ab	785±134ab	77±15	205±39	1091±115

*Grouping using Fisher's unprotected LSD (least significant difference) method at 95% confidence. Means that do not share a letter are significantly different. Mean values between bag types were for all other traits not significant and hence are not grouped by LSD. α Intactness score; 1= collapsed, 2= shrinks or touches inflorescence, 3= fully intact. β Water score; 1= no. moisture in bag, 2= bag moist, 3= water collects in bag.

respectively (Table 1). Examination of the bags after the completion of pollination process at the removal of bags did not reveal any obvious signs of any other damage and all the bags were found to be in fairly good condition.

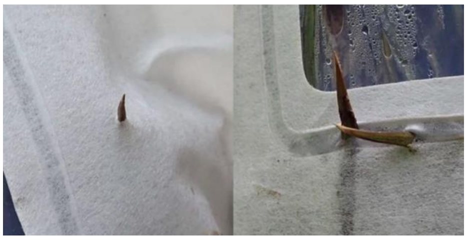

Figure 3 Examples of small holes observed in a few bags caused by protrusion of the spiny bracts of the female inflorescence of oil palm.

Seed Production Parameters

All 78 inflorescences that were pollinated produced well developed fruit bunches that were harvested and processed. From these bunches, only two seed lots showed poor seed development, and were given a seed health score of 1 and 2, from a bunch produced using bag DWB27 and DWB28, respectively. These were excluded from further analysis giving n=19 for each bag type. These two discarded seed lots were not associated with any particular palm or worker. All other seed lots appeared to be healthy and fully developed (i.e score of 3), and therewere no apparent differences in general seed quality between seed produced using different pollination bags (Tables 2, 3). According to the Dami OPRS seed production standards, all seeds showing signs of abnormal development (or possible damage due to processing) were discarded (Figure 4). For each seed lot (i.e, seeds from one bunch), the number of healthy seeds and the number of discarded seeds were counted. No significant difference was observed between bags for the mean number of healthy seeds obtained per bunch and mean number of discarded seeds per bunch. However, the unprotected LSD showed significantly more number and weight of abnormal seeds in DWB27 than DWB26 (Table 2). The overall mean count of total number of seeds per bunch varied from 1411 to 1746 for DWB26 andDWB27 with nonsignificant difference (Table 3). The number of healthy seeds per bunch after the second sort varied from 1047 for DWB26 to 1197 for DWB27 (Table 3). Overall, it represented an average discard rate of 28% for all bag types. The weights of healthy seeds and abnormal/discard seeds was also measured for each seed lot. There was no significant difference between bag types for the weight of the healthy seeds (mean of 100 seeds varied from of 374 g for DWB26 to 381 g for DWB01, Table 3). For the discarded seeds, the average weight was considerably lower, as expected, with a mean per 100 seeds of 220 g. They reported that bunches isolated with

Table 3 Mean values with standard errors for four bag types for different traits; N=20(five workers and 4 replications of each bag type).

Bag type *	Weight (g) healthy seeds (2nd sort)	Seed health (score, 1 to 3)	Total no.of seeds	Abnormal + discard seedsas % of total no. of seeds	Abnormal + discard seedsas % of total seed weight	Weight ofall seeds(kg)	Seed weight of 100 healthy seeds (g)	Seed weight of100 abnormal +discard seeds (g)	Seed weight of 100 all type seeds (g)
DWB01	4337±433	3.00±0.06	1577±164	28.03±1.80	18.69±1.43	5.36±0.56	381±8.4	226±9.5	337± 8.3
DWB26	3912±433	3.00±0.06	1411±164	27.08± 1.80	17.48±1.43	4.71±0.56	374±8.4	220±9.5	330± 8.3
DWB27	4412±422	2.90±0.06	1746±160	30.34±1.76	20.61±1.40	5.67±0.55	375±8.2	223±9.3	328± 8.1
DWB28	4026±422	2.95±0.06	1546±160	29.16±1.76	19.17±1.40	5.02±0.55	375±8.2	211±9.3	328± 8.1

*Mean values between for bag types for all traits were not significant and hence are not grouped by LSD.

Figure 4 Example of seeds of oil palm following seed sorting: Figure 4a, some normal healthy seeds; Figure 4b, discarded abnormal or damaged seeds. On average, the proportion of discarded seeds was 28%.

polyester bags (DWB01) produced 13% more seeds per bag than the HDPE bags and 6% more seeds per bag than those using canvas.

Our research widens the scope of the previous findings by Bonneau *et al*. (2017) and shows that there is no effect of changes to strength related parameters of duraweb® and PCB performance on main seed production parameters of seed count, seed weight and discard rate when evaluated on 9 year old clonal palms in one of the Dami SUPERFAMILY® seed gardens. Although some minor bag damage was observed in two of the bag types with greater tensile strength than the standard bag material, the very low frequency of the damage was not sufficient to conclusively attribute it to any particular material. When the bag damage occurs sometimes after pollination has taken place, the risk of contamination would be minimal. Since 100% assurance against damage might only be achieved if strength parameters are increased to such an extent that other characteristics (e.g air permeability) would negatively affect the overall performance of the PCB, a more feasible approach to avoid this type of damage may be to use a slightly larger bag allowing for more room for the developing fruit bunch. This would require a trade-off against operational and economic issues such as the risk of excess material around the peduncle causing the damage, or other causes of seed loss related to inflorescence growth or damage following the pollination. A larger scale trial would be needed to understand these trade-offs more fully. Nonetheless, considering that no insects were found to have penetrated the PCBs in this study, these findings support the further development and use of such alternative materials to produce PCBs for oil palm.

CONCLUSION

Pollination control bags in oil palm hybridization must have strong fabric to withstand various types of damage. However, although strength is an important characteristic, creating materials with even greater strength does not appear to perform better. This study demonstrated that three carefully selected PCBs made from novel nonwoven fabrics with increasing strength (DWB26, DWB27, DWB28) did not differ significantly from the standard duraweb® bags (DWB01) for most of the hybrid seed parameters. Selection of appropriate PCBs should be based on a careful trade-off between a number of properties of the material and the bag itself.

ACKNOWLEDGEMENT

We are thankful to NBPOL Management for allowing the use of their asset in Papua New Guinea at Dami OPRS for this study. The assistance of the Dami Seed Production Unit, especially Jane Gavuri, is gratefully acknowledged.

REFERENCES

Adhikari L, Anderson MP, Klatt A, Wu

YQ. 2015. Testing the efficacy of a polyester bagging method for selfing switchgrass. Bioenerg Res. 8: 380–387.

Bonneau L, Eli D, Vovola P, Virk DS. 2017. Comparing pollination bag types for micro environmental parameters influencing seed production in oil palm. J Oil Palm Res. 29: 168–179.

Clifton-Brown JC, Senior H, Purdy SJ, Horsnell R, Lankamp B, MuE ennekhoff A K, Virk D, Guillemois E, Chetty V, Cookson A, Girdwood S, Clifton-Brown G, Tan ML, Awty-Carroll D, Bentley AR. 2018. Investigating the potential of novel nonwoven fabrics for efficient pollination control in plant breeding. PloS ONE. 13(9): 1–21.

Corley RHV, Tinker PB. 2016. *The Oil Palm. Fifth edition.* Chichester (UK): Wiley Blackwell.

Gharaei R, Russell SJ. 2022. Overview of nonwoven product applications. In: Russell SJ, editor. Handbook of nonwoven 2nd Ed. Kidlington (UK): Woodhead Publishing. p. 13–47.

Gitz DC, Baker JT, Xin Z, Burke JJ, Lascano RJ. 2015. The micro-environment within and pollen transmission through polyethylene sorghum pollination bags. Am J Plant Sci. 6: 265–274.

Trammell M, Pittman DG, Virk DS, Senior H. 2020. Assessing the effectiveness of nonwoven fabric pollination tents for improved grass breeding. J Plant Breed Crop Sci. 12: 200–218.

Vogel KP, Sarath G, Mitchell RB. 2014. Micromesh fabric pollination bags for switchgrass. Crop Sci. 54: 1621–1623.