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Agronomic performances of Pak Choi grown with different soil cover

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ABSTRACT

An important aspect in the cultivation of vegetables is the quality of the product to be marketed, free from dirt and damage and the practice of mulching could be an option, but there is scarse information. The aim of this study was to evaluate the influence of mulching on the production traits of three cultivars of Pak Choi. The experiment was set up during March to May 2013 using a split plot randomized block design, with four replications. Soil cover treatments (white agrotextile, black agrotextile, black plastic, silver plastic, tifton straw and bare soil) were arranged in the plots, and three cultivars of Pak Choi (Green Pak Choi, White Pak Choi and Chingensai Natsu Shomi) in subplots. Height and diameter of shoots, number of leaves, fresh weight of the head and petiole, base diameter, dry weight of stem, petiole, and leaf were evaluated thirty-five days after transplantation. The total dry weight and leaf area were measured, and then we estimated the yield. There was a significant effect of soil cover and cultivar. In general, the cover with synthetic materials showed higher values on production of Pak Choi. The cultivar White Pak Choi was better adapted to the growing conditions, with an average yield of 57.78 t/ha.

Keywords: *Brassica campestris* var. *chinensis*, mulching, non-wovenfabric, polyethylene.

RESUMO

Desempenho agronômico de Pak Choi cultivado com diferentes coberturas do solo

Um aspecto importante no cultivo das hortaliças é a qualidade do produto a ser comercializado, livre de sujeira e danos e a prática de cobertura do solo poderia ser uma opção, mas as informações são escassas. O objetivo desse estudo foi avaliar a influência de coberturas de solo sobre as características de produção de três cultivares de Pak Choi. O experimento foi conduzido de março a maio 2013 usando o delineamento de blocos ao acaso, com quatro repetições. Os tratamentos de cobertura do solo (tecido não tecido branco, tecido não tecido preto, plástico preto, plástico prata, palha de tifton e solo nu) foram dispostos nas parcelas, e as três cultivares de Pak Choi (Green Pak Choi, White Pak Choi e Chingensai Natsu Shomi) dispostas nas subparcelas. Altura e diâmetro da parte aérea, número de folhas, massa fresca da cabeça e pecíolo, diâmetro do colo, massa seca de caule, pecíolo, e folhas foram avaliados 35 dias após o transplante. Foram medidos a massa total da parte aérea e o rendimento. Houve um efeito significativo da cobertura do solo e cultivar. Em geral, a cobertura com materiais sintéticos mostrou valores mais elevados na produção de Pak Choi. A cultivar White Pak Choi foi melhor adaptada às condições de cultivo com um rendimento médio de 57,78 t/ha.

Palavras–chave: *Brassica campestris* var. *chinensis*, mulching, agrotêxtil, polietileno.

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Pak Choi cabbage (*Brassica campestris* var. *chinensis*), also known as Chinese white cabbage, is a specie of light or dark green leaves forming a kind of rosette, with succulent light green or white petioles (Reghin *et al*., 2002a). This annual vegetable has optimal growth and development at temperatures between 15 and 20ºC (Maroto, 1995). The cultivation of this vegetable is not yet widespread in the world, and it is cultivated mainly in Asia. However, it is an attractive vegetable of easy commercialization, consumed especially in Oriental restaurants (Alves *et al*., 2003). This type of product is rarely found in supermarket shelfs, opening opportunities for small producers.

An important aspect in the cultivation of vegetables, especially leafy ones, is the quality of the product to be marketed. It must have good appearance, free from dirt and damage. In this sense, the practice of mulching is an option to increase the yield and quality of this vegetable (Reghin *et al.*, 2002a). This practice is widespread among vegetable producers and aims to avoid direct contact of lower leaves with the ground, which under higher humidity conditions spoil quickly.

Both synthetic and organic materials (crop residues) can be used for soil cover. Organic materials are traditionally used, especially in 'low-tech' crops (Mitchell *et al.*, 2004). The soil cover with crop residues is made in a thick enough for that the sunlight is partially blocked, so as to inhibit the germination of weeds in the soil.

Otherwise, mulching with plastic has been used worldwide for over thirty years (Mitchell *et al.*, 2004) and it has provided increases in growth and yield in many vegetables. The use of plastic films in agriculture has benefits such as increased productivity, early yield, less soil compaction, which occurs by the action of water droplets, increased soil temperature, soil moisture conservation, reduced evaporation, low incidence of weeds and diseases, and reduced loss of nutrients by leaching (Sampaio & Araújo, 2001). The color of the material is a determining factor in the microclimate of the crop canopy. Black plastic absorbs 91% of incident radiation, and thus is commonly used in cultures at lower temperatures, since it provides increases of up to 2.8°C compared to bare soil (Moura *et al.*, 2009).

Studies developed with tomato showed that although the production in the first cycle provided by soils covered by plant material is lower, the production in subsequent cycles tends to increase under such coverage when compared to the soil covered with black plastic (Chellemi *et al.*, 1999). Plant residues may contribute with considerable reserves of nutrients, whose availability depends on the rainfall and the carbon/nitrogen ratio, and by reducing leaching of nutrients and soil compaction (Rosolem *et al.*, 2003).

Other material introduced into crops is the double-sided plastic, black and silver. This plastic combines the advantages of black plastic, increasing soil temperature, with the reflection characteristics of silver plastic on the management of insects and diseases (Mitchel *et al.*, 2004). A study conducted by Verdial *et al.* (2000) reported a higher yield and better quality of plants of lettuce cultivar Lucy Brown in cultivation on double-sided plastic. Mulching with double-sided plastic (black/silver) and rice husk promoted a better development of lettuce plants compared with the bare soil and cultivated directly on *Brachiaria* in Northern Brazil (Ferreira *et al.*, 2009).

Other different materials for soil cover are also used. Ferreira (2001) using black plastic and carnauba straw observed lower soil temperature compared with bare soil to the melon cultivation. Costa *et al.* (2002) observed a 25% increase in yield of cantaloupe using silver and yellow plastic compared to bare soil. In addition, Olinik *et al.* (2011), testing zucchini cultivars obtained higher yield when grown on silver polyethylene, against the black polyethylene, black polypropylene (NWF), rice husk and bare soil.

An alternative material, with lower cost and being spread in the cultivation of vegetables, is the agrotextile, row cover, or polypropylene. According to Reghin *et al.* (2002b), the use of black agrotextile provided the highest yield of Veneza Roxa lettuce, compared to rice straw mulch (153.68 and 127.71 g, respectively).

Under brazilian growing conditions, studies show that mulching materials promoted lower temperature range in the soil than synthetic materials, with values of 2.7°C against 4.3°C amplitude under black plastic (Araújo, 2011). According to Wien & Minotti (1987), the soil cover increases the availability and absorption of nutrients. Surveys conducted by these authors found increases in the availability of nitrogen, phosphorus, potassium, calcium, magnesium and boron in the soil when using plant mulching.

The objective of this study was to evaluate the influence of different soil covers on production of three cultivars of Pak Choi.

MATERIAL AND METHODS

The experiment was conducted during March to May 2013 at the experimental farm of Universidade Estadual do Oeste do Paraná, Marechal Cândido Rondon, Paraná state, Brazil, under field conditions. The climate was classified as Cfa, subtropical, according to Köppen classification. The maximum, minimum and average air temperature during the experiment was 31.5°C, 5.3°C and 19.8°C, respectively. The precipitation during the experiment was of 248 mm.

Chemical analysis of an Oxisol (640 g/kg clay) collected at the depth of 0-20 cm, showed: pH ($CaCl_2$)= 6.0; Organic Matter = 17.8 g/dm^3; P= 32.6 mg/dm^3; K= 0.86 cmol$_c$/dm^3; Ca= 6.9 cmol$_c$/dm^3; Mg^{2+}= 3.2 cmol$_c$/dm^3; T= 10.9 cmol$_c$/dm^3 and basis saturation (%) = 74.5.

The experiment was conducted in a split plot randomized block design, with four replications. In the plots the soil cover treatments were arranged: white row cover (white agrotextile, weight of 25 g/m^2), black row cover (black agrotextile, weight of 25 g/m^2), black plastic (black polyethylene, 25 microns), double-sided plastic black/silver (black/silver polyethylene, 25 microns), tifton straw and bare soil. In the subplots, three cultivars of Pak Choi (Green Pak Choi, White Pak Choi and Chingensai Natsu Shomi) were assigned.

The seedlings were grown in polyethylene trays of 200 cells containing commercial substrate under protected cultivation. The transplanting occurred when the seedlings had 4-5 mature leaves (30 days after sowing). The fertilizer was applied according to Trani *et al.* (1997) for lettuce crops. Irrigation was carried out by spraying, according to FAO standard evapotranspiration (Allen *et al.*, 1998). After the planting fertilization (440 kg/ha N, 300 kg/ha P_2O_5 and 120 kg/ha K_2O) and incorporation of fertilizers, the plots were covered with soil cover materials, which were fixed with metal clips at the ends of the plots and then were opened holes in the spacing determined. Fertilization was divided into three times (at 7, 14 and 21 days after transplantation), in a total of 90 kg/ha N.

The experimental plots consisted of 48 plants, and each subplot consisted of 16 plants, in four rows, spaced 30 cm between plants and between rows. The working area was defined as the two central rows, and harvested a total of four plants per subplot.

Plants were harvested 35 days after transplanting, at the maximum vegetative development. These were evaluated in the field for the height and diameter of the plant, measuring up the four central plants of each plot, with the aid of a graduated ruler. Then these plants were collected and taken to the laboratory, where, with a digital caliper, was measured the diameter of the base, measured the total head weight, of fresh leaves and of petioles and counting the number of leaves. After, the different parts of the plants were placed in paper bags and dried in a forced air oven at 65±5°C, until constant weight. Subsequently, the plant parts were weighed on a precision scale and calculated the total dry weight.

Leaf area was estimated by the method proposed by Benincasa (2003). Sub-samples were taken from leaves, from which, leaf discs were taken with known area. Subsequently, with the values of dry weight of the discs and of leaves the leaf area was calculated. Yield (t/ha) was estimated based on the fresh weight of the four plants evaluated at harvest time.

The analysis of variance was run by the statistical program SISVAR (Ferreira, 2011), and the means compared by Tukey test ($p<0.05$).

RESULTS AND DISCUSSION

A significant interaction was detected between soil cover and cultivars of Pak Choi for fresh weight of the head, fresh and dry petiole weight and yield. For other variables there was no interaction; so, the factors were studied separately.

Cultivar White Pak Choi showed higher values of fresh weight of the head when grown on silver plastic soil cover compared to bare soil and white row cover (Table 1). Similar results were registered by Cantu *et al.* (2013), when evaluated with arugula growing on different mulching. These authors showed higher production of fresh matter when the crop was cultivated under double-sided black and white plastic, and black plastic in relation to the growing without cover. This indicates that the use of soil cover has benefits over soil devoid of any kind of cover. The other cultivars were not affected by soil cover.

Mulching with plastic materials promoted higher fresh weight for White Pak Choi. This is probably due to increased soil temperature when using these materials resulting in improved uptake of water and nutrients by the roots in these conditions, thus favoring the development and accumulation of weight by the plants. According to Araújo (2011), the temperature in the surface layer of soil covered with black or transparent film increases considerably compared to bare soil. The use of plastics reduces the latent heat flux and increases the sensitive heat flux to soil, providing increased heating as compared to other types of coverage (Araújo *et al*., 2003).

Regarding soil coverages, for black row cover and Tifton straw, cultivars White Pak Choi and Chingensai Natsu Shomi had higher fresh weight of the head, the latter did not differ from the cultivar Green Pak Choi. For silver and black plastics, the cultivar White Pak Choi resulted in higher values for this variable. For soil cover with white row cover and bare soil, no difference was observed with respect to cultivars.

The results of fresh weight are lower than found by Dartora *et al.* (2013) when cultivated Canton Pak Choi in protected ambient, and obtained fresh weight of shoots of 720.6 g per plant when used the highest level of nitrogen (195 kg/

Table 1. Fresh weight of head, fresh weight of petioles, dry weight of petioles per plant and yield of three cultivars of Pak Choi according to soil cover (massa fresca da cabeça, massa fresca dos pecíolos, massa seca dos pecíolos e produtividade de três cultivares de Pak Choi em função da cobertura do solo). Marechal Cândido Rondon, Unioeste, 2013.

Cover	Fresh weight of head (g/plant)			Fresh weight of petioles (g/plant)		
	Green Pak Choi	White Pak Choi	Chingensai Natsu Shomi	Green Pak Choi	White Pak Choi	Chingensai Natsu Shomi
White row cover	362.45aA	330.42bA	374.14 aA	248.41aA	203.92bA	237.27aA
Black row cover	280.22aB	465.92abA	367.11 aAB	184.14aB	287.59abA	244.38aAB
Silver plastic	269.26aB	520.03aA	390.96 aB	173.08aB	323.27aA	256.64aAB
Black plastic	261.16aB	474.19abA	346.28 aB	171.01aB	299.80abA	219.43aAB
Tifton straw	262.65aB	405.78abA	316.11 aAB	169.03aA	245.57abA	202.83aA
Bare soil	333.28aA	358.86bA	336.92 aA	225.13aA	214.27abA	216.97aA
CV plot(%)		18.36			21.30	
CV subplot(%)		21.67			23.62	
	Dry weight of petioles (g/plant)			Yield (t/ha)		
White row cover	6.56aA	5.86aA	6.03aA	40.27aA	36.71 bA	41.57aA
Black row cover	4.73abB	7.00aA	5.91aAB	31.13aB	51.76abA	40.79aAB
Silver plastic	4.75abB	7.75aA	5.27aB	29.91aB	57.78aA	43.43aB
Black plastic	4.30abB	7.13aA	4.65aB	29.01aB	52.68abA	38.47aB
Tifton straw	3.86bB	6.20aA	4.50aAB	29.18aB	45.08abA	35.12aAB
Bare soil	5.64abA	5.54aA	5.24aA	37.03aA	39.87bA	37.43aA
CV plot(%)		19.39			18.36	
CV subplot(%)		19.30			21.67	

*Means followed by the same uppercase letter in the row and lowercase letter in the column are not significantly different at 5% probability by Tukey test (médias seguidas da mesma letra maiúscula na linha e letra minúscula na coluna, não diferem entre si pelo teste de Tukey a 5%).

Table 2. Height (HEI), plant diameter (PD), basal diameter (BD), fresh weight of leaves (FWL), dry weight of leaves (DWL), total dry weight (TDW), stem dry weight (SDW), leaf area (LA) and number of leaves (NL) per plant, of three cultivars of pak choi according to soil cover {altura (HEI), diâmetro da planta (PD), diâmetro basal (BD) massa fresca das folhas (FWL), massa seca das folhas (DWL), massa seca total (TDW), massa seca dos pecíolos (SDW), area foliar (LA) e número de folhas (NL) por planta, de três cultivares de pak choi em função da cobertura do solo}. Marechal Cândido Rondon, Unioeste, 2013.

Cultivar	HEI	PD	BD	FWL	DWL	TDW	SDW	LA	NL
	(cm)			(g)				(dm^2)	
White Pak Choi	30.77a	37.92a	8.28a	161.21a	10.28a	19.12a	2.24a	363.77a	16.12b
Ching. Natsu Shomi	22.63b	34.77b	7.85a	123.35b	7.64b	15.23b	2.31a	245.08b	18.68a
Green Pak Choi	23.15b	33.44b	8.27a	97.94c	6.37c	13.11c	1.76b	212.65c	16.27b
CV plot (%)	8.06	4.51	10.20	16.56	17.92	16.06	32.35	19.68	12.34

*Means followed by the same letter are not significantly different at 5% probability by Tukey test (médias seguidas da mesma letra, na coluna, não diferem entre si pelo teste de Tukey a 5%).

ha). This demonstrates that species are subjected to interference of both growing environment and management applied.

Greater fresh weight of petioles was verified for White Pak Choi, when grown on silver plastic mulching, compared with white row cover, with no differences among the other materials (Table 1). For soil coverages with black agrotextiles, silver and black plastics, the cultivar White Pak Choi had higher fresh weight of petioles than Green Pak Choi, being Chingensai Natsu Shomi intermediate. For the other types of soil cover used (white row cover, Tifton straw and bare soil), the fresh weight of petioles was not different between cultivars. Hachmann *et al.* (2010), examinating Chinguensai Choyou grown on different soil covers and floating blanket in western Paraná, observed that plants grown on black plastic had higher fresh weight of petioles.

The fresh weight of petioles is an important indicator in the choice of cultivars. Table 1 shows that the cultivar Green Pak Choi has up to 68% of the total weight of the plant composed of stems, while the cultivar White Pak Choi has at most 63% of the total plant weight represented by petioles. Genotypes with greater weight of petioles are best employed in the preparation of dishes using that part of the plant. This genetic material can replace the Chinese cabbage in stews and in yakissoba, with advantage of being more crunchy, juicy and tasty (Sakama, 2013).

The cultivar Green Pak Choi accumulated higher dry weight of petioles when grown on white agrotextiles, compared to Tifton straw (Table 1). The other cultivars showed no effect of soil cover for this characteristic. However, even without statistical difference, it is observed that for the cultivar White Pak Choi, higher values of dry weight were achieved in the cultivation on silver plastic.

Silvered films reflect almost all the energy radiated by the sun. In periods of low light or in denser plantings, the energy reflected by silver films may favor the photosynthesis of leaves located at the bottom of the plant canopy and thus contribute to the production of photoassimilates, which compose the plant dry weight (Sampaio & Araújo, 2001).

With regard to the cultivars, crops on black row cover and Tifton straw presented higher dry weight of petioles for White Pak Choi than Green Pak Choi. Chingensai Natsu Shomi had intermediate performance among cultivars for this characteristic (Table 1).

The yield of White Pak Choi cultivar was higher when cultivated on silver plastic than on white row cover and bare soil. For the other cultivars there was no effect of soil cover on crop yield (Table 1). This increased yield is due to changes in soil and air temperature near the coverage, water balance and nutrient availability. The plastic coverage conserves moisture in the layer near the soil surface, causing the roots to concentrate on the warmer and more fertile layer, which generates a better absorption of nutrients and earlier development of plant. (Araújo, 2011). Similar results were obtained by Ferreira *et al.* (2009), working with three lettuce cultivars in different soil covers, which achieved a higher productivity when the cultures were grown on silver plastic and rice husk, compared to bare soil.

With respect to the materials of soil cover, the black row cover and Tifton straw provided higher yields for the cultivars White Pak Choi and Chingensai Natsu Shomi, but the latter was not different from cultivar Green Pak Choi. The difference between cultivars is inherent to the genetic material and its interaction with the environment conditions.

The highest yield obtained in this experiment was 57.78 kg/ha, which is far below the reported by Dartora *et al.* (2013) who obtained yield of 112 t/ha when applied 195 kg/ha nitrogen, indicating the importance of fertilization for the crop.

The height and diameter of the plants was higher for the cultivar White Pak Choi (Table 2). The cultivar White Pak Choi also had higher fresh and dry weight of leaves, total dry weight and leaf area than the cultivar Chingensai Natsu Shomi, which in turn showed higher values for these variables compared to the cultivar Green Pak Choi. The basal diameter was not significantly different between the cultivars. For height and plant diameter and basal diameter, Feltrim *et al.* (2003), testing different plant densities with and without application of nitrogen in the crop of Pak Choi, hybrid Chouyou, observed mean values of 21.57, 27 and 7.17 cm respectively, lower than the results found herein. Dartora *et al.* (2013) evaluated the influence of different nitrogen levels on growth and productivity of Canton Pak Choi and obtained the highest plant height (29.48 cm) at a level of 140 kg/ha.

Plant height and diameter, basal diameter, leaf fresh weight, and number of leaves are variables with most importance, since they indicate the adaptability of the material in relation to the environment. The variation in the results obtained is justified because these characteristics are related to genetics of each cultivar, but may also be influenced by the cultivation environment and may result in morphological and physiological changes of plants (Hermes *et al*., 2001).

The stem dry weight was lower for the cultivar Green Pak Choi. Regarding the number of leaves, the prominent cultivar was the Chinguensai Natsu Shomi. Feltrim *et al.* (2003) for this component, observed 17.85 leaves when plants were fertilized with 40 kg/ha nitrogen, indicating that this variable varies with cultivar, time, place and culture conditions.

During the cultivation period, we observed early tasseling in the cultivar White Pak Choi. This is a characteristic of the cultivar, which is better suited to crops in warmer conditions, and tends to bloom early under colder conditions (Rokewood, 2012). This earliness with which the material entered the reproductive phase can be justified by the low air temperature recorded during the experiment. During most of the crop cycle the minimum air temperatures were below 15°C, resulting in the tasseling of the cultivar White Pak Choi. This may also explain the higher plant height observed for this cultivar, showing that there was an increase in stem for the emergence of the flower tassel.

The soil cover is an important practice in the cultivation of Pak Choi, yielding 44.91% more than the cultivation without mulching. The cultivar White Pak Choi obtained the highest yield (57.78 t/ha) under the growth conditions of the experiment. In general, the soil cover with synthetic materials provided higher values of productive characteristics of Pak Choi.

Comparing the results obtained in this experiment with other studies, it is evidenced that vegetable species have different production responses in relation to the different materials for soil cover, which is related to the ability of species to adapt to the changes performed in the environment of cultivation. Thus, it is necessary to conduct further studies to see how each species will behave on the use of mulching materials in different seasons of the year and may indicate an ideal material to be used in each season.

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