PHYSIOLOGICAL RESPONSES OF WEEDS SUBJECTED TO BLACK PLASTIC MULCHING, AN ALTERNATIVE PREPLANT WEED CONTROL

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Abstract

Weed is a crucial problem in agricultural system, as well as the non-cropland region. Enormous amount of herbicides has been used to control weeds, causing environmental, health and herbicide resistance problems. Mulching has been used as an alternative non-chemical weed controls. Plastic mulching has been commonly used as a covering material throughout the growing season. However, there is no report of using the black plastic mulching as a preplant weed control. In this study, we therefore evaluating the potential of 3 types of black plastic mulching: sun shade net, black woven plastic sheet, black plastic film as a preplant weed control. The evaluation was based on the physiological responses of weeds subjected to different types of the mulches, the weed controlling ability 1-month after mulching, and soil parameters. Photosynthetic rate, transpiration and leaf greenness of the weeds subjected to the black plastic film and the black woven plastic mulches were less than 30% of those in the control from 2-week after mulching. The plastics also completely damaged weed leaves after 3 weeks. Together with the significant lower weed density at 30-day after mulching - only 1.4% and 14% of the control (no mulching), respectively, the black plastic film and the black woven plastic were suggested to be the most effective plastic mulches for preplant weed control, with no changes in soil properties.

Keywords: **Weeds, plastic mulch, physical weed control, non-chemical weed control**

Introduction

Weeds are undesirable plants growing in an area. Many weeds are capable of rapid growth and reproduction. Weeds often cause yield losses in crop field and other negative effects i.e., itchiness and habitats for pests and poisonous animals (Chauhan, 2020). Weeds also possess the high variation, leading to the difficulty in controlling. Chemical weed management methods are widely used because they are quick and effective to destroy weeds, as well as more cost effective (Zhang, 2003). The inappropriate herbicide usage led to the environmental toxicity, health problems, herbicide resistance weeds, and the residues in the soil (Damalas and Eleftherohorinos, 2011). Preplant weed controls were mostly depended on the combination of mechanical methods, like tillage, and uses of

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herbicides, such as paraquat, glyphosate, dicamba, atrazine 2,4-D and diuron (Ikley, 2020). The safety and side effects of these herbicides are remained controversial in many countries around the world (Mallory-Smith and Roma-Burgos, 2020).

The alternative non-chemical weed control recently gets more attention. Plastic mulches are widely used because of its ability of maintaining soil moisture, preventing weed growth and soil degradation from inclement weather (Qin *et al.*, 2018). Moreover, plastic cover reduced labor cost in weed controls and the use of chemical herbicides, as well as increased soil temperatures in cold countries (Schonbeck and Evanylo, 1998). However, the soil temperature increment by black plastic film is less than white plastic film because of its lower light transmission and heat radiation trapped under the plastic sheet (Moreno and Moreno, 2008). To our knowledge, the black plastic mulch promoted the germination and productivity of crop plants such as potato, maize, muskmelons, watermelons, eggplants and tomatoes (Lament, 1993; Qin *et al.*, 2018; El-metwally and El-wakeel, 2019). All the studies on black plastic mulches were based on their efficacies in weed controls during growing seasons and the productivity of crop plants under those mulching. Interestingly, using the plastic mulches as the preplant weed control, together with the physiological responses of weeds during mulching, has been under the attention. However, the price of each type of plastic mulch is also another factors on farmer's technological implementation. Therefore, the purpose of this study is to evaluate the efficiency of different types of plastic mulches for pre-planting weed control and the physiological response of weeds to identify the most effective plastic mulch in cost and controlling ability in preplant weed controls.

Materials and Methods

The experiment was conducted at the organic farm, Suranaree University of Technology between July-September 2020. The experimental plots were placed near the water reservoir where the soil moisture content is high year-round. Three types of plastic used in this experiment were 1) Sun shade net that can filter the light up to 50%, the main material is PE, and cost ~5 Baht/m^2 (SH-02, Fonte, Thailand); 2) Black woven plastic sheet that can filter the light more than 99%, the main material is PE, and cost ~24 Baht/m^2 (99, Thailand); 3) Black plastic film with high flexibility but low water infiltration, and cost ~2 Baht/m^2 (marine fish, Thailand).

The experimental design was RCBD with 4 treatments: 1) Control (no mulch), 2) Double-layered sun shade net, 3) Black woven plastic sheet, and 4) Black plastic film with 3 biological replications (plots). The sun shade net was double-layered to reduce the light transmission to near zero, being comparable with the other 2 plastic mulches. In each plot, each plastic sheet was cut in to the size of 1×2 m^2 and bound to the ground with wood sticks at the corners of the rectangles. Before the experiment, 9 species of weeds were found in the area as shown in Table 1. Each type of plastic sheet was placed in the selected area, kept each treatment 50 cm apart, with random order of treatments in each replication. Before mulching and every week during mulching, the physiological responses were collected of weeds. Soil parameters were also recorded on the day of the plastic removal.

Physiological Response of Weeds

The net photosynthetic rate, stomatal conductance, and transpiration rate were measured from 10.00 am - 1.00 pm, when the average light intensity was 1,335 µmol m^{-2} s^{-1}, using ADC photosynthesis meter, model LCi-5 (Bio Scientific, UK). The measurements were recorded when the plastic sheets were opened. The measurements were randomly measured on 3 waterkanon (*Ruellia tuberosa* L.) plants per replicate. The waterkanon was chosen due to its equally distributed across the area and its large leaf, which was more convenient to measure by the photosynthesis meter. The SPAD values were also collected with Leaf Green meter, model SPAD 502 (Konica Minolta, JAPAN), together with the other parameters from the photosynthesis meter.

Table 1. Weed species in the experimental area

Common name	Scientific name	Family	Weed type	Life cycle
Blady grass	*Imperata cylindrica* (L.) Raeusch.	Poaceae	Narrowleaf	Perennial
Creeping panicgrass	*Panicum repens* L.	Poaceae	Narrowleaf	Perennial
Crowfoot grass	*Dactyloctenium aegyptium* (L.) P. Beauv.	Poaceae	Narrowleaf	Annual
Finger grass	*Digitaria adscendens*	Gramineae	Narrowleaf	Annual
Diamnel flower	*Oldenlandia corymbosa* L.	Rubiaceae	Broadleaf	Annual
Star Grass	*Cynodon plectostachyus*	Poaceae	Narrowleaf	Perennial
Waterkanon	*Ruellia tuberosa* Linn.	Acanthaceae	Broadleaf	Annual
Mexican daisy	*Tridax procumbens* L.	Compositae	Broadleaf	Annual
Pygmy groundcherry fruit	*Physalis minima* Linn.	Solanaceae	Broadleaf	Annual

Soil Parameter Measurement

Soil temperature was measured using a digital thermometer, model 4180CC (Traceable® Products, U.S.A) equipped with the TP-K02 probe at the depth of 5 cm from soil surface. The soil moisture content was measured by moisture meter, model HH2 (Delta-T Device, UK), acquiring data in the unit of percent volumetric soil water content (%). Three values were obtained from each plot. After 4 weeks of mulching, the top 15-20 cm of soil profiles in each plot were collected for electrical conductivity (EC) and pH measurements.

Soil samples were dried indoors until they can be ground and sieved through a 2 mm soil sieve. Soil samples were weighed 10 g, add 90 mL of distilled water, placed into a plastic bottle and shook at 160 rpm for 30 min. The soil solutions were retrieved from the bottles and measured with an EC/pH meter (WTW, inoLab, Germany).

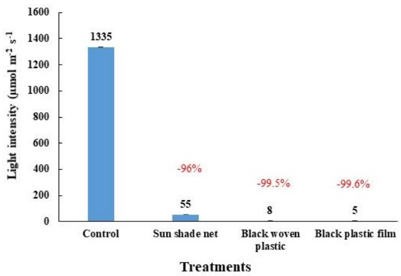


Figure 1. Light intensity (Q) measured by the light sensor on the photosynthesis meter. Values are the Mean ± SE (n = 3). The red letters on the bars are the percent reduction of light intensity, compared the full sunlight in the control condition

Weed Density

The weed density was recorded 30 days after the plastic removal. Weed densities were randomly collected from the middle part of the plots with a 50×50 cm^2 quadrat. One sampling per plot. All samples were dried at 70 degree Celsius. Dry weight of each sample was used to calculate weed density, which are reported in the unit of g DW m^{-2}.

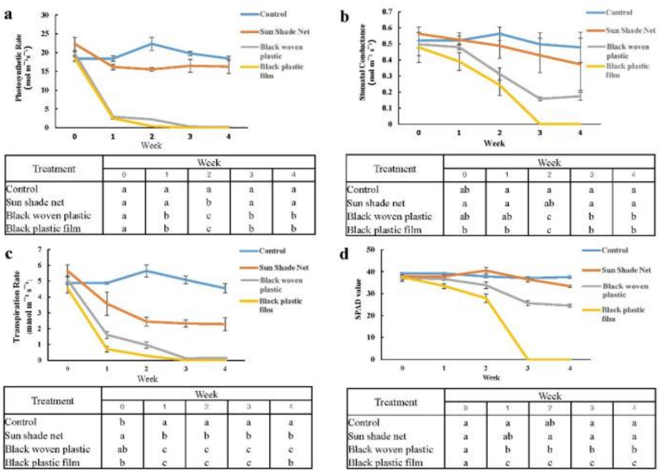
Statistical Analysis

The data were analyzed by one-way ANOVA and Duncan's test at the 95% confidence level (P≤0.05) using the SPSS 14.0 program for Windows.

Results and Discussion

Physiological Response of Weeds

Plastic mulches directly control weeds by reducing the amount of light transmitted to weeds (Bitomský *et al.*, 2018), led to the reduction in photosynthetic rate (Niu *et al.*, 2019). From the light intensity measurement under each type of plastics, the double-layered sun shade net let light pass only 4.3% (only 55 µmol m^{-2} s^{-1} from full sun light of 1,335 µmol m^{-2} s^{-1}), but the black woven plastic and the black plastic film let the light pass only 0.5 and 0.4%, respectively (Figure 1). The continuously decrease in photosynthetic rate from before mulching until 4-week after mulching (Figure 2(a)) probably caused by the limited light intensity contributed by



Treatment	Week 0	1	2	3	4
Control	a	a	a	a	a
Sun shade net	a	a	b	a	a
Black woven plastic	a	b	c	b	b
Black plastic film	a	b	c	b	b

Treatment (b)	Week 0	1	2	3	4
Control	ab	a	a	a	a
Sun shade net	a	a	ab	a	a
Black woven plastic	ab	ab	c	b	b
Black plastic film	b	b	c	b	b

Treatment (c)	Week 0	1	2	3	4
Control	b	a	a	a	a
Sun shade net	a	b	b	b	b
Black woven plastic	ab	c	c	c	c
Black plastic film	b	c	c	c	b

Treatment (d)	Week 0	1	2	3	4
Control	a	a	ab	a	a
Sun shade net	a	ab	a	a	a
Black woven plastic	a	b	b	b	b
Black plastic film	a	c	c	c	c

Figure 2. Physiological responses: (a) Photosynthetic Rate (b) stomatal conductance (c) transpiration rate (d) leaf greenness of waterkanon (*Ruellia tuberosa* L.) measured weekly under different black plastic mulches. The 0 value in all measurement means there was no more attached leaves to be measured. Values are the Mean ± SE (n = 3). The different letters in the column indicate significant differences at the 95% confidence level (P≤0.05)

each plastic mulches. Different types of the mulches gave the different physiological response of weeds with high correlation the light penetration efficiency. Surprisingly, only about 55 µmol m^{-2} s^{-1} was enough to maintain the leaf greenness (Figure 2(d)) and slightly reduced the photosynthetic rate at 1,355 µmol m^{-2} s^{-1}, with no significant difference from that of the control. This might implied that the weeds would be killed only when there is light less than 1 percent and it needed at least 3 weeks to let the photosynthesis to be fully inhibited (Figure 2(a)). The black woven plastic and black plastic film were the fastest and most effective mulch to reduce weed photosynthesis and inhibit weed growth (Figures 3 and 4). El-metwally and El-wakeel (2019) also found that the black plastic mulching was more effective than the organic mulches, herbicide, and hoeing.

Moreover, the reduction in photosynthetic rate may result from carbon dioxide shortage from the effect of stomata closure (the decrease in stomatal conductance; Figure 2(b) and the lack of high energy compounds, such as ATP and NADPH, resulting from light limitation (Hidayati *et al*., 2016). The lower stomatal conductance also caused less transpiration (Figure 2(c)), which might benefit the soil water conversation in some circumstances.

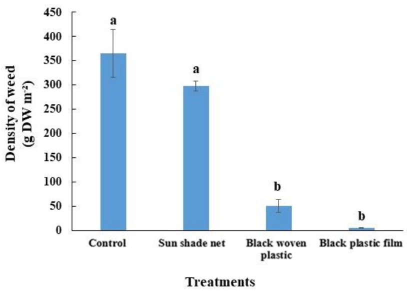


Figure 3. Weed density at 30 days after the plastic mulch removal. Values are the Mean ± SE (n = 3). The different letters above the bar indicate significant differences at the 95% confidence level (P≤0.05)

To evaluate the persistence of controlling effects, after 4-week mulching the plastics were removed, allowing the remaining of weeds to expose to the light. Thirty days after the plastic removal, weeds can grow again at the different density in all treatments (Figures 3 and 4). Weed density after 30 days of the mulching with the black woven plastic and black plastic film revealed the significant lower weed density, compared to the control and sun shade net (Figures 3 and 4). The weed species collected from each treatment were identified. The finger grass, creeping panicgrass and waterkanon, which are the dominant species in the area, were able to emerge and grow in all treatments (Table 2). At the end of mulching, there is no alive weed under black woven plastic and black plastic film (Figure 4), but after 30 days of the plastic removal some small weed seedling were found. Heat generated at the surface of the plastics usually enough to destroy the meristems, leaves and roots of weeds, but inadequate to damage seeds deposited in the soil (Mashingaidze *et al*., 1996). The new seedlings can germinate from the seed accumulated in the soil or dispersed from the nearby weeds when obtaining the appropriate light, temperature, and moisture (Mashingaidze *et al*., 1996). Moreover, the long period of darkness usually results in the germination inhibition of weed seeds, which are usually considered as positive photoblastic species-the species require light to activate the germination (Riemens *et al*., 2004). Darkness induced acute degradation of starch so after continuous darkness plant cells suffered from energy shortage and ultimately death (Seluzicki *et al*., 2017).

Figure 4. The weekly changes of weed coverage in each plastic treatment and 30 days after the removal the plastic sheet

Table 2. Weed species collected from each treatment 1-month after plastic mulch removal

Treatments	Common name	Scientific name	Family	Weed type	Life cycle
Control	Creeping panicgrass	*Panicum repens* L.	Poaceae	Narrowleaf	Perennial
	Finger grass	*Digitaria adscendens*	Gramineae	Narrowleaf	Annual
	Diamnel flower	*Oldenlandia corymbosa* L.	Rubiaceae	Broadleaf	Annual
	Star Grass	*Cynodon plectostachyus*	Poaceae	Narrowleaf	Perennial
	Mexican daisy	*Tridax procumbens* L.	Compositae	Broadleaf	Annual
	Crowfoot grass	*Dactyloctenium aegyptium* (L.) P. Beauv.	Poaceae	Narrowleaf	Annual
	Waterkanon	*Ruellia tuberosa* Linn.	Acanthaceae	Broadleaf	Annual
Sun shade net	Blady grass	*Imperata cylindrica* (L.) Raeusch.	Poaceae	Narrowleaf	Perennial
	Creeping panicgrass	*Panicum repens* L.	Poaceae	Narrowleaf	Perennial
	Finger grass	*Digitaria adscendens*	Gramineae	Narrowleaf	Annual
	Waterkanon	*Ruellia tuberosa* Linn.	Acanthaceae	Broadleaf	Annual
Black woven plastic	Finger grass	*Digitaria adscendens*	Gramineae	Narrowleaf	Annual
	Diamnel flower	*Oldenlandia corymbosa* L.	Rubiaceae	Broadleaf	Annual
	Star Grass	*Cynodon plectostachyus*	Poaceae	Narrowleaf	Perennial
	Blady grass	*Imperata cylindrica* (L.) Raeusch.	Poaceae	Narrowleaf	Perennial
	Waterkanon	*Ruellia tuberosa* Linn.	Acanthaceae	Broadleaf	Annual
	Pygmy groundcherry fruit	*Physalis minima* Linn.	Solanaceae	Broadleaf	Annual
Black plastic film	Creeping panicgrass	*Panicum repens* L.	Poaceae	Narrowleaf	Perennial
	Finger grass	*Digitaria adscendens*	Gramineae	Narrowleaf	Annual
	Waterkanon	*Ruellia tuberosa* Linn.	Acanthaceae	Broadleaf	Annual

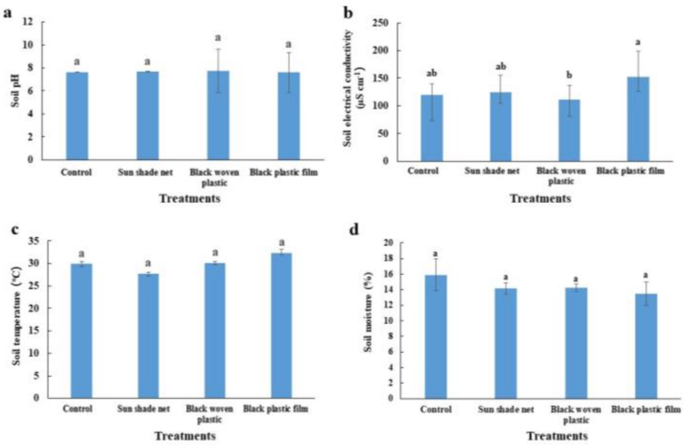


Figure 5. Soil properties (a) soil pH (b) soil electrical conductivity (c) soil temperature (d) soil moisture after each type of plastic mulching. Values are the Mean ± SE (n = 3). The different letters the different letters above the bar indicate significant differences at the 95% confidence level (P≤0.05)

Soil Parameters

The pH of soil in each treatment were between 7-8, soil conductivity were between 110-152 µS cm^{-1}, soil temperature for all treatments was between 29-33°C, and soil moisture content were between 13-15%. There was no significant difference among treatments on all measured soil parameters (Figures 5(a, b, c, and d), respectively). Haque *et al*. (2018) also found that the black plastic mulch does usually not alter soil temperature and soil pH. In the coastal area, black plastic mulch reduce water evaporation, led to the lower soil EC (Haque *et al*., 2018), while in our experimental area, there was no sign of the salinity problem (EC<4 dS m^{-1}), so the EC was not affected by mulching. These findings supported our notion that the inhibition effects were directly from the insufficient light, without any effect from the alteration of soil properties.

Although the black plastic is expensive, with the method of application as demonstrated in this study and the durability of the plastics per se, the plastic can be reused many times, which potentially costs less than labor cost for manual and chemical weed control (Vavrina and Roka, 2000). Moreover, black plastic mulches can be used as a preplant weed control in the places that chemical are prohibited, like in organic farming, the lands with severe herbicide resistance weeds, or other areas aim to reduce the use of herbicides. From economic stand point, the black plastic film would be the most appropriate mulching material for preplant weed control due to its affordable cost of only ~2 Baht/m^2, and the most effective controlling ability (Figure 3).

Conclusions

Black plastic film was the most effective mulch that can be used as an alternative method for preplant weed. The mechanism of weed control was directly through the light limitation, without any alteration in soil properties. The duration of mulching need to be until the target weeds were completely dead (with no photosynthetic activity).

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