

EVALUATION OF THREE PLASTIC MULCH COLORS ON THE GROWTH OF NOVA MANDARIN (CITRUS RETICULATA) SEEDLINGS IN CAÑETE – PERU

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ABSTRACT: Plastic mulching is a low-cost technology whose effect on growth depends on the material's optical and thermal properties, which vary with color. In Cañete, mandarin (*Citrus reticulata*) production faces moisture loss, weed pressure, and soil thermal variability, with no local evidence on the most suitable mulch color for the Nova variety. This study evaluated the effect of three mulch colors (white, black, and blue) on the height increment of Nova mandarin seedlings at I.E.S.T.P. “Cañete”, with implications for production management. We used a randomized complete block design (RCBD) with census sampling ($n = 18$; sample = population) across three treatments and six replicates. We analyzed height increment using one-way ANOVA ($\alpha = 0.05$). Mulch color had a significant effect ($F(2,15) = 4.19$; $p = 0.036$; critical $F = 3.68$), so we rejected the null hypothesis. Black mulch produced the greatest average increment (1.50 cm), followed by blue (1.34 cm) and white (1.30 cm); however, Tukey's post-hoc test ($HSD = 0.22$ cm) did not detect significant pairwise differences. Given the equivalent acquisition cost across treatments, mulch-color selection is a performance-based decision rather than a budget-based one. Black mulch is suggested as a preferred option, pending validation with larger sampling and yield data through harvest.

Keywords: plastic mulch, production management, technology adoption, agricultural innovation, *Citrus reticulata*, resource efficiency.

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INTRODUCTION

A mandarin grower in Cañete who wants to improve his results has few low-cost options available. He can irrigate more, but water is scarce and pumping it is expensive. He can weed more frequently, but that means paying more for labor. Plastic mulching is one of the few practices that addresses several of these constraints at once—water, weeds, and soil temperature—with a relatively low investment. That is why it is important not only to know whether mulching “works,” but also which color to use, since that is the specific decision the grower must make before purchasing a roll of plastic.

Mulching involves covering the soil surface around the plant with organic or inorganic material to protect the crop and soil from atmospheric agents and promote yield (Arenas et al., 2013). It is an ancient practice: people have used mulching with lithic materials for over a thousand years in both the Old and New Worlds to combat drought (Lightfoot, 1996). In its plastic form, popularized since the 1950s under the term “plasticulture” (Kasirajan & Ngouajio, 2012), it mainly reduces water evaporation, modifies soil temperature, and physically blocks weed growth (Díaz González & Santos Coello, 2012). What varies by color, above all, is how much light is reflected and how much heat is transmitted to the soil.

The agronomic literature is consistent with this. Arenas et al. (2013) note that, in citrus orchards, black mulch reduces light transmission to the soil, inhibits weed growth, and decreases direct water evaporation. Quezada-Martín et al. (2011) found, in bell peppers, that white and silver mulches reflected between 150% and 290% more radiation than brown, blue, and clear mulches, and Dickerson (2002) indicates that white and silver mulches keep the soil cooler, which can be an advantage in very hot climates. Zribi et al. (2011, 2015) document that mulch reduces direct evaporation of water from the soil and maintains higher soil moisture, which, with proper irrigation management, allows for more efficient water use (Arenas et al., 2013)—a relevant point in a valley where water resources are seasonal.

For citrus crops in particular, Olmos-Ruiz et al. (2025) compared white and black plastic mulch, pruning debris, and an unmulched control on lemon trees and found that the type of mulch significantly influenced the evaluated parameters: black plastic and pruning debris increased the number of fruits per tree, while white plastic did not differ from the control,

suggesting that the most suitable color depends on the crop and local climate and is not a universal rule. Díaz González and Santos Coello (2012) note that plastic mulch improves root establishment and nutrient uptake, and Arenas et al. (2013) note that it reduces soil compaction and increases the volume occupied by roots. In new citrus plantations, moreover, mulch is installed along with the sapling—that is, from the earliest stages of cultivation, which precisely constitute the time frame covered by this study. In newly established dwarf apple orchards, for example, researchers have compared organic mulches and other soil management practices in terms of their effects on temperature, soil moisture content, and tree growth (Walsh et al., 1996).

Why should color matter? Black mulch absorbs almost all the solar radiation it receives; its albedo is low, and it transfers that heat to the soil through conduction; hence, it heats up more and, by blocking light, prevents photosynthesis by any weeds beneath it (Lamont, 1993). White mulch does the opposite: its high albedo reflects much of the radiation back into the atmosphere, so the soil heats up less (Dickerson, 2002). Silver or aluminum mulch, with high reflectance, keeps soil temperatures low and, as a temperature-unrelated side benefit, tends to repel aphids—vectors of viral diseases—thereby reducing their incidence (Dickerson, 2002). Blue mulches, by contrast, alter the radiation reflected back toward the foliage in different ways, with effects on growth that vary by crop and still require further research (Dickerson, 2002).

The problem is that this physical logic rarely reaches the average farmer. In the Cañete Valley, it is generally known that “covering the ground with plastic helps,” but local evidence is lacking on which color is best for Nova mandarin in particular, and there is no clear understanding of the cost of that decision relative to the benefits. This study aims to bridge the gap between the international literature and what local growers can apply using their own information.

DEVELOPMENT

Practical Rationale

For a grower, the question isn't "Does mulching work?"—that's already been well established in the literature—but rather "What color should I buy?" Having evidence generated in Cañete—rather than just from different climates or crops—allows growers to direct that expenditure toward the option with the best cost-benefit ratio, rather than deciding based on habit or whatever the nearest supplier offers.

Mulching affects at least three inputs that directly impact the producer's bottom line: irrigation water, because a plastic film reduces surface evaporation; labor, because fewer weeds mean fewer days spent weeding; and, to some extent, plant protection products, since weeds serve as hosts for pests. None of these savings is spectacular on its own, but over a growing season they can shift the profit margin of a crop—such as mandarins—that competes in a market with tight pricing. In this study, these water and labor savings were not measured directly; they are presented here as the basis for the justification, drawing on the cited literature, and treated as assumptions—not original findings—in the discussion.

The paper also argues that colored mulch is an inexpensive, easy-to-install technology—two factors that favor adoption among small-scale producers—but these alone are not sufficient if no one specifies which color to use. In that sense, comparing the three colors under real-world conditions on the campus of the I.E.S.T.P. "Cañete" is not merely an academic exercise: it is the pilot test that local farmers need before investing their own money.

Problem Statement

What is the effect of three colors of plastic mulch (white, black, and blue) on the height growth of 'Nova' mandarin (*Citrus reticulata*) seedlings on the campus of the I.E.S.T.P. "Cañete," and what are the implications for production management and technology adoption among citrus growers in the area?

Objectives

General objective: To evaluate the effect of three colors of plastic mulch (white, black, and blue) on the height growth of mandarin (*Citrus reticulata*) seedlings of the 'Nova' variety on

the campus of the I.E.S.T.P. “Cañete,” and to identify their implications for the production management of local citrus growers.

Specific Objective: To analyze the effect of the three plastic mulch colors on the height of mandarin seedlings and discuss their implications for the technological and economic decision-making of mandarin growers in the Cañete Valley.

Hypothesis

Alternative hypothesis (Ha): The color of the plastic mulch has a significant effect on the height growth of mandarin (*Citrus reticulata*) seedlings of the ‘Nova’ variety.

Null hypothesis (Ho): The color of the plastic mulch has no significant effect on the height growth of mandarin (*Citrus reticulata*) seedlings of the ‘Nova’ variety. Independent variable: color of the plastic mulch (white, black, blue).

Dependent variable: height growth of mandarin (*Citrus reticulata*) seedlings of the ‘Nova’ variety.

METHODOLOGY

Scope of the Study

The study was conducted on the IESTP “Cañete” campus, located at km 13 of the Imperial-Quilmaná Highway, in the district of Quilmaná, province of Cañete, department of Lima.

Geographic coordinates (WGS 84):

Latitude: 12° 58' 48.14" S

Longitude: 76° 23' 09.60" W

Decimal coordinates: -12.98004, -76.38600

The trial was established in May and evaluated from May through December, for a total duration of 8 months. The climate is very dry and semi-warm, with average temperatures ranging from 16 °C to 23 °C throughout the year and very low annual precipitation; the soil has favorable agricultural characteristics, with a predominance of sandy and sandy-loam

textures. Regarding soil reaction, a pH of approximately 7.47—considered neutral to slightly alkaline—influences nutrient availability and crop development.

Research Type, Level, Method, and Design

The study was experimental and explanatory, using an inductive-deductive method. A completely randomized block design (CRBD) was used, comparing three treatments corresponding to the colors of the plastic mulch being evaluated (white, black, and blue) across all the ‘Nova’ variety mandarin (*Citrus reticulata*) seedlings available on campus.

Population, Sample, and Experimental Units

The population consisted of 18 mandarin (*Citrus reticulata*) seedlings of the ‘Nova’ variety available at the experimental campus. The experimental unit consisted of a single seedling. Given the small and accessible size of this population, a census sampling method was used: the sample coincided with the total population (sample = population = 18 seedlings), distributed across three treatments, each with six replicates, corresponding to white (T1), black (T2), and blue (T3) mulch.

All seedlings received the same standardized agronomic management (irrigation, fertilization according to the institutional nursery’s standard program, and preventive phytosanitary monitoring), so that mulch color was the only variable differing among the treatments.

Variables and Indicators

The independent variable was plastic mulch color (nominal qualitative variable: white, black, blue).

The technical management of the seedlings (irrigation, fertilization, cultural practices) was kept constant across treatments and is considered a control variable, not an indicator of mulch color.

The dependent variable was mandarin seedling growth, assessed by plant height increase (cm), calculated as the difference between the height recorded at the beginning and at the end of the evaluation period. This trial did not measure soil temperature, soil moisture, weed incidence, or foliage color.

Techniques, Procedures, and Instruments

Data collection was conducted in the field by periodically measuring plant height across the three treatments and recording it in a field notebook. In the laboratory, data were tabulated and analyzed using a one-way analysis of variance (ANOVA) at a significance level of 0.05 to compare mean plant height increase among the three mulch colors. Before this, we assessed compliance with the assumptions of normality and homogeneity of variances. Additionally, Tukey's HSD test was applied using the ANOVA mean square error to identify specific differences between treatment pairs.

The experimental procedure included land preparation, planting seedlings, differentiated placement of mulch by color in each treatment row, initial irrigation, and periodic mulch maintenance during the evaluation period (May–December).

For project management purposes, we prepared a budget to estimate the costs of implementing this technology at the experimental field scale (Table 3), which is relevant to the production-cost analysis discussed in the discussion section.

Table 1

Estimated Budget for Trial Implementation

Category	Number of items	Amount (S/.)
Materials (seedlings, plastic, irrigation)	7	1,524.00
Tools and field supplies	6	170.00
Freight and transportation	1	150.00
Contingencies (10%)	—	184.40
Total		2,028.40

Note. Contingencies amount to 10% of the sum of the first three items.

RESULTS

The black mulch (T2) showed the greatest average increase in height (1.50 cm), followed by the blue mulch (T3) at 1.34 cm, and, lastly, the white mulch (T1) at 1.30 cm.

To determine whether these descriptive differences were statistically significant, we performed a one-way analysis of variance (ANOVA) to compare mean plant height increases among the three mulch colors. Table 2 presents the results.

Table 2

Descriptive statistics for the increase in plant height at the end of the observation period for each of the three plastic mulch colors evaluated

Treatment	<i>n</i>	Average height increase $\pm$ SE (cm)	Tukey Group
White mulch (T1)	6	1.30 $\pm$ 0.08	a
Black mulch (T2)	6	1.50 $\pm$ 0.04	b
Blue mulch (T3)	6	1.34 $\pm$ 0.05	c

The calculated F statistic (4.19) exceeded the critical F value (3.68) for 2 and 15 degrees of freedom, and the associated p-value (0.036) was below the established significance level ($\alpha = 0.05$). Consequently, we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_a): the color of the plastic mulch has a statistically significant effect on the increase in height of ‘Nova’ mandarin seedlings under the conditions of this study.

Table 3

One-way analysis of variance (ANOVA) for plant height increase by mulch color

Source of variation	SC	gl	MC	F	p-value (critical F-value)
Between treatments	0.1820	2	0.0910	4.19	0.036 (3.68)
Error	0.3258	15	0.0217	—	—
Total	0.5078	17			

However, since a one-way ANOVA does not identify which pairs of treatments differ from one another, Tukey's HSD test for comparing means was applied, calculated based on the mean square error ($MSE = 0.0217$; $df = 15$; $n = 6$ per treatment; $q(0.05, 3, 15) = 3.67$), which yielded a critical value of $HSD = 0.22$ cm. The differences between treatment pairs (black, white = 0.20 cm; black, blue = 0.16 cm; blue, white = 0.04 cm) were all below this threshold; therefore, no pairwise comparison reached statistical significance (Table 1). This indicates that, although mulch color had a significant overall effect on height increase, the available statistical evidence does not allow us to conclude that any specific color is significantly superior to another when considered individually; black mulch can only be described as having the highest average trend.

DISCUSSION OF RESULTS

Black mulch showed the greatest increase in height observed, which is by no means an unexpected finding: Arenas et al. (2013) note that black mesh mulch reduces evaporation and inhibits weed growth in citrus, and Lamont (1993) explains that it absorbs nearly all solar radiation and transfers it to the soil as thermal energy, which, in the first few weeks of a young plant's life, can promote growth. Rather, it confirms that the physical mechanism described in the introduction is consistent with conditions in Cañete; however, the Tukey test did not confirm that this difference compared with the other colors was statistically significant.

The blue mulch showed a descriptively intermediate increase in growth between the other two colors—a pattern consistent with what Dickerson (2002) notes for this color: its effects on growth vary depending on the radiation reflected toward the foliage of each crop and require further investigation. This study did not evaluate the advantage of repelling aphids and reducing the risk of viral diseases—which the same author describes for silver or aluminum mulches—but this could justify using reflective mulches in scenarios where pest pressure is the primary problem. White mulch, on the other hand, showed the smallest increase in height, a result that was also expected: because it has a high albedo, it cools the soil (Dickerson, 2002; Quezada-Martín et al., 2011), which is an advantage in very hot

climates but offers no benefit when, as in this case, there was no problem of excess heat to address.

What does this mean for crop management?

Translated into a field decision: if a mandarin grower in Cañete must choose a single mulch color and prioritizes early plant growth, black mulch is the option with the best descriptive performance in this trial, although Tukey's comparisons did not statistically distinguish between the three colors. This does not depend on aesthetic preference or local availability, but on a measured effect on plant height increase, which was statistically significant in the overall model ($p = 0.036$), although no confirmed paired differences were found.

The same reasoning extends, indirectly, to water and labor use. Mulch of any color reduces soil evaporation (Zribi et al., 2011, 2015), so part of the irrigation savings would come simply from implementing the technology; according to the literature, black mulch would provide better weed control, resulting in fewer days of weeding.

Costs and Expected Return

The trial budget (Table 1) reveals a simple but useful fact: mulch film, in any of its three colors, costs practically the same and represents a small fraction of the total cost of establishing the crop. If the cost of purchasing black, white, or blue mulch is practically identical, then the decision about which color to use should be based on performance rather than price; in that regard, black shows the most favorable trend, although it is not statistically distinguishable from the other two colors. In short, there is no real economic trade-off among the three colors, which simplifies the grower's decision.

However, this argument has a limitation that should be noted: this study measured the increase in plant height, not the kilograms of fruit harvested or the revenue per hectare. Moving from “the plant grew taller” to “the producer earns more money” is a reasonable leap, but it is not demonstrated here; that would require tracking the crop through to harvest and recording both yield and selling price.

Technology Adoption by Farmers

The fact that a technology is inexpensive and easy to install does not guarantee adoption; farmers almost always lack local evidence they can rely on. The studies cited in this paper (Arenas et al., 2013; Olmos-Ruiz et al., 2025; Quezada-Martín et al., 2011) were conducted in other countries or on other crops, and it is reasonable for a citrus grower in Cañete to doubt that those results apply to their own plot. A trial conducted on the I.E.S.T.P. campus, using the Nova variety and under local climate conditions, serves as the “local proof of concept” often missing for a technical recommendation to become standard field practice. For that to happen, it will likely take more than just statistical data: technical support, a visible field demonstration, and perhaps showing the expected savings in soles—not just in centimeters of height.

Self-criticism: How Solid Is This Evidence?

It is worth subjecting one’s own results to the same scrutiny applied to someone else’s study. First, the sample size is small: 18 plants in total, 6 per treatment, on a single campus and during a single growing season. An ANOVA with that number of observations can detect large differences, but it is not very sensitive to moderate ones. In fact, Tukey’s comparisons did not distinguish between treatment pairs despite the overall significance, and a single plant with atypical behavior within a group can significantly skew the mean. Second, the authors did not measure soil temperature and moisture—variables the introduction itself says explain why color matters; they inferred the mechanism from the literature rather than testing it in this experiment. Third, the design does not explicitly control for microvariations within the campus (partial shade, slope, soil type by block), which could be confused with the effect of color if the treatments were not perfectly randomized; nor was it described whether the edge effect between neighboring plots was controlled for, which is relevant given that the 18 plants may have been relatively close to one another. Fourth, and perhaps most importantly: the increase in plant height after a few months indicates early vigor, not final yield; there is no guarantee that the observed advantage of black mulch will be maintained, amplified, or even reversed by harvest time.

None of these limitations invalidates the central finding: the overall difference in color was statistically significant and is physically explainable; however, they do limit the scope of the recommendation: this evidence is sufficient to justify a grower testing black mulch on a portion of their plot, but not to categorically assert that it is superior in all scenarios involving Nova mandarins in Cañete. A follow-up trial with more replicates, a control treatment without mulch, soil measurements, and harvest data would resolve most of these issues.

CONCLUSIONS

With a full sample of 18 seedlings (6 per treatment), plastic mulch color had a statistically significant effect on the increase in height of Nova mandarin plants ($F = 4.19$; $p = 0.036$); therefore, the null hypothesis is rejected.

Black mulch showed the greatest average increase (1.50 cm), followed by blue (1.34 cm) and white (1.30 cm); however, the Tukey test did not find significant differences between pairs of treatments, so this difference should be interpreted as a descriptive trend rather than as a statistically confirmed superiority of one color over another.

Since the three colors cost practically the same, the choice between them does not depend on budget but on observed performance, which simplifies the grower's decision: at equal cost, black mulch is recommended as the preferred option to promote early growth, with plausible—though not measured in this study—additional benefits in terms of water savings and reduced weeding labor, which are presented here as assumptions derived from the literature and not as our own results.

Locally generated evidence can make it easier for citrus growers in Cañete to adopt this technology, especially if it is accompanied by technical assistance and a clear estimate of savings in soles, not just in centimeters of height.

The results should be interpreted with an awareness of the limitations inherent in a small sample size, a single growing season, and the absence of significant differences between treatment pairs according to Tukey's test: a follow-up study is recommended that includes a control treatment without mulching, direct measurements of soil temperature and moisture,

a greater number of replicates, and yield data through harvest, to confirm whether the early advantage of black mulch persists through to the final economic outcome.

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