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Applicability of plastic mulch and conservation strip tillage for potato production in Bangladesh

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ABSTRACT

Application of plastic mulches in potato production is rarely used by farmers in Bangladesh although it has a good prospect for saving irrigation water, weed control, maintaining tuber quality, and increasing yield. A study was conducted in experimental farm at Rural Development Academy (RDA), Bogura, Bangladesh to evaluate the precision of irrigation water for potato production using different colored plastic mulches i.e, black and blue in combination with conservation strip tillage and control (no-mulch). Four different treatments were prepared where some of the phenological characteristics of plants as well as yield of potato were compared among treatments by applying the same amount of irrigation water. The results showed that treatment with black plastic mulch had the highest tuber growth as well as yield of 25.1 t ha^{-1} compared to other treatments while other treatments such as blue plastic mulch, control, and strip tillage had a yield of 16.37, 13.75, and 15.75 t ha^{-1}, respectively. Potato plants having black plastic mulch took less time to mature in comparison to other treatments. Black plastic mulch restricts soil moisture evaporation and keeps the soil warm. In conclusion, potato production with various mulches has a great scope in a semi-arid region like Bangladesh and present experimental results will help to improve the understanding of potato growers for adopting best mulch management practices.

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1. Introduction

Potato (*Solanum tuberosum*) is one of the main foods across the world which accounted for 37% of global food demand (Olivares & Hernández, 2019). Potatoes can produce more dietary energy with less water in comparison to rice, wheat, and maize (Jannat et al., 2021). Moreover, potato is the most important nongrain crop in the world and, thus, the increase in potato production is crucial for future global food security (Raymundo et al., 2018). Potato is the third major crop after the rice and wheat cultivated widely in Bangladesh during winter (Anowar et al., 2015; Ferdous et al., 2014). Recently, Bangladesh has also started exporting potatoes to Malaysia, Sri Lanka, Benin, Vietnam, Canada, Bahrain, Qatar, Myanmar, Nepal, Oman, Kuwait, Brunei, Saudi Arabia, United Arab Emirates, and Singapore (Ahmed et al., 2017). Potato can grow and yields well in cool and humid climates while extreme temperature can cause adverse effects on yield. Thus, the cultivation of potatoes is highly sensitive to climatic variables such as temperature and rainfall. It also needs a high and nearly constant soil matric potential, a high soil oxygen diffusion rate, adequate incoming solar radiation, and optimal soil nutrients for optimal growth (Olivares et al., 2020). King et al. (2020) reported that the potato is vulnerable to water stress relative to many other traditional crops. As a result, irrigation plays an important role for commercial potato production schemes in both arid and semi-arid areas (Olivares et al., 2017).

Agriculture is the largest water consumer in the world which accounts for 70% of total water use at global scale (Qin et al., 2018). Considering the growing water shortage, non-irrigated crop cultivation plays a prime role in the worldwide food supply. Thus, agricultural water management is a major concern to save water in agricultural land. Therefore, conservative and efficient water use has been practiced for many years in the water-limited environments of the world with great success. Moreover, one of the most significant goals of cropping system management is the efficient utilization of available natural resources (Tolessa, 2019). In contrast, conservation of agricultural water by using appropriate soil management practices may be an efficient option to save water as well as raise production in agricultural farming. Water scarcity is one of the most significant factors restricting crop yields globally (Olivares et al., 2011). Due to reduced rainfall and increased soil-moisture evaporation, arid and semi-arid regions of the world have especially faced extreme water shortage problems (Chen et al., 2019). As a result, in those regions that aim to conserve soil humidity, farming practices are introduced. Various activities will ensure sustainable agricultural land cultivation through the management of tillage and water supplies (Kader et al., 2017). One of them is mulching practice.

Mulch is a preventive layer covering the surface of the soil by organic and inorganic materials (Kader et al., 2019). Nowadays, mulching is a very popular agricultural practice to grow different crops especially winter vegetable crops. Mulching is a protective soil surface layer by reducing evaporation and conserving soil moisture (Singh et al., 2015). Plastic mulch is good option than organic mulching for both soil and the environment in short-term high-value crop production. It also modifies plant microclimate by changing the radiation budget. Plastic mulch decreases water losses in soil surface layers by reducing evaporation (Komariah et al., 2011), redistributing soil humidity, and keeping the topsoil warmer during the winter (Zhao et al., 2012). Mulching improves crop yields in both quantity and quality because of the variety of benefits and mulching also increases water use efficiency by lowering evaporation loss (Ferdous et al., 2017). However, contradictory results were also found of using a different color of mulching in a potato field. For example, potato yields in plastic mulch use are controversially affected with yield reduction recorded in a few studies (Ibarra-Jiménez et al., 2011) where other studies show the increase in yield (Li et al., 2018; Wang & He, 2012). So, depending on climatic locations, mulch-color and types of mulch may influences the potato yield which need to consider in deep investigations.

Many varieties of colored plastic film mulches have been used in the agriculture firming sector with various formulas for various purposes. Black, clear, silver plastic mulching is used mostly in the agricultural sector because of its availability and its role in light absorption and crop physiology (Kader et al., 2019). Each type of plastic film color has its optical characteristics and show different soil temperature depending on the soil and crop types. Among them, black plastic mulching is the most available and widely used because it can heat the soil by absorbing a high amount of radiation than other color plastic (Amare & Desta, 2021) while the effects of uncommon colors like blue plastic mulch on the crop environment are not properly studied yet. Moreover, the film colors may influence the soil temperature which impacted crop growth and development in the winter crops such as potato. Therefore, it is crucial to investigate the effects of different color plastic mulches on potato productivity in various regions.

On-farm water management of upland fields has special attention globally by considering higher productivity and profitability. Conservation tillage is another common method for sustainable water management practice which increases soil organic matter content, improves soil hydraulic characteristics, and reduces soil and erosion (Olivares et al., 2015). Conservation tillage might help agricultural productivity by reducing topsoil loss due to wind erosion and retaining soil moisture. Many researchers recognize the benefits of combining strip tillage and mulching for soil moisture conservation. For example, tillage with plastic-film mulch can enhance the soil environment to improve the economical cultivation of the vital crop (Zhang et al., 2011). To increase the efficiency of water, use in the agricultural field, conservation tillage, and various mulch materials can be applied to the upland field which may significantly contribute the crop productivity. Conservation agriculture plays a vital role in conserving soil and water, enhancing biodiversity which needs to investigate for upland crop cultivation. In contrast, mulching is a layer of coating material layered over the soil for controlling soil hydro-thermal environment and modifications of crop microclimate (Kader et al., 2017). The mulching technique with strip-tillage may establish a linkage between soil and agro-ecosystem, which can modify the crop growing environment and preserve soil health. Therefore, the combined effects of conservation tillage and mulching need to be investigated for upland crops considering the water-saving and farm profitability under changing climates.

Application of mulching with conservation strip tillage is a new approach to restore soil-environment which can be used in high valued winter vegetable crops in the different parts of Bangladesh. To the best of the authors' knowledge, no such study has been reported using the combination of different mulches and strip tillage of potatoes in the northwest region of Bangladesh. Therefore, an experiment is conducted to use plastic mulch combined with conservation tillage for potato production in comparison to existing management practices. The objective of the study is to assess the applicability of plastic mulches with strip tillage in comparison to existing practices for potato production. The rest of this paper is arranged as follows. The materials and methods of the experiment are presented in Section 2. Then, the results and discussions are presented in Section 3 and Section 4, respectively. The paper ends with the conclusions.

2. Materials and methods

2.1. Study area and climate

A field experiment was conducted in the experimental farm of Rural Development Academy (RDA) Bogura, Bangladesh from December 2020 to March 2021. The study site is located in between the latitude 24.70 N and longitude 89.39 E and 20 m above the mean sea level. The study area is a subtropical monsoon climate characterized by huge fluctuations of rainfall, air temperature, and humidity. The following weathers are recorded in the study area such as humid summer from March to June; rainy monsoon season from June to October; and winter from November to March. The daily average temperature is 24.8 °C where the average maximum and minimum temperatures are 34.6 °C and 11.9 °C in summer and winter, respectively. The mean total annual rainfall in the study site is 1610 mm (Islam & Shamsad, 2009). Rainfall is distributed from April to October and July is the peak rainfall month over the year. The predominant soil type is sandy loam with a pH value ranging from 5.5 to 6.5.

Figure 1. Experimental layout of different treatments of (A) black and blue color mulching (B) raised bed with strip-tillage and (C) control (no-mulch).

2.2. Treatment descriptions

Land size of 140 m^2 was prepared in the experimental farm of RDA, Bogura. The total land is divided into four different treatments with 35 m^2 size of each plot. The treatments were classified as a raised bed with strip tillage, black color plastic mulch, blue color plastic mulch, and Control. In this study, we used a randomized block design with three replications of each treatment plot. The field layout of each treatment plot is illustrated in Figure 1 and the description of each treatment is as follows: For raised bed treatment, a power tiller along with a raised bed attachment was used for preparing the raised bed. The top and bottom widths of the raised bed were 25.4 cm and 53.4 cm, respectively. A total of 8 beds were prepared, where bed to bed distance and depth were 60 cm and 12.7 cm, respectively as shown in Figure 1B.

In black and blue mulch treatment, black and blue colored plastic mulches were used for the experimental period. The thickness of both mulches was 0.4 mm, and one layer of plastic mulch was used in both treatments. Each treatment contains four beds where the width of each bed was 60 cm. Furthermore, each bed was divided into two rows of 30 cm apart to maintain uniformity. A total of 56 holes (diameter of 7 cm) per bed was dug to plant potato seed maintaining seed to seed distance at 25 cm as shown in Figure 1A.

In the control treatment, control practice was applied without mulches but had potato plants. The control plot was prepared by a tractor which takes greater time than raised bed with a power tiller. Then, the four raised beds were prepared to maintain width of 60 cm by man-powered labor using a spade. The distance between beds was maintained at 30 cm as shown in Figure 1C. The potato tuber planting method was the same as black and blue plastic mulch treatments.

2.3. Crop selection

The potato variety "Asterix" (*Solanum tuberosum L.* cv. Asterix) was selected for this experiment. This variety has the greatest yield and greatest number of tuber per hill compared to other popular varieties like cardinal, granola, Diamant, Felsina, and Provento (Eaton et al., 2017). It is also popular in Bogura district of northern Bangladesh and easily accepted by potato growers.

2.4. Fertilizer application

The fertilizer dose used in the experiment is shown in Table 1. In this study, all the required doses of fertilizer were spread over the field before the tillage operation and land preparation. The recommended dose of fertilizer was applied based on the climatic location in Bangladesh following (BARC, 2018)

Table 1. Amount of fertilizer used for the experiment.

Fertilizer name	Common name	Total application/ (140 m^2 plot)	Application rate (kg ha^{-1})
Organic fertilizer		40.0	2857.2
Nitrogen (N)	Urea	3.0	214.3
Phosphorus (P)	TSP	4.0	285.7
Potassium (K)	MP	2.0	142.9
Sulphur (S)	Gypsum	1.0	71.4
Zinc (Zn)	Zinc sulphate	0.1	7.5
Boron (B)	Borax	0.3	17.9
Magnesium (Mg)	-	0.3	17.9

Figure 2. Raised bed attachment with power tiller (left) and tractor with rotary tiller (right).

Table 2. Mean monthly air temperature, solar radiation, relative humidity (%), rainfall, and wind speed throughout the whole study period.

Periods	Air temperature (°C)			Solar radiation ($W m^{-2}$)	Relative humidity (%)	Rainfall (mm)	Wind speed ($km h^{-1}$)
	Max	Min	Mean				
December	24.8	12.1	17.3	65.2	78.5	0.0	0.51
January	28.7	7.2	16.2	53.3	83.4	0.0	0.47
February	33.9	10.2	21.1	57.3	69.9	0.0	0.47
March	32.4	16.1	23.8	39.3	76.5	0.0	0.54

2.5. Pesticides application

Pesticides were applied to control various pests after 13 days of planting on 12 January 2021. The pesticide *Emitaf* (imidacloprid) by name was sprayed at a dose of 1ml $liter^{-1}$ to control Colorado potato beetles. For controlling late blight disease of potato, Acrobat MZ ((Dimethomorph (9%) + Mancozeb (60%)) was applied at a dose of 2 kg ha^{-1}. An intercultural operation like weeding was done every 15 days after the plantation.

2.6. Tillage operation

For the raised bed treatment, a power tiller attached with raised bed cum strip-tillage equipment was used for both tillage and bed preparation. This equipment makes the hill of having a top width of 25.4 cm and bottom width of 53.4 cm. For the rest of the treatments, a rotavator adjusted with a tractor was used for the tillage operation. The conservation tillage method is applied here by tilling previously cultivated rice straw with the soil. Figure 2 illustrates raised bed attachment with a power tiller (left) and a tractor with a rotary tiller (right). In this study, all the fertilizer was applied before the tillage operation because field soil is completely covered by mulching film.

2.7. Irrigation

In total, three furrow irrigation was applied during the whole growing period of potatoes. Groundwater was used as irrigation in the potato field which was pumped from nearest borehole. The irrigation water was measured by volumetric method using a tank size of 100 liters.

2.8. Climatic measurement

A portable automatic weather station was installed near the experimental field manufactured by Weihai JXCT Electronics Technology Co. Ltd, China. This weather station was used to measure various meteorological parameters like temperature, wind speed, humidity, solar radiation, rainfall, and atmospheric pressure. The weather station was set at 2 m height and hourly data were recorded throughout the study period.

2.9. Harvesting

Haulms were manually pulled out 80 days after sowing (DAS) when they get matured. The tubers were held underground for another 25 days to allow the skin to be hardened before manual harvest.

2.10. Agronomic measurement

Plant heights (about 10 plants) were measured for each treatment during 14 days intervals. Plant height at various stages, tuber weight, diameter, tuber size, yield per plant, and total yield per treatment were recorded through the growing period and during harvest.

2.11. Statistical analysis

Potato growth and yield data were analyzed using the R-software package (http://www.R-project.org), and means were compared based on Tukey's HSD (Honestly Significant Difference) test at a 5% significance level.

3. RESULTS

3.1. Meteorological data analysis

Monthly average air temperature, solar radiation, relative humidity, rainfall, and wind speed are shown in Table 2 and the trend of daily weather data is illustrated in Figure 3. Figure 3 shows that January month has the lowest temperature while March has the highest temperature. The climatic data varied with the months and the maximum solar radiation is found for December and the minimum is for March.

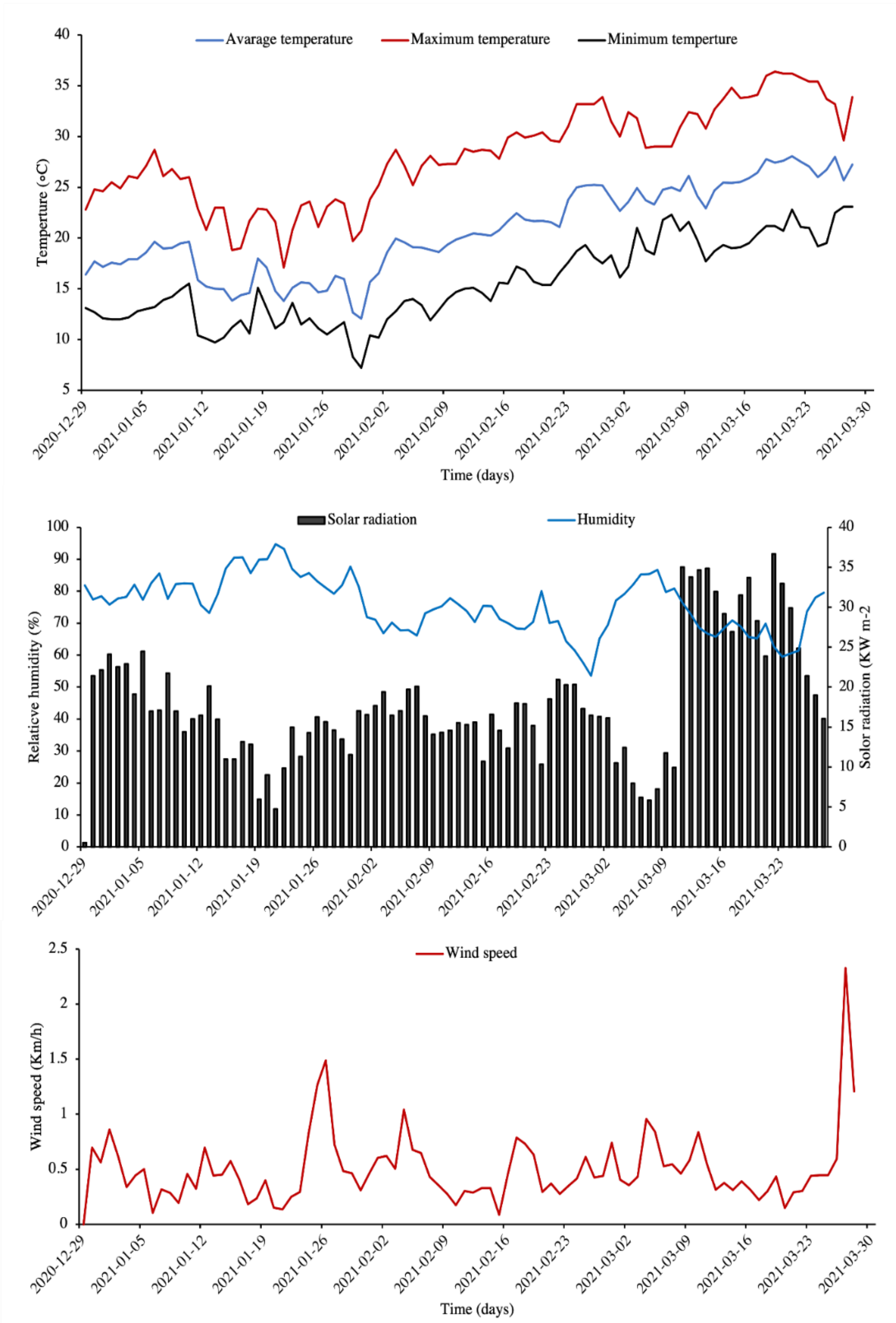

Figure 3. Climatic parameters during the potato growing season of 2020-2021 in Bangladesh.

January is the most humid month while February is less humid. As there was no rainfall during the whole study period, so the value is zero for each month as presented in Table 2. The maximum wind speed is recorded during last week of March as shown in Figure 3 and Table 2. The variations of weather data including solar radiation influence the potato crop growing environments under different mulching and strip tillage treatments.

3.2. Irrigation

The amount of irrigation is presented in Table 3. Akanda et al. (2017) found that the evapotranspiration of winter potatoes is 162 mm in Bangladesh. To meet this water demand, irrigation needs to be applied accordingly. There may be three types of irrigations such as drip, sprinkler, and furrow that are applied for potato production. Though drip irrigation is the most efficient of these three types, it is only applicable for large-scale potato cultivation. On the other hand, sprinkler irrigation is not cost-effective, and it has more water loss than others. So, the furrow irrigation method is applied in this study. As this study aims to use less water to assess the yield of potatoes, a total of 119.8 mm irrigation water was applied in the whole growing period of potato. First irrigation was applied after the 15 days of sowing. Irrigation water was applied at a discharge rate of 19 lit min^{-1} per treatment shown in Table 3.

Table 3. Amount of irrigation applied in each treatment (35 m^2 size) during the potato cultivation period.

Date	Days after sowing (DAS)	Discharge rate per treatment (l/min)	Irrigation application time (hours)	Treatment size (m^2)	Irrigation amount (mm)
15 Dec. 2020	15	19.0	1.5	35.0	48.9
12 Jan. 2021	43	17.1	1.5	35.0	43.8
1 Feb. 2021	62	15.7	1.0	35.0	26.9

The total time of irrigation was 90 minutes. So, the amount of irrigation per treatment was 48.2 mm. For second and third irrigation, the amount was 43.9 mm and 26.9 mm, respectively as shown in Table 3. Also, plastic mulches help to conserve soil moisture and reduce evaporation loss.

3.3. Tillage

We used conservation tillage in this study to conserve the soil structure, moisture and to reduce soil preparation costs. The tilling depth of the soil were 6 inches (15.2 cm) and 5 inches (12.7 cm), respectively using a rotary tiller mounted tractor and the power tiller with raised bed attachment (Figure 1B, and 2). It took 7 minutes and 22 seconds to prepare the raised bed with the strip-tillage method in this study. For the rest of the three treatments, it took around 21 minutes for land plowing using a rotary tiller and after those beds were prepared manually using a spade. It is worth mentioning that raised bed with a strip-tillage method is time-efficient.

3.4. Tuber characteristics

Potato tubers are highly variable in shape and color, all four treatment potato tubers had long oval shapes with red skin color. The color of the flesh was light yellow. They had a medium shallow depth of eyes with medium smoothness of the skin. There were no identifiable differences between the potato tubers of four different treatments as shown in Figure 4. Potato tuber characteristics are a vital component for the processing periods and skin color varies from yellow to pink or purple depending on the types of varieties (Custers, 2015).

3.5. Potato growth and yield

Figure 5 shows the growth of potato on different days after sowing. On the other hand, Figure 5 shows the average plant height at different growing periods. Values of plant height of four treatments are also presented in Table 4. Plants with black mulch have more growth rate than that of other treatments. Figure 6 shows that plants with black mulch reach their highest growth on 44 DAS compared to other treatments whereas plants with raised bed have their lowest growth. On 72 DAS, plants with raised bed treatment reach their highest growth in comparison to other treatments and plants with black mulch treatment have the lowest growth. In our study, we found lower root depths in mulching treatment and greater root depths by no-mulch treatment shown in Table 4. In case of mulching treatments, potato seeds were sown into the hole of mulch cover, and the bed shape was uniform. It may result in lower root depth than that of uncovered treatment (raised bed and no-mulch). Moreover, the bed shape is changed due to irrigation, weeding, and intercultural operation. As a result, the relative root depth seems greater in un-mulched treatment.

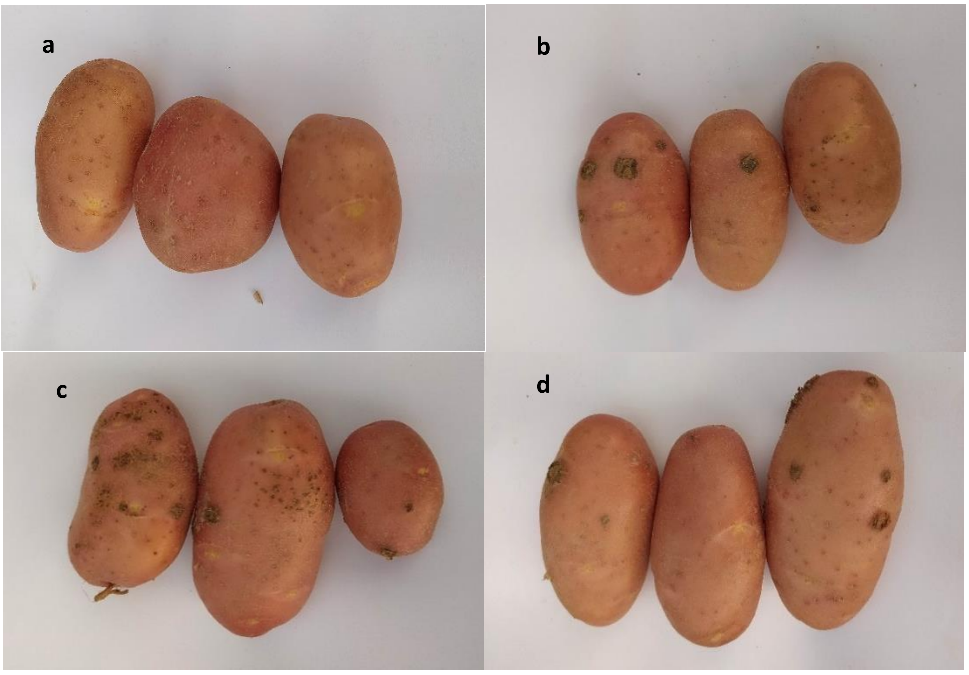

Figure 4. Physical characteristics and color appearance of potato tuber at the time of harvesting from different treatments: (a) blue Mulch; (b) black mulch; (c) control and (d) raised bed.

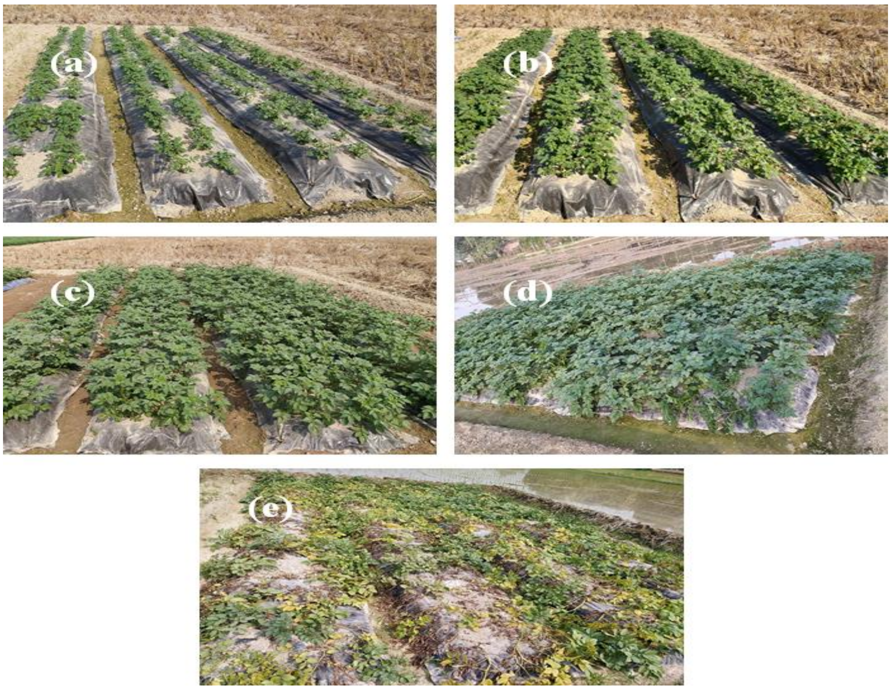

Figure 5. Plant at different days after sowing (a) 30 DAS, (b) 35 DAS, (c) 44 DAS, (d) 54 DAS, (e) 73 DAS.

Table 4. Plant height at different days after sowing of potato under two types of mulching, raised bed and control practice

DAS	Blue Mulch (cm)	Black Mulch (cm)	Control (cm)	Raised Bed (cm)	Significance
30	16.28b ± 1.15	21.18a ± 1.20	13.59c± 1.26	11.30c ± 1.06	S
45	36.40b ± 1.09	39.09b ± 1.72	32.49c ± 1.59	28.42bc ± 1.04	S
59	31.70b ± 2.36	30.20b ± 2.01	28.70b ± 1.89	31.11b ± 1.25	S
71	23.67a ± 2.03	20.42a ± 2.24	23.67a ±2.60	25.58a ± 1.20	NS

Remarks: the values are shown as mean ± standard error; means were calculated from 10 randomly selected samples S significantly different, NS not significantly different. The lower-case letters within each line indicate significant differences ($P < 0.05$) by Tukey's HSD test.

In summary, it can also be said that plants with black mulch mature more rapidly and plants with raised beds mature slowly compared to other treatments. Different analyzed components of potato growth and yield are presented in Table 5. For calculating tuber weight per plant, 10 samples were collected randomly. Potato plants under black mulching treatment bear maximum weight per plant. Potato cultivating in the raised bed is the second-highest weight per plant. Blue mulching and control treatment potatoes have the almost same weight per plant. For analyzing maximum tuber depth from topsoil, 5 samples were collected randomly at each treatment. Potatoes with different mulches have low tuber depth from the topsoil whereas potatoes in control treatment have higher tuber depth than that of other treatments. There was not any significant difference found in the tuber number per plant for the above four treatments.

Table 5. Analyzed parameters of two mulching treatments, raised bed and control treatment.

Analyzed components	Blue Mulch	Black Mulch	Control	Raised Bed	Significance
Total weight (g plant^{-1})	0.29a ± 0.03	0.47c ± 0.05	0.29b ± 0.03	0.32bc ± 0.04	S
Maximum tuber depth from topsoil (cm)	7.40c ± 0.33	8.0a ± 0.27	13.10b ± 0.43	10.0b ± 0.50	S
No. of tuber per plant	6.40a ± 0.75	6.20a ± 0.74	5.80a ± 0.58	5.40a ± 0.68	NS
Tuber length (mm)	8.70a ± 0.84	9.28a ± 1.15	7.33a ± 0.35	7.66a ± 0.58	NS
Tuber diameter (mm)	14.64a ± 1.14	15.57a ± 1.04	13.77a ± 0.63	14.37a ± 0.68	NS
Tuber yield (t ha^{-1})	16.37	25.10	13.75	15.75	-

Remarks: the values are shown as mean ± standard error; means were calculated from 10 randomly selected samples S significantly different, NS not significantly different. The lower-case letters within each line indicate significant differences ($P < 0.05$) by Tukey's HSD test.

4. DISCUSSIONS

4.1. Effect of mulching on soil moisture conservation

Plastic mulch makes a thin plastic film on the soil surface which helps to restore soil moisture (Kader et al., 2017). It helps to reduce evaporation loss from the soil surface. The potato plant growth and yield using plastic mulches are much higher than raised bed and control treatments. Plastic mulches result in the early maturing of potatoes for harvesting. The tuber number, size, and weight per plant are higher in plastic mulch treatments compared to control and raised bed treatments because the soil under mulching has greater water-retaining capacity. Plastic mulching also has higher water use efficiency than no-mulch practices for potato cultivation (Gao et al., 2019; Li et al., 2018; Qin et al., 2014; Zhao et al., 2014). For sustainable water management practice mulching is a crucial factor in the agricultural sector.

4.2. Weed infestation of mulching compared to no-mulch

Figure 7 **Error! Reference source not found.**illustrates the vegetation infestation between blue and black plastic mulches after their removal. There is a growth of vegetation in all the treatments though black mulch has the lowest vegetation infestation among all treatments. Blue mulch has more vegetation growth than control and raised bed treatments. There is also the presence of different earthworms and soil insects in both plastic mulches. It can be seen that mulching treatments showed lower weed growth than no-mulch treatments.

4.3. Potato variety yield analysis

The potato tuber yield varied with treatment and it can be ordered as black mulching (25.10 t ha^{-1}) > blue mulching (16.37 t ha^{-1}) > raised bed (15.75 t ha^{-1}) > control (13.75 t ha^{-1}) shown in Table 5. It shows that mulching treatments provided greater yield than no-mulching and conforms with the previous results found in Siddique et al. (2015). They found that potato of Asterix variety has tuber yield of 25-30 t ha^{-1} in Bangladesh. Eaton et al. (2017) concluded that the yield of Asterix variety of potato is 29.60 t ha^{-1} and their results show each plant has about 13 tubers whereas the current study finds about 7 tubers per plant. Mahmood et al. (2002) showed that the yield of a cardinal variety of potato was 17 t ha^{-1} for plastic mulch and 11.48 t ha^{-1} for control treatment in Bangladesh which are also similar to present results. The potato from the plastic mulch treatments has weightier jumbo tubers than other treatments in this study which is also confirmed by Wang et al. (2009).

4.4. Plant height analysis

Figure 6 shows that potato plants with black mulch have the most growth rate and also have a rapid maturing rate. The maximum plant height of this treatment is 45.7 cm which is the tallest compared to other treatments. Potatoes with blue plastic mulch have the second-highest growth rate after black mulch although its maturing time is almost the same as the control treatment. The maximum height of the plants using blue mulch is 40.1 cm. Potatoes with raised bed treatments have the lowest plant height increasing rate and it's maturity rate is also slower than other treatments. Eaton et al. (2017) recorded a maximum potato plant height of 61.3 cm. Plastic mulch increases the soil temperature compared to other non-mulch soil. This higher soil temperature might be the reason for the greater plant height of mulching treatment plants. In our study, black plastic mulch treatment showed the greater plant height at 30, and 45 DAS shown in Table 4 which indicates the greater radiation effects of black mulching helps to enhance potato growth and development ultimately higher plant height. On the other hand, black mulch treatment showed the lowest plant height at 71 DAS compared to other treatments. Black mulching has a capacity for earlier crop development and quicker harvesting due to greater radiation effects increased soil temperature in winter crops (Kader et al., 2017). Probably, black mulching treatments received higher solar radiations and drying effects of potato leaf diminishing the plant height earlier in black treatment at 71 DAS than other treatments as shown in Table 4 and Figure 6e.

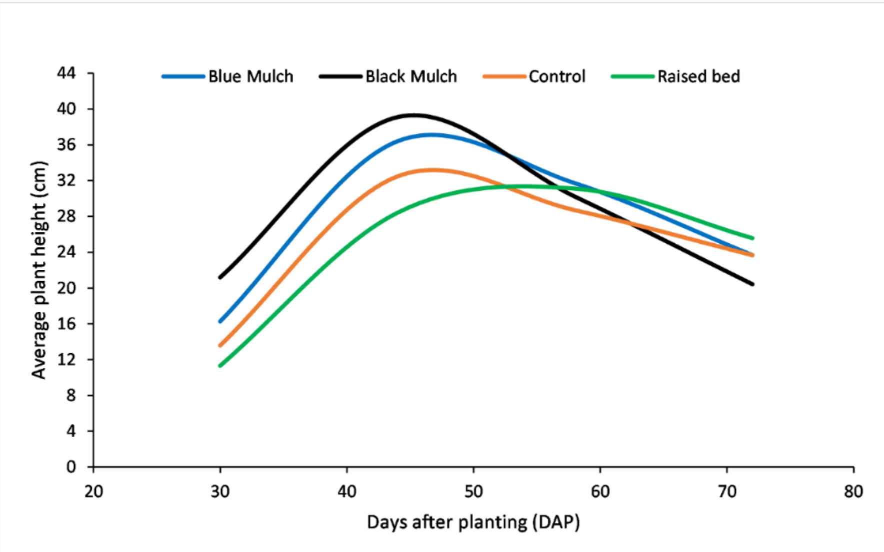

Figure 6. Average plant height on different days after planting.

Figure 7. Vegetation infestation after the removal of mulch at time of potato harvesting (a) blue mulch, (b) black mulch

4.5. Opportunity of potato mulching in Bangladesh

From the above growth and yield analysis, it can be said that potato production with plastic mulch and strip tillage gives the best yield compared to other traditional practices. Plastic mulch has a greater increase in yield than straw mulch (Li et al., 2018). Specifically, black plastic mulch has more yield rate than blue-colored plastic mulch in this study area. Gao et al. (2019) also found the same result and suggested using black plastic mulch in the potato field. Plastic mulching especially using black plastic mulch increases the soil temperature under the plastic which increases the plant growth and yield. Though the initial cost of plastic can be high, there is a huge yield difference between black plastic mulching and control practice. In the semi-arid region like Bangladesh where there is optimum environment prevails for potato cultivation, there is a huge scope of using plastic mulch in the potato field. As the demand for potatoes is rising day by day, this method can be a good solution to increase the yield of the potato.

Potato is a highly profitable crop among the other crops cultivated by farmers in Bangladesh (Begum et al., 2017). Moreover, potato is the second-largest crop in terms of cultivated area after rice in Bangladesh. It provides around 6% of the daily per-capita calories and protein consumed in rural areas due to available production; it is also regarded as an extra earning source for many farmers in Bangladesh (Jannat et al., 2021). The production of potatoes is increasing gradually in Bangladesh and creating demands on advanced water-saving methods like mulching. Our findings may serve as the basis for future research in potato by combining irrigation and agronomic aspects in Bangladesh. It would also play a significant role in the potato growers in Bangladesh that addresses the mulching and strip tillage simultaneously for sustainable soil and water conservation practices.

Future studies should be conducted using transparent and straw mulching to compare the result with this study and could be analyzed the role of mulch under changing climate on potato cultivation in Bangladesh. Further study on soil moisture and water use efficiency due to the application of plastic mulch should also be conducted and interaction effects of soil-mulch-root-water of potato plant need to be investigated. Although, there are some negative impacts of using plastics on the environment. So, impact analysis of plastic mulching use should be conducted in the large field practice from the study area perspective. Considering the negative environmental effects of plastic film contamination, the creation and use of new biodegradable mulching film should be undertaken. Finally, this type of study should be done with different potato varieties in different regions in Bangladesh, and farmers' perception, social acceptance, and cost-benefit analysis of using mulch in potato fields may need deep investigation.

5. CONCLUSION

The effects of plastic mulch and conservation tillage have a great impact on potato plant phenology and yield. The combination of these two systems can drive sustainable soil and water management. In this study, the same amount of irrigation was applied for each treatment but there was a variation of yield in each treatment. The treatment having black plastic mulch has the highest yield where the traditional control practice has the lowest yield. However, blue plastic mulching and raised bed with strip-tillage treatments had second and third most yield, respectively. Treatments having plastic mulch have more water-retaining capacity than those treatments without mulch. Plant height, tuber weight, number of tubers per plant have a greater value in treatments with plastic mulch. Moreover, plants of black plastic mulching have the largest plant height at different growth stages, and plants of raised bed treatment have the lowest height. There is also less vegetation infestation in the mulching treatments. Further studies should be conducted on the applicability of mulching with conservation tillage on different upland crops to evaluate the variation of yields in this region.

Declaration of Competing Interest

The authors declare no competing financial or personal interests that may appear and influence the work reported in this paper.

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