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RESEARCH PAPER

Agronomic and Economic Impact of Mulching Systems on Strawberry Cultivation in North-East India

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ABSTRACT

A two-year field investigation (2017–2018) was conducted at research and farmer's field sites in Meghalaya, India, to evaluate the agronomic performance and economic viability of seven strawberry (*Fragaria × ananassa Duch.*) cultivars under three mulching systems-black polyethylene, paddy straw, and Deenanath grass. Using a split-plot design, growth, yield, quality parameters, runner production, weed suppression, and disease incidence were recorded. Black polyethylene mulch produced the tallest plants, highest leaf number, and superior weed control, reducing weeding costs by 25–30%. Deenanath grass mulch achieved the highest proportion of early yield (85%), enabling earlier market entry. 'Festival' and 'Camarosa' produced the largest fruits, while 'Sweet Charlie' recorded the highest per-plant yield. Economic analysis revealed high profitability, with net returns of ₹ 4.19 lakh per bigha in College of Post Graduate Studies in Agricultural Sciences, CAU research site and ₹ 8.48 lakh in Sohliya village over six years, aided by premium prices from early harvest under plasticulture. The findings demonstrate that strategic mulching and cultivar selection can significantly enhance productivity, fruit quality, and profitability in North-East Indian strawberry production systems.

HIGHLIGHTS

- Evaluated seven strawberry cultivars under three mulching systems in Meghalaya, India.
- Black polyethylene mulch enhanced growth, yield, and weed suppression, cutting weeding costs by 25–30%.
- Deenanath grass mulch produced the highest early yield proportion (85%), improving market timing.
- 'Festival' and 'Camarosa' yielded the largest fruits; 'Sweet Charlie' gave the highest per-plant yield.
- Economic returns reached up to ₹ 8.48 lakh per bigha in plains over six years under plasticulture.
- Integrated mulching and cultivar selection improves profitability and productivity in North-East India.

Keywords: Strawberry cultivation, mulching systems, yield performance, economic returns, *Fragaria × ananassa*, Meghalaya, plasticulture

The cultivated strawberry (*Fragaria × ananassa Duch*.) holds a prominent place in the global fruit market, largely due to its visually appealing fruits and distinct, pleasant flavour. It demonstrates remarkable adaptability, thriving in a wide range of climatic conditions from temperate and sub-tropical plains to high-altitude tropical areas and even arid regions such as Israel. However, due to its shallow root system, strawberry plants are susceptible to damage and mortality during periods of drought. In recent years, India has seen a surge in strawberry cultivation, with several agro-based enterprises being established by major business groups to facilitate large-scale fruit production. Given its status as a herbaceous annual, strawberry is also well-suited for cultivation in home gardens, rooftop setups, and containers. Globally, it is considered a nutritious addition to diets and is highly sought after by the food processing industry for the

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production of jams, ice creams, candies, toffees, and other value-added products.

To enhance productivity, several large-fruited, high-yielding cultivars such as 'Chandler', 'Pajaro', 'Etna', 'Sweet Charlie', 'Selva', 'Douglas', 'Confictura', 'Dana', 'Belrubi', 'Gorella', and 'Addie' have been introduced into India from Europe and North America. Among these, some day-neutral varieties-such as 'Selva', 'Majestic', 'Phenomenal', 'Brighton', 'Etna', and 'Fern'-show potential for adaptation to Indian agro-climatic conditions. Farmers in regions around Delhi and in states like Haryana, Punjab, Maharashtra, Karnataka, and Uttar Pradesh have been successfully cultivating strawberries during the winter season, sourcing planting materials from the hill states of Himachal Pradesh and Uttarakhand. This dual advantage enables hill farmers not only to grow the fruit but also to profit from the sale of planting materials for use in the plains.

Strawberry cultivation has expanded into various agro-climatic zones across India, including states such as Jharkhand, Meghalaya, Leh (Jammu and Kashmir), Lucknow, Chhattisgarh, and Rajasthan. The use of polyethylene in commercial cultivation has proven beneficial in reducing winter-related damage, minimizing plant mortality, and improving yield. For instance, the use of low plastic tunnels over strawberry beds has been reported to accelerate harvest by about a month, reduce soil erosion, and increase yields by approximately 20%. Additionally, black polyethylene mulch eliminates the need for weeding. In higher elevation areas, these plastic tunnels can be replaced in summer with anti-hail or anti-bird nets, further improving fruit quality and advancing harvest times, as observed under various agro-climatic settings (Albregts and Chandler, 1993).

Mulching remains a vital part of strawberry production systems. Depending on climate and material availability, both synthetic and organic mulches are employed across the country. Research by Himelrick (1982) demonstrated that strawberries grown on black polyethylene mulch produced more runners and fruits compared to those grown on bare soil. Similarly, several studies have highlighted the positive effects of organic mulches on strawberry growth and yield (Rebandel and Przysiccka, 1981; Badiyala and Aggarwal, 1981; Hassan *et al*. 2000; Lille *et al*. 2003). In light of these findings, the present study was designed to evaluate the performance of promising strawberry genotypes in agro-climatic regions of Meghalaya.

MATERIALS AND METHODS

The present study utilized a diverse collection of strawberry cultivars exhibiting a range of fruit and plant traits (refer to Tables 1–3). The research was conducted at two distinct locations: at the research plot of College of Post Graduate Studies in Agricultural Sciences (CPGS-CAU), Umiam, Meghalaya and at the farmer's plot of Sohliya village located 28 km from Umiam. In College of Post Graduate Studies in Agricultural Sciences, CAU research plot, all 7 cultivars were evaluated during the years 2017–2018, while in Sohliya, 5 of these cultivars were studied under farmer's field conditions.

For each cultivar and replication, data were collected from five randomly selected plants. The traits observed included plant height, leaf number, plant spread, date of harvest, average fruit weight, total soluble solids (TSS), fruit count per plant, yield per plant and per hectare, runner production, and disease response, specifically to leaf spot caused by *Mycosphaerella fragariae*. Disease severity was assessed both in nursery beds and in potted plants by randomly sampling 50 leaves and rating them on a scale of 0 to 5. The percentage of disease intensity was then calculated using McKinney's formula (McKinney, 1923), and these scores were used to determine the disease severity for each genotype.

Strawberry plants were spaced at 30 cm intervals within rows set 45 cm apart. Each 150×60 cm bed accommodated 10 plants. For optimal fruit yield, runners were removed immediately upon emergence in designated beds, while additional beds were maintained for combined fruit and runner production. Each treatment was replicated three times, with five beds per cultivar in each replicate. Standard agronomic practices, including drip irrigation and plant protection measures, were employed across all trials to ensure uniform growth conditions.

In the College of Post Graduate Studies in Agricultural Sciences, CAU research site, the impact of black and transparent polyethylene mulching was examined for its effects on weed suppression, earliness in fruiting, yield, and overall fruit quality.

At the Sohliya village site, the experiment followed a split-plot design. The main plots comprised three mulching treatments- black polyethylene, paddy straw, and Deenanath grass (*Pennisetum pedicellatum* Trin.)- While the subplots consisted of the 33 strawberry genotypes, with three replications per treatment. Each replication consisted of raised beds (20 cm in height, 1.0 m in width, and 2.0 m in length). Runners were planted at a 30 cm × 30 cm spacing, allowing for 10 plants per square meter (20 plants per bed). For black polyethylene mulch, UV-stabilized sheets 150 microns thick were used, with 6-cm diameter holes pre-punched at 30 cm intervals to facilitate planting. These sheets were laid out before transplanting the runners. In contrast, the organic mulches-paddy straw and Deenanath grass- were applied to a thickness of about 10 cm after plant establishment, marked by the emergence of new leaves. Recommended agronomic, irrigation, and plant protection protocols were uniformly implemented for all treatments to ensure successful strawberry cultivation.

RESULTS AND DISCUSSION

The growth and yield performance of seven strawberry cultivars was evaluated under black polyethylene, paddy straw, and Deenanath grass mulches (Tables 1–4). On average, black polyethylene mulch produced the tallest plants (14.8 cm), the greatest number of leaves per plant (44.3), and the widest plant spread (31.2 cm). Paddy straw and Deenanath grass mulches showed no significant difference in plant height or spread, though paddy straw generally supported a higher leaf count (26.4) than Deenanath grass (18.8). Among the cultivars, 'Chandler' attained the greatest plant height under black polyethylene (14.8 cm), while 'Sweet Charlie' grown with Deenanath grass recorded the lowest (5.8 cm). Leaf production was highest in 'Chandler' on black polyethylene (44.3 leaves/plant) and lowest in 'Sweet Charlie' on Deenanath grass (11.4 leaves/plant).

During the summer season in hill regions, the plastic coverings on tunnels were replaced with anti-hail or anti-bird nets, which improved both yield and fruit quality (Himelrick, 1982; Pramanick *et al*. 2003; Locascio and Smart, 1968). While protected

Table 1: Plant Characteristics of Strawberry Cultivars Grown at Sohliya Village with Three Kinds of Ground Covers

Cultivar	Plant Height (cm)			No. of Leaves/Plant			Plant Spread (cm)		
	Black Poly.	Paddy Straw	Deen. Grass	Black Poly.	Paddy Straw	Deen. Grass	Black Poly.	Paddy Straw	Deen. Grass
Camarosa	12.5	11.2	6.8	38.5	26.4	15.4	26.1	24.2	21.8
Chandler	14.8	11.7	12.5	44.3	23.1	14.2	31.2	21.8	22.4
Festival	12.9	11.5	11.8	40.6	20.8	18.8	24.8	20.5	22.3
Sweet Charlie	11.2	12.8	5.8	34.3	21.2	11.4	22.1	22.4	14.4
Nabila	14.1	11.3	10.7	34.3	21.3	20.5	27.4	22.5	23.5
Mean (Mulches)	13.1	11.7	9.52	38.4	22.5	16.06	26.3	22.2	20.8

Table 2: Yield Characteristics of Strawberry Cultivars Grown at Sohliya village with Three Kinds of Ground Covers

Cultivar	Percent of total yield before peak fruiting			Fruit weight (g/fruit)			Yield (Kg/10 plants)		
	Black Poly.	Paddy Straw	Deen. Grass	Black Poly.	Paddy Straw	Deen. Grass	Black Poly.	Paddy Straw	Deen. Grass
Camarosa	66.2	81.8	65.4	4.2	3.6	4.2	0.75	0.90	1.04
Chandler	68.8	97.5	86.8	5.1	4.7	4.3	0.77	0.96	0.87
Festival	82.0	65.1	93.2	4.5	4.1	3.9	0.92	0.69	0.61
Sweet Charlie	84.2	73.5	81.2	4.5	5.5	4.3	0.71	0.88	1.07
Nabila	75.8	71.3	98.5	3.7	4.2	4.1	1.49	0.89	0.55
Means due to mulches	75.4	77.8	85.0	4.4	4.42	4.16	0.92	0.86	0.82

cultivation systems for strawberries have shown promise in trials conducted in Brazil, their adoption in India should be approached with caution. Several studies have reported that protected environments can reach considerably higher temperatures than open fields (Montero *et al*. 1985), which in some cases may negatively impact production by reducing fruit size (Iuchi, 1993). In the present investigation, cultivar and line comparisons were made for fruit weight, total soluble solids (TSS), number of fruits per plant, yield per plant, and yield per hectare (Table 3). However, no significant differences in yield were detected among the different mulch treatments.

The proportion of total yield obtained before peak fruiting—a key indicator of yield distribution—was highest on average in Deenanath grass mulch (85.0%) and lowest in black polyethylene (75.4%). 'Nabila' under Deenanath grass mulch showed the highest early yield percentage (98.5%), while 'Camarosa' under Deenanath grass had one of the lowest (65.4%). Fruit weight averaged around 4.4 g across mulch types, with slight variation; the largest mean fruit weight (4.42 g) occurred under paddy straw, though differences among mulches were small. In terms of yield, 'Nabila' under black polyethylene achieved the highest (1.49 kg/10 plants), while several cultivar–mulch combinations produced less than 0.7 kg/10 plants.

Data from the College of Post Graduate Studies in Agricultural Sciences, CAU research plot (Table 3) confirmed large differences in fruit size, sweetness, and productivity among cultivars. 'Festival' had the largest fruits (18.5 g), followed closely by 'Camarosa' (17.3 g), while 'Winter Dawn' produced the smallest (3.5 g). According to Nitsch (1950), Janick and Eggert (1968), and Moore *et al*. (1970), those differences in fruit size were primarily due to plant vigor, competition among fruits in the inflorescence number and size of developed achenes, climatic conditions, irrigation, and plant nutrient status. The highest total soluble solids (TSS) were in 'Winter Dawn' (11.9 °Brix) and 'Sweet Charlie' (11.42 °Brix), while 'Chandler' recorded the lowest (8 °Brix). These results are in agreement with the findings of Perkins-Veazie (1995) who reported that TSS content varies from 4o to 12°Brix in strawberry. According to Shaw (1990), environmental conditions rather than genetic inheritance during production influenced the soluble solids content.'Sweet Charlie' also had the highest fruit number per plant (23) and yield per plant (254 g), whereas 'Winter Dawn' had the lowest yield (63 g). These variations in yielding potential are markedly influenced by environmental

Table 3: Characteristics of Strawberry Cultivars Grown at College of Post Graduate Studies in Agricultural Sciences, CAU research plot

Cultivars/Lines	No.of runners/ plant	Leaf spot severity (0-5 scale)	Fruit Wt (g)	TSS (°Brix)	No. of fruits/ plant	Yield/ plant (g)	Yield/ha (quart)
Camarosa	6.9	4.3	17.3	10.0	12	209	140
Chandler	10.1	4.5	15.8	8	14	240	160
Festival	11.0	4.9	18.5	8.5	10	186	124
Sweet Charlie	15.4	4.2	11.7	11.42	23	254	171
Nabila	9.4	3.5	9.0	9.5	17	154	103
Sabrina	10.1	3.6	5.1	9.3	22	113	76
Winter Dawn	15.4	4.7	3.5	11.9	18	63	42
Standard deviation	3.14	0.52	5.94	1.43	4.89	69	46.2

Table 4: Effect of Plastic Soil Mulch on Weed Growth on Strawberry Plots in College of Post Graduate Studies in Agricultural Sciences, CAU research plot; the Values are presented as the Percentage of the Weed Biomass Weighed in the Naked/Bare (Unmulched) Plots

Mulch	Weed biomass (% of naked or unmulched soil)^z			
	23rd March 2017		6th June 2017	
	Fresh Wt.	Dry Wt.	Fresh Wt.	Dry Wt.
Black polythene	28.2	17.8	15.4	13.2
Transparent Polythene	62.7	57.8	17.6	16.5

^{z}*Means of percent values from twenty 0.90-m^2 plots.*

parameters like photoperiod, temperature, and light intensities (Avidov, 1986). Runner production varied widely, from as few as 6.9 runners in 'Camarosa' to 15.4 in both 'Sweet Charlie' and 'Winter Dawn'. Leaf spot severity (0–5 scale) was highest in 'Festival' (4.9) and lowest in 'Nabila' (3.5). Protected cultivation has been used for strawberry cultivation in order to protect plants from harsh weather and for a better control of diseases (Passos, 1997).

Weed suppression was greatest under black polyethylene mulch, where fresh weed biomass was reduced to 28.2% of that in unmulched plots in March and to 15.4% by June, with corresponding reductions in dry weight (17.8% and 13.2%, respectively). Transparent polyethylene mulch was less effective, especially early in the season. These results align with earlier reports (Wang *et al.* 1998) highlighting the role of plastic mulch in improving soil moisture conservation, reducing labor for weeding, and enhancing crop performance. The weed growth under the black polyethylene mulch was limited (29.3 to 15.9% of the weed growth observed on un-mulched strawberry beds). The translucent/transparent polyethylene mulch was less effective in preventing weed growth. The black polyethylene mulched beds did not require any weeding, while the un-mulched beds required weeding at 20- to 30-day intervals. Being a shallow rooted crop, strawberry was prone to extreme weather. The plastic mulch played a pivotal role in minimizing plant mortality and increasing productivity. Black polyethylene mulching resulted in a better soil moisture regime and considerably reduced weed growth, which reduced the labor cost for weeding by 25 to 30%. Covering the strawberry bed with miniplastic tunnels induced early cropping and total yield by 20% and reduced winter injury.

Commercialization of strawberry

Strawberry is widely recognized as a high-value fruit crop with strong commercial potential in both domestic and export markets. Its appeal lies not only in its distinct flavor and nutritional benefits but also in its ability to command premium prices, particularly when marketed early in the season. As an early crop, fresh strawberries can sell for ₹ 200 per kg (1 US$ = ₹ 44.43) to ₹ 300 per kg, whereas prices later in the season generally drop to ₹ 80–100 per kg due to increased supply and changing consumer demand. Under favorable climatic conditions, combined with the adoption of recommended agronomic practices, strawberry cultivation can be highly profitable. For instance, from an area of one bigha (approximately one-fifth of an acre), net returns may reach ₹ 4.19 lakh annually in hill regions (equivalent to US$ 9,430.85) and as much as ₹ 8.48 lakh per season in the plains (US$ 19,086.78) after six years of sustained cultivation (Tables 5 and 6). These figures underscore the crop's economic importance, as also reflected in enterprise cost analyses reported by Fonsah *et al.* (2002) and profitability evaluations of different cultivation technologies presented by Lille *et al.* (2003).

Table 5: Economics for Strawberry Production at College of Post Graduate Studies in Agricultural Sciences, CAU research site (1 bigha)

Capital Costs

Description	Amount (INR)
Cost of drip irrigation system	10,000.00
Cost of 300 L refrigerator	30,000.00
Cost of plastics and infrastructure for tunnels	25,000.00
Total capital outlay	65,000.00

Recurring Costs (Over 6-Year Period)

Description	Amount (INR)
Cost of strawberry plants in 1st and 4th year @ ₹ 2/plant	20,000.00
Field preparation (twice)	5,000.00
Cost of chemicals, manures, fertilizers, etc.	10,500.00
Labor charges @ ₹ 2000/month	1,50,000.00
Marketing costs	21,000.00
Total recurring costs	2,06,500.00

Total outlay: ₹ 2,71,500.00

Projected Returns

Description	Amount (INR)
1st year @ 200 g/plant, ₹ 60/Kg	60,000.00
2nd year @ 300 g/plant, ₹ 60/Kg	90,000.00
3rd year @ 200 g/plant, ₹ 60/Kg	60,000.00
4th year @ 200 g/plant, ₹ 60/Kg	60,000.00
5th year @ 300 g/plant, ₹ 60/Kg	90,000.00
6th year @ 200 g/plant, ₹ 60/Kg	60,000.00

Sale of strawberry plants	2,70,000.00
Total receipt	6,90,000.00
Net profit @ 6th year (in the hills)	4,18,500.00

Note: *1 ha = 2.47 acres = 12.5 bigha.*

Table 6: Cost Estimates of Strawberry Cultivation at Sohliya village (Per Bigha)

Capital Costs

Description	Amount (INR)
Cost of drip irrigation system	10,000.00
Cost of 300 L refrigerator	30,000.00
Cost of plastics and infrastructure for tunnels	25,000.00
Total capital outlay	65,000.00

Recurring Costs (Over 6-Year Period)

Description	Amount (INR)
Cost of strawberry plants in 1 + to 6th year @ ₹ 2/plant	60,000.00
Field preparation (six times)	15,000.00
Cost of chemicals, manures, fertilizers, etc.	10,500.00
Labor charges @ ₹ 3000/month	1,50,000.00
Marketing costs	63,000.00
Total recurring costs	2,98,500.00

Total outlay: ₹ 3,63,500.00

Projected Returns

Description	Amount (INR)
1st year @ 400 g/plant, ₹ 100/Kg	2,00,000.00
2nd year @ 400 g/plant, ₹ 100/Kg	2,00,000.00
3rd year @ 400 g/plant, ₹ 100/Kg	2,00,000.00
4th year @ 400 g/plant, ₹ 100/Kg	2,00,000.00
5th year @ 400 g/plant, ₹ 100/Kg	2,00,000.00
6th year @ 400 g/plant, ₹ 100/Kg	2,00,000.00
Total receipts	12,00,000.00
Net profit after 6th year (in the plains)	8,47,500.00

Note: *1 ha = 2.47 acres = 12.5 bigha.*

Despite its profitability, strawberry production is associated with several challenges. The crop has highly specific growth requirements, including sensitivity to temperature fluctuations, susceptibility to certain pests and diseases, and a need for precise irrigation management. Its short shelf-life and narrow marketing window demand efficient post-harvest handling and rapid distribution to consumers. Establishing a strawberry enterprise requires substantial initial investment, particularly in land preparation, irrigation infrastructure, and planting material. Costs for conventional systems vary significantly: the matted row system, for example, can be established for around US$ 2,000 per acre (Ernst, 2003), while the more intensive plasticulture system may require up to US$ 10,000 per acre (Karcher, 2002). The higher cost of plasticulture is offset by its ability to produce fruit earlier and to achieve yields up to twice that of matted row systems. The advantage of early harvest is significant, as it allows growers to capture the highest market prices available at the start of the season before the market becomes saturated.

Organic strawberry cultivation presents a different set of production and economic considerations. Continuous cropping is generally not possible because organic systems rely on crop rotation to maintain soil health and reduce disease pressure. As a result, the production cycle is shorter—typically limited to one or two fruiting years—while yields are generally lower and more variable compared to those achieved in conventional systems. In addition, organic production tends to require substantially more labor, sometimes up to twice that of conventional methods (Pritts and Handley, 1999), due to increased demands for manual weeding, pest management, and other cultural practices. Because of these higher production costs and the potential for reduced yields, organic growers must consistently secure premium market prices to ensure profitability.

Overall, while strawberry cultivation can deliver excellent economic returns, success depends on careful consideration of production systems, investment capacity, and market timing. Conventional plasticulture systems offer high productivity and early market access but require greater upfront investment, while organic systems can access niche premium markets but demand more labor and carry greater yield risks. For both systems, achieving profitability relies on aligning production with periods of peak consumer demand, minimizing losses through efficient post-harvest handling, and adhering to the best agronomic practices suited to the specific production environment.

CONCLUSION

The use of mini plastic tunnels over strawberry beds advanced cropping by nearly one month and increased total yields by about 20%, while also reducing winter injury and associated plant mortality. In summer, particularly in hill regions, the plastic sheets on these tunnels were replaced with anti-hail or anti-bird nets, which further enhanced yields and improved fruit quality. Black polyethylene mulch played a key role in maintaining a favourable soil moisture regime, significantly reducing both weed growth and irrigation needs. In its absence, strawberries-being a shallow-rooted crop-require almost daily irrigation during the summer months.

The results of this study also indicated considerable variability among the strawberry genotypes evaluated in terms of fruit and yield characteristics. This diversity suggests substantial potential for improvement in these traits through selection and breeding. In tropical and sub-tropical regions, strawberries are cultivated profitably during the winter months, with planting material generally sourced from the hills. Hill growers, therefore, not only benefit from fruit sales but can also supplement their income by producing planting stock for winter cultivation in the plains.

In contrast, growers in the plains are unable to produce their own disease-free planting material due to plant mortality during extreme summer temperatures and the high risk of infection from diseases, especially those transmitted by aphids and other insect pests. Strawberries remain a highly commercialized fruit crop, commanding premium prices of ₹ 200–300 per kg in the early season and ₹ 80–100 per kg later in the season. Under favorable weather conditions and with adherence to recommended management practices, net profits from one bigha (about one-fifth of an acre) can range from ₹ 4.19 lakh per annum in the hills to ₹ 8.48 lakh per season in the plains by the sixth year of cultivation.

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