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Article

Cauliflower Cultivars Associated with *Urochloa decumbens* Straw Mulch in Integrated Weed Management

Cultivares de Couve-Flor Associados a Palha de ***Urochloa decumbens*** *no Manejo Integrado de Plantas Daninhas*

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ABSTRACT - In vegetable farming, the reduction in the use of herbicides has been an important factor in the definition of the production system. The objective of this research was to evaluate crop yield of cauliflower cultivars grown on *Urochloa decumbens* straw mulch, as well as the effect of the association between straw and cultivars on weed management. The treatments were arranged in a 2 x 4 factorial scheme: two managements (with or without *U. decumbens* straw mulch) and four cauliflower cultivars (Barcelona, Bromus, Júlia and Lisblanc). The experiment used a randomized block design with four replicates. There was no interference of straw mulch on crop yield of cauliflower cultivars. Hybrids Barcelona and Júlia presented yields of 22.0 and 23.9 t ha^{-1}, respectively, and they did not differ from each other. The Bromus and Lisblanc materials did not adapt to the edaphoclimatic conditions of the region, which resulted in reduced cultural control and high weed emergence after weeding. *U. decumbens* straw had high control of the weed community (581.2 pls m^{-2} - without straw and 8.3 pls m^{-2} - with straw). It is concluded that the *U. decumbens* straw as mulch is an effective tool in integrated management of weeds in cauliflower crops, without interfering with crop yield, and its potential to control weed community density is approximately 98.6%, at 22 days after transplanting. The adaptability of the cauliflower cultivar to the region has a high impact on weed management.

Keywords: *Urochloa decumbens*, *Brassica oleracea* var. botrytis, straw mulch, cultural management.

RESUMO - No cultivo de hortaliças, a redução no uso de herbicidas tem sido um fator importante na definição do sistema de produção. O objetivo deste trabalho foi avaliar o desempenho produtivo de cultivares de couve-flor sobre palha de ***Urochloa decumbens****, assim como o efeito da associação da palha e dos cultivares no manejo de plantas daninhas. Os tratamentos foram dispostos em esquema fatorial 2 x 4, sendo dois manejos (com ou sem cobertura morta com palha de* ***U. decumbens****) e quatro cultivares de couve-flor (Barcelona, Bromus, Júlia e Lisblanc). O experimento foi realizado no delineamento em blocos ao acaso com quatro repetições. Não houve interferência da cobertura morta no desempenho produtivo dos cultivares de couve-flor. Os híbridos Barcelona e Júlia apresentaram produtividades de 22,0 e 23,9 t* ha^{-1}*, respectivamente, não diferindo entre si. Os materiais Bromus e Lisblanc não se adaptaram às condições edafoclimáticas da região, o que reduziu o controle cultural e resultou em elevada emergência de plantas daninhas após a capina. A palha de* ***U. decumbens*** *exerceu elevado controle da comunidade infestante (581,2 pls* m^{-2} *– sem palha e 8,3 pls* m^{-2} *–*

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com palha). Conclui-se que a palha de U. decumbens como cobertura morta é uma ferramenta eficaz no manejo integrado de plantas daninhas no cultivo da couve-flor, sem interferir na produtividade da cultura e com potencial de controle da densidade da comunidade infestante de aproximadamente 98,6%, aos 22 dias após o transplante. A adaptabilidade do cultivar à região apresenta elevado impacto no manejo de plantas daninhas da couve-flor.

Keywords: *Urochloa decumbens*, *Brassica oleracea* var. botrytis, cobertura morta, manejo cultural.

INTRODUCTION

Weed interference on cauliflower crop results in high yield losses (Qasem, 2007). However, in recent years, increasing concern for the environment and human health has stimulated the development of non-chemical weed control through the use of physical and cultural methods (Price and Norsworthy, 2013; Cavalieri et al., 2018). Also worth of notice is the low availability of herbicides for vegetable farming; therefore, an integrated use of alternative weed control methods is important (Pannacci et al., 2017).

Mulching has proven to be an economically viable technique, especially in small areas. In organic farming systems, because of restrictions on the use of chemicals, mulching can be quite advantageous as a means of weed control (Resende et al., 2005). However, the type of mulch in use can influence weed management (Queiroga et al., 2002; Campiglia et al., 2010; Sediyama et al., 2010) and crop yield (Torres et al., 2017). *Brachiaria* has been noted for its easy establishment and considerable biomass production during the year, which results in excellent mulch (Timossi et al., 2007). Moreover, it is generally easily accessible in cropping areas. However, it is scarcely used in areas cultivated with vegetables.

Particularly for cauliflower crops, adaptability varies widely according to cultivar and edaphoclimatic conditions (Morais Jr et al., 2012); thus, the study of more competitive genotypes adapted to a particular region may also complement weed control (Colquhoun et al., 2017; Cavalieri et al., 2018). Another aspect to be considered is that different cultivars of a particular vegetable may have different levels of adaptability to the same production system (Meagy et al., 2013; Renaud et al., 2014; Resende et al., 2016), and one should evaluate the viability of *Brachiaria* as a mulch option for cauliflower cultivation, as well as the adaptability of commercial cultivars in this cultivation system.

Previous studies have shown that vegetables differ in their response to mulching (Resende et al., 2005; Santos et al., 2011; Ferreira et al., 2013). For this reason, further research is needed to identify residues that have adequate weed control, without, however, reducing crop yield (Price and Norsworthy, 2013).

Therefore, the evaluation of cultivars in environments with low use of chemical inputs allows the selection of more appropriate materials for a production system (Renaud et al., 2014), e.g., mulch without herbicides.

Thus, the objective of this research was to evaluate adaptability and crop yield of cauliflower cultivars grown on *Urochloa decumbens* mulch, as well as the effect of the association between straw and cultivars on weed management.

MATERIAL AND METHODS

The experiment was carried out in the city of Presidente Prudente, SP, at a geographical location of 22°07’21"S and 51°23’17"W, at 460 m of altitude. According to the Köppen classification, the climate is Aw (tropical wet with dry winter), with average temperature in the coldest month above 18 °C and precipitation in the driest month below 60 mm (CIIAGRO, 2014). Table 1 shows data on maximum, minimum and average temperatures and rainfall during the cauliflower cultivation period.

The experiment was carried out in soil classified as Red-Yellow Ultisol, from February to July. The chemical analysis of the soil, according to the methods proposed by Raij et al. (2001),

Table 1 - Data on maximum, minimum and average temperatures and rainfall during cauliflower cultivation

Period	T°C$_{Maximum\ average}$	T°C$_{Minimum\ average}$	T°C$_{Average}$	Rainfall (mm)
February	33.7	20.8	27.2	129.7
March	31.4	19.7	25.6	183.3
April	30.1	18.4	24.3	101.2
May	27.0	15.0	21.0	59.5
June	27.3	14.8	21.0	10.8
July	26.1	13.2	19.6	86.7

Source: CIIAGRO (2014).

showed the following characteristics in the 0-20 cm arable layer: pH in $CaCl_2$, 5.4; organic matter, 16 g dm^{-3}; base saturation, 80.0%; Ca, 58 mmol$_c$ dm^{-3}; Mg, 7.0 mmol$_c$ dm^{-3}; H + Al, 18 mmol$_c$ dm^{-3}; P$_{resin,}$ 20 mg dm^{-3}; K, 5.3 mg dm^{-3}; Zn, 3.3 mg dm^{-3}; Fe, 30.0 mg dm^{-3}; Mn, 15.7 mg dm^{-3}; Cu, 0.8 mg dm^{-3}; and B, 0.13 mg dm^{-3}. The soil had sandy loam texture with 833, 103 and 64 g kg^{-1} of total sand, silt and clay, respectively.

The experiment used a randomized block design with four replications. The treatments were arranged in a 2 x 4 factorial scheme, and two managements (with or without mulch with *Urochloa decumbens* straw) and four cauliflower cultivars (Barcelona, Bromus, Júlia and Lisblanc).

The seedlings were produced in 288-cell expanded polystyrene trays; sowing was performed on February 17 and transplanting in the field, on March 31.

Tillage of the experimental area consisted of plowing with a disc plow containing 14 discs (26") and harrowing using a leveling disc harrow with 24 discs (24"). Spacing was 0.5 m between plants and 1.0 m between rows, with density of 20,000 pl ha^{-1}. A sprinkler irrigation system was used.

The experimental unit was represented by an area of 14.0 m^2: 3.5 m long and 4.0 m wide. Four cauliflower rows were planted, in a total of 28 plants in the plot. *U. decumbens*, which had been obtained from an adjacent area, was mowed with a mechanical mower. The straw was evenly distributed in the plots on the day after transplanting, in an amount of 10.2 t ha^{-1}, considering the dry matter weight of straw.

The area for evaluation was composed of the two central rows, and two plants were discarded from the ends of the rows.

Fertilization before planting and topdressing fertilization were based on the recommendations of Trani et al. (1996), according to soil analysis. The formula 4-14-8 (NPK) was used for fertilization before planting. Topdressing fertilizations were performed at 20, 30, 45 and 55 days after transplanting (DAT), with ammonium sulfate and potassium chloride as sources. Fertilizations with boric acid and sodium molybdate were performed through foliar spraying.

Weeds from the experimental area were sampled before weeding (22 DAT) and at the time of harvest, with the aid of a 0.50 m quadrat, thrown once in each experimental unit. The plants were counted and identified, and dry matter weight was determined in a forced air circulation oven at 65 °C to constant dry matter weight.

At 38 DAT, canopy spread - which demonstrates the soil shading ability of plants - was determined in five plants of the usable area, measured from the ends of the largest opposite leaves of the plant.

Harvesting began at 120 days after emergence of the plants in the trays and lasted for 27 days. The plants were harvested when inflorescences were fully developed, with tightly packed flower buds, and compact and firm heads. At harvest, the following parameters were determined: cycle (days), obtained from the average of the plants in the usable area; inflorescence circumference (cm); inflorescence height (cm); fresh inflorescence weight (kg pl^{-1}); stem diameter (cm), final stand and total yield (kg ha^{-1}).

Data were subjected to analysis of variance with the statistical software Sisvar (Ferreira, 2011), and the means were compared by Tukey's test at 5% probability.

RESULTS AND DISCUSSION

There was no interaction between cultivars and management with straw mulch for crop yield and yield components of cauliflower. The independence between the factors shows that the adaptability of the evaluated materials was similar when they were cultivated on *U. decumbens* straw.

As for the straw factor, there was no difference for yield or yield components of cauliflower (Table 2). Previous studies have shown that vegetables differ in terms of yield when mulching is used. Tifton grass mulch provided increased dry matter weight of lettuce (Ferreira et al., 2013). For garlic, there was no effect of rice straw mulch (Trani et al., 2008). Despite the advantages of mulching for a reduction in temperature and an increase in soil moisture retention, there was also no difference in carrot yield after mulch of *Cynodon* spp. (Resende et al., 2005) and *Pennisetum purpureum* (Santos et al., 2011) was used, compared to uncovered soil. According to Teixeira et al. (2009), materials with higher carbon/nitrogen (C/N) ratio, such as grasses, have the advantage of remaining longer in the soil; however, there is a tendency for greater immobilization of nutrients, especially nitrogen.

Table 2 - Yield performance and yield components of different cauliflower cultivars in autumn-winter, with or without *Urochloa decumbens* straw as mulch

Management practices	CS	CIRC	HEI	SD	FW	CYCLE	FS	TY
	(cm)				(kg pl^{-1})	(days)	(pl ha^{-1})	(kg ha^{-1})
With straw mulch	49.9a	66.8a	13.1a	3.9a	1.3a	132.5a	14017.9a	17.4a
Without straw mulch	48.9a	67.7a	13.2a	4.0a	1.3a	130.9a	13214.3a	17.4a
Cultivars								
Barcelona	54.1a	70.0a	12.8bc	4.0a	1.18b	125.7c	19,107.1a	22.0a
Bromus	48.0ab	62.5b	12.7c	4.4a	1.25ab	124.3c	9,107.1b	11.2b
Júlia	53.5a	71.0a	13.4ab	3.7a	1.37ab	134.4b	18,035.7a	23.9a
Lisblanc	42.0b	65.5b	13.5a	3.8a	1.52a	142.2a	8,214.3b	12.5b

Means followed by the same letters in the columns do not differ significantly by Tukey's test (p>0.05). CS - canopy spread at 38 days after transplanting; CIRC - inflorescence circumference; HEI -inflorescence height; SD - stem diameter; FW - inflorescence fresh weight; CYCLE - medium cycle (emergence at harvest); FS - final stand; TY - total yield.

There was a difference in the cultivars for all variables (Table 2) except for stem diameter, with a mean value of 3.9 cm, which was higher than the values found by Monteiro et al. (2010), which ranged from 2.81 to 3.09 cm.

There was a difference for canopy spread of the plants (Table 2) among the materials; Lisblanc showed the lowest value (42 cm), which was statistically lower than those found for Barcelona (54.1 cm) and Júlia (53.5 cm), which interferes with their soil shading ability. According to Paolini et al. (2006), these differential characteristics among genotypes can be explored in integrated weed management.

For inflorescence circumference (Table 2), the results for Barcelona and Julia were worth of notice. Inflorescence height was higher for Lisblanc (13.5 cm) than for Bromus (12.7 cm) and Barcelona (12.8 cm).

The cycles (Table 2) of the mid-season materials of Bromus (124.3 days) and Barcelona (125.7 days) were the earliest, but they did not differ from each other. Júlia's cycle (134.4 days) was intermediate, and Lisblanc showed the longest cycle among the evaluated materials (142.2 days).

Fresh inflorescence weight (1.52 kg) of Lisblanc was higher than that of Barcelona (1.18 kg), but it did not differ for Bromus (1.25 kg) and Júlia (1.37 kg). Despite the formation of inflorescence, Bromus and Lisblanc materials did not adapt to the region at that time of cultivation. Incidence of bacteriosis in these cultivars significantly interfered with final stand, reducing total yield per hectare by approximately 50%, compared to the Barcelona and Julia materials, which did not differ from each other, with yields of 22.0 and 23.9 t ha^{-1}, respectively.

Morais Jr. et al. (2012) also found bacteriosis-related differences in adaptability of cauliflower cultivars. The yield values which were found are in agreement with those reported by Monteiro et al. (2010) and Zanuzo et al. (2013), who reported a variation between cultivars from 14.6 to 23.7 t ha^{-1} and from 5.1 to 18.9 t ha^{-1}; altitude in these places was 614 and 384 m, respectively. However, there is a lack of information in the literature about the materials evaluated in this essay.

Weed evaluation carried out before weeding at 22 days after transplanting showed no effect of cultivars on density or dry matter weight of weeds (Table 3). The early stage of development of the cauliflower seedlings and wide spacing between rows of the plants explain the similarity between the materials in cultural control. However, the straw of *U. decumbens* had a strong effect on emergence of the weed community, with suppression of approximately 98.6% of the density value found in management without straw (581.2 pl m^{-2}), in comparison to the use of mulch (8.3 pl m^{-2}). These data corroborate those of Silva Hirata et al. (2009), who found an infesting community of 904 pl. m^{-2} in a tomato crop in management without mulch and 5 pl m^{-2} in management with planting of *U. decumbens*. This finding highlights the potential of this grass in the vegetable farming system. The physical effect on weed seeds with scarce reserves to overcome the straw layer, reduction in temperature fluctuation, possible release of allelopathic substances and increased activity of seed-spoiling microorganisms are some of the possible suppressing effects of mulching on the soil seed bank.

Table 3 - Density and dry matter weight of weeds in the cultivation of different cauliflower cultivars with or without *Urochloa decumbens* straw as mulch at 22 days after transplanting

Management	22 days after transplanting					
	Density (pl m^{-2})			Dry matter weight (g m^{-2})		
	Total(1)	Grasses	Dico(2)	Total	Grasses	Dico
With straw mulch	8.3b	0.7b	1.4b	0.2b	0.0b	0.0b
Without straw mulch	581.2a	117.4a	237.5a	6.9a	2.3a	2.8a
Cultivars						
Barcelona	298.6a	50.0a	134.7a	4.4a	1.6a	1.6a
Bromus	261.1a	41.7a	91.7a	2.7a	0.7a	1.2a
Júlia	304.2a	63.9a	123.6a	2.7a	0.7a	1.3a
Lisblanc	315.3a	80.5a	127.8a	4.5a	1.7a	1.6a

Means followed by the same letters in the columns do not differ significantly by Tukey's test (p>0.05). (1) Total = grasses + dico + Benghal dayflower + purple nutsedge. (2) Dicotyledons.

Despite the initial stage of weeds, which resulted in low dry matter accumulation, the difference between the management practices was significant (6.9 g m^{-2} and 0.2 g m^{-2} without and with straw mulch, respectively) (Table 3). These results are in agreement with those of Campiglia et al. (2010), who found 93% suppression of weed biomass in tomato by the straw of *Avena sativa*. The authors underlined that the technique can be used in tomato crops in integrated weed management programs.

There was a suppressive effect of straw mulch on grasses and dicotyledons, with a higher density of dicotyledons compared to that of grasses at 22 DAT (Table 4). Among the species, *Cyperus difformis* (variable flatsedge), *Amaranthus* sp., *Eleusine indica*, *Chenopodium album* and *Commelina Benghalensis* were worth of notice. The species *Cenchrus echinatus*, *Portulaca oleracea* and *Richardia brasiliensis* were also present. These species were almost completely suppressed by the presence of straw. The lowest control was found for *C. benghalensis*, although it was also high (89.1%).

The difference in adaptability between the evaluated materials resulted in an effect on the weed community emerged after weeding. There was a significant interaction between management practices and cultivars for density and dry matter weight of dicotyledons, grasses and total (grasses + dicotyledonous + Benghal dayflower + purple nutsedge) (Table 5).

For weed management using straw, there was no difference among the cultivars, which shows that the mulch maintained satisfactory control of the weed community even though there was low shading from the cultivars whose final stand was reduced.

Table 4 - Weed species in the cultivation of different cauliflower cultivars with or without *Urochloa decumbens* straw as mulch, before weeding (22 days after transplanting) and at harvest

Weed species	Initial density (pl m^{-2})							
	Cultivars							
	Barcelona	Bromus	Júlia	Lisblanc	Barcelona	Bromus	Júlia	Lisblanc
	Without straw mulch				With straw mulch			
Amaranthus sp.	147.2	63.9	97.2	116.7	0.0	0.0	0.0	0.0
Bidens Pilosa	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0
Cenchrus echinatus	11.1	0.0	0.0	102.8	0.0	0.0	0.0	2.8
Chenopodium album	80.6	69.4	69.5	116.7	0.0	0.0	2.8	0.0
Commelina benghalensis	44.4	72.2	58.3	55.6	8.3	5.6	2.8	8.3
Cyperus difformis	175.0	177.8	172.2	150.0	0.0	0.0	0.0	0.0
Eleusine indica	88.9	83.3	127.8	55.5	0.0	0.0	0.0	0.0
Portulaca oleracea	19.5	19.5	44.5	13.9	0.0	0.0	0.0	0.0
Richardia brasiliensis	19.5	25.0	27.8	2.8	0.0	0.0	0.0	0.0
Sida sp.	2.8	5.6	2.8	2.8	0.0	0.0	0.0	2.8
Total	589.0	516.7	602.9	616.8	8.3	5.6	5.6	13.9
	Density at harvest (pl m^{-2})							
Amaranthus sp.	1.4	18.0	0.0	20.8	1.4	5.6	1.4	0.0
Bidens pilosa	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0
Chenopodium album	2.8	8.3	4.2	2.8	0.0	0.0	1.4	0.0
Commelina benghalensis	5.5	9.7	1.4	6.9	5.6	1.4	4.2	9.7
Cyperus difformis	0.0	0.0	0.0	6.9	0.0	7.0	0.0	1.4
Digitaria horizontalis	0.0	1.4	0.0	6.9	0.0	0.0	1.4	0.0
Eleusine indica	0.0	5.6	2.8	11.1	0.0	2.8	0.0	1.4
Gnaphalium spicatum	18.1	204.2	118.0	237.4	4.2	9.7	11.1	11.1
Portulaca oleracea	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Richardia brasiliensis	0.0	0.0	0.0	0.0	0.0	5.6	4.2	2.8
Sida sp.	0.0	2.8	0.0	0.0	0.0	2.8	0.0	0.0
Total	27.8	251.4	126.4	294.4	11.1	34.7	23.7	26.4

Table 5 - Density and dry matter weight of weeds in the cultivation of different cauliflower cultivars with or without *Urochloa decumbens* straw as mulch at harvest

Cultivar	Harvest					
	Density (pl m^{-2})					
	Total[(1)]		Grasses		Dicotyledons	
	With straw mulch	Without straw mulch	With straw mulch	Without straw mulch	With straw mulch	Without straw mulch
Barcelona	11.1Aa	27.8Ac	0.0Aa	0.0Ab	5.5Aa	22.2Ac
Bromus	34.7Ba	251.4Aab	2.8Aa	6.9Ab	23.6Ba	234.7Aab
Júlia	23.6Ba	126.4Abc	1.4Aa	2.8Ab	18.0Ba	122.2Abc
Lisblanc	26.4Ba	294.4Aa	1.4Ba	18.0Aa	13.9Ba	262.5Aa
	Dry matter weight (g m^{-2})					
Barcelona	1.9Aa	2.6Ab	0.0Aa	0.0Ab	0.8Aa	1.7Ab
Bromus	21.4Ba	77.2Aa	3.2Aa	8.7Aab	15.2Ba	59.7Aa
Júlia	2.5Aa	8.7Ab	0.2Aa	1.4Ab	1.8Aa	7.3Ab
Lisblanc	10.8Ba	70.8Aa	0.6Ba	23.0Aa	7.0Ba	46.2Aa

Means followed by the same letters, lowercase in the columns and uppercase in the rows do not differ significantly by Tukey's test ($p>0.05$). [(1)] Total = grasses + dicotyledonous + Benghal dayflower + purple nutsedge.

For management without straw, the reduction in the stand of Lisblanc and Bromus materials resulted in low cultural control of the weed community, with high weed dry matter accumulation compared to Barcelona and Júlia (Table 5). The results corroborate those of

Colquhoun et al. (2017), who found that the reduction in the establishment of carrot cultivars resulted in a competitive advantage for weeds.

Lisblanc showed higher grass density in the straw-free management than the other cultivars, which demonstrates that grasses are favored by reduced shading provided by this material. Yasin et al. (2017), in a study on the effect of light on grasses, found that reduced light intensity led to a decrease in biomass, plant height and number of leaves. Thus, the adaptability of materials to cropping regions significantly contributes to weed management.

In general, there was a marked reduction in the density of grass species at harvest, and the weed community was predominantly composed of *Gnaphalium spicatum* (Table 4). According to Lorenzi (2008), this is an annual or biannual plant, with 15 to 30 cm height, propagated by seeds; it has a clear preference for shaded soils with high organic matter and vegetation in the winter season. The cauliflower crop was harvested in July, which coincided with the vegetative phase of the species. The species *Amaranthus* sp., *Chenopodium album* and *Commelina Benghalensis* were also found, although in lower density.

The results show that mulching with *U. decumbens* is a promising alternative for use in the cauliflower production system, especially in smaller areas, e.g., family farms or organic crops, as it has high potential to reduce the use of herbicides and the need for weed control labor.

In conclusion, the adaptability of the cauliflower cultivar to the region has a high impact on weed management. The use of *U. decumbens* straw as mulch is an effective tool for integrated weed management, with a control potential of approximately 98.6%, without, however, interfering with cauliflower yield.

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