# AFIS SEED COAT NEPS BASELINE RESEPONSE FROM DIVERSE MEDIUMS

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## Abstract

An extensive literature search has revealed that no papers have been published regarding selectivity calculation of the AFIS seed coat neps (SCN) determination over interfering material in cotton. A prerequisite to selectivity measurements is to identify suitable fiber medium(s) that give baseline SCN response (< 8 cnt/g fiber) for spiking experiments. In this paper, seed coat nep selectivity in AFIS determinations was defined. A formula for SCN was derived and modeled to calculate selectivity from actual data. Additionally, SCN selectivity was calculated from the published literature and data produced in this paper. The concept of twin-axial blending of slivers in the AFIS was introduced and tested, and several diverse fiber mediums, with little or no seed coat fragments, were evaluated for selectivity studies. Low SCN selectivity values were found from published AFIS data and new results produced in this study. Twin-axial blending of slivers from two different fiber sources was possible. Commercial scoured and bleached cotton, rayon (from wood), and hand harvested/hand ginned cotton were evaluated as diverse mediums for experiments. The hand harvested/hand ginned cotton and rayon provided good fiber mediums for the investigation. The scoured and bleached cotton produced a high count of neps and SCN; SCN selectivity was minimal.

## Introduction

Seed-coat fragments in baled cotton are some the most difficult impurities to remove in textile processing. These fragments come from seed or mote (underdeveloped or aborted ovules) crushed during processing (Brown and Ware, 1958). Seed damage may occur in the field, harvesting and in ginning (Boykin, 2008).

Microscopic test methods have been developed to identify and quantify seed coat fragments (SCF) in cotton (Jacobsen et al., 2001; ASTM D2496, 1985). The Advanced Fiber Information System (AFIS) provides an automated instrumental test method (Zellweger Uster, 1996) measuring seed-coat fragments, referred to by Uster as seed-coat neps (SCN). Seed-coat neps are entanglements of SCF, which remain with attached fiber during opening. Seed-coat neps differ from the traditional neps, which are entanglements of fiber only.

A literature search revealed that no papers have been published on AFIS selectivity for SCN. Microscopically obtained numbers of SCF were significantly different compared to AFIS SCN (Jacobsen et al. 2001). In that study, a stereo-dissecting microscope was used with a standard film camera attachment; the films were scanned and converted to digital images. The authors suggested that the AFIS does not detect the same impurities counted by the manual method or the entities are categorized differently (e.g., nep instead of SCN). Another study obtained SCF by ASTM D2496 using low power magnification (x3) and detected visually by the operator (Boykin, 2008). Results compared to AFIS SCN were lower or higher, with little correlation, when averaged within a variety.

A more recent study demonstrated the addition of isolated SCF to hand-cleaned cotton affected the levels of SCN and neps (Bel, 2011). The author suggested that the opener in the AFIS breaks up the SCF into smaller particles. These smaller particles may become tangled with fibers and are classified as neps.

The present study was performed using both ASTM D2496 (x3 and higher magnification) and the AFIS. The objective was to define AFIS SCN selectivity, calculate selectivity values from Bel's data (2011), identify diverse fiber mediums that are suitable for selectivity studies involving dilution and spiking with various entities, develop a technique to blend – within the AFIS – similar or diverse fiber mediums for analysis, and present a case study of a fiber medium where SCN count by AFIS > SCF count by D2496.

## Fundamentals

To understand fundamentals of AFIS SCN selectivity it is necessary to review the nep detection method by AFIS. In brief, a sliver is passed through a mechanical individualizer that separates all entities from each other (neps, trash, fiber). Neps and fibers enter an air stream, and waste (trash, dust, large SCN) enters another. Neps and fibers pass through the same light sensor. Based on the waveforms (light sensed versus time) an algorithm categorizes the neps into fiber neps or SCN. Neps and SCN are counted and sized. A patent review of the sensor-algorithm shows redundancy is built into the system to provide more information and improve accuracy and precision (Shofner et al. 1993).

AFIS SCN selectivity is defined herein as the overall discrimination factor between SCN count per gram fiber and other impurities counted as SCN. If the real SCN count is high and the count as SCN from the non-lint particles is low then obviously the calculated selectivity is going to be good.

A SRRC-derived math model for SCN selectivity is given by Eq. 1 where $SCN_s$ is AFIS selectivity for SCN, $SCN_d$ is SCN measured in a sample (cnt/g), and $SCN_i$ is SCN measured in the isolated interferent.

$$SCN_s = (SCN_d - SCN_i)/SCN_i = SCN_d/SCN_i - 1 \qquad (1)$$

Note that the model reduces to a simple ratio subtracted by 1. Simulation of the model is depicted in Figure 1. As the ratio of $SCN_d/SCN_i$ approaches zero, the limiting value for $SCN_s$ is -1. Consider an example calculation where $SCN_d$ is 5 cnt/g and $SCN_i$ is 1 cnt/g; $SCN_s = (5/1 - 1) = 4$.

Selectivity of AFIS for seed-coat neps, $SCN_s$, is influenced by a two-step process. The first step is concerned with the individualizer and splitting the air-flow into two streams. Entities may be generated in the individualizer by crushing and removed by cross-contamination into the waste stream. Cross-contamination into the nep-fiber stream may also occur. In the second step, individualized neps and fibers enter the same light sensor; a complex wave-form of light versus time is generated. The discriminating algorithm categorizes neps and seed coat neps.

However, the specific selectivity of the system for SCN is unknown. Specific selectivity is the selectivity not influenced by step one. It may be envisioned as the selectivity produced when seed-coat neps are dropped into the SCN sensor air stream followed by non-lint entities.

Because the specific selectivity is not known at this time, and the overall selectivity has yet to be demonstrated, it is necessary to compare AFIS response to a standard method. ASTM D2496 is used in which low power magnification is used to identify seed coat fragments in fiber webs by visual examination.

## Materials and Methods

### Fiber Mediums

For this study, three types of fibers were used. The first was a commercially-available mechanically cleaned scoured and bleached cotton referred to by the vendor as cotton balls; it was extremely neppy. The next was a hand harvested/hand-ginned cotton that was free of neps and seed coat fragments. The third was a de-lustered rayon that was cut into 12.5 mm lengths. The rayon was chosen for its cellulosic content and would be a good substitute for cotton because it would be free of seed coat fragments and may produce a small nep count in AFIS processing. The rayon was produced from wood.

### SCN Fiber Mediums Evaluated

Several fiber mediums were evaluated with the intent on using them as a carrier fiber for SCF and SCN measurements. The ideal fiber mediums for the experiments would contain little or no SCF, limited neps produced in opening in the AFIS, and entrap a known number of spiked entities for measurement. The cotton balls were eliminated as a possibility because of its extreme neppiness. The hand harvested/hand ginned samples were an ideal candidate, except for the fact that it is difficult and time consuming to produce. The rayon was evaluated as a medium to which neps and seed coat fragments could be added to it while entrapping them for testing. The rayon proved to be a good resource; no seed coat fragments, limited neps, and was capable of capturing added neps and seed coat fragments.

**Blending Twin-Axial Slivers for AFIS Analysis**

Varying the percentage, by weight, of cotton balls in a sliver to be AFIS tested was an interesting option to generate data to provide more information on AFIS selectivity for SCN. Twin-axial slivers were blended uniformly in the AFIS by side-by-side slivers of varying weight at a fixed total weight of 0.5 g/sliver.

Once the sliver weights were determined for each fiber component in a 25/75%. 50/50, and 75/25% combination, cotton balls and rayon, respectively, fibers of each source were drawn out into a sliver, then joined with the other component by slight entanglement so that the conjoined sliver remained intact in the AFIS until it was opened.

**AFIS Analysis**

All slivers, the 100% content and the blends were analyzed on the Uster AFISPro at the U.S. Ginning Laboratory in Stoneville, MS. All slivers were 0.5 grams, 25 cm long of randomly selected fibers with 5 replicates of each being analyzed.

**ASTM D2496**

Three-gram samples of individual fibers were prepared in a 20 cm by 28 cm web. Three replicates of each, the commercial cotton, the hand-ginned cotton and the rayon were all evaluated for seed coat fragments following the method at the U.S. Ginning Laboratory, Stoneville, MS.

## Results and Discussion

**Calculated Selectivity Values**

Table 1 gives the calculated seed-coat neps selectivity ($SCN_s$) values from published AFISPro data (Bel and Xu, 2011). In that study, five cottons from the ATMI 2001 Variety study were hand cleaned; SCF and trash particles were removed. Unexpectedly, the AFIS classified entities in the air stream entering the fiber-nep sensor as SCN from the extracted fibers. The count ranged from 3 to 14 SCN/g fiber. Ten particles of isolated SCF were then added per gram extracted cotton and the SCN measured by the AFIS ranged from 15 to 32 cnts/g.

To calculate $SCN_s$ by Eq. 1, $SCN_i$ is the seed-coat neps in the extracted cotton and $SCN_d$ the observed seed-coat neps in the same medium after spiking with 10 seed-coat fragment particles. The calculated $SCN_s$ values ranged from 0.5 to 7. To understand the physical meaning of the selectivity values, consider the A1-1 cotton calculation. The observed seed-coat neps in the spiked sample ($SCN_d$) was 27 cnt/g; however, the seed-coat neps in this extracted fiber medium ($SCN_i$) was 9 cnt/g compared to 0 cnt/g if there had been no such entity detected. The ratio $SCN_d/SCN_i$ is 3 and $SCN_s$ is 2.

Since the hand cleaned ATMI cottons were free of SCF, no SCN should have been detected by the AFIS. To help understand this phenomena all available AFIS SCN and neps data on cleaned fibers – (Bel and Xu, 2011) and the current study – was included in Figure 2 to provide for a more rigorous test of possible relationships. From Bel and Xu (2011) the data (cnt/g) included the five hand cleaned ATMI cottons, one combed cotton (0 SCN and 20 neps), and a polyester (2 SCN and 43 neps). From the current study (Table 2) two samples were included in the figure: a hand harvested/hand ginned cotton (0 SCN and 32 neps) and rayon (6 SCN and 111 neps).

The data split into two significant linear relationships as shown in Figure 2 and the lines converge as the counts approach zero. The SCNs in the figure represent false positive counts and provide additional findings to confirm the small $SCN_s$ values reported in Table 1. Additional experiments will be run and results compared with the present study to help understand the underlying mechanisms in AFIS detection of SCN and fiber neps.

**Baseline Fiber Mediums**

Three diverse fiber mediums were evaluated as SCN baseline mediums (i.e., little or no SCN detected by the AFIS) for dilution and spiking experiments in selectivity studies. The three mediums were hand harvested/hand ginned cotton, rayon, and cotton balls (Table 2). Hand harvested/hand ginned cotton would be expected to be free of SCF and SCN since the opportunity to form this entity has been removed. Machine harvesting and ginning have been implicated in producing seed coat neps (Boykin, 2008).

The ASTM reference method test for SCF and the AFIS detection of SCN found no seed coat entities. Note also that the absence of SCN confirms that the threshold values of the digital signal processor (DSP) in the particular AFIS used to run the tests was not biased to producing false positive counts (Baldwin, 1995).

The rayon used in this research is, of course, free of seed coat fragments since it was produced from wood pulp. The ASTM method resulted in a negative test for SCF compared to an AFIS SCN count of 6/g fiber. This low count of SCN may be the result of waveforms of unknown material traveling through the sensor being compared with the standard waveforms in the classification software or of threshold values of the DSP set for cotton rather than rayon. Based on an arbitrarily concentration of SCN of < 8 cnt/g fiber, hand harvested/hand ginned cotton and rayon were accepted as suitable mediums for experiments.

**<u>Twin-Axial Slivers for AFIS Analysis</u>**
The AFIS response to cotton balls (Table 2, high levels of SCN and neps) is of particular interest since it provides the opportunity to demonstrate if blending twin-axial slivers in the machine is a viable technique. Blending of different proportions by weight of cotton balls and rayon at fixed total weight of 0.5 g/sliver was evaluated on two different AFIS instruments (Figures 3 and 4). Linear relationships were obtained on both machines for neps and SCN. AFIS1 gave the higher response.

As observed in Figure 1, the lines in Figures 3 and 4 converged as the counts approached zero. The statistical test for difference, the p values, increased in going from 100% cotton to 100% rayon. At the $p = 0.05$ level, the nep counts differ in the two test instruments but not the SCN.

**<u>Actual and Predicted SCN in Cotton Balls</u>**
The high counts associated with the cotton balls precluded extrapolating the trend lines in Figure 1 to predict the SCN in extracted cotton balls. Instead, the consistency of the ratio of SCN/neps was evaluated for polyester and rayon (Table 3). The means and standard deviation of the ratios (0.0465 and 0.0541) are 0.0503 and 0.0054. This is an interesting finding since rayon is a cellulosic material and polyester is not.

Cotton balls as received produced a SCN/neps ratio of 235/3343 = 0.0703. Since the neps are the sum of SCN and neps, the nep count in the as received material was corrected for SCN in the extracted fiber as follows: 235 – 186 = 49; 3343 – 49 = 3294. The corrected ratio for the extracted material is: 186/3294 = 0.0565, which is in close agreement with the rayon. Both rayon and the extracted cotton balls were analyzed on the same AFIS.

To arrive at a predicted value of SCN for the cotton balls, the ratio for the rayon was multiplied by the nep value for the extracted cotton balls: 0.0541 x 3294 = 178 SCN. The predicted SCN in the extracted cotton balls agrees well with the actual value of 186.

The calculated seed coat selectivity in the as received cotton balls, $SCN_s = 0.263$. Only 49 of the 235 SCN are attributed to actual seed coat neps in the as received fibers. The remaining SCN, 186, are attributed to misclassification of SCN by the AFIS. High levels of neps in the as received and extracted material may be the source of the discrepancy.

## <u>Conclusions</u>

Misclassification of SCN by the AFIS has been found in a review of published data and the current study. The extent of the errors was quantified in terms of selectivity values for seed-coat neps and resulted in poor SCN selectivity, < 3. Diverse baseline fiber mediums that produced little or no SCN, such as hand harvested/hand ginned cotton and rayon, provided additional information in probing AFIS results.

Blending of different samples was accomplished in the AFIS by the concept of twin-axial slivers. Two slivers were combined side-by-side of varying individual weight and fixed total weight. This approach eliminated the need for pre-blending outside the AFIS and provided for more uniform analysis.

There is a critical need to examine the waveforms that the classification software uses to identify the entities that pass through the AFIS fiber-neps sensor. Also, collection and post analysis of the AFIS test slivers by the reference method will provide further understanding of the AFIS.

## Disclaimer

Use of a company or product name is for information only and does not imply approval or recommendation by the United States Department of Agriculture to the exclusion of others.

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Table 1. Calculated AFISPro SCN selectivity for ATMI cottons (Bel and Xu, 2011).

| | Cnt/g fiber | | | Seed Coat Neps |
|---|---|---|---|---|
| | Extracted fiber | Added 10 SCF | Ratio | Selectivity |
| Cotton | $SCN_i$ | $SCN_d$ | $SCN_d/SCN_i$ | $SCN_s$ |
| A1-1 | 9 | 27 | 3.00 | 2.00 |
| A1- 9 | 14 | 32 | 2.29 | 1.29 |
| A1-12 | 10 | 15 | 1.50 | 0.50 |
| A1-19 | 3 | 24 | 8.00 | 7.00 |
| A1-21 | 6 | 20 | 3.33 | 2.33 |
| Means | 8 | 24 | 3.62 | 2.62 |

Table 2. Baseline fiber medium evaluation.

| | Mean cnt/g fibers | | |
|---|---|---|---|
| | Seed Coats | | Neps |
| Fiber Medium | ASTM (SCF) (3g/sample) | AFIS (SCN) (0.5 g/sliver) | AFIS (0.5 g/sliver) |
| Hand harvested/hand ginned | 0 | 0 | 32 |
| Rayon | 0 | 6 | 111 |
| Cotton balls | 16 | 235 | 3343 |

Table 3. Actual versus predicted seed coat neps (SCN) in cotton balls.

| | Cnt/g fiber | | |
|---|---|---|---|
| Fiber | SCN | Neps | SCN/Neps |
| Polyester | 2 | 43 | 0.0465 |
| (Bel and Xu, 2011) | | | |
| Rayon | 6 | 111 | 0.0541 |
| | | | |
| Cotton balls: | | | |
| as received | 235 | 3343 | 0.0703 |
| extracted | 186 | 3294 | 0.0565 |
| predicted | 178 | | |
| | 3294 x 0.0541 (rayon) = 178<br>consistency: 0.0541/0.0565 = 0.9575 ± 0.0017 | | |
| $SCN_s$ | $SCN_d/SCN_i$ -1 = 235/186 – 1 = 0.263 | | |

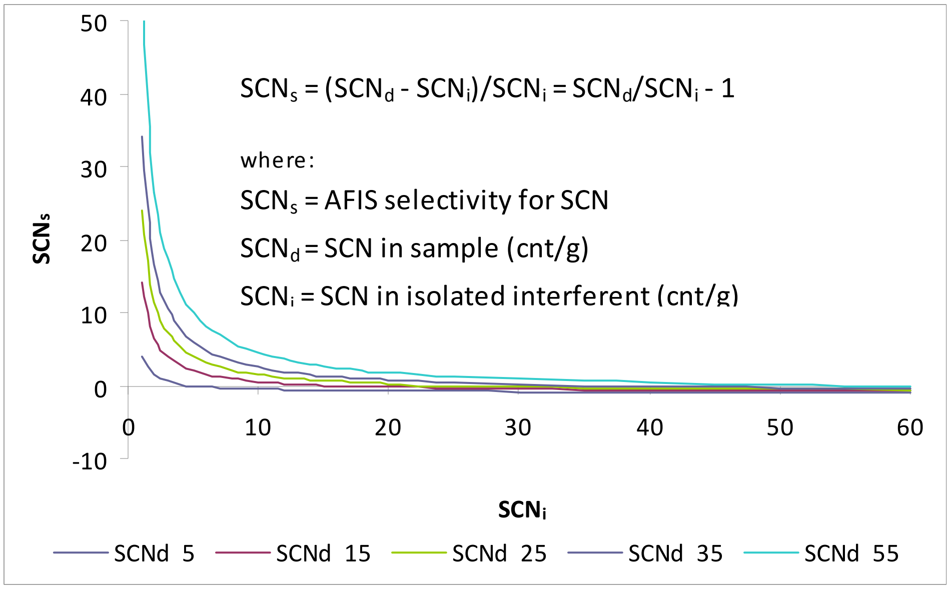


Figure 1. Variation of AFIS seed coat neps selectivity with SCN count observed in the sample and in the isolated interferent.

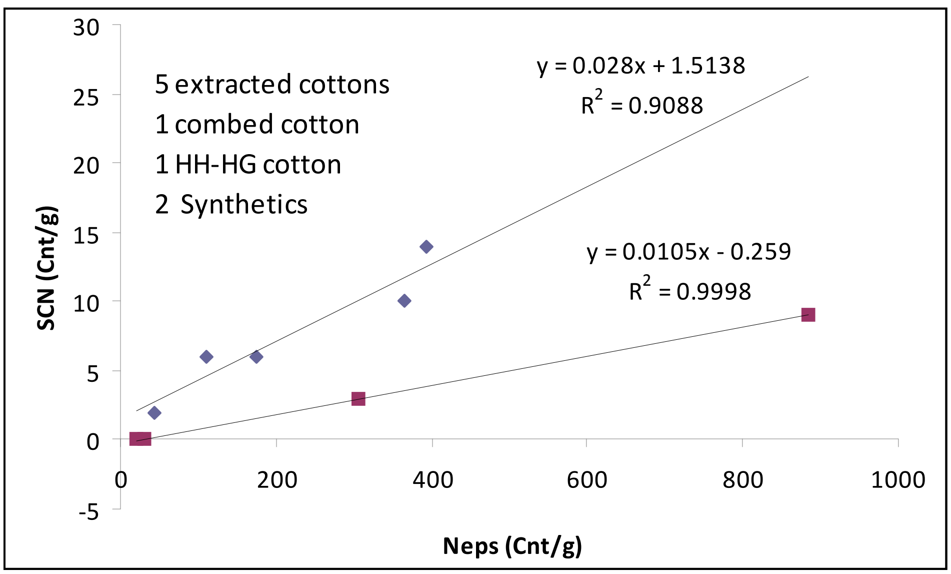


Figure 2. Dependence of SCN on fiber neps from AFIS results on fibers known to be free of seed coat fragments.

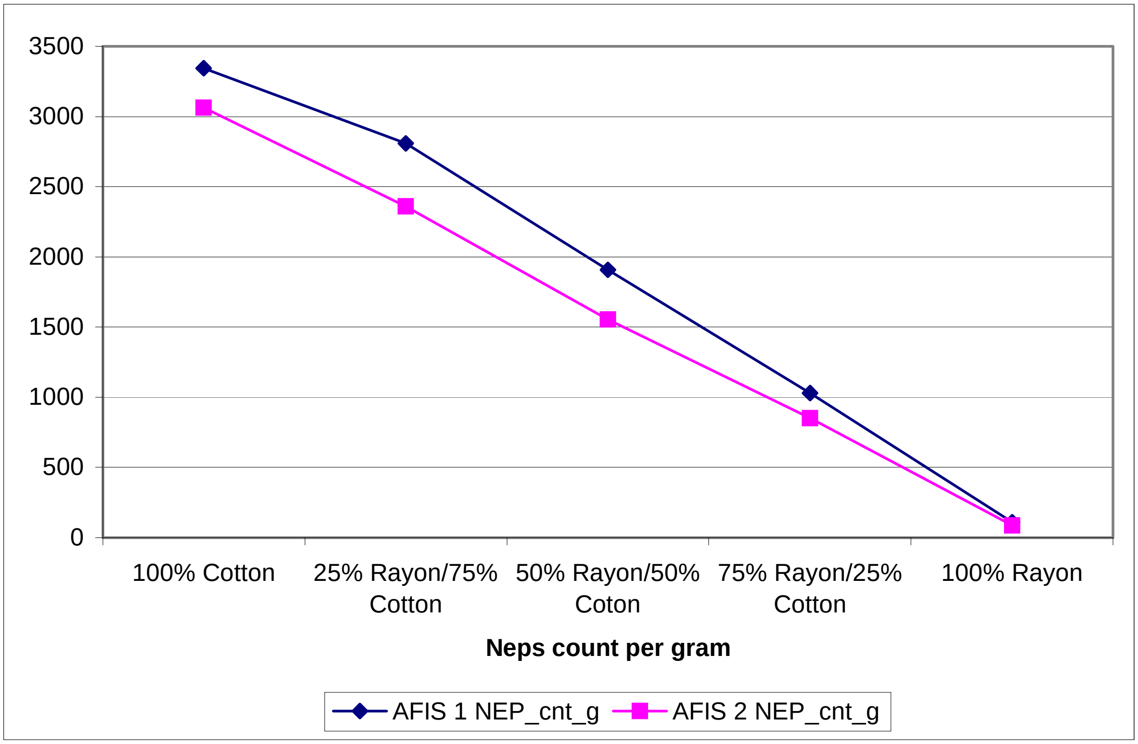


Figure 3: Demonstration of twin-axial sliver blending in the AFIS, fiber neps count.

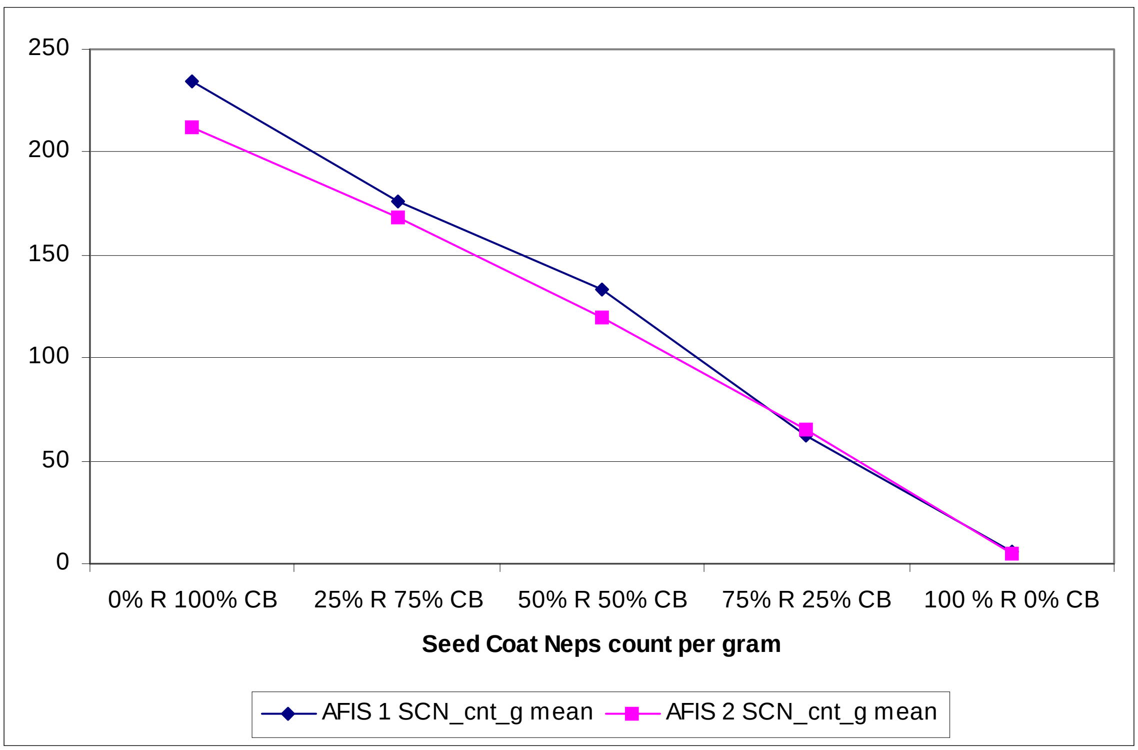


Figure 4: Demonstration of twin-axial sliver blending in the AFIS, seed coat neps count.