

Effect of Mulching Materials on Yield and Water Productivity of Drip-Irrigated Tomato

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ABSTRACT

Mulching is promoted alongside drip irrigation as a way of getting more tomato from less water, yet the claim is usually made for all mulches at once, as if straw, black polyethylene and a biodegradable film behaved alike. This narrative review asks what published work can and cannot say about how organic and plastic mulches affect yield and water productivity of drip-irrigated tomato. It draws on research into soil evaporation, root-zone temperature, weed suppression, irrigation scheduling, and the performance and fate of mulch films, and it reports no new data. Mulches act mainly by reducing evaporation from the soil surface and by altering soil temperature, so their benefit depends on climate, soil, season and crop cover, and it tends to be largest early in the season and in dry, warm conditions. Organic and plastic materials trade different advantages: residues add organic matter but compete with other uses and may harbour pests, whereas films are effective and cheap but leave a disposal problem and, increasingly, a microplastic concern. Reported comparisons are also hard to line up because water productivity is defined in several ways and is often measured against applied water, not water actually consumed. The review concludes that a mulch benefit is plausible but conditional, and it sets out the measurements that would make future comparisons fair.

Keywords: Mulching; Drip irrigation; Tomato; Water productivity; Plastic film; Organic mulch; Narrative review

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1. Introduction

Tomato is one of the most widely grown vegetables in the world, and in many dry and semi-dry regions it is now grown under drip irrigation, with a mulch laid over the bed. The pairing is so common that its logic is rarely questioned: drip delivers water to the root zone, mulch keeps it from escaping, and the crop gets more from every litre [1, 2]. Growers choose among straw and other plant residues, black and clear polyethylene, coloured films and, more recently, biodegradable films, and advisory leaflets often present them as interchangeable

routes to the same end.

They are not interchangeable, and the claim that mulch raises yield and water productivity is really several claims bundled together. A mulch can reduce evaporation, change soil temperature, suppress weeds and alter how rain reaches the soil, and each of these matters differently in different climates and at different stages of the crop [3, 4]. Water productivity is itself a slippery term, because it can be written per unit of water applied, per unit consumed or per unit of money earned, and a mulch may look better under one

definition than under another [5, 6]. A grower reading a trial report needs the answer to a simple question: would this have worked in my field?

There is also a cost side that is easy to leave out. Plastic films leave residues that are hard to remove and may fragment into smaller particles in the soil [7, 8], organic mulches have competing uses as fodder and fuel [9], and biodegradable films do not always break down as advertised [10]. This review asks what published work can and cannot say about how mulching materials affect yield and water productivity of drip-irrigated tomato, and where the honest answer is that it depends. It is a narrative review and reports no new data. The aim is a fair account of what is known and what is merely repeated.

2. Literature Review

2.1 How Mulch Changes the Bed

A mulch sits between the soil and the air, and most of what it does follows from that position. By covering the surface it cuts the exchange of water vapour, so less water leaves the soil by evaporation; by absorbing, reflecting or transmitting light it changes how much heat reaches the soil; and by intercepting rain and irrigation it alters where water goes (Figure 1). Reviews of mulching materials describe these effects in general terms and stress that their size depends on the material, its thickness or colour, and the weather [1, 11]. Because these effects share a single physical cause, the covering of the surface, they tend to arrive together. A film that warms the soil also reduces evaporation, so a gain in yield cannot be credited to one effect without measurements of both.

Under drip irrigation the picture is a little different from that under flood or sprinkler systems. Drip wets only part of the soil, near the emitter, and the wetted volume and the mulch cover can overlap in ways that matter for how much water is lost and where roots forage [2]. A film laid over a drip bed also stops rain from reaching the soil beneath it, so the grower is entirely dependent on the drip line for water in that zone. That can be an advantage, since the amount applied is controlled, and a risk, since a blocked emitter has nowhere to be compensated by rain. Mulch and drip are not independent: the mulch changes what the drip line has to do, and the drip line changes how much a mulch can add, so crediting either one alone is a simplification. Cover also matters. A narrow strip of film over the bed leaves the furrows bare, where evaporation carries on, so the fraction of the surface covered is worth reporting alongside the

material.

2.2 Plastic Films and Their Microclimate

Polyethylene film has become the standard mulch for intensive vegetable production because it is cheap, strong and easy to lay over a raised bed. Work on plastic mulches in vegetable crops describes how film colour determines what happens to light and heat: dark films absorb much of the radiation and warm the soil beneath, clear films let more through, and reflective or coloured films redirect part of the light into the canopy [3, 4]. For tomato, studies of coloured films have linked growth and yield to the temperature of the root zone, not to colour as such [12].

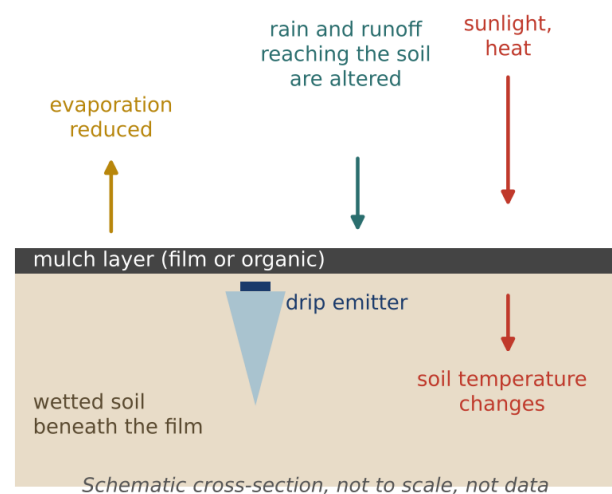


Figure 1. Energy and water pathways at a mulched drip bed (schematic, not data).

2.3 Organic Mulches

Straw, crop residues, cover-crop material and similar organic mulches work differently. They insulate more than they heat, they buffer the soil against swings in temperature, and as they decompose they add organic matter that improves soil structure [11, 13]. Experience with tomato grown in cover-crop mulch suggests that this approach can suit low-input systems [14], and comparisons of several organic and inorganic materials show that the amount of evaporation they prevent depends strongly on the material and the depth applied [15].

Organic mulches come with their own difficulties. The residue has to come from somewhere, and in many farming systems it is already used for feed, fuel or bedding, so recommending it as a mulch may simply move a shortage from one place to another [9]. Whether leaving residue on the surface helps soil health depends on the system as a whole, not on the mulch layer alone [13, 16]. Thick organic layers can also keep soil cool and wet for longer than a crop wants in a cool season,

and they may shelter pests; these are practical matters that trial reports mention less often than yield. These points apply with equal force to any new input in drip-irrigated vegetables, not only to mulch.

2.4 Biodegradable Films

Biodegradable films were developed to keep the benefits of a plastic cover without the burden of removing it. Reviews of polyethylene and biodegradable mulches describe their promise and their limits [17], and field comparisons in tomato have found that some biodegradable films can match polyethylene in soil conditions and crop production [18, 19]. The caveat is that performance is uneven: in trials across several tomato production regions, films that were potentially biodegradable deteriorated at different rates depending on the product and the site [10]. Table 1 sets the three mulch groups side by side.

What happens after the season is the harder question. A film that is not removed has to be broken down by soil microbes, and how quickly and completely that occurs depends on temperature, moisture and microbial community [20, 21]. It is fair to ask whether a film that fragments and lingers solves the plastic problem or only moves it underground [22]. A meta-analysis of agronomic comparisons found that biodegradable mulches do not perform identically to polyethylene across all conditions, which fits the general caution that the category is broad [23].

Table 1. Qualitative comparison of mulch groups used with drip-irrigated tomato.

Attribute	Organic mulch (straw, residues)	Plastic film (black, clear, coloured)	Biodegradable film
Water loss	Moderate; depends on depth [11, 15]	Strong where film covers the bed [1, 4]	Similar to film while intact [18, 19]
Soil warming	Usually cooler, buffered [1]	Warmer; colour decides [3, 12]	Close to polyethylene early on [18]
Weeds	Variable, depth dependent	Good under opaque films [4]	Good until breakdown [10]
Organic matter	Adds carbon [13, 16]	None	Little; fragments remain [21]
Disposal	Incorporated or left	Removal and disposal [7]	Not removed; breakdown varies [20, 22]
Main limit	Supply and competing uses [9]	Residue and microplastics [8, 37]	Cost and uneven breakdown [10, 23]

Note: Qualitative comparison drawn from the cited literature; no figures are given because responses depend on site, season and material.

2.5 Water Productivity, Irrigation Scheduling and the Limits of Efficiency

Water productivity has been defined and criticised at length. Reviews of the topic describe an appealing idea whose use in practice is complicated by what is counted in numerator and denominator [5, 24]. Under deficit irrigation, a deliberate shortfall of water relative to full demand, yields can be maintained in some crops with less water, and the same literature warns that responses depend on crop stage and sensitivity [25, 26]. Tomato studies under reduced irrigation show that yield, fruit quality and water productivity may not move together [27]. Which of these outcomes a grower values most is a local decision, not a universal one.

Irrigation scheduling interacts with mulch in ways that are easy to overlook. If a mulched plot is watered on the same fixed schedule as a bare one, it will receive more than it needs, and any difference in productivity will reflect that choice more than the mulch itself [28, 29]. At the scale of a river basin the problem is subtler still, and the definition chosen decides which of these views a reader is being offered. Water saved in one field can be used elsewhere, and the apparent gain from more efficient irrigation may disappear or even increase total consumption [30, 31]. These arguments do not diminish the value of mulch to the grower, but they caution against reading a field-scale saving as a basin-scale one [32]. For a smallholder the field-scale figure is the one that matters; for a water authority it is not, and a review should say which of the two it has in mind. Small daily savings in water can still add up across a whole season.

3. Materials and Methods

3.1 Scope and Question

The review asks a question in two parts: how do organic, plastic and biodegradable mulches plausibly affect yield of drip-irrigated tomato, and how do they plausibly affect water productivity? It was divided into the sub-questions that a fair comparison would have to answer: what the mulch was, how irrigation was scheduled, how water and yield were measured, and what happened to the material after the season.

3.2 Literature Assembly

The review draws on peer-reviewed work in four areas: the physics and agronomy of mulching; the performance and fate of plastic and biodegradable films; the definition and measurement of water productivity; and the wider literature on residue

use and irrigation efficiency. Sources were chosen for relevance, citation in the field and clarity of method. Studies of other crops are used where tomato evidence is thin, and are flagged as such.

We did not run a formal systematic search and we do not claim one. This is a narrative synthesis, and the choice of sources reflects the authors' judgement. The practical consequence is that the review is a better guide to what a fair trial should report than to the size of any particular effect, and it avoids quoting figures from individual studies that could not be checked against their sources. Reviews of this kind are more useful when they say where the evidence stops than when they smooth it over.

3.3 Appraisal Framework

To judge how far a report can be trusted, we asked four questions. Was the mulch described well enough to identify it, including colour, thickness and material [3]? Was irrigation scheduled independently of the mulch treatment, or fixed to a calendar [28]? Which definition of water productivity was used, and was water applied or water consumed measured (Table 2)? And was the fate of the material, its removal, breakdown or incorporation, considered at all [7]? None of these distinctions is difficult, but each one is easy to blur in a short report.

Table 2. Common definitions of water productivity and what each leaves out.

Definition	Denominator	What it can hide
Yield per applied water	Water applied through the drip system	Rain, stored soil water and losses [5]
Yield per water consumed	Water consumed by crop and soil	Soil evaporation and transpiration are lumped [6, 24]
Yield per transpired water	Water passing through the crop	Needs partitioning that is rarely measured [6]
Return per unit of water	Water applied or consumed	Price swings and grading rules [26]
Basin-scale productivity	Water depleted in the system	Savings at field scale may not reach the basin [30, 31]

Note: Definitions follow the cited water-productivity literature; values are not compared across definitions.

4. Results

4.1 What the Literature Supports About Yield

Across crops, soil mulching has been associated with higher yield and better water use, and a meta-analysis of cereals found benefits on average while showing that the response varied with climate, soil and management [33]. For tomato,

trials with plastic and organic mulches report improvements in marketable yield in some conditions [18, 34], and cover-crop mulches have performed well in low-input systems [14]. The consistent finding is therefore not that mulch always raises yield but that it often does under conditions in which soil evaporation or early-season cold limits the crop. Even then, the size of the gain is rarely reported in a way that lets a reader separate the mulch from the weather of that particular season, which is the main reason we avoid quoting single-trial figures.

Reported benefits were less clear where conditions already favoured the crop. A mulch can do little for a tomato canopy that already shades the soil, and the extra heat under dark film is no help in a hot summer [3, 12]. Evidence from other crops makes the same point: mulching raised wheat yield in a dry environment partly by conserving soil water [35], and its effect would be expected to shrink where water was not limiting. Studies of the other mulch types show the same conditional pattern (Figure 2), so a general statement about yield should be read with that in mind and with the local climate and season in view.

4.2 What the Literature Supports About Water Productivity

Water productivity reports are harder to interpret than yield reports, for the reasons set out in Table 2. A mulch that reduces evaporation lowers the amount of water consumed without necessarily changing transpiration, so yield per unit of consumed water may improve even if yield itself does not [6, 24]. If the mulch also raises yield, the two effects multiply. But in many reports water is measured as the quantity applied through the drip system, and if mulched and unmulched plots receive the same amount, differences in productivity are simply differences in yield, and the evaporation saving is invisible [5].

	Organic mulch	Plastic film	Biodegradable film
Evaporation control	+	++	++
Soil temperature	~	+/-	+/-
Weed suppression	~	++	+
Soil organic matter	++	0	0
Disposal burden	0	--	~
Supply and cost	~	+	-

++ strong benefit, + some, ~ mixed, 0 none, - some drawback, -- strong drawback
qualitative reading of the literature; schematic, not data

Figure 2. Qualitative matrix of mulch benefits and drawbacks as described in the literature (not data).

Timing is the other half of the story. Evaporation from bare soil is largest while the canopy is small and weakens as leaves shade the bed, so the benefit of a mulch should be front-loaded (Figure 3). The reasoning is physical and widely accepted [1, 6], but it is rarely tested directly in tomato by splitting the season, and we found no basis for putting a number on it. It implies that mulch matters most for crops transplanted into warm, dry conditions and least for those that close their canopy early.

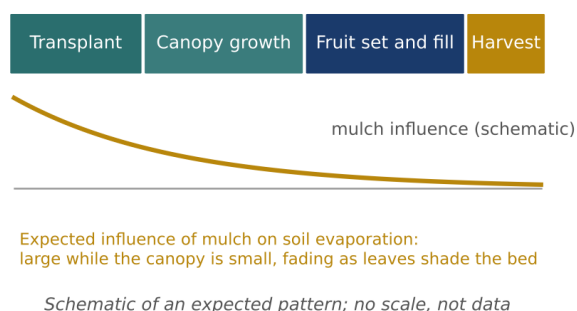


Figure 3. Schematic timeline of how mulch influence is expected to change over a tomato season (not data).

4.3 Plastic, Organic and Biodegradable Materials Compared

Comparisons of materials within one trial are fewer than comparisons of mulch with bare soil. Where they exist, the differences between a biodegradable film and polyethylene have often been small in soil conditions and in crop production while the film was intact [18, 19], but the later performance of the biodegradable films was less predictable [10]. Organic mulches tend to cool and buffer the soil, which helps in hot climates and hinders in cool ones [1, 34].

The honest summary is that no material wins everywhere. A black film is a strong choice for early warmth and weed control; an organic layer is attractive where residue is cheap and the climate is hot; a biodegradable film is attractive where removal costs are high and the soil biology allows breakdown [17, 23]. Which of these a grower should choose depends on local conditions, and a trial from one climate says little about another. This is why the same mulch can look excellent in one report and unremarkable in the next.

4.4 Residues, Disposal and Hidden Costs

The costs of plastic mulch fall largely after the harvest. A review of plastic mulching asked whether short-term agronomic gains are traded for long-term soil degradation, and noted how little is known about the fate of film fragments [7]. Analyses of mulch residue in agricultural soils

describe film fragments accumulating and harming production in some settings [36, 37], and plastic mulching is now recognised as a source of microplastics in soil [8, 38]. Microplastics can affect soil structure and function in ways that are only starting to be understood [39].

Biodegradable films do not escape these concerns automatically. The soil microbial effects of such films, and the completeness of their breakdown, remain open questions [20, 21]. Organic mulches avoid the plastic problem, but they carry the opportunity cost of the residue [9, 16]. Any account of cost per unit of water or per tonne of fruit that leaves these items out is flattering the mulch. A saving that disappears once labour and disposal are priced is not one a hired worker or a farm accountant would see.

4.5 Quality and Comparability of the Evidence

Reports on mulch in tomato share several features that limit comparison (Table 3). Many compare a single mulch with bare soil, so they cannot rank materials. Many describe a film simply as plastic, without colour, thickness or supplier [3]. Irrigation is often scheduled identically across treatments, which hides the water saving [25, 28], and water productivity is often reported against applied water alone. Short trials at one site are common, and the weather of that season can swamp the effect of the mulch [33]. Reading across such reports, a reader should ask what was compared, how the water was scheduled and measured, and what the climate was. The point is not that a trial is poor, only that its result travels less far than its abstract suggests.

Table 3. Comparability problems in mulch trials and what a fair report would contain.

Problem	Consequence	Remedy
Mulch compared only with bare soil	Cannot rank materials [1]	Include a second mulch and a bare control
Irrigation set by the same schedule	Mulched plots over-watered [25, 28]	Schedule from soil water or evaporative demand
Water measured as applied only	Productivity unclear [5]	Report applied and consumed water
Short season or single site	Weather confounds the effect [33]	Repeat across seasons and sites
Film described as "plastic"	Colour and thickness unknown [3]	State colour, thickness, supplier
Residue and disposal ignored	Costs understated [7, 36]	Account for removal and fate

Note: Problems are those discussed in the cited literature; they are not attributed to any single study.

5. Discussion

5.1 Interpretation and Practical Reading

The main finding of this review is a conditional one. Mulch is most likely to help where soil evaporation is a large share of water loss, where early-season soil temperature limits growth, or where weeds compete with a young crop, and least likely to help where the canopy closes quickly and water is not limiting [1, 6]. That fits what is known about the mechanisms and explains why reported effects vary so widely between sites and seasons, and even from one grower's field to the next.

The second conditional concerns water. A grower may well use less water on a mulched bed if irrigation is scheduled from soil moisture, and may use the same or more if it is not [25, 28]. The mulch saves evaporation, but the grower decides whether that saving is realised. The same arithmetic can come out differently on neighbouring farms, which is why a single trial in a single field cannot be generalised. Seen this way, a small difference between two mulches is not evidence that the two are equivalent.

5.2 Limitations

This is a narrative review and shares the limitations of that form. The selection of sources reflects judgement, no formal search or quality scoring was done, and the review does not quote numerical results from individual tomato trials, because these could not be checked against the primary reports for this article. A reader who needs an effect size should consult the original studies directly.

The review also draws on evidence from other crops and from general soil physics, which are imperfect proxies for drip-irrigated tomato. Cereal meta-analyses describe different canopies, root systems and water demand [33, 35]. We used them to frame hypotheses, and the conclusions should be read in that light. A reader who needs firmer ground should treat these sections as hypotheses to be tested against the primary studies.

5.3 Implications for Trial Design

A trial that could settle the question would include at least two mulch materials and a bare control, describe each material in full, and schedule irrigation from measured soil water or evaporative demand so that the mulched and bare plots are not simply watered the same [25, 28]. It would report both applied and consumed water and state which definition of productivity it used [5, 6]. It would run for more than one season and ideally at more than one site [33].

On the economic and environmental side, the trial would record the cost of the material, of laying and removing it, and of disposal, and it would follow the fate of the material after the season, including residues left in the soil [7, 36]. These requirements are demanding, but a smaller number of well-documented trials would serve growers better than a larger number of thin ones. Nothing in this reading argues against mulching tomato; it argues for measuring what the mulch actually does.

5.4 Directions for Future Work

Three needs stand out. First, a formal systematic review with a transparent search and quality appraisal of tomato mulch trials. Second, head-to-head trials of organic, plastic and biodegradable mulches under drip with independent irrigation scheduling. Third, long-term work on what happens to film and residue in the soil [8, 39], so that the full cost of each option can be stated. Each would be a modest study by the standards of the field and together they would narrow the uncertainty far more than another small trial of the usual kind.

6. Conclusion

Mulching is a plausible way to improve yield and water productivity of drip-irrigated tomato, particularly where evaporation or early cold limits the crop. The evidence, as we can responsibly summarise it, does not establish how large the benefit is, which material is best, or how much of any saving survives a full accounting of water, labour and disposal. What the literature does show is when benefits should be largest, why trials disagree, and what a fair comparison would report.

For the practitioner the message is practical rather than discouraging. Mulch can be used well, provided irrigation is scheduled from the soil and not the calendar, the material is chosen for the local climate and the end of its life is planned. For the researcher, the opportunity is a set of well-described, well-scheduled and fully accounted trials that turn a plausible practice into a measured result.

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9. Conflict of Interest

The authors declare no conflict of interest.

10. Author Contributions

P.J. conceived the review and wrote the sections on mulch materials and residues. P.W. wrote the sections on horticultural practice and trial design. F.M. wrote the sections on water productivity and irrigation. All authors revised the manuscript and approved the final version.

11. Ethics Statement

This is a review of published literature. No human participants or animals were involved and no ethical approval was required.

12. Data Availability

No new data were generated. All sources are cited in the reference list.

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