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Colored polyethylene film mulches on weed control, soil conditions and peanut yield

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ABSTRACT

A two-year field experiment was conducted to investigate the effects of colored polyethylene (PE) films on weed control, soil temperature and moisture, and pod yield of peanut. By setting a clear PE film (CF) as control, three colored PE films were studied: black-clear-black color-matching film (BCF), silver grey film (SF) and black film (BF). The colored PE films were effective in controlling weeds compared with CF, while BF had the optimal weed control effect. Compared with CF, the colored PE films were not sensitive to air temperature, and had smaller daily temperature variations. Soil moisture at 0–40 cm depth was higher mulched with the colored PE films than those with CF, and the highest moisture occurred in BF. Peanut covered colored PE films remained higher chlorophyll content and net photosynthetic rate in the late growth stage. Compared with CF, the pod yields with BCF, SF and BF were significantly increased by 12, 7, and 5% in 2012, and 14, 10, and 5% in 2013, respectively. The treatments of SF and BCF get higher yields in 2012 and in 2013. Accordingly, SF and BCF may be better field-management options for weed control and high yield in peanut field.

Keywords: *Arachis hypogaea* L.; mulching; mechanical control; heat dissipation; water evaporation

Peanut (*Arachis hypogaea* L.), cultivated in 24.6 million ha with the total production of 41.3 million tons and productivity of 1676 kg/ha during 2012, is the mainstay to livelihood of millions of small-holder farmers residing in semi-arid tropic regions of the world, especially in Asia and Africa (Pandey et al. 2014). Plastic film mulching has been a common agricultural practice since it was introduced to China in 1978 (Dong et al. 2009, Zhang et al. 2012). Polyethylene (PE) film mulching can conserve soil moisture and raise soil temperature (Dong et al. 2008), promote growth and increase yields (Li et al. 2004, Dong et al. 2009). In peanut production, clear plastic film is the most commonly used, however, higher temperature under the clear mulch during pod development may restrict pod and kernel growth (Reddy et al. 1988), and weed control also could be a problem (Waterer 2000), which will reduce the pod yield. During the last decade, many industries have developed a variety of colored plastic films for mulching, which have additional benefits related to altered quantity and quality of reflected light into the plant canopy (Andino and Motsenbocker 2004), and have the effect of regulating the environment, suppressing weeds, controlling crop growth and pests and diseases (Bond and Grundy 2001, Mahajan et al. 2007). The effects of colored plastic mulches had been studied in some vegetable crops such as tomato *Lycopersicum esculentum* (Csizinszky et al. 1999), strawberries *Fragariaananassa* (Kasperbauer 2000), muskmelon *Cucumis melo* (Brandenberger and Wiedenfeld 1997), and watermelon *Citrullus lanatus* (Andino and Motsenbocker 2004). However,

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information concerning the yield of peanut grown on different colored PE films in temperate regions is lacking. Therefore, our experiments were designed and conducted for the first time in field to evaluate the effect of different colored PE films on weed control, soil temperature and moisture, photosynthesis rate and the yield of peanut, attempting to provide an effective solution for high peanut yield and ecological weed control.

MATERIAL AND METHODS

Experimental sites. Field experiments were conducted in 2012 and 2013 on a typical soil, classified as silt loam, at the experimental station of Shandong Institute of Peanuts, Laixi, Shandong province, China. Precipitation during the peanut growing periods was 418.7 mm in 2012 and 494.6 mm in 2013. The high air temperature was in the range 20–33°C and 21–36°C, and the low air temperature was in the range 10–25°C and 15–25°C, in 2012 and 2013 growing seasons, respectively.

Experimental design. A randomized complete block design with three replications was used with four kinds of PE films mulching including clear PE film (CF) as control, black-clear-black color-matching film with the 25 cm clear band in middle of the film (BCF), silver gray film (SF), and black film (BF), all films are 0.008 mm thick and 90 cm width. Alternating ridges (50 cm wide and 15 cm high) and furrows (50 cm wide) were used with only the ridges mulched with film. Two rows of peanut were sown with two seeds in one hole in each ridge on 1 May 2012 and 4 May 2013 with 25 cm row-spacing and 16 cm seed spacing, and the density is 125 000 holes/ha. The peanut cultivar is Huayu 22. Each plot was 3 × 10 m^2. The peanut was harvested on 8 September 2012 and 10 September 2013. Before ridging, 500 kg/ha of triple compound fertilizer (15% N-4.3% P-8.3% K) were applied, and there were no irrigation and herbicide during the whole growth period.

Soil measurements. Soil temperatures at 5 cm and 10 cm depth were measured with thermometer during the pod setting and filling stage at 8:00, 14:00 and 20:00. At the same time, soil moisture was measured at 20 cm intervals to a depth of 40 cm by gravimetric method (Black 1965).

Weed control assessment. The species and density of weeds were collected in 1 m^2 at three random locations per plot when peanut was harvested. All weeds were identified, counted and recorded for the species and density calculation referred to the China's farmland weed color map (Tang 1989). The total weed biomass was determined after drying at 105°C for 30 min initially and then at 75°C for 48 h (Zhang et al. 2011).

Growth parameters. Photosynthesis rate was determined by using a portable photosynthesis meter (LI-6400XT, LI-COR, Lincoln, USA) at the four growth stages (flowering, pod setting, pod filling, and maturing stage) on a clear day between 11:00–14:00 on the third top leaf of peanut. The measurements were performed on five plants for each experimental plot. The leaf chlorophyll relative content was determined by a soil-plant analysis and development (SPAD) meter (SPAD-502Plus, Konica Minolta, Tokyo, Japan), which is a portable and non-destructive diagnostic tool for the measurement of relative chlorophyll content in leaves, on the same leaf as photosynthesis rate measured. The pod yield was determined by a area of 10 m^2 in the center of each plot. Five holes per plot were sampled for testing pod number per plant, immature pod number and young pod number, full pod number. The pods were air-dried for one week and then the number that each kilogram contains was calculated.

Statistical analysis. The data were analyzed using ANOVA in DPS 7.05 (Zhejiang, China). Mean comparisons were performed using the Fisher's *LSD* test at $P < 0.05$. Figures were conducted by Origin 8 (Northampton, USA).

RESULTS AND DISCUSSION

Weed control. Weed density and weight of biomass varied with mulch color (Table 1). During the two growing seasons, a most of weed density was recorded on plots covered with CF (52 weeds/m^2 with a dry weight of 225.2 kg/ha in 2012 and, 61 weeds/m^2 with a biomass of 273.6 kg/ha in 2013). Compared with the CF, plots covered with BCF, SF and BF showed significantly ($P \leq 0.05$) lower weed infestation. The lowest weed infestation was on plots covered with BF. Similar observations recorded by Sudha and Nanjappa (1999) and Lalitha et al. (2001). By reducing the light transmittance, the colored mulches were able to resist the growth of weeds despite their heavy infestation, while the

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Table 1. Effect of different polyethylene film mulching on weed infestation in peanut at harvest

	Weed species	Density (plant/m²)			
		CF	BCF	SF	BF
2012	*Digitaria sanguinalis* (L.) Scop.	18.2^{a}	12.2^{ab}	10.6^{b}	9.2^{b}
	Echinochloa hispidula (Retz.) Nees.	10.4^{a}	5.4^{b}	5.8^{b}	4.4^{c}
	Abutilon theophrasti Medicus.	8.2^{a}	3.2^{b}	3.2^{b}	4.2^{b}
	Portulaca oleracea L.	2.6^{b}	3.6^{a}	–	–
	Eleusine indica (L.) Gaertn.	2.8^{a}	2.0^{ab}	1.4^{b}	1.0^{b}
	Acalypha australis L.	–	–	–	–
	Commelina communis Linn.	–	–	–	–
	Setaria viridis (L.) Beauv.	7.4^{a}	3.2^{b}	2.2^{b}	1.2^{b}
	Xanthium sibiricum Patrin ex Widder	2.4^{b}	2.0^{b}	4.2^{a}	1.0^{b}
	total density	52.0^{a}	31.6^{b}	27.4^{bc}	21.0^{c}
	number of species	7^{a}	7^{a}	6^{b}	6^{b}
	weed biomass (kg/ha)	225.2^{a}	146.8^{b}	135.7^{b}	104.7^{c}
2013	*Digitaria sanguinalis* (L.) Scop.	20.2^{a}	10.0^{c}	12.2^{b}	10.4^{c}
	Echinochloa hispidula (Retz.) Nees.	13.4^{a}	5.2^{b}	4.0^{bc}	5.2^{b}
	Abutilon theophrasti Medicus.	6.0^{a}	4.0^{ab}	2.6^{b}	3.0^{b}
	Portulaca oleracea L.	1.2^{b}	3.6^{a}	5.2^{a}	1.0^{b}
	Eleusine indica (L.) Gaertn.	6.0^{a}	2.8^{b}	2.0^{b}	–
	Acalypha australis L.	2.6	–	–	–
	Commelina communis Linn.	3.4^{a}	–	1.4^{b}	–
	Setaria viridis (L.) Beauv.	8.2^{a}	2.2^{b}	–	–
	Xanthium sibiricum Patrin ex Widder	–	1.4^{b}	2.0^{ab}	2.8^{a}
	total density	61.0^{a}	29.2^{b}	29.4^{b}	22.4^{c}
	number of species	8^{a}	7^{b}	7^{b}	5^{c}
	weed biomass (kg/ha)	273.6^{a}	140.2^{b}	149.7^{b}	112.5^{c}

Values within a column followed by the same letter are not significantly different (*LSD*, $P < 0.05$). CF – control film; BCF – black-clear-black color-matching film; SF – sliver gray film; BF – black film

clear mulch had weaker suppression of weeds. Bond and Grundy (2001) also observed that colored PE films had the function of improving soil conditions besides the function of inhibiting the growth of weeds, which can reduce the use of herbicide and is friendly to environment.

Soil temperature. At 8:00, the soil temperature covered with colored PE films had no significant difference at both the seasons expect at 80 days after mulching (DAM) in 2013 (Table 2). But at 14:00, soil covered with CF had the highest temperature, while soil covered with BF had the lowest temperature, which agreed with the studies of Park et al. (1996) and Subrahmaniyan and Zhou (2008), where it was shown that soil temperature was higher under transparent film mulch, compared to black PE film mulch. At 20:00, this trend was reversed. It could be seen that the colored PE films may act as an obstacle to reduce the thermal radiation from the soil to the air during the night, and contributing to reduction of heat dissipation from the soil and thus slowing the soil temperature decrease at night relative to the clear PE film (Díaz-Pérez and Batal 2002). Ngouajio and Ernest (2005) also observed that colored PE films could delay the process of temperature decrease and had smaller variations in temperature. As a result, the favorable temperature played a crucial role for the growth of crop (Soltani et al. 1995, Díaz-Pérez and Batal 2002, Gao et al. 2007, Wang et al. 2009).

Soil moisture. Soil water content within the 0–40 cm depth showed substantially different patterns with large variations during two growing seasons (Figure 1). In 2012, soil water content in the top 0–20 cm layer at 20 DAM were 8.74, 11.97 and 17.38% higher under BCF, SF and BF compared to CF, respectively. During the whole growing season, soil moisture under colored plastic films was significantly higher compared to CF. BF had the highest soil water content among treatments. No significant differences between BCF and SF were found in

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Table 2. Effects of different polyethylene film mulching on soil temperature (°C) at 5 cm and 10 cm below surface

Treatment	2012									2013								
	days after mulching																	
	80			100			120			80			100			120		
	8:00	14:00	20:00	8:00	14:00	20:00	8:00	14:00	20:00	8:00	14:00	20:00	8:00	14:00	20:00	8:00	14:00	20:00
Depth 5 cm																		
CF	26.8^{a}	34.0^{a}	28.2^{c}	26.7^{a}	32.6^{a}	28.4^{c}	26.0^{a}	31.2^{a}	27.8^{c}	24.3^{a}	36.7^{a}	29.3^{c}	26.3^{a}	39.1^{a}	30.1^{b}	23.9^{a}	33.1^{a}	28.0^{c}
BCF	27.0^{a}	33.5^{b}	28.8^{b}	26.7^{a}	31.9^{b}	28.8^{b}	25.8^{a}	30.7^{b}	27.8^{c}	24.1^{a}	35.9^{b}	31.3^{b}	26.3^{a}	38.0^{b}	31.1^{a}	24.2^{a}	32.9^{a}	28.6^{b}
SF	26.8^{a}	33.1^{bc}	29.4^{a}	26.7^{a}	31.7^{b}	29.2^{a}	26.1^{a}	30.2^{c}	28.5^{b}	25.1^{b}	35.4^{c}	31.3^{b}	26.5^{a}	37.3^{c}	30.9^{a}	24.0^{a}	33.4^{a}	29.2^{a}
BF	27.1^{a}	32.9^{c}	29.5^{a}	27.0^{a}	31.5^{b}	29.4^{a}	26.3^{a}	29.8^{cd}	29.2^{a}	25.5^{b}	33.4^{d}	32.1^{a}	26.6^{a}	36.9^{cd}	31.0^{a}	23.8^{a}	32.1^{b}	28.4^{b}
CV%	0.56	1.46	2.08	0.56	1.50	1.53	0.80	1.99	2.37	2.07	3.98	3.85	0.72	2.55	1.49	0.71	1.69	2.41
Depth 10 cm																		
CF	26.6^{a}	34.3^{a}	28.9^{b}	26.6^{a}	31.3^{a}	28.7^{c}	24.8^{a}	30.8^{a}	26.2^{b}	25.0^{b}	33.9^{a}	30.8^{b}	25.6^{a}	33.9^{a}	30.4^{c}	23.1^{a}	32.6^{a}	25.5^{c}
BCF	26.6^{a}	32.3^{b}	29.2^{b}	26.5^{a}	30.8^{b}	28.6^{c}	25.1^{a}	30.4^{ab}	26.0^{b}	25.4^{a}	33.1^{b}	31.3^{ab}	25.6^{a}	33.5^{b}	30.9^{b}	23.4^{a}	32.0^{b}	26.3^{a}
SF	26.6^{a}	31.2^{c}	29.0^{b}	26.4^{a}	30.7^{b}	29.0^{b}	25.0^{a}	29.6^{b}	26.8^{a}	25.6^{a}	32.2^{c}	31.6^{a}	25.9^{a}	33.6^{b}	31.3^{a}	23.2^{a}	32.0^{b}	25.8^{b}
BF	26.7^{a}	31.1^{c}	29.7^{a}	26.9^{a}	30.3^{bc}	29.4^{a}	25.3^{a}	29.2^{bc}	27.0^{a}	25.7^{a}	30.0^{d}	31.7^{a}	26.0^{a}	32.5^{c}	31.5^{a}	23.3^{a}	31.5^{c}	26.5^{a}
CV%	0.19	4.61	1.22	0.81	1.34	1.24	0.83	2.43	1.80	1.22	5.21	1.29	1.40	1.82	1.57	0.56	1.41	1.76

Values within a column followed by the same letter are not significantly different (*LSD*, $P < 0.05$). *CV*% (coefficient of variation) = standard deviation/average × 100%. CF – control film; BCF – black-clear-black color-matching film; SF – sliver gray film; BF – black film

the whole growing season except at 60 DAM and 80 DAM. A similar trend was also observed in 20–40 cm soil layer (Figure 1). In 2013, the patterns of soil water content in 0–20 cm and 20–40 cm layers were similar throughout the growing season. The topsoil moisture under BCF, SF and BF at 20 DAM was 8.70, 10.15 and 11.88% higher than that of CF, respectively. During the peanut

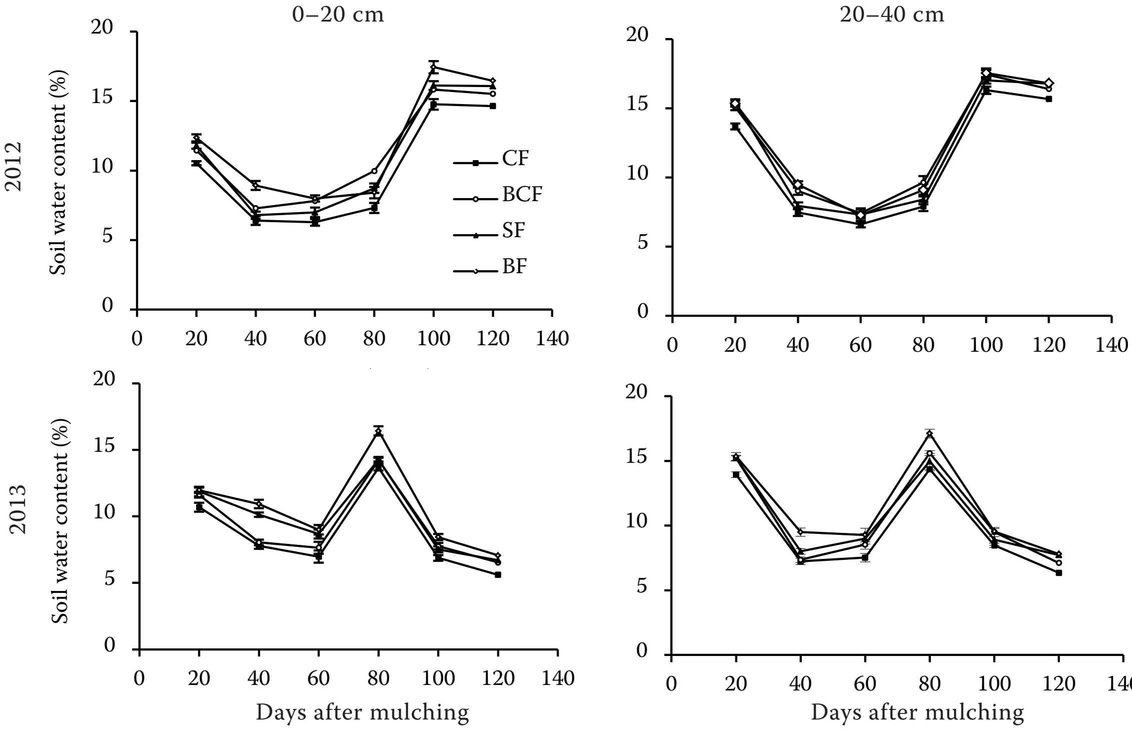

Figure 1. Different polyethylene film mulching on soil water content at 0–40 cm of peanut in the experimental years. CF – control film; BCF – black-clear-black color-matching film; SF – sliver gray film; BF – black film

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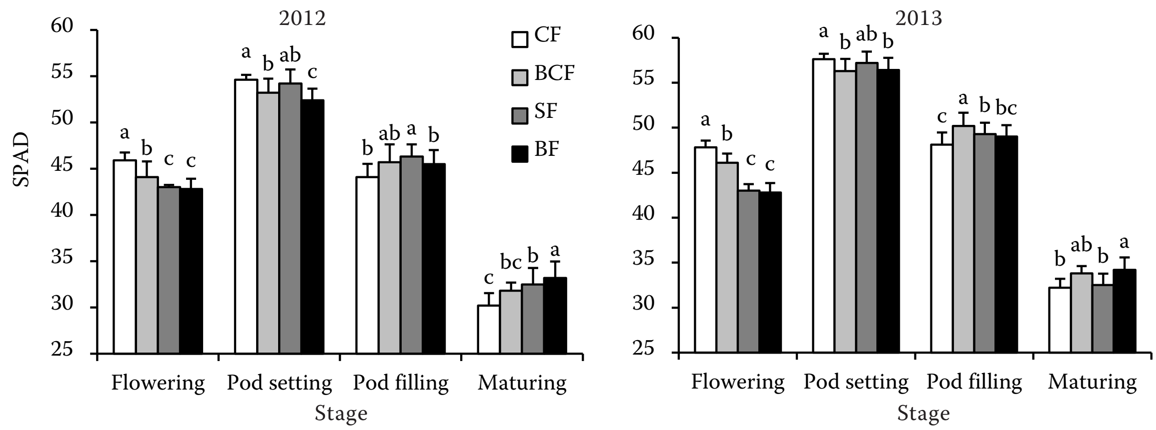

Figure 2. Effect of different polyethylene film mulching on the content of peanut chlorophyll in the experimental years. Values within a column followed by the same letter are not significantly different (*LSD*, $P < 0.05$). SPAD (soil and plant analyzer development): by measuring the absorption rate of the leaf between two wavelength intervals, to evaluate the relative chlorophyll content in leaves. CF – control film; BCF – black-clear-black color-matching film; SF – sliver gray film; BF – black film

growing season, the colored plastic film mulching treatments retained more water than CF, and the differences all reached the significant level except at 40 DAM and 80 DAM. BF had the highest soil water content, but significant differences among the treatments were observed only at 40 DAM. Films mulching could reduce the loss of water evaporation from the soil surface by forming a barrier between the soil and the atmosphere (Zhang et al. 2011). A higher temperature of CF may accelerate the moisture evaporation lost and promote the use of soil water by plant root system (Anikwe et al. 2007, Li et al. 2010).

Leaf chlorophyll relative content. In 2012, at flowering stage and pod setting stage, the chlorophyll SPAD of CF mulching treatment were the highest, and that of the BF mulching was the lowest. However, at pod filling stage, the chlorophyll SPAD of the colored PE film mulching treatments were higher than that of the CF mulching treatment, and the SF mulching treatment had the highest chlorophyll SPAD (Figure 2). At the maturing stage, the chlorophyll SPAD with BCF, SF and BF were significantly increased by 5.30, 7.62, 9.93%, compared with CF. In 2013, a same trend was found except the chlorophyll SPAD of BCF mulching treatment which was higher than that of the SF mulching treatment in pod filling stage. Suitable soil conditions can promote the growth of peanut, and make the peanut maintain higher chlorophyll content. The lower chlorophyll SPAD under CF mulching treatment at the later growth stage was mainly due to the early senescence of leaf, which was caused by the indisposed soil conditions –

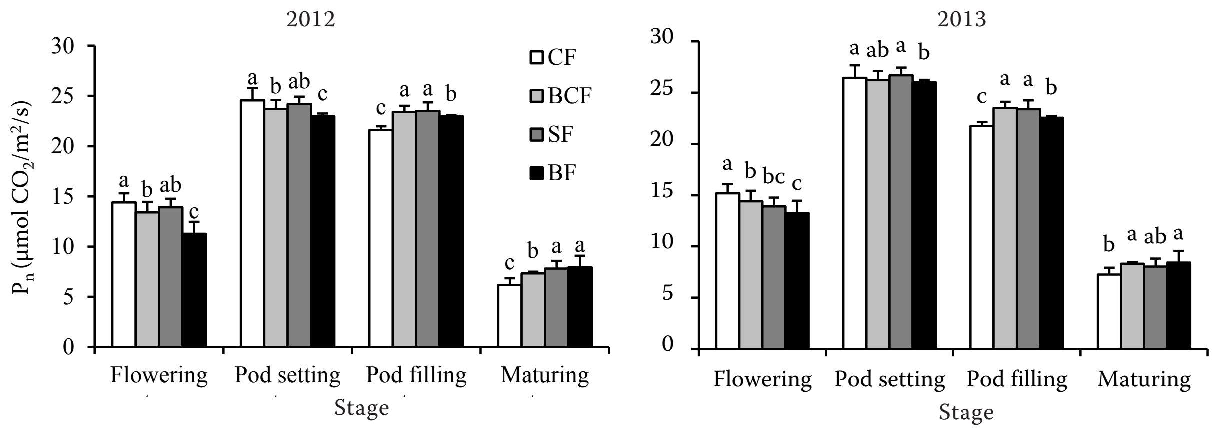

Figure 3. Effect of different polyethylene film mulching on the net photosynthetic rate (P_n) of peanut in experimental years. Values within a column followed by the same letter are not significantly different (*LSD*, $P < 0.05$). CF – control film; BCF – black-clear-black color-matching film; SF – sliver gray film; BF – black film

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Table 3. Effects of different plastic film mulching on plant productivity and pod yield of peanut in 2012 and 2013

	Treatment	Productivity per plant				Pods per kg	Yield (kg/ha)
		pods per plant	full pod number	immature pod number	young pod number		
2012	CF	27.00[a]	13.70[c]	4.80[a]	8.50[a]	635.20[a]	4430.20[c]
	BCF	27.43[a]	17.30[a]	3.80[b]	5.33[c]	622.80[ab]	4700.50[b]
	SF	24.70[bc]	15.20[b]	2.00[c]	7.50[b]	594.70[c]	4943.30[a]
	BF	25.20[b]	16.50[a]	3.20[b]	5.50[c]	617.00[bc]	4613.30[b]
2013	CF	27.00[b]	15.33[c]	6.00[a]	5.67[a]	616.67[a]	4568.63[d]
	BCF	29.00[a]	18.00[a]	5.50[b]	5.50[a]	608.67[ab]	5196.08[a]
	SF	23.00[c]	16.00[b]	5.26[b]	4.32[b]	554.67[c]	4941.18[b]
	BF	22.99[c]	16.33[b]	3.33[c]	3.33[c]	588.24[b]	4732.56[c]

Values within a column in the same year followed by the same letter are not significantly different (*LSD*, $P < 0.05$). CF – control film; BCF – black-clear-black color-matching film; SF – sliver gray film; BF – black film

higher temperature and lower soil water content (Soltani et al. 1995, Wang et al. 2009).

Net photosynthetic rate. In 2012, at the flowering and pod setting stage, the net photosynthetic rate of the colored PE film mulching treatments was all lower than that of CF mulching treatment, and the BF mulching treatment had the lowest net photosynthetic rate (Figure 3). However, at the pod filling and maturing stage, this trend was reversed. The highest net photosynthetic rate was found in the SF mulching treatment at the pod filling stage, which was 8.80% higher than the CF mulching treatment. In 2013, the trend of the net photosynthetic rate was similar to that of 2012, except the BCF mulching treatment that had the highest net photosynthetic rate in the pod filling stage. Higher chlorophyll content provided the material basis for increasing the functional leaf photosynthetic rate (Sayed 2003). The higher functional leaf photosynthetic rate under colored plastic films in the later growth stage of peanut were similar to the chlorophyll SPAD, which was mainly due to the suitable soil conditions.

Peanut yield. Yields under the BCF, SF and BF mulching treatments were all significantly higher compared to CF mulching treatment (Table 3). Although the colored film mulching treatments expect BCF had the lower number of pods per plant, the immature pod number and young pod number were lower compared to CF mulching treatment. The reason may be higher photosynthetic rate and chlorophyll content that could help the peanut needle into soil at the flowering and pod setting stage, but the lower photosynthetic rate and chlorophyll content in the late growth stage were not conductive for pod enlargement. In 2012, the highest yield was obtained at the SF mulching treatment, by 11.58, 7.15, and 5.17% higher than that of CF, BF, and BCF, respectively. In 2013, however, the BCF produced the highest yields, which was by 13.73, 9.79, and 5.16% higher than that of CF, BF, and SF, respectively. There were differences in pod yield between the seasons, which can be partly explained by weather in experimental season (data not presented). The more favorable soil environment under the colored mulches, especially during the late growing seasons, resulted in the higher photosynthetic rate and chlorophyll content, which made the higher full pod number and pod weight and then increased the peanut yield. The effective weed control was also the main reason for the higher peanut yield, which was in agreement with the findings of Ramakrishna et al. (1991).

In conclusion, the colored PE films had significant effects on soil temperature, moisture and peanut growth. Throughout the two growing seasons, the colored PE films considerably inhibited the growth of weeds, increased the soil moisture at the 0–40 cm depth, and provided a proper soil temperature. The high soil moisture and suitable soil temperature postponed the senescence of peanut, and remained higher chlorophyll content and net photosynthetic rate in the late growth stage of peanut. The highest peanut yield was obtained from the plot with the silver-gray PE film in 2012, and the black-clear-black color-matching film in 2013. Accordingly, the silver-gray and black-clear-black color-matching films mulching may be the better field-management options for peanut high yield in the sandy soil. To

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maximize the beneficial effects of the sliver-gray and black-clear-black color-matching PE films, further studies should be conducted.

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