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Review

Sustainable Potato Growth under Straw Mulching Practices

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Abstract: Extreme heat, droughts, pests, diseases, and short bursts of heavy rain make potato production unsustainable. This unfavorable environment negatively affects potato productivity and yield levels. Within the next few years, conditions will likely deteriorate even more. In potato cultivation, straw mulching has been shown to increase yields by promoting the growth of beneficial bacteria in the soil. Mulching improves soil humidity, decreases transpiration, and cools the soil in dry and hot regions. There is a global decline in potato yields per hectare due to poor nutrient management, moderately humid years, and high disease pressure caused by *Phytophthora infestans* and *Alternaria species*. Farmers must take cultivation measures to achieve economic efficiency and adequate yields. A range of practices contributes to better potato yields and productivity, such as the use of appropriate fungicides, planting high-yielding varieties, and increasing row spacing. These practices complicate cultivation and affect profits. Furthermore, inorganic nitrogen in the soil regularly causes acidification, eroding soil fertility. As a result of land preparation, straw residues from rice and maize are collected from the field and destroyed or burned, which depletes nutrients and pollutes the air. Returning these residues to the soil, however, can improve its quality. Integrating rice and maize straw mulching into potato cultivation practices can enhance agricultural sustainability, productivity, and yield. This review will focus on using rice and maize straw mulching in cultivating potatoes. Straw mulching promotes sustainable potato growth, increasing productivity and quality while minimizing reliance on chemical inputs. Such practices can mitigate the need for synthetic fertilizers to enhance sustainable agriculture, ensure long-term growth, improve soil health, increase yields, and promote sustainable agriculture.

Keywords: potatoes; mulching; rice; maize; soil fertility; sustainability; straw

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1. Introduction

The potato (*Solanum tuberosum* L.) is the world's most abundant food crop, producing 371 million tons on 18 million acres in 2019 [1]. Potato tubers contain vitamins B3, B6, and C and starch and polyphenols. According to United States Department of Agriculture (USDA) statistics, approximately 99 million metric tons (MMT) of potatoes were produced in China in 2020/21, a 3% increase from the estimated 96 MMT produced in 2019/20 [2]. Potatoes occupy 36% of the total farmland in northwestern China, making them the essential tuber crop [3]. Approximately 60% of China's potato production is eaten directly, 10% is processed, 12% is the seed, 5% is food, and 13% is lost during storage, according to a report by the U.S. Department of Agriculture [4]. There is a relatively low yield of fresh potatoes per hectare in China compared to the United States and New Zealand [5] due to drought [6], disease, and pest infestations. As measured by an average tuber yield per hectare, China's yield of fresh potatoes is 64.84% and 64.44% lower than that of the United States and New Zealand, respectively. Since potato grows in temperate climates, high atmospheric temperatures (mean temperature > 17 °C) limit tuber growth and production. The potato is, therefore, grown exclusively during the winter season (November–March) [7]. However, the limited soil moisture availability prevents profit-making crops from being grown globally during the winter. High temperatures negatively affect potato growth and yield significantly when the mean temperature exceeds 17 °C [8]. A high-temperature delays or prevents tuber formation in most cases, with the formation of tubers rarely occurring above 30 °C. Potatoes are grown in countries with temperatures between 15 and 18 °C and ample rainfall or irrigation during the growing season. Organic farming differs from conventional agriculture in not using synthetic chemicals [9]. There is no doubt that plant protection issues are the most significant problems encountered in organic potato production. Developing a rotation plan and placing the potato crop in the rotation is critical to growing organic potatoes. The rotational design prevents crop diseases and pest outbreaks [10]. Potato yield decreases by 15% over time if cropping frequency is increased to one-third of the rotation, primarily because of nematodes [11].

As straw mulching techniques can be used to increase soil moisture retention, control weeds, improve soil structure, and preserve nutrients for the cultivation of potatoes, this offers a significant opportunity for sustainable cultivation [12]. In addition to enhancing root growth, straw mulching facilitates nutrient absorption and improves the plant's overall health, all of which increase potato production [13]. It has been shown that the progressive breakdown of straw mulch results in more organic matter being incorporated into the soil, improving soil fertility and boosting microbial activity [14]. To promote sustainable potato farming, it is imperative to conduct scientific research to determine the most effective rates, timing, and environmental suitability of straw mulching techniques [15,16].

A conceptualization and understanding of organic farming require consideration of its objectives and practices. In organic farming, we aim to create agricultural ecosystems that mimic natural ecosystems [17,18]. Mulching the soil and green manuring can create a permanent cover for the soil, along with intercropping, mixed crops, and relay crops. Mulch is essentially dead organic material applied to soil to cover it with dead organic matter. In contrast to covering the soil with live companion plants, mulch does not negatively affect the crop. Increasing soil organic matter and preventing soil erosion are two benefits of mulching [19,20].

As organic material sources, rice and maize straw have great potential. Due to the increased productivity and quality of rice and maize mulching during potato cultivation, a product that, until now, has been highly dependent on chemical inputs can be made more productive by using these inputs [21,22]. Mulching is economically advantageous because compost's high potassium content can replace costly commercial potassium (K) sources, such as KCl [23]. Consequently, the use of pesticides can be drastically reduced while mulching application is practiced. As a result of reducing the number of agrochemicals used, after implementing integrated organic farming, pesticide concentrations will be reduced annually [24].

Using straw mulch reduces the transmission of viruses transmitted by aphids. Potatoes are a valuable crop in organic agriculture, but their vegetative propagation makes them susceptible to several diseases [25]. Due to these factors, virus diseases transmitted by aphids can seriously reduce yields. From an agronomic and plant protection perspective, this review describes and evaluates the application of straw mulch to organic potatoes. Mulching with straw is more labor-intensive in the early summer but may add organic matter to the soil over the long run [26].

In northeast Indian potato crops, $CaSO_4$, $ZnSO_4$, farm yard manure, and straw mulch are utilized to protect against high temperatures [27,28]. The implementation of integrated soil management increases soluble sugar content, chlorophyll content, and superoxide dismutase activity, leading to increased tuber bulking rate and yield. A similar conclusion was reached in a previous research, which suggests that $CaSO_4$, $ZnSO_4$, farm yard manure and straw mulch mitigate the effects of high temperatures on potato growth [29]. In addition to improving the membrane integrity, chlorophyll content, total soluble sugars, and superoxide dismutase activity of the soil, this soil management strategy increases its fertility. Straw mulching has been shown to improve potato yields, sustainability, and farm productivity even beyond temperature reductions. To match our study objectives and aims with the literature, this review will focus on (1) determining how rice and maize straw-based compost affect potato production, (2) ensuring that compost-based farming of potatoes without inorganic fertilizers is a basis for organic farming, and (3) examining the pros and cons of straw mulching as a sustainable potato-growing method.

2. The Growing Trend toward Organic Potato Practice

There is a significant economic and social impact associated with organic potato farming. This is especially true when the potatoes are directly sold to consumers [30]. Several features of organic potato farming make it distinctive, including plant protection, rotational design, seed and tuber preparation, and weed control. Growing organic potatoes presents the most significant challenge in terms of plant protection [31]. An organic crop production system emphasizes management practices that promote biodiversity, the biological activity of the soil, the use of minimal off-farm inputs, and the restoration of ecological harmony. There was a significant increase in organic potato production in the United States between 2008 and 2016. Organic potato acreage doubled from 8000 to 17,000 acres between 2008 and 2016, and organic potato sales increased fivefold, from $30 to $150 million. [32,33]. There are several factors that affect the quality of potato tubers. For potato plants to grow, develop, yield, and produce high-quality tubers, nitrogen is essential. A major difference between conventional and organic potato production is the nitrogen source and form.

To ensure growth, potatoes must be rotated and planted in organic agriculture. In addition to preventing crop diseases and pest outbreaks, rotational farming increases yields. It is estimated that nematodes affect 15% of rotations, which results in a decline of one-third in potato yields [34]. In addition to controlling potato wart (*Synchytrium endobioticum*), late blight (derived from oospores), and tobacco rattle virus (derived from nematodes), short cropping breaks can also be beneficial. Cropping seed potatoes once is recommended at a maximum frequency of 20%, i.e., once every five years [35]. In Britain, organic farmers grow potatoes less than once every four years. It is recommended to plant legumes as pre-crops for potatoes to improve soil structure, make it friable, and increase organic matter degradation capabilities. In contrast to grain legumes, grass-legume mixtures (leys) are assessed as the efficient and suitable pre-crop for a high-yield potato crop. Grass-clover leys grown for one year vs. two years showed variable results [36].

In organic potato farming, pre-sprouting is recommended before planting; this measure aims to avoid late blight by seedling development before planting [37]. *P. infestans* terminates vegetation early, resulting in a 12–28% yield increase in years with pre-sprouting before sprouting [37]. Pre-sprouting is also recommended as an additional control measure against *R. solani* [38].

When growing organic potatoes, weed control is typically implemented in two stages: in the early stages of planting, harrowing (chain) and re-ridging (again) twice, and in the later stages when the plants are grown [39]. Besides killing weeds, re-ridging also breaks up soil crusts that prevent soil aeration, builds stable ridges with more potato roots, and prevents potatoes from greening. As a consequence of late blight infections, which drastically reduce competition between potato plants for light, water, and nutrients, in late summer, weed levels are often high; high weed levels can impede harvest and, therefore, weeds and haulm are cut off before harvest, or sometimes hand weeding is performed [40]. Seed tubers are used to propagate the potato crop vegetatively. Whether the tubers are produced organically or conventionally differs from the production of potatoes for human consumption and industrial purposes. Producing seed potatoes has many peculiarities, notably narrowing size limits and controlling tuber-transmitted viral diseases [41].

3. Agronomic Effects of Straw Mulch in Potatoes

Understanding how straw mulch application affects agronomic parameters, especially yield, is crucial before it is adopted in practice. First, we will examine the abiotic requirements for potatoes, followed by a description of cereal straw properties and their use. Finally, we will summarize the known soil effects of mulches.

3.1. Growing Potatoes Requires Abiotic Conditions

Frost, heat, and drought are among the stresses that potato plants may encounter [42]; tubers are damaged below −1°C to −3 °C (the daily mean temperature at 2 m height) and above 29 °C; optimum temperatures for fermentation are around 17 °C [43]. It is recommended that the water holding capacity be 60–80% of the available water. Potato yield responses to soil texture are weaker than those of other crops (e.g., rye). The potato can be grown on various soil types, and only clays or sands with high moisture content reduce yield [44]. Water availability is crucial on lighter sandy soils. If potatoes are grown on clay soils, their quality parameters will be negatively impacted, while they benefit when grown on sandy soils. As for soil structure, potatoes do not tolerate crusty soil and need friable, loose soil that warms quickly [45].

3.2. Straw Properties, Yield and Uses

Research shows that wheat and rye straw have average yields (5.5 t ha^{-1} dry matter) when temperate climate conditions prevail. In comparison, summer wheat (4.5 t ha^{-1} dry matter) and winter barley (4.0 t ha^{-1} dry matter) have lower yields when temperate climate conditions prevail [46]. Recent figures indicate that winter wheat yields have increase considerably over the last few decades, ranging from 7.0 to 9.0 t ha^{-1}. A three-year experiment with 20 varieties of wheat straw showed yields between 5.2 and 7.2 tons ha^{-1} for organic farming [47]. Most of the straw used in animal husbandry is used for bedding, binding dung, and occasionally for fodder [48]. It was found that three-quarters of all straw consumed in Germany in 1974 was used for this purpose, while 20% of the remaining material was incorporated into the soil and 5% was burned. The law currently prohibits burning straws on the field [49,50].

While cereal straw has low nitrogen content (0.4% dry matter), it contains high levels of carbon, leading to a high C/N ratio of between 85 and 100 (summer barley, as well as rice and maize) [51]. A cereal straw can have K content of 1.0 % (in rice) to 2.5 % (in maize) and a P content of 0.07–0.17% [52]. The dry organic matter in straw is primarily organic, with cellulose accounting for about 45 percent, and lignin for 15–18%. Additionally, it is estimated that straw contains between 3–5% SiO_2 as dry matter [53].

In a study, 55 winter wheat varieties and 25 summer wheat varieties were evaluated for physical and structural properties. On average, it was found that winter wheat straw was 95 cm long, and summer wheat straw was 89 cm long. These straws had a total weight of 1.6 g and 1.3 g and a diameter of 3.5 and 3.1 mm, respectively [54]. Winter wheat grown organically grew to a length of 90–110 cm. Despite its small size, straw holds a lot of water, with a capacity of about 200% its weight [55].

There are several factors that affect the speed of nutrient release from straw so that it can be utilized by the potato crop. These factors include soil pH, air temperature, soil moisture, straw C/N ratio, and soil aeration [56]. There is a range of time between 2 and 10 weeks for straw mineralization, which impacts how nutrients are utilized by potatoes [57]. It has been found that potassium (K) is released from straw at a higher rate than phosphorus (P) and nitrogen (N). Consequently, the type of straw used for potato mulching must be considered when determining the optimal timing [58]. A study has been conducted to investigate whether silicon (Si) in grass straw could decrease plant diseases [59]. The release of silicon from straw may impact the time that other vital nutrients undergo mineralization [60]. As well as its mineral composition, straw's effectiveness as a mulch can be influenced by its composition. It is possible that a high mineral content straw will negatively affect the soil's pH and nutrient balance, while a low mineral content straw may not provide sufficient nutrients for a potato crop [61]. When determining the optimal time frame for mulching potatoes with straw, it is crucial to consider the straw's diversity and mineral composition [62]. Straw mulching techniques can help farmers increase the sustainability of potato farming by carefully analyzing these factors.

3.3. Economic Costs and Benefits of Mulching for Potato Production

The costs and benefits of synthetic chemicals, fertilizers, and mulches are always considered before they are used. In terms of soil health and crop performance, mulching materials are not as expensive as other, synthetic materials. Mulches can eliminate the need for pesticides [63] or other methods used for weed control. It was found by different researchers that mulching practices had significant effects on the cost of cultivation, gross monetary returns, net monetary returns, and benefit-to-cost (B:C ratio) ratios during two years of potato crop experiments [64,65]. In potato crops, mulching practices have a significant impact on economic parameters. As a result of straw mulching, the cost of cultivation, gross monetary returns, net monetary returns, and benefit–cost ratio are significantly higher than with unmulched cropping [66].

3.4. The Composition of Different Types of Mulches and Their Role in Potato Growth and Development

The application of mulch can enhance agricultural productivity by augmenting crop yields, mitigating water loss, and suppressing weed proliferation [67]. Potato farming utilizes various mulches, including organic, synthetic, and inorganic variants. Various mulches, such as those derived from plant leaves, straw, and wood, can decompose and enhance soil quality. Additionally, they offer a protective function during the decomposition process, as outlined in Table 1. The application of wood chip mulch aids in retaining soil moisture and serves as a barrier against the proliferation of weeds [68]. Using organic mulches creates a favorable habitat for soil organisms, particularly earthworms, thereby augmenting the microbial activity within the soil and averting compaction [69]. Organic mulch can mitigate the impact of early frosts and weed competition for light, nutrients, and water on potato plants.

Table 1. The composition of various mulches and their role in the development of potatoes.

Types of Much	Role	Composition	References
Straw mulch	Straw mulch is inexpensive and offers decent defense against frost, weeds, and soil erosion while being easy to apply. Because it is an insulator, the straw ensures the soil stays warm during winter and cool during summer. Additionally, it helps retain moisture, which is essential for the growth of potatoes.	The dried stalks of wheat, oats, or rice are the primary components of straw mulch.	[70,71]
Compost mulch	Compost is a good mulch for potatoes since it enriches the soil. Compost mulch enhances soil quality, lowers soil erosion, and aids in moisture retention. It is made up of degraded organic materials.	Organic waste, such as food scraps, leaves, and yard clippings, is broken down into a nutrient-rich soil supplement.	[72,73]

Table 1. *Cont.*

Types of Much	Role	Composition	References
Leaf mulch:	Rich in nutrients and organic matter, leaf mulch is an excellent choice for potatoes. Leaf mulch helps retain soil moisture, improves soil aeration, and inhibits vegetation growth. It consists of decomposing foliage.	It is produced by stacking dried leaves and permitting them to decompose over time.	[74]
Hay mulch	Hay is another popular potato mulch. It helps maintain soil moisture and inhibits vegetation growth.	Hay mulch is composed primarily of dried grasses and is simple to apply.	[75]
Wood chip mulch	Wood chips, a frequently employed mulching material for potatoes, offer exceptional moisture retention, weed inhibition, and enhancement of soil composition.	These products are composed of fragmented wood chips.	[76]

4. Straw Mulching and Soil Health

4.1. Straw Mulching and Soil Properties

Straw mulch has been reported to increase soil moisture [77]. Mulched soils retain up to 6% more moisture than unmulched soils (top 30 cm). Typically, mulched soils retain 2 to 3 percent more moisture (Figure 1). It has been found that mulch increases soil moisture for two main reasons: (1) improved infiltration [78]—as a result of the mulch intercepting raindrops, the soil becomes less compacted and pore sealing is increased; (2) reduced evaporation, or better moisture conservation. Many studies have shown that shading significantly influences evaporation control [79,80]. The effect of straw mulch on evaporation decreases as the amount of straw is increased, i.e., the effectiveness of straw applications at already light weights is almost the same as that of heavier applications [80].

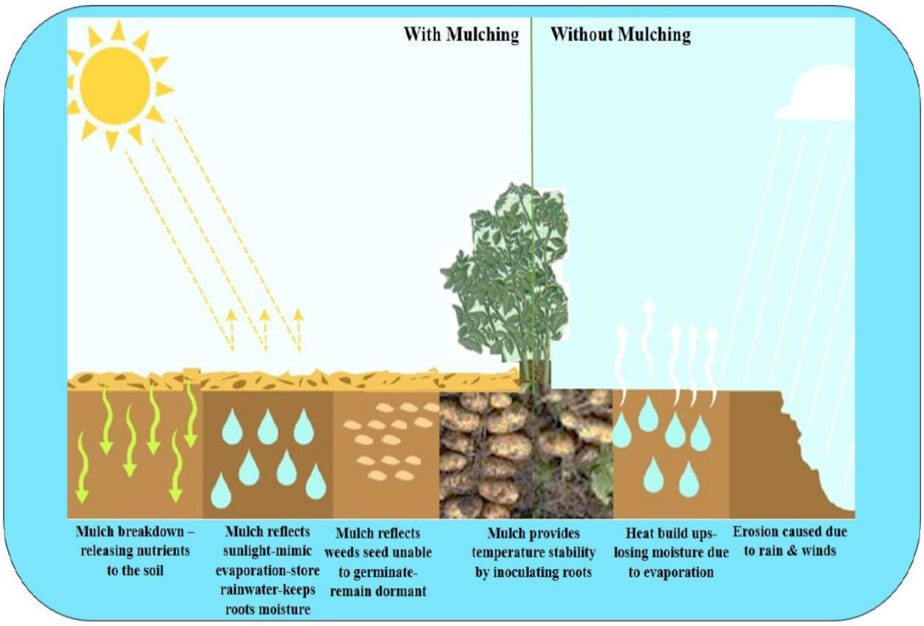

Figure 1. Mulching can dramatically increase soil nutrition and stop the weed population, as it prevents sunlight from reaching the seeds. By reducing evaporation, it protects plant roots against temperature fluctuations and retains moisture in the soil. As a result, wind and/or rain erosion can be reduced (or prevented).

In addition, mulch suppresses weeds and reduces evaporation (Figure 1). Straw has a higher albedo than covered soil, which lowers surface temperatures, and mulch increases dew formation [63]. Increasing soil moisture decreases soil depth, i.e., it is most apparent in the upper layers of soil. A second critical condition that influences the effect of mulch on soil moisture is the amount of rainfall: Since mulch intercepts precipitation and causes it to evaporate before it reaches the soil, it has the most significant effect when rainfall is low [55].

In several studies, straw mulch has been shown to stabilize soil temperatures. Increasing soil temperature under straw mulch in winter [81] or mimicking soil temperatures in winter decreased average and maximum soil temperatures in summer by 1 to 6 K [67]. Under heavier mulches, soil temperatures will decrease more than under lighter mulches [82]. A decrease in temperature differences between mulched and unmulched soil occurs during the season, even though straw darkens [83].

It has been demonstrated that straw mulch reduces runoff and soil erosion. To combat soil erosion, straw mulch decreases runoff, decreases runoff velocity, inhibits rill formation [84], increases infiltration [62], and minimizes the impact of raindrops on the soil, thereby reducing aggregate soil breakup [85]. After conducting a series of experiments with straw, it was concluded "Water flow over the surface plays a lesser role in erosion-causing than raindrop impact" [86]. The mulch was mainly responsible for eliminating raindrop impact (Figure 1).

4.2. Straw-Mulched Soil Chemical Properties

According to some early studies, mulched soil has a lower nitrate concentration than unmulched soil [87]. Similarly, silt loam soil tested under mulch (8 tons/acre) had lower nitrate levels than straw-covered soils [88]. In addition, straw mulch may indirectly alter soil nitrate levels during the growing season (Figure 1). In either case, soil nitrate content increases or decreases based on soil moisture or temperature. Straw's high C/N ratio can immobilize soil nitrogen, making soil nitrogen unavailable for microbial activity [89]. A common practice on arable farms is to incorporate straw into the soil after the harvest of cereals. In addition to increasing soil organic matter (slight increase of 0.2% after one year), straw mulch has been shown to increase soil fertility on a short-term basis as well [90].

4.3. Straw Mulching and Soil Biota

Straw mulch has been shown to benefit a variety of soil biota. Evidence shows that the earthworm populations increased under straw mulch [91]. Mulch protects the soil from excessive desiccation by providing readily available food for earthworms. Consequently, earthworms consume straw, reducing its thickness. In both straw-mulched and unmulched potato fields, soil samples were taken and analyzed for soil fauna, but it was not specified how much straw was applied, and the sampling dates varied [92]. The effects of straw mulch on soil are summarized as (1) an increase in soil moisture, (2) a decrease in soil temperature, (3) a dramatic reduction in runoff and erosion, and (4) a moderate increase in organic matter. The effects of straw incorporation on soil nitrate levels vary depending on the soil temperature and moisture; nitrogen immobilization increases earthworm activity and other soil biotas.

The Effect of Straw Mulching on Soil Microorganisms

Research has demonstrated that the utilization of straw mulching has a substantial influence on the microorganisms present in the soil [93]. Straw mulching significantly increased soil microbial biomass and activity [94]. On the other hand, a researcher concluded that the augmentation in microbial biomass was ascribed to the supplementary carbon and nutrients supplied by the straw, thereby promoting the proliferation of microorganisms [95]. Furthermore, the application of straw mulching resulted in an augmentation of the variety of soil microorganisms, potentially contributing to establishing a more robust and enduring soil ecosystem [96]. The rationale is that heterogeneous microbial populations exhibit the enhanced capacity to execute various tasks, including but not limited to nutrient circulation and pathogen inhibition, which are critical for preserving soil well-being [97].

Nevertheless, it should be noted that specific research endeavors have failed to demonstrate favorable impacts of straw mulching on soil microorganisms [98]. Furthermore, previous research has shown that mulching straw did not significantly affect soil microbial activity or biomass [99]. The observed incongruity could be attributed to variations in the experimental methodology or external factors such as climatic conditions and soil composition [100]. However, the literature indicates that straw mulching can significantly impact soil health by fostering microbial growth and diversity [101]. Consequently, this can result in enhanced soil fertility, efficient nutrient cycling, increased water-holding capacity, and crop productivity.

5. Nitrogen Dynamics, Weeds, Yield, and Soil Erosion in Organic Potatoes with Straw Mulch

The application of straw mulch reduced disease activity in a variety of crops, including lupins and rapeseed [102]. The seed potato industry, where tuber-transmitted viruses remain a significant problem, has adopted this approach [103]. Cereal straw mulch for potatoes growing in parts of North America was widespread several decades ago. Straw mulch was recognized as a helpful anti-degeneration tool. Seed potatoes were sprayed for virus control, but straw mulch in potatoes became obsolete when its function to increase soil moisture was replaced by sprinkler irrigation, and herbicides were used to suppress weeds. Due to this shift, many beneficial effects of straw mulch were lost, including reducing soil erosion [104].

Despite straw mulch being able to affect tuber yield, its impact has been variable. Different climatic conditions may have contributed to this variation (Figure 1). Despite increased yields from straw mulch under hot and dry summer conditions [50], straw mulch has also been reported to reduce yields in some cases. This was attributed to below-optimal soil temperatures, low nitrate levels in the soil, and mulching too early [105]. Historically, high application rates (10 t ha^{-1} and more) have been associated with yield reductions in cooler climates. Applying more mulch improved soil moisture and temperature [106]. There is no doubt that straw mulch is incredibly effective in preventing soil erosion as well as controlling viruses. A significant reduction in erosion (80% or more) occurs even when cotton straw is used in quantities of 1.5 to 2.5 t ha^{-1}, leaving part of the soil uncovered [107]. Potato virus Y (P.V.Y.) and aphid infestation in potatoes were consistently reduced when straw was added in small to moderate amounts (3.5 to 5 t ha^{-1}).

Consequently, small to moderate amounts of straw should be applied under temperate climate conditions, where soil moisture rarely restricts potato growth. By doing so, the risk of reduced yields in cool or wet growing seasons will be minimized. This method was evaluated over three years by 11 field experiments conducted at two German sites. In both fields, straw mulching increased yields by 2.5–5 t ha^{-1}. During organic potato growing conditions, straw mulch was quantified to determine its effectiveness in preventing soil erosion [108].

6. Potato Diseases and Straw Mulching

The production of potatoes can be seriously hindered by a wide variety of pre- and post-harvest diseases, even under conventional farming conditions. In organic potato production, disease management is a serious problem as it is influenced by the crop physiology and nutritional availability that confer a plant's ability to withstand disease stress. *P. infestans*, the fungus that causes late blight, is likely the most common cause of ware potato diseases [109]. Many diseases and pests are responsible for high economic losses in organic ware potatoes, including black scurf (*Rhizoctonia solani*), *Alternaria solani* (early blight), silver scurf (*Helminthosporium solani*), bacterial diseases such as soft rot, blackleg (*Erwinia carotovora*), common scab (*Streptomyces scabies*), Colorado potato beetles (*Leptinotarsa decemlineata*) and their larvae (*Agriotes specie*), potato cyst nematodes as well as

Globodera rostochiensis and *G. pallida* [110]. The use of straw for potato growing in North America dates back to the 20th century [111], but today it is almost unheard of in commercial agriculture. Experimental evidence suggests straw mulch may improve commercial potato growing in several important ways, both from an environmental and economic perspective, due to its demonstrated ability to reduce soil erosion [15]. In addition, straw mulch has been shown to prevent virus transmission to seed potatoes [112]. Moreover, straw mulch can control nitrogen losses by immobilizing soil nitrate after harvest [113].

6.1. Microclimate

As a result of its ability to reduce evaporation, straw mulch can increase soil moisture. This effect appears responsible for the lower daytime air humidity and higher temperatures following mulching [114]. In contrast, straw-mulched soil had a higher nighttime temperature than unmulched soil [115], which may explain the higher nighttime relative humidity in mulched plots. A further benefit of mulching is that it reduces relative humidity at night as the air temperature is lower, due to increased air humidity [116]. There may also be a higher extent of dew formation as a result of increased air humidity [117].

6.2. Late Blight

A high-humidity environment is crucial to developing infections with *P. infestans* [118]. Despite the higher likelihood of infection at night than during the daytime, there was no increase in disease severity when mulched potatoes had a moister nocturnal microclimate. However, there was a general reduction in disease following mulch application, although this was not significant when the experiments were considered separately [119]. Due to the prevailing weather conditions (frequent and heavy rains), straw mulch may reduce disease severity by interfering with rain splash dispersal. Compared to the other varieties used in this experiment (e.g., Nicola) with an upright plant architecture [120], Christa tended to "lay down" more than the other varieties used. Therefore, rain splash dispersal may be more critical for horizontal varieties. The straw mulch may have impeded the spread of late blight due to its ability to reduce raindrop impact on the soil [121].

Additionally, mulched and unmulched plants have different nutritional statuses, which may influence late blight severity. Potato leaves' nitrogen content positively affects *P. infestans* [122]. Even though there is no direct evidence that straw-mulched potatoes have lower nitrogen content in their leaves [123]. Additionally, a previous research conducted with Hydro-N-Tester, straw mulched plants were found to be less dark green (more yellow) than control plots, indicating that late blight susceptibility may have decreased [124].

6.3. Black Scurf

The occurrence of black scurf depends on several factors, such as the amount of humus in the soil, the level of weed infestation, and the amount of straw used in the pre-crop [125]. In addition, antagonists in the soil, such as *Verticillium biguttatum*, highly influence disease levels [126]. Even though straw mulch is known to influence soil physical and chemical parameters and soil microbial populations, black scurf is unaffected by straw mulch [127].

The fungus *R. solani*, which survives on plant debris over winter in arable fields, may benefit from straw incorporation into the soil after wheat harvest, increasing the risk that emerging potatoes will become infected [128]. It is, therefore, not recommended to incorporate straw into the soil after winter wheat harvest on arable farms with potato crops. Using straw mulch after the emergence of potatoes is, therefore, considered a strategy to combine plant protection (for *R. solani*) with the closed cycle principle (for soil organic matter) [129]. For a cultural technique such as straw mulch to be accepted, late blight and black scurf neutralized in this study are critical factors.

7. Advantages and Disadvantages of Mulches

Mulching covers the soil's surface with organic or inorganic material to retain moisture, prevent weed growth, and boost soil fertility. Various materials, such as leaves, grass clippings, wood chips, straws, and plastic sheets, can be used for mulching [74]. It assists with soil moisture retention, temperature control, weed control, and the addition of beneficial organic matter [75]. However, some mulches may not degrade as expected and may build up on the soil's surface over time, impairing plant growth and luring pests like slugs and rats, as shown in Table 2. Gardeners can take precautions like rotating different types of mulch every year or installing a protective layer of hardware cloth underneath the mulch to avoid these downsides.

Table 2. Advantages and disadvantages of mulches.

Advantages	Disadvantages	References
Mulches help plants get a head start by keeping the soil toasty and retaining heat from the sun. Compared to crops produced without mulch, those grown on it are ready for harvest 14–21 days earlier.	Special equipment and expertise are required for applying plastic mulches in fields.	[130,131]
The use of mulches significantly reduces nutrient loss due to soil surface runoff. Mulches aid in water conservation because they prevent water from evaporating.	Black film's high temperature increases the risk of "burning" or "scorching" young plants and seedlings.	[132,133]
Mulching preserves soil compactivity, resulting in easily broken up and eroded soil. Plants growing in a mulched field have a more robust root system because the soil is better able to hold air.	Organic mulches increase soil acidity, which further affects crop productivity.	[134,135]
Mulching reduces soil and water erosion, which is crucial for agriculture in dry locations. Mulching aids in crop yield in dryland environments.	The removal and disposal of polyethylene mulches pose significant agronomic, financial, and environmental constraints.	[136,137]
Mulching reduces soil-borne diseases, improving both crop quality and productivity.	Plastic mulch is hard to recover and use again.	[138,139]
Mulches slow the development of weeds and pests	Mulches in some areas are attractive to pests like slugs and rats and other rodents.	[102,140]

8. Conclusions and Future Perspectives

Through a variety of adaptations in the future, potato production and yield can be preserved despite less and less favorable growing conditions. More favorable growing conditions are being established for potato crops through cultivation methods. As a result of flat soil planting in dry, rain-fed areas, soil water is conserved at the tuber level better. At the same time, mulched cultivation provides better soil water availability and more favorable temperatures.

Additionally, mulching potatoes enhances growing conditions by attenuating biotic and abiotic stresses. As long as a thick layer of mulch is applied at planting (20–30 tons/ha is insufficient, and 40 tons/ha is sufficient), biotic stress can be attenuated by ultimately hindering weed germination and growth. Furthermore, mulch acts as a sponge and inhibits rain splashes, which reduces the spread of *A. solani* and *P. infestans*. *A. solani* and *P. infestans* splash their sporangia on young leaves when heavy rain falls. Mulching inhibits splashing, a primary source of inoculum, and reduces the incidence of blight diseases. The degradation of organic material by microorganisms also produces ammonia and/or volatile organic acids due to the decomposition of the mulch. In addition, this will further slow and kill primary *Phytophthora* inoculum and antagonistic microorganisms present in the soil that are detrimental to cultivation. In addition, the mulch provides a home for an increased number of natural enemies that help control other pest insects such as Colorado beetles.

Harvested potatoes from ridged and mulched cultivation significantly differ in size, quality, and yield. Cultivars differ in size based on their planting conditions. Unlike conventional ridge cultivation, mulched cultivation produces significantly larger tubers for sensitive varieties like Ratte. Compared to conventional ridge cultivation, mulched cultivation does not affect the size of more robust and drought-resistant varieties (Agria).

To improve the quality of potatoes (dry matter and specific gravity), it is essential to use organic material for mulching. Straw mulch significantly reduces dry matter and specific gravity compared to ridge cultivation, resulting in lower-quality tubers. Comparatively, mulch from flax loaves does not affect the quality parameters of ridge cultivation. Mulched cultivation produces significantly higher yields than ridged cultivation (+39.5% on average), no matter the farmers using which cultivar.

A future cultivation method that uses mulch to enhance potato yield and productivity is a promising one for ensuring crop productivity under less favorable growing conditions. However, more research is needed to address unanswered questions regarding the widened cultivation of crops under the mulching method. More research would be needed to determine whether mulch is economical, what application rate gives the best results, whether time savings exist, and which cultivars are most productive under mulch.

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