A Comparative Study of Disposable Agriculture Coveralls Based on Wearer Trials

Yanmei Li, Charlotte Coffman, Susan Ashdown* and Jintu Fan*

Department of Fiber Science & Apparel Design, College of Human Ecology, Cornell University, USA

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*Corresponding author: Susan Ashdown and Jintu Fan, Department of Fiber Science & Apparel Design, College of Human Ecology, Cornell University, USA, Email: spa4@cornell.edu; jf456@cornell.edu

Abstract

Agricultural workers require well-fitting, comfortable, durable, and protective coveralls that can keep them clean and safe from dirt, stain, and harmful contaminants, at an economical price. Many researchers have studied the fitting, comfort, and durability of protective coveralls from different perspectives. Crow & Dewar [1] used rubber sheeting with horizontal and vertical slits to determine areas of stress in combat coveralls to determine minimum seam strength requirements. Airey [2] discussed the requirements of agricultural coveralls and proposed a range of garments suitable for agricultural applications. Ashdown & Watkins [3] focused on the development of a mobility analysis test and applied it for investigating the mobility issues of disposable coveralls. Huck et al. [4,5] studied the effects of adding ease at a specific area of a garment on a range of motion measures and subjective perceptions of fit comfort and mobility. They particularly examined alternative coverall designs of added crotch ease. Boorady et al [6] investigated restrictions in mobility, problems with tears and issues regarding wearing practices and donning when pesticide applicators wearing coveralls with their equipment under varying working positions. Based on the requirements of functional garments, Boorady [7] discussed the concept of “functional ease”, which is essential for functional garments to be adaptable to the movement of the wearer while maintaining its purpose. Jeon & Moon [8] studied the size specifications and consistency as well as the regularity and fitness of disposal protective coveralls available to Korean agricultural workers.

There have also been considerable studies focused on the thermal comfort of protective coveralls [9-14]. Both the properties of fabric materials and garment styles were considered in these investigations.

Although considerable work has been carried out in the past, findings vary greatly due to the subjectivity in wearer trials.
and variations in actual working environments. Today, many different types of agricultural coveralls are available in market, but their performance in terms of fit, durability and protection have not been systematically evaluated from the end users’ prospective, and hence presents real problems in the selection and further development of such agricultural cover all. In order to better understand how some of the typical designs of agricultural coveralls perform in actual use conditions and how their performance relates to design and construction, in this study, we compared the performance of three typical styles—one traditional coverall and two modified coveralls that followed the results or suggestions of earlier researchers and added an elastic area or extensible area to improve mobility. 49 agricultural workers in four states participated in the wear trials. The trial logs and questionnaires about final evaluations of the coveralls were analyzed.

**Garment samples**

Three styles of agricultural coveralls are compared in this study. The first one is the traditional disposable coverall available on the market shown in (Figure 1). It has an attached hood, front zipper closure, and elastic at waist, wrists and ankle.

The second style is modified from the traditional coverall. As shown in (Figure 2), it has elastic panels added to the traditional style in the underarm and back area. The third style is the newly developed pleat design, labeled as “P” in this study. The new design, shown in (Figure 3), has pleats covering the underarm, buttock, and knee areas. The pleats are intended to provide mobility.

| Fabrics | Weight (g/m²) | Thickness (mm) | Bending Rigidity (μN-m) | tensile strength (N) | tensile extension (%) | tear strength (N) |
|---------|---------------|----------------|-------------------------|----------------------|-----------------------|-------------------|
|         |               | wrap | weft | diagonal | warp | weft | diagonal | warp | weft | diagonal | warp | weft |
| B& R    | 121           | 0.47 | 1.21 | 1.63 | 1.25 | 121.98 | 48.14 | 66.93 | 55.31 | 56.81 | 45.89 | 19.16 | 42.90 |
| P       | 123           | 0.33 | 0.97 | 1.04 | 0.62 | 113.10 | 34.87 | 62.19 | 79.34 | 102.39 | 85.33 | 28.80 | 76.57 |

Covers all in these three styles were made in five different sizes ranging from Small to XX Large based on Size USA data. The “B” and “R” styles were made of the Klee guard fabric and the “P” style was made of proshield fabric, both from DuPont. Their mass per unit area were determined by weighing fabric samples of specific area, and their thickness (under 0.196N/mm²) and bending rigidity were tested using the Siro FAST (Fabric Assurance by Simple Tests) system and listed in (Table 1). As can be seen, the fabric for “P” style is thinner and softer. The tensile and tear strength of fabrics were tested by Instron universal material testing machine. Although the tensile strength of fabric for “P” style is a slightly less than that of the fabric for “B & P” style, its tear strength is much greater.
The abrasion resistances of the two fabrics were tested using the Martindale abrasion tester according to ASTM D4966. (Figure 4) shows the images after 1000 abrasion cycles. Clearly, the fabric for “P” style is less resistant to abrasion. All test cover all are approved for use with particulate and low toxicity pesticides that carry a ‘Caution’ label.

Wearer trial experiments

To evaluate the effects of design features of the above three styles of coveralls on the ease of movement, fit and durability during routine wear, these three sets of coveralls were provided to agriculture workers in four states: California, Colorado, New York and Hawaii. Each cover all of these three styles was worn for 2 to 4 hours over a 2 week period under routine working conditions.

Written logs (provided) are made by the wearers. Dates and times worn, general environmental conditions, tasks, and whether the coveralls tore and how, as well as general comments on the fit and mobility of the cover all were recorded. After the 2 week period, the coveralls and logs were collected, and questionnaires about the performance of the coveralls were conducted.

Results and Analysis

Distribution of wearers

Out of the 147 records, 62 recorded the degree of fit, which is shown in (Figure 7 (a)). 85% responded that their coveralls provided good or moderate fit. Further analysis showed that “P” style had the most records of poor fit and the least records of good fit. In contrast, “R” style had the most records of good fit and the least records of poor fit. The results are plotted in (Figure 7 (a)). 13 records showed the “P” style was not acceptable while 9 records were for of “B” style and “R” style respectively, which is shown in (Figure 7 (b)).

40 comments or suggestions were presented in altering the style of the coveralls for better fit. The common suggestion for three styles include adding pocket for cell phone or tools, removing ankle elastic and adding leg opening zippers for boots, using different color, using comfortable fabrics to avoid heat stress. But for the “P” style, 3 comments focused on the sang of pleats that can be expended but did not lie flat. 3 complained
Durability and dirt stains

Table 2: Rating of Worn Area in Terms of Tear, Abrasion and Dirt Stains.

| Worn scale       | Very Small Area | Small Area | Medium Area | Large Area | Very Large Area |
|------------------|-----------------|------------|-------------|------------|-----------------|
| Size of Worn Area (inches) | less than 1” | 1” to 2” | 2” to 3” | 3” to 5” | larger than 5” |
| Rating of Worn Area | 1              | 2          | 3           | 4          | 5               |

Analysis of tear records

Among the total of 147 records, there are 33 records with tears in different locations. The overall tear quantities, locations, and ratings are shown in (Figure 8).

It can be seen from (Figure 8 (a) & (b)); the sleeve (wrist, elbow and arm) section has the least tear risk for three styles. The sections with high tear risk are different in three styles. “R” style as a whole has lowest tear risk. The relative higher tear risk sections occurred on torso and ankle, while “P” style has the highest tear risk in most of sections except sleeves section. “B” style has higher tear risk in hip, ankle and knee sections.

Table 3: Results of Paired Samples T tests of Tearing Rating.

| Pair Difference | Mean | Std Deviation | Std. Error Mean | 95% Confidence Interval of Difference | T | Df | Sig. (2-tailed) |
|-----------------|------|---------------|-----------------|--------------------------------------|---|----|----------------|
|                  |      |               |                 | lower limit                          |   |    |                 |
| pair 1          | B-R  | -1.646        | 5.353           | .773                                 | -3.200 | -0.091 | .038 |
| pair 2          | B-P  | -.510         | 4.088           | .584                                 | -1.684 | .664  | .387 |
| pair 3          | R-P  | -1.184        | 3.860           | .551                                 | -2.293 | -.075  | .037 |

With regard to the number of tears, further analysis showed that some tears (8 records) were caused by stressed seams that form grin hole, and some (3 tears) appeared on the bottom zipper that might be caused by the sewing quality. There were 6 holes in the pleated areas of the cover all. It appeared that the pleated structure was not ideal in resisting tears.

Paired samples T test was used to determine the significance of the tear ratings between the three styles. The results are shown in (Table 3).

Thus it can be seen that “R” style has a significantly different (P<0.05) tear performance from “B” style and “P” style. Furthermore, the mean tear rating of “R” style is 0.80, which is significantly less than that of the other two styles’ mean abrasion rating, which is 1.47 for “B” and 1.98 for “R”, respectively. As can be seen, the mean tear rating of “R” style was the lowest, indicating the “R” style was the best in resisting tear.

Analysis of abrasion records

Figure 9: Abrasion ratings of three styles in different body parts.
In (Figure 9), the accumulated abrasion ratings of the three styles in different body parts are presented. The mean abrasion rating of "P" style is 2.17, which is significantly greater than that of the other two styles’ mean abrasion rating, which is 0.52 for "B" and 0.65 for "R", respectively. As can be seen, the "P" style had the highest abrasion rating, indicating the worst performance in abrasion resistance. The “B” style has the lowest abrasion rating, indicating the best abrasion resistance.

Paired samples T tests were again carried out to analyze the significance of the differences between the three styles in terms of abrasion resistance. The results are shown in (Table 4).

**Table 4: Results of paired samples T tests of Abrasion Ratings.**

| Pair Difference | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of Difference | T | df | Sig.((2-tailed)) |
|-----------------|------|----------------|-----------------|---------------------------------------|---|----|-----------------|
| pair 1          | B - P| -1.646         | 5.353           | -3.200 - .091                         | -2.130 | 48 | .038           |
| pair 2          | B - R| -.125          | 3.119           | -1.031 .781                           | -.278  | 48 | .782           |
| pair 3          | P - R| 1.521          | 4.722           | .150 2.892                            | 2.231  | 48 | .030           |

Table 4 shows the "P" style had a significantly different abrasion performance (P<0.05) from the "B" and "R" style. It should be noted that the fabric for the "P" style had much weaker abrasion resistance than that for "B" and "R" style. So, the poor abrasion performance of "P" style is the likely caused by the poor abrasion resistance of its fabric.

**Analysis of dirt stain records**

Among the total 147 records, there are 123 records with dirt stains in different body parts. That means dirt stains are hard to avoid. (Figures 10 (a) and (b)) plot the accumulated number of dirt stains and dirt ratings in different body parts, respectively. A comparison of the numbers of the dirt stains of the three styles are shown in (Figure 10(c)).

From (Figure 10 (a) and (b)), it can be seen that dirt stains were more frequent in the arm, thigh, lower leg and the torso areas. Further analysis shows the recorded count of dirt stains for “B” style is 43, while both of that for “P” and “B” style are 40. As can be seen, the “B” style acquired the most dirt stains.

Paired samples T test was used to analyze the significance of the difference between the three styles in terms of dirt ratings. The results are listed in (Table 5).

**Table 5: Results of Paired Samples T Tests of Dirt Ratings.**

| Pair Difference | Mean | Std. Deviation | Std. Error Mean | 95% confidence interval of difference | T | DF | Sig.(2-tailed) |
|-----------------|------|----------------|-----------------|---------------------------------------|---|----|----------------|
| pair 1          | B - R| 1.40816        | 8.11613         | -5.3649 3.35282                       | 1.215 | 48 | .230           |
| pair 2          | B - P| -.12245        | 10.27686        | -2.58526 2.34036                     | -.083  | 48 | .934           |
| pair 3          | R - P| -1.53061       | 11.48024        | -4.28132 1.22009                    | -.933  | 48 | .355           |

The results showed that the three coverall styles had no significant differences in preventing dirt stains. However, dirt stains (7 dirt records) were reported in the pleated areas, indicating that the pleats might be prone to catch dirt.

**Discussion**

After analyzing the data of the relatively large scale wearer trials of three typical agricultural coverall styles, administered in four states, the following can be observed:

i. Based on the fit ratings and reports of the wearers, most of the coveralls had acceptable fit. The “R” style, which had elastic panels in the back, had the most records of good fit and the least records of poor fit, indicating the least complaints about its
Three styles of disposable agricultural overalls were evaluated through wearer trials. These three styles are a traditional coverall from the marketplace (labeled as “B”), a modified coverall of the same style with elastic panels in the back (labeled as “R”) and the new design with incorporated pleated sections (labeled as “P”). By analyzing the data of the wearer trials and wearers’ feedbacks, it was found that the pleat design in “P” style was the least preferred in terms of fitting as the pleats were opened in stretch movements and present a hindrance due to the fact that they did not lay flat. Instead, users preferred the “R” style as the elastic panels under the arms and at back provides adjustability for fitting. The “R” style also showed the least tear damage in high tear risk areas (i.e. torso, ankle and lower leg), while the “P” style has the higher tear risk in most sections except the sleeve section. In terms of abrasion resistance, the “B” style is most preferred, followed by the “R” and “P” style. No significant differences were found among the three styles in terms of dirt resistance.

Analyzing the data of the wearer trials and wearer’s feedbacks showed “P” style behaved the worst performance in fit, tear and abrasion. These results were partly affected by its fabric, partly affected by the pleats structure. While “R” style was the most preferred that showed best fit and durability properties among these three styles. No significant differences were found among the three styles in terms of dirt resistance. Furthermore, some feedback and suggestion of wearers can be used for the future improvement can be made by adding pockets, using larger zipper pulls, removing ankle elastic and adding leg opening zippers, and making adjustable fit at different areas of the body of cover all.

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