



Comparison of Agricultural Coating Types for the Protection and Performance of Canary bean (*Phaseolus vulgaris*) Crops in Carhuaz, Ancash, Peru

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ABSTRACT

Background: The growing demand for sustainable solutions in agriculture has promoted the use of bioplastics as an alternative to conventional polyethylene and organic mulches in crop management.

Methods: The research was conducted at the Tuyu Ruri Ecological Experimental Center, located in the district of Marcará, Carhuaz, Ancash, at an altitude of 2800 meters above sea level. A completely randomized design was used with four treatments (including the control) and three repetitions. The treatments compared were the bioplastic coating "Mater-Bi," polyethylene (LDPE) and organic mulch (kikuyu grass residue). The variables evaluated included the number of weeds 30 days after sowing, the number of Rhizobium nodules in the roots and the bean yield at harvest.

Result: The Mater-Bi treatment showed an average of 6.3 weeds, 50 nodules and 5.66 Ton/ha of dry beans; the LDPE treatment had 5.7 weeds, 33.3 nodules and 4.08 Ton/ha; and the organic mulch had 9 weeds, 59.7 nodules and 4.80 Ton/ha. No statistically significant differences were found in the data obtained and the different coatings showed similar effects on weed control, root nodule formation and yield.

Key words: Agricultural coatings, Crop protection, Mulch and bean yield, Rhizobium nodules.

INTRODUCTION

Agricultural coatings, also known as mulches, have been a common practice in crop production since ancient times. According to Zribi *et al.* (2011); Zhong *et al.* (2025) and Zhang *et al.* (2023), living mulches naturally formed in crops and were used to reduce water loss, control erosion and manage weeds competing with crops (Chen *et al.*, 2024; Priya Raja *et al.*, 2022; Kumar *et al.*, 2024). Plastic coatings (low-density polyethylene, LDPE) are used worldwide to protect crops from unfavorable growing conditions, such as harsh weather, insects and birds. Moreover, the use of plastics in agriculture began in developed countries and has gradually spread to developing nations (Kasirajan and Ngouajio, 2012; Semou, Sergaki and Tremma, 2022) and the amount of plastic used for these purposes is alarming, as Espi *et al.* (2006) noted. In regions with high evapotranspiration, the use of mulches, covers, or mulch is particularly relevant, as it helps reduce soil temperature and maintain the moisture necessary for plants, thus decreasing water loss through evaporation (Hernández *et al.*, 2008). Additionally, mulches aim to protect the soil and improve its physical, chemical and biological properties, which benefits subsequent crops (Sánchez *et al.*, 2010).

On the other hand, the use of common plastic in agriculture has substantially expanded worldwide over the past ten years because polyethylene films are cheaper, easier to produce, highly flexible and durable (Somanathan *et al.*, 2022). However, improper disposal of used plastic

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films has led to soil pollution and environmental contamination, as stated by Somanathan *et al.* (2022). The massive use of petrochemical plastics has become a real problem for health and the environment (Inoue and Ishikawa, 2019; Younis and Kamran, 2024). What was once an easy and cheap solution has become a real problem, especially for agricultural soils everywhere (Gao *et al.*, 2025; Becerra *et al.*, 2024; Li *et al.*, 2024; Kuchlan *et al.*, 2017).

In response to this situation, biodegradable plastic technology has started to be developed, as these materials deteriorate quickly when exposed to microorganisms due to their ability to completely degrade most organic and inorganic materials, including lignin, starch, cellulose and hemicelluloses (Kale *et al.*, 2015). Thus, biodegradable and less harmful plastics present a viable alternative to petrochemical plastics Younis and Kamran (2024).

Bioplastics, made from bio-based materials, have a high potential to be compostable, making continuous technological development, innovation and global support key factors for their commercialization and application (Kumar *et al.*, 2024; Kouchakinejad *et al.*, 2024). Furthermore, various types of microorganisms, both aerobic and anaerobic, photosynthetic bacteria, archaea and lower eukaryotes, are responsible for the decomposition of bioplastics in the soil (Kumaravel *et al.*, 2010; Picho *et al.*, 2024).

On the other hand, biodegradable films, such as those from the Mater-Bi brand, are used in crop production due to their significant agronomic advantages that favor sustainable agriculture. These films are placed around the plants' soil surface, acting as mulches. Their main function is to conserve moisture, regulate soil temperature, control weed growth and optimize soil nutrient utilization, improving crop yields (Somanathan *et al.*, 2022).

Various studies have examined the effects of agricultural coatings on crop protection and harvest performance. According to Esser and Houghton (2008), using plastic mulches has proven effective in reducing water loss and improving growth conditions in areas with high evapotranspiration. However, using conventional plastics poses an environmental problem in the long term, as indicated by Somanathan *et al.* (2022), who highlight soil pollution and public health issues associated with using non-biodegradable plastics. In this context, studies on bioplastics, such as those by Younis and Kamran (2024), suggest that biodegradable materials, like Mater-Bi, could represent a more sustainable alternative, as these plastics degrade quickly and do not harm the environment. However, there are few studies specifically focused on the application of these coatings in the cultivation of Canary beans (*Phaseolus vulgaris*) in the Andean region, which highlights the importance of this research. Given the excessive use of low-density polyethylene (LDPE) by agro-exporting companies in the Callejón de Huaylas and the increasing soil pollution observed in the fields, the following research question was posed: What is the efficiency of the Mater-Bi bioplastic coating compared to LDPE and organic mulch in protecting and performing Canary beans under the conditions of Marcará, Carhuaz and Ancash?

Thus, this study aims to compare the efficiency of three types of quilted (polyethylene, biodegradable Mater-Bi bioplastic and organic kikuyu material) in the protection and performance of the Canary bean crop (*Phaseolus vulgaris*) under the conditions of Carhuaz, Ancash, Peru. In this way, the research seeks to provide evidence that allows farmers in the region to make informed decisions about using more sustainable and efficient agricultural quilted to improve the mulching and yield of the Canary bean crop and the health of agricultural soils in the region.

MATERIALS AND METHODS

Population or universe

This term refers to the agricultural area where the results of this research are applicable. In this case, it encompasses

the inter-Andean valleys of the Peruvian highlands, specifically between 2500 and 2900 meters above sea level, which present agroecological characteristics similar to those of the study area.

Unit of analysis and sample

A single Canary bean plant represented the unit of analysis and the sample consisted of twelve plants per experimental treatment.

This study is a technological investigation, as it aimed to assess the efficiency of the bioplastic coating Mater-Bi (1 meter wide, 15 microns thick and black) compared to the LDPE coating (with the same width, thickness and color) and an organic mulch (kikuyu grass residues), to evaluate the protection and production of Canary beans (*Phaseolus vulgaris*). The research was conducted at a correlational and explanatory level. It was correlational because the goal was to establish a cause-and-effect relationship between the coatings used (independent variable) and the protection and yield of the crop (dependent variables) and it was explanatory. After all, it aimed to explain the effect and efficiency of these mulches on the dependent variables.

Additionally, a completely randomized experimental design (CRD) was employed, with four treatments, including the control and three repetitions; 12 experimental units were used. The surface area of each experimental unit was 1.68 m² (small plots) and a high planting density of 0.60 cm × 0.35 cm (two rows with 6 plants each) was employed, using the "three-seed method" (three seeds per hole). The crop cycle lasted 5 months (from October 2023 to February 2024), starting with gravity irrigation and later, rain provided the required moisture.

The unit of analysis was the individual Canary bean plant (*Phaseolus vulgaris*) and the sample consisted of 12 plants per experimental treatment. This allowed for a representative evaluation of the yield and protection parameters for each treatment (Table 1).

Randomization involves the random distribution of treatments or experimental units (small plots) in each repetition, as shown in (Fig 1).

Data collection techniques and instruments

Various techniques, such as observation, measurement, counting and weighing, were used for data collection in the experimental field. The instruments used were a measuring tape for distance and area measurements, a data sheet for recording obtained data and a balance for weighing the yields. Observation techniques allowed the

Table 1: Treatments and types of coating.

Treatments	Types of Coating
Treatment one (T-1)	No mulch (Control)
Treatment two (T-2)	Bioplastic Mater-Bi, Italy
Treatment three (T-3)	Polyethylene (LDPE), Peru
Treatment four (T-4)	Organic mulch (Kikuyu)

researchers to observe, record and analyze events of interest related to the crops (Fagarasanu *et al.*, 2002).

Data processing

The collected data were analyzed using the statistical technique of Analysis of Variance (ANOVA), with a confidence level of 95%. The goal was to determine whether the treatments had statistically significant differences. Leading to the rejection of the alternative hypothesis concerning bean yield, even compared to the control without mulch. Fig 2 shows the flowchart followed in this research.

Diagnosis of the cultivation area

The environmental and agricultural conditions of the Marcará region, Carhuaz and Ancash are analyzed. This includes the climate, soil type, agricultural practices and plastic pollution, which is crucial for establishing the experiment's foundation.

Experiment setup

Homogeneous plots are selected and properly prepared for planting the Canary beans. The land is conditioned, the appropriate variety of beans is planted and the experimental treatments (LDPE, Mater-Bi, Kikuyo) are randomly distributed.

Application of coverings

After planting, the corresponding coverings are applied: low-density polyethylene (LDPE), biodegradable bioplastic Mater-Bi and organic kikuyo material, ensuring uniform coverage of the plots.

Evaluations through parameters

Periodic measurements assess plant growth, germination, soil moisture, temperature and weed control in each treatment. These data allow for monitoring the impact of the coverings.

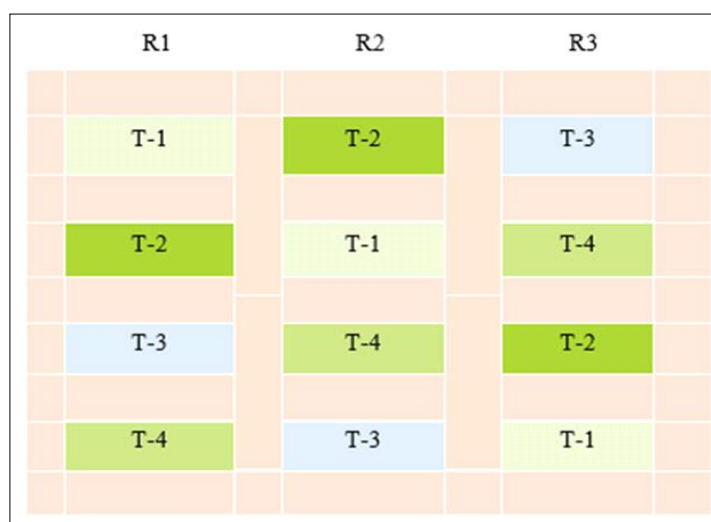


Fig 1: Randomization of treatments and experimental scheme.

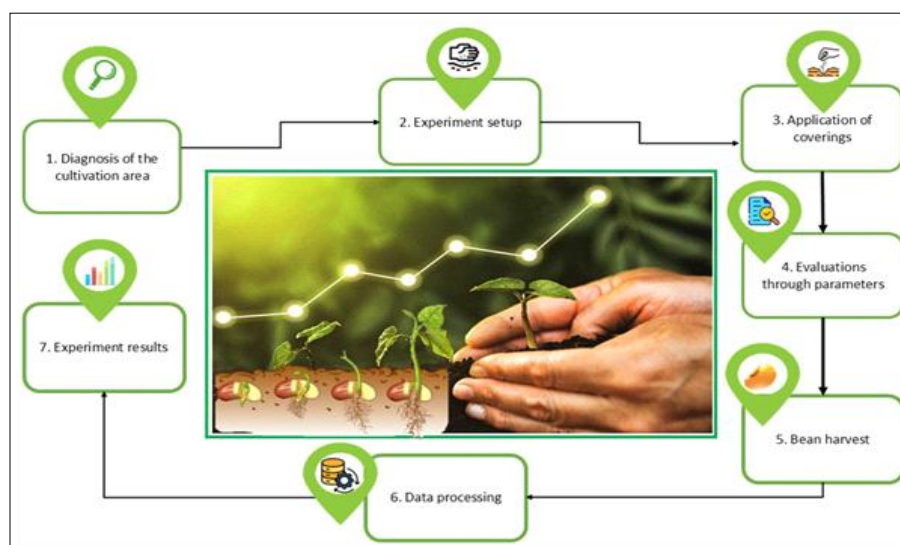


Fig 2: Flowchart of the research.

Bean harvest

The plants are harvested when they reach physiological maturity and the total weight of the harvest from each treatment is measured to assess yield.

Data processing

The collected data is organized and processed through statistical analyses (such as ANOVA) to compare the effects of the coverings on yield, weed control and soil conditions.

Experiment results

The results are presented and the yield and effects of the different coverings on canary beans are compared. Conclusions are discussed about which coating is the most

effective and sustainable in the Carhuaz, Ancash region.

The following figures illustrate the development and analysis of the experiment conducted with the Canary bean crop (*Phaseolus vulgaris*). Fig 3(a) shows the initial diagnosis of the cultivation area, providing an overview of the selected land, which shows contamination from using LDPE plastics. Fig 3(b) illustrates the experiment setup, where homogeneous plots are selected and prepared for planting and the experimental treatments of coverings (LDPE, Mater-Bi and kikuyo) are randomly distributed. Fig 3(c) shows the application of coverings, detailing the application of the different materials: low-density polyethylene (LDPE), biodegradable bioplastic Mater-Bi and organic kikuyo material, ensuring uniform coverage of the plots. Fig 3(d)



Fig 3: Experiments.

presents the periodic evaluations, measuring parameters such as plant growth, germination, soil moisture, temperature and weed control for each treatment. Finally, Fig 3(e) shows the bean harvest process when the plants reach physiological maturity and the yield of each treatment is evaluated based on the total harvest weight.

RESULTS AND DISCUSSION

The use of coverings or mulch in agriculture significantly impacts soil health and plant growth. In the case of legumes such as the canary bean (*Phaseolus vulgaris*), the use of mulch can influence the formation of bacterial nodules in the roots, which are essential for nitrogen fixation. This process allows legumes to convert atmospheric nitrogen into a form that plants can utilize, improving soil fertility.

Crop protection

Regarding crop protection, the parameters of weed presence and the presence of rhizobium nodules in the roots were analyzed.

Weed presence

The number of weeds was determined in the case of the Mater-Bi and LDPE coverings by counting the number of weeds that grew in the 8 cm diameter circular holes made in the films when planting the canary bean seeds. It was observed that the weeds grew around the seedlings. In the case of organic mulch and no mulch treatments, weeds were counted throughout the entire area of the plot. The following results were obtained (Table 2).

According to the evaluation conducted 30 days after planting, it was found that the no mulch treatment was completely invaded by weeds, covering around 90% of the area. In contrast, the treatments with covering presented an average of 6.3 weeds for the Mater-Bi treatment, 5.7 for the LDPE and about 9 weeds in the organic mulch treatment. This shows that the first two coverings have a similar effectiveness in controlling weeds. The weeds appear between the small spaces left in the organic mulch when the entire Kikuyu grass is placed without chopping.

Presence of bacterial nodules

The covering helps retain soil moisture, which favors root development and colonization by beneficial nitrogen-fixing bacteria like rhizobium. These bacteria are responsible for forming nodules in the roots of legumes and their presence has been counted. The results are (Table 3).

The results obtained are compared with the description in the following standard Table 4 of the International Center for Tropical Agriculture (CIAT, 1998).

Table 6: Analysis of variance for canary bean yield (Ton/Ha).

	Sum of squares	gl	Mean square	F	Sig.
Between groups	145,572,917	3	48,524,306	,691	,583
Within groups	561,950,000	8	70,243,750		
Total	707,522,917	11			

Canary bean yield

After harvest, the stages of pod removal, drying and weighing of the harvested canary beans were carried out in grams per experimental unit (g/UE) for each treatment and repetition, with the average in tons per hectare (Ton/Ha) shown in the Table 5.

After obtaining the results related to yield, an analysis of variance was carried out to test the alternative hypothesis, according to which the different coverings have different effects on crop yield. The results are shown in the following Table 6.

It can be observed that, for a 5% significance level, where $p > 0.05$ indicates that the p-value is greater than 0.05, meaning that the alternative hypothesis is rejected

Table 2: Number of weeds per treatment.

Repetitions	Treatments			
	No Mulch	Mater-Bi	LDPE	Organic
R1	Many	7 units	4 units	8 units
R2	Many	6 units	6 units	10 units
R3	Many	6 units	7 units	9 units
Average	Covers 90%	6,3 units	5,7 units	9,0 units

Table 3: Number of bacterial nodules per plant.

Repetitions	Treatments			
	No mulch	Mater-Bi	No mulch	Organic
R1	25	40	40	60
R2	10	50	30	54
R3	48	60	30	65
Average	27,7	50,0	33,3	59,7

Table 4: Description of the number of nodules.

Scale	Number of nodules	Denomination
4	Greater than 100	Very abundant
3	from 50 - 100	Abundant
2	From 10 - 50	Median
1	from 1 - 10	Few
0	0	None

Table 5: Average dry weight of canary bean.

	R1	R2	R3	Average (g/UE)	Average (Ton/Ha)
T-1	790	545	1 070	801,7	4,30
T-2	920	1 160	1 090	1 056,7	5,66
T-3	640	820	890	783,3	4,08
T-4	680	690	1420	930,0	4,80

and the null hypothesis (H_0) is accepted. This suggests that there are no significant differences between the mean values of the four treatments, indicating that the different coverings do not present statistically significant differences in their effect on the canary bean yield, even when compared to the control treatment without mulch.

In Fig 4, the boxplot related to the yield is shown. It can be seen that the treatment with the Mater-Bi covering has a slightly higher yield, followed by the organic mulch

treatment, then the no mulch treatment and lastly, the LDPE treatment; however, the differences are not significant.

This section analyzes the comparison between the four treatments: T-1, without mulch (control group); T-2, Mater-Bi bioplastic, supplied by a project partner company based in Italy; T-3, polyethylene (LDPE) made in Peru; and T-4, organic mulch. According to Zribi *et al.* (2011), LDPE plastic films are the most commonly used due to their low cost, but their intensive use is causing soil pollution

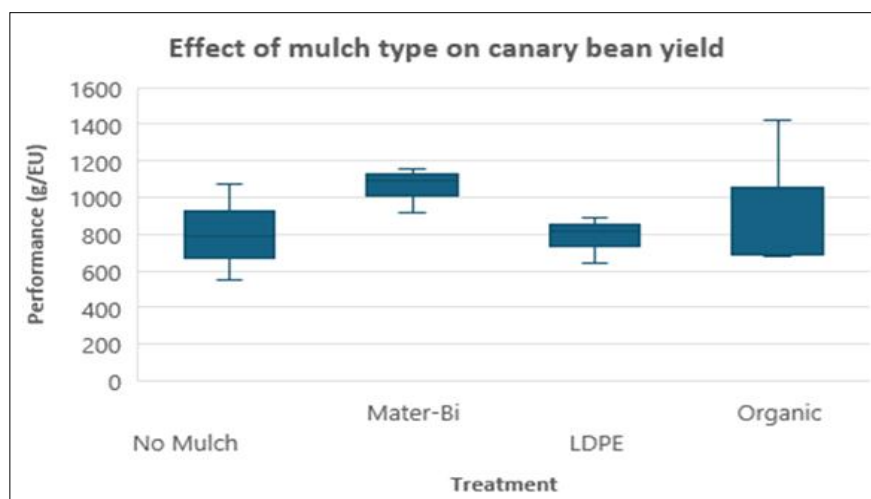


Fig 4: Simple boxplot of yield (g/EU) by type of mulching.

Table 7: Comparison of results with previous research.

Evaluated aspect	Results from the present research	Results from previous research	Reference
Weed presence (5 th week)	90% weeds in T-1 (without mulch) and proper control in T-2, T-3, T-4 infestation in T-2 and T-3.	The use of biodegradable mulches controls weeds, showing low	(Zribi <i>et al.</i> , 2011); (Lamont, 2017)
Plant condition (6 th week)	Yellowing leaves in T-1 (chlorosis)	Plants with mulch do not show chlorosis, indicating better nutrient absorption.	(Zribi <i>et al.</i> , 2011)
Rhizobium nodules (Average per Plant)	T-1: 27.7 nodules; T-2: 50.0 nodules; T-3: 33.3 nodules; T-4: 59.7 nodules	Organic mulch and Mater-Bi favor nodule formation, with more nodules. in organic mulch	(Bhatnagar, 2024); (Biswas <i>et al.</i> , 2025)
Bean yield (Ton/Ha)	T-2: 5,66 Ton/Ha; T-4: 4,80 Ton/Ha; T-1: 4,30 Ton/Ha; T-3: 4,08 Ton/Ha	Biodegradable mulches, especially Mater-Bi, show improvements in crop yield, although without significant differences compared to the control.	(Somanathan <i>et al.</i> , 2022) (Sellami <i>et al.</i> , 2024)
Environmental impact (Pollution)	High pollution in T-1 (non-biodegradable plastic)	Biodegradable and organic mulches have a lower environmental impact compared to conventional plastics.	(Moreno <i>et al.</i> , 2009); (Briassoulis, 2006)
Residue removal cost	High removal cost for T-3	Biodegradable and organic mulches have lower removal costs due to their faster degradation.	(Moreno <i>et al.</i> , 2009)
Crop protection	Greater protection in T-2 and T-3 against weeds, moderate in T-4	The use of biodegradable and organic mulches improves weed control and promotes healthy growth.	(Lamont, 2017); (Briassoulis, 2006)

because of the high stability and persistence of the residues. Therefore, this plastic is progressively being replaced by other biodegradable alternative materials.

In the Callejón de Huaylas region, exporting companies for strawberries, blueberries and other crops currently use these polluting plastics, likely affecting the surrounding environment. Lamont (2017) states that mulches can also have disadvantages, such as environmental risks caused by some non-biodegradable plastic mulches, whose residues can contaminate the fields where they were applied. Other authors, such as (Briassoulis, 2006), share similar opinions.

The use of plastics poses a serious landscape impact problem due to their slow degradation, persistence in the field and the potential for soil contamination. The cost of removing plastic residues is very high (Moreno *et al.*, 2009), which is why using biodegradable materials has great potential.

Degradation can be biological (through bacteria or other biological agents) or through solar radiation. Below, Table 7 compares the results obtained in this research with those found in previous studies on the use of different types of mulches for bean cultivation. Key aspects are analyzed, such as weed presence, plant condition, Rhizobium nodule formation, bean yield, environmental impact, cost of residue removal and crop protection.

As shown in the table, the results obtained in this research largely coincide with those from previous studies. Regarding weed presence, organic mulch (T-4) and Mater-Bi bioplastic (T-2) proved to be the most effective, similar to what was reported by (Zribi *et al.*, 2011) and (Lamont, 2017), who highlighted that biodegradable mulches effectively control weeds. In terms of bean yield, although T-2 (Mater-Bi) showed the highest yield, no significant differences were found, which is consistent with the findings of (Somanathan *et al.*, 2022), who also indicated that biodegradable mulches may slightly improve yield without being statistically decisive.

CONCLUSION

The Mater-Bi and LDPE treatments showed similar efficacy in weed control, with averages of 5.7 and 6.3 weeds per plant, respectively. The organic mulch (Kikuyu residues) was less efficient (9.0 weeds/plant) due to the gaps between leaves that facilitated weed emergence. This suggests that both bioplastic and polyethylene are effective in reducing weed competition in the canary bean crop.

In terms of nodulation, the organic mulch had the highest number of Rhizobium nodules (59.7 per plant), followed by Mater-Bi (50.0) and LDPE (33.3), far exceeding the control (27.7). These results indicate that mulches favor nodule formation, especially organic and bioplastic. Regarding crop yield, no statistically significant differences were observed between treatments. Mater-Bi reached 5.66 Ton/Ha, followed by organic mulch (4.80), control (4.30) and LDPE (4.08), indicating that the different mulch types

did not significantly affect productivity.

Finally, Mater-Bi demonstrated comparable performance to polyethylene in weed control and nodulation. Its additional benefit of being biodegradable makes it a more sustainable alternative. However, long-term studies are recommended to evaluate its impact on soil, microbial biodiversity and profitability for growers. Future research should consider other types of bioplastics, different crops and diverse agroecological conditions.

Conflict of interest

All authors declare that they have no conflict of interest.

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