# Study on Physical and Mechanical Properties of Agricultural Netting Products

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## Introduction

The agricultural industry utilizes textile products for a variety of applications in the production of plants and crops. Agriculture nets are textile fabrics used extensively as covers for shading and protection purposes and for harvesting and post-harvesting practices. Anti-hail, anti-bird, shading, and windbreak nets have long been used to cover vegetables and decorative plants from environmental hazards (e.g., hail, wind, snow, rain, and sand storms) and pests (e.g. birds, fruit bats, and insects), as well as from excess solar radiation. In recent years, photoselective nets, which possess special sunlight transmission properties, have gained popularity in use for fruit orchards. In addition to protecting crops against environmental hazards and pests, photoselective nets can also alter the microclimate and solar radiation (wavelength and amount of diffuse radiation) under nets, therefore providing a sustainable solution to agriculture production. Preliminary literature review revealed that much of the research on agricultural netting products was focused on their impact on the growth of plants and crops. Net properties, such as basic fabric characteristics and physical/mechanical properties, are kept as an industry secret by manufacturers and are not available to the public. However, these properties are critical information to be considered at net selection and for future product development and innovation. Due to the unavailability of this information to net users, selection of nets is more based on empirical and economic considerations rather than scientific knowledge around the world. The purpose of this research was to delve into the basic fabric characteristics and physical/mechanical properties of various agricultural netting products. These included three most renowned photoselective nets and eleven other net products, which served for comparison purposes.

## Materials and Testing

The three photoselective nets were ChromatiNets® blue, red, and white, obtained from the Tree Fruit Research & Extension Center at Wenatchee, WA. Other nets were purchased from retail channels and they were US Net shading cloths with different levels of shading power and colors, LGH shading clothes of different colors with 60% shading power, a DeWitt Bird Block net, a Naltex Net, and a film. The fiber content and construction of the products are shown in Table 1. The net characteristics and physical/mechanical properties assessed included yarn size, fabric thickness, tensile strength and elongation, tearing strength, abrasion resistance, stiffness, and covering power. All tests, with the exception of covering power, were conducted by following ASTM Standard test methods (D1577 and D3776/3776M-09 for yarn size, D1777-07 for thickness, D5034-09 for tensile strength and elongation, D1424-09 for tearing strength, D3884-09 for abrasion resistance, and D1388-14 for flexibility) with the only exception that the testing was conducted under ambient conditions (21±1°C and 30±2% RH). Covering power was evaluated by analyzing the product images using ImageJ software.

**Results and Discussion**

The fabric characteristic results are shown in Table 1 along with the product information, including yarn size, fabric thickness, and covering power. Table 2 shows only part of the physical/mechanical property results due to page limit.

Table 1. Product Description and Results for Characteristics

| Product Number | Product Name | Product Description | Fiber Content | Construction | Yarn Size (Tex) | Thickness (mm) | Coverage Power |
|---|---|---|---|---|---|---|---|
| 1 | ChromatiNet® Blue | Photoselective | polyethylene | braided | 72 | 0.52±0.01 | 52% |
| 2 | ChromatiNet® Red | Photoselective | polyethylene | braided | 76 | 0.61±0.05 | 63% |
| 3 | ChromatiNet® White | Photoselective | polyethylene | braided | 68 | 0.53±0.03 | 60% |
| 4 | LGH Black | 60% shade | polyethylene | 2-ply knit | 47 | 1.02±0.05 | 70% |
| 5 | LGH Green | 60% shade | polyethylene | 2-ply knit | 53 | 1.24±0.02 | 68% |
| 6 | LGH Sand | 60% shade | polyethylene | 2-ply knit | 50 | 1.07±0.01 | 68% |
| 7 | LGH White | 60% shade | polyethylene | 2-ply knit | 49 | 1.03±0.05 | 66% |
| 8 | US Net Black | 60% shade | polyethylene | knit | 46 | 1.26±0.04 | 67% |
| 9 | US Net Green | 70% shade | polyethylene | knit | 47 | 1.50±0.03 | 73% |
| 10 | US Net Red | 80% shade | polyethylene | knit | 45 | 1.37±0.06 | 84% |
| 11 | US Net White | 22% shade | polyethylene | knit | 58 | 1.25±0.09 | 75% |
| 12 | DeWitt Bird Block | Fused net | nylon | fused | 64 | 1.38±0.06 | 16% |
| 13 | Naltex | Fused net | polypropylene | fused | 196 | 0.90±0.02 | 60% |
| 14 | Polyethylene Film | Film | polyethylene | film | n/a | 0.13±0.02 | 100% |

Table 2. Results for Physical/Mechanical Properties

| Product Number | Tensile Load (warp) (N) | Tensile Elongation (warp) (%) | Tearing Strength (warp) (N) | Stiffness (warp) (mg) |
|---|---|---|---|---|
| 1 | 250±15 | 26±2 | 36.6±9.4 | 380±30 |
| 2 | 254±26 | 26±1 | 41.4±6.5 | 290±15 |
| 3 | 247±15 | 25±2 | 41.2±7.7 | 332±27 |
| 4 | 599±39 | 121±2 | ~64* | 170±13 |
| 5 | 1017±39 | 91±3 | > 64 | 354±27 |
| 6 | 601±23 | 119±3 | > 64 | 183±18 |
| 7 | 567±32 | 84±29 | ~64* | 143±25 |
| 8 | 166±7 | 128±5 | 43.5±5.8 | 83±3 |
| 9 | 345±21 | 116±3 | 63.4±0.8 | 110±8 |
| 10 | 344±8 | 109±3 | 30.1±0.9 | 91±6 |
| 11 | 266±42 | 55±5 | 41.8±4.0 | 57±3 |
| 12 | 25.8±2.9 | 85±8 | --- [‡] | 71±23 |
| 13 | 64±13 | 84±29 | 5.8±1.0 | 372±12 |
| 14 | 163±1 | 651±13 | 12.0±0.4 | 36±8 |

*: some of the testing values exceeded the machine testing limited (64N) and some of the values are close to 64N.
‡ :Product was not testable due to large openings.

During installation and use, nets are constantly being stretched, abraded, and torn by machine, installation workers, tree branches, and net supporting structures. Therefore, tensile strength and elongation, tearing strength, abrasion resistance, and stiffness are critical properties that influence the installation process and durability of nets. Based on the results, the photoselective nets have relatively high stiffness and abrasion resistance compared to most other products tested due to the braided structure and relatively high yarn size. The tensile load of all photoselective nets are significantly lower than all the LGH shading clothes based on t-test and elongation are lower than all other products based on t-test ($p<0.001$). The tearing strength is in the middle among all products. Since there is little research has been completed regarding the desired physical/mechanical property values on net products, there is no base for the authors to interpret the sufficiency of these properties. The next step of this research is to collaborate with horticulture researchers on finding out the needs in term of material properties and further study the durability especially the photo degradation of the nets.