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RESEARCH

Harvest Management Effects on Canopy Height and Light Interception of 'Performer' Switchgrass and its Relationship with Weed Infestation

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ABSTRACT

Defoliation management can determine the presence or absence of desirable forage species. Canopy characteristics and light interception are two critical determinants of productivity and can influence weed pressure. The objectives of this study were to determine the effect of the factorial combination of four defoliation heights (clipped to 10, 20, 30, and 40 cm; DH) and four defoliation frequencies (clipped every 3, 6, 9, and 12 wk; DF) on light interception, canopy height, and weed canopy cover and frequency for 'Performer' (*Panicum virgatum* L.) switchgrass and to relate the abovementioned responses to previously reported productivity measurements. The experiment was conducted for 2 yr (2016 and 2017) at the Central Crops Research Station, Clayton, NC. The 16 treatments were allocated in a randomized complete block design replicated four times. Across years, light interception before harvest ranged from ~45 to 88%, canopy height ranged from 35 to 97 cm, and weed cover and frequency ranged from 0 to 75 and 0 to 95%, respectively. Greater canopy height was associated with greater light interception and lower weed infestation. Weed infestation occurred mainly for treatments harvested every 3 and 6 wk and defoliated to lower stubble heights; however, there was no impact of DH for DF treatments harvested every 9 and 12 wk. Canopy light interception values of at least 70% obtained in our study were associated with defoliation thresholds previously reported in the literature for sustained yields of 'Performer' switchgrass. Switchgrass canopy light interception values of at least 70% were achieved with canopy heights before harvest of ~60 cm tall.

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Abbreviations: DF, defoliation frequency; DH, defoliation height; DM, dry matter; PAR, photosynthetic active radiation.

Switchgrass (*Panicum virgatum* L.) is a C_4 grass broadly adapted throughout the United States (Hitchcock and Chase, 1950; Moser and Vogel, 1995). Switchgrass has become an increasingly important forage in the central and southeastern United States because of its productivity during the hot summer months when cool-season grasses are relatively unproductive or dormant (Moser and Vogel, 1995; Moore et al., 2004; Parrish and Fike, 2005). In North Carolina specifically, spring growth of switchgrass is not as severely damaged by late winter cold or late spring frost; consequently, grazing can start by mid-April or early May, producing an average of 322 (± 55) kg beef gain ha^{-1} by 1 June and before 'Coastal' bermudagrass [*Cynodon dactylon* (L.) Pers] is ready to graze (Burns et al., 1984).

Intense defoliation regimes, such as those characterized by short regrowth periods combined with low stubble heights, can affect plant persistence through low light intercepted by the canopy, diminished stored energy in reserve organs for regrowth (Chaparro et al., 1996), and increased weed infestation (Beaty and Powell, 1976). However, the impact of imposing defoliation regimes may vary by plant cultivar (Ashworth et al., 2014). At the end of a 4-yr defoliation trial, Ashworth et al. (2014) reported lower visual stand ratings for lowland switchgrass cultivars 'Alamo' and 'Kanlow' when clipped to 20 cm or lower, compared with the upland switchgrass cultivar 'Cave-in-Rock'.

Cultivar 'Performer' of switchgrass was developed from three cycles of selection occurring under natural environmental conditions in North Carolina, and it was released because of greater digestibility compared with cultivars 'Alamo' and 'Cave-in-Rock'

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(Burns et al., 2008). A previous study by Bekewe et al. (2018) concluded that, after 2 yr of imposing defoliation treatments, there were three defoliation thresholds that ensured the persistence of 'Performer' switchgrass. Persistence in that study was defined as sustained dry matter (DM) yield; however, DM yields were different by about twofold among the three thresholds, leaf/stem ratio was greater for the lower yielding treatments, and some treatments were discontinued due to loss of switchgrass stand and observed presence of weeds (Bekewe et al., 2018). Clipping every 3 wk to 40-cm stubble height resulted in DM yield of 4.4 Mg ha^{-1}, ≥6 wk to 20-cm stubble resulted in DM yield of 7.1 Mg ha^{-1}, and ≥9 wk to 10-cm stubble resulted in DM 10.9 Mg ha^{-1} (Bekewe et al., 2018). Information on light interception, canopy height, and weed infestation, and their relationship as a function of defoliation regimes, should aid understanding of the switchgrass responses reported in the literature.

The interception of light by the canopy is a fundamental requirement for crop growth (Monteith, 1972; Purcell, 2000) and plant competition (Barnes et al., 1990) and is a critical management tool to ensure pasture productivity and persistence (Brougham, 1956; Wallau et al., 2016). In situations where weed suppression by crop competition is the goal, what is being managed is light (McLachlan et al., 1993; Holt, 1995). Data on productivity responses for 'Performer' have been previously reported (Bekewe et al., 2018); therefore, the objectives of this study were (i) to characterize and compare canopy height and light interception of cultivar 'Performer' of switchgrass as a function of a wide range of defoliation management treatments, (ii) to determine canopy cover and frequency of weeds as a function of the treatments imposed, and (iii) to draw relationships among canopy height, light interception, and weed infestation responses measured in this study and previously reported productivity measurements. We hypothesized that weed infestation will be greater in treatments with lower switchgrass canopy light interception and lower canopy heights before and after clipping.

MATERIALS AND METHODS

Experimental Site and Plot Management

The experiment was conducted for 2 yr (2016 and 2017) at the Central Crops Research Station, Clayton, NC (35°40′ N, 78°29′ W). A 50- by 51-m area of well-established (>8 yr) 'Performer' switchgrass was used for this experiment. A detailed description of plot management was provided by Bekewe et al. (2018). In summary, plot management in the years prior to this trial consisted of annual maintenance fertilization with a single clipping to ~10-cm stubble height in late September followed by residue burning on February of each year. The accumulated biomass from the 2015 growing season was clipped and removed from the plots in late September 2015 in preparation for this trial. The soil type was classified as Wedowee sandy loam (fine, kaolinitic, thermic Typic Kanhapludults). Fertilization was based on soil-test analyses of the surface soil (0 to 15 cm deep) and followed the recommendations for growing switchgrass by the North Carolina Department of Agriculture and Consumer Services (Hardy et al., 2014) with N fertilizer broadcasted applied in a single application in mid-April for both years at rates of 141 and 176 kg N ha^{-1} yr^{-1} in 2016 and 2017, respectively. The last freeze event in spring occurred on 3 Mar. 2016 and 23 Mar. 2017. The first freeze event at the end of the growing seasons occurred on 13 Nov. 2016 and 4 Nov. 2017. Total annual rainfall from February to November was 1437 mm in 2016 and 1150 mm in 2017, vs. the 30-yr average of 1066 mm.

Treatments and Experimental Design

There were 16 treatments total resulting from the factorial combination of four levels of defoliation frequency (DF; clipped every 3, 6, 9, and 12 wk) and four levels of defoliation height (DH; clipped to 10-, 20-, 30-, and 40-cm stubble height). The experimental design was a randomized complete block design replicated four times. Treatments were imposed for 2 yr (2016 and 2017). The experimental unit size was 5 m wide by 5 m long (25 m^2) surrounded by an additional 1-m-wide alley of planted switchgrass between experimental units. Samples were collected within a centered 7.5-m^2 area (3 m long by 2.5 m wide). The first harvest event of the growing season, for the 3-wk DF, occurred when switchgrass canopy height was, on average, ~40 cm tall, and it occurred on 9 May 2016 and 18 May 2017; consequently, Day 0 to calendarize DF treatments was set to 18 Apr. 2016 and 27 Apr. 2017. The last harvest events of the seasons occurred on 19 Oct. 2016 and 15 Oct. 2017.

Response Variables

Canopy Height

Canopy height was measured before each harvest event. Plant height was defined as the distance from the soil level to the average height of the canopy, and it was determined by taking five randomly located measurements per plot using a ruler. The sampling points were located in the centered area of the plot and avoiding at least 1-m distance from the edges of the plot. The average of the five measurements provided an estimate of switchgrass canopy height per experimental unit. Canopy height was calculated by averaging the five canopy height measurements per experimental unit across harvest events.

Light Interception

Light interception of photosynthetic active radiation (PAR) by the switchgrass canopy was measured before and immediately after each harvest event. Light interception was characterized using a SunScan Canopy Analysis System (Dynamax) to measure transmitted PAR and incident PAR. The system consisted of two sensors, a 1-m-long quantum sensor that was placed at ground level to determine transmitted PAR, and an unshaded beam fraction sensor that was placed outside the plots to measure incident PAR. Both sensors are synchronized to take PAR readings simultaneously. Measurements were taken between 1200 and 1500 h EDT. Canopy light interception was determined at four randomly selected locations within each experimental unit. The average of the four observations per experimental unit provided an estimate of light interception for each harvest event. Values were averaged across harvest events to provide an estimate of canopy light interception per treatment. Switchgrass canopy light interception was calculated as

$$\text{Light interception } (\%) = \left(1 - \frac{\text{transmitted PAR}}{\text{incident PAR}}\right)100$$

Weed Canopy Cover and Frequency

For the purpose of this study, weeds were defined as plants other than switchgrass. Weed infestation was characterized by estimating weed canopy cover and frequency. Weed canopy cover is a measurement explaining the amount of ground area covered by weeds (Allen et al., 2011), and weed frequency is a measurement of the distribution of weeds in that area (Castillo et al., 2014). Weed infestation was characterized targeting midseason active growth of switchgrass and it was measured on 6 Aug. 2016 and 10 Aug. 2017, respectively. Among several other factors, weed pressure is a site-specific reflection of historical site management (Buhler et al., 1997; Dieleman et al., 2000). The plots at the initiation of this experiment were free of weeds and they were uniform stands of switchgrass; therefore, it was uncertain the level of weed pressure that could be observed as a result of treatments imposed. A 1-m^2 quadrat divided into 25 20- by 20-cm smaller squares (five rows of five) was placed at two random locations within each experimental unit. Weed canopy cover was estimated visually using a 0 to 100% scale in each square, with 0% corresponding to no weeds and 100% corresponding to weeds completely covering the area of the square. Weed frequency was determined on the same dates and using same quadrat-locations that were used to estimate canopy cover. Presence or absence of weeds was recorded at each of the 25 squares per quadrat. Weed frequency was calculated by counting the number of squares per quadrat where weeds were present and expressed as percentage of total number of quadrats counted. The average of the two quadrats per experimental unit provided an estimate of weed canopy cover and frequency per experimental unit.

Statistical Analysis

Results of the statistical analysis were considered significant if $P \leq 0.05$. Analyses of variance were performed with DF, DH, year, and their interaction effects as fixed effects. Year was treated as a fixed effect to evaluate potential carryover effects from year to year, and it was analyzed as a repeated measure with covariance structure modeled using Autoregressive Order 1 based on smaller Akaike information criterion values. Block was considered a random effect. For canopy height and light interception data, the analysis was set up using PROC MIXED in SAS (SAS Institute, 2010). Because of significant interaction effects of year with DF and year with DH, data are reported by year. Within year, response surface regressions were performed using the RSREG procedure of SAS. The complete model used was a second-order polynomial of the form:

$$y = \beta_0 + \beta_1\text{DF} + \beta_2\text{DF}^2 + \beta_3\text{DH} + \beta_4\text{DH}^2 + \beta_5(\text{DF} \times \text{DH}) + \varepsilon$$

where y is the response variable, β_0 is the intercept, β_1 and β_2 are the linear and quadratic coefficients for DF, respectively, β_3 and β_4 are the linear and quadratic coefficients for DH, respectively, β_5 is the interaction coefficient for DF and DH, and ε is the experimental error term. The GLM procedure of SAS was used to test the significance of coefficient estimates in reduced models (Freund and Littell, 2000). Terms that were not significant in the full model were retained in the reduced model only when there was a presence of higher order terms (e.g., nonsignificant linear effects of DF and DH were included in the reduced model when there was a significant DF × DH interaction; similarly, a nonsignificant linear effect was included in the reduced model when there was a significant quadratic effect). Table 1 shows the effects (coefficient estimates) in the reduced model. Contour plot figures were fitted using the ggplot2 package (Wickham, 2009) in R software (R Core Team, 2016). For weed canopy cover and frequency, ANOVA was set up using GLIMMIX in SAS (SAS Institute, 2010), and treatment contrasts were set up using the LSMESTIMATE procedure in SAS. Linear and nonlinear regressions for light interception with canopy height, weed cover, and weed frequency were performed using treatment means using JMP Pro 13 (SAS Institute, 2016).

RESULTS AND DISCUSSION

Canopy Height

The statistical models for canopy height included all terms from the complete model except the quadratic term for DH in both years (Table 1, Fig. 1). Across years, canopy height ranged from 35 to 97 cm (Table 1, Fig. 1). There was a DF × DH interaction effect in both years. The interaction effect occurred because, as stubble height increased from 10 to 40 cm, canopy height increased to a greater extent for treatments defoliated every 3 and 6 wk compared with 9 and 12 wk (Fig. 1). The lowest canopy height before harvest was ~35 cm, and it occurred when switchgrass was clipped every 3 wk to 10-cm stubble height.

Working with cultivar 'Pangburn' of switchgrass, Beaty and Powell (1976) reported that clipping to 15-cm stubble height each time the canopy reached a height of 91 cm yielded twice as much than when clipped every time it reached 61-cm height. In addition, they reported that overutilization of the grass at the start of the growing season, such as clipping monthly for three consecutive months starting in May, resulted in lower yields, lower tiller numbers, and weed infestation, to the point that weeds shaded the switchgrass tillers. However, the previously cited authors did not report canopy light interception measurements, nor estimates of magnitude of weed infestation. Working with 'Alamo' switchgrass, Seepaul et al. (2014) reported concurrent lower canopy heights at harvest and lower total herbage mass for treatments that were frequently clipped to a stubble height of 5 cm. Bekewe et al. (2018) indicated that frequently defoliated treatments had lower DM yield and required clipping to greater stubble heights to ensure productivity and persistence of 'Performer' switchgrass.

Table 1. Coefficient estimates for the fitted regression model: estimated response = $b_0 + b_1\text{DF} + b_2\text{DF}^2 + b_3\text{DH} + b_4\text{DH}^2 + b_5 (\text{DF} \times \text{DH})$ or a reduced form of the model for responses reported.†

Model‡	Coefficient estimate b_0	b_1	b_2	b_3	b_4	b_5	R^2	Figure
CH-16	11.98	3.73	0.257	1.29	–	–0.117	0.96	1
		0.001§	0.001	0.001	–	0.001		
CH-17	9.04	5.01	0.18	1.17	–	-9.4×10^{-2}	0.93	1
		0.001	0.0171	0.001	–	0.001		
LIAH-16	0.262	–	–	2.47	–0.022	–	0.85	–
		–	–	0.001	0.012	–		
LIAH-17	–15.99	3.04	–0.271	4.12	-5.1×10^{-2}	–	0.90	2
		0.033	0.004	0.001	0.001	–		
LIBH-16	20.16	4.44	–	1.73	-1.1×10^{-2}	-9.3×10^{-2}	0.86	3
		0.001	–	0.001	0.046	0.001		
LIBH-17	3.19	7.04	–0.145	2.78	-2.4×10^{-2}	–0.114	0.86	3
		0.001	0.038	0.001	0.002	0.001		

† DF, defoliation frequency; DH, defoliation height.

‡ CH, canopy height (cm); LIAH, light interception after harvest (%); LIBH, light interception before harvest (%). Trailing digits indicate the year.

§ For each model, values in the second row indicate significance level $P(|t| > t_\alpha) = \alpha$.

Light Interception

In general, greater light interception after harvest occurred for higher stubble heights (i.e., 30- and 40-cm DH). There were interaction effects of year with both DF and DH; therefore, data were analyzed by year. In 2016, there was a DH effect only. Light interception in 2016 increased from 23 to 64% with linear and quadratic effects (Table 1) as DH increased from 10 to 40 cm. In 2017, there were DF and DH effects. Light interception in 2017 increased (with linear and quadratic effects) from 25 to 72% as DH increased from 10 to 40 cm; however, averaged across DH treatments, light interception after harvest in 2017 decreased from 55% for DF every 3 wk to 46% for DF every 12 wk (Table 1, Fig. 2). Greater light interception by higher stubble heights was expected; however, the extent of the response was unknown for 'Performer' switchgrass. For 'Florakirk' bermudagrass [*Cynodon dactylon* (L.) Pers.], Pedreira et al. (2000) reported light interception levels of 22 and 78% for stubble heights of 8 and 24 cm, respectively. For 'Mott' elephantgrass (*Pennisetum purpureum* Schum.), whose growth habit and plant morphology are more similar to switchgrass, Chaparro et al. (1996) reported that light interception increased from 11 to 60% as stubble height increased from 10 to 46 cm.

Light interception before harvest ranged from 45 to 88%, and it increased as a function of greater DH and longer regrowth intervals (Table 1, Fig. 3). There were interaction effects of year × DH and year × DF × DH; therefore, the data were analyzed by year. There was a DF × DH interaction effect in both years (Table 1). In 2016, light interception before harvest increased from 47 to 77, 57 to 76, 68 to 78, and 78 to 80% for DF treatments harvested every 3, 6, 9, and 12 wk, respectively, as DH increased from 10- to 40-cm stubble height (Table 1, Fig. 3). In 2017, light interception before harvest increased from 45 to 82, 59 to 86, 70 to 87, and 79 to 85% for DF

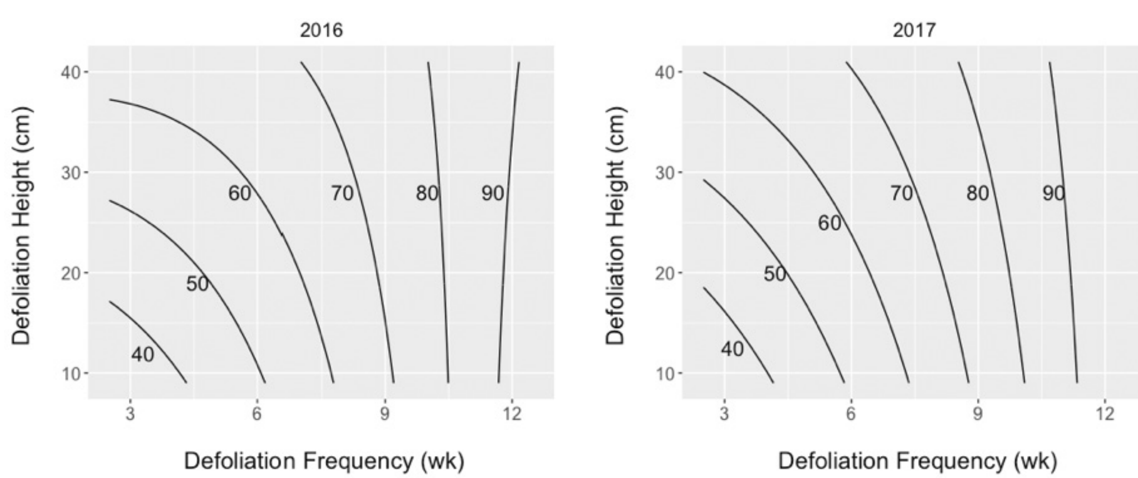

Fig. 1. Canopy height (CH) before harvest of 'Performer' switchgrass as a function of defoliation frequency (DF) and defoliation height (DF) in 2016 (CH-16) and 2017 (CH-17). Models to generate surface contours were: CH-16 = 11.98 + 3.73 (DF) + 0.257 (DF^2) + 1.29 (DH) – 0.117 (DH × DF), R^2 = 0.96; and CH-17 = 9.04 + 5.01 (DF) + 0.18 (DF^2) + 1.17 (DH) – 0.094 (DF × DH), R^2 = 0.93.

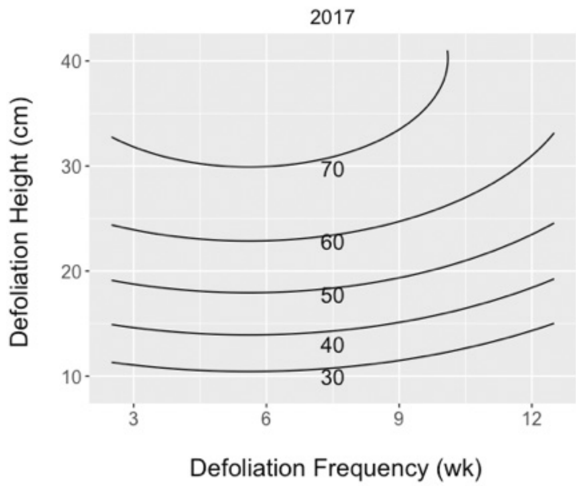

Fig. 2. Light interception after harvest (LIAH) by the residual stubble height as a function of defoliation frequency (DF) and defoliation height (DH) in 2017 (LIAH-17). Surface contour was generated using the model LIAH-17 = –15.99 + 3.04 (DF) – 0.271 (DF^2) + 4.12 (DH) – 0.051 (DF × DH), R^2 = 0.90.

treatments harvested every 3, 6, 9, and 12 wk, respectively, as DH increased from 10- to 40-cm stubble height (Table 1, Fig. 3). The lowest values for light interception (≤65%) were observed for treatments harvested every 3 wk to 10- and 20-cm stubble height and every 6 wk to 10-cm stubble height. Light interception values before harvest were ≥70% for all DH treatments harvested every 9 and 12 wk.

Chaparro et al. (1996) reported that rhizome mass, rhizome total nonstructural carbohydrate concentration, and N reserves were reduced by frequent, close defoliations for 'Mott' elephantgrass. Under continued frequent defoliation at lower stubble heights, the leaf area of forage plants may not be able to support the plant's growth needs; subsequently, regrowth is then dependent on mobilization of stored reserves (Booysen and Nelson, 1975; Harris, 1978). If stored reserves are diminished over time and not allowed to replenish due to intense defoliation regimes, the result is subsequent weakened and loss of stands. The previous reports coincide with the results reported for 'Performer' switchgrass by Bekewe et al. (2018). Frequently clipped treatments to lower DH (i.e., harvest every 3 wk to 10- and 20-cm stubble height) imposed during 2 yr to a well-established switchgrass stand (>8 yr old) were discontinued due to loss of switchgrass stand and observed presence of weeds (Bekewe et al., 2018). Understanding thresholds for light interception can help define defoliation strategies to optimize yields, forage nutritive value, and to prevent weed pressure (Brougham, 1956; Parsons and Penning, 1988). Working with limpograss [*Hemarthia altissima* (Poir.) Stapf et C.E. Hubb], Wallau et al. (2016) concluded that light interception values to trigger initiation of defoliation and conducive to optimize growth and utilization of forage may be influenced by plant growth habit and sward structure. The relationship between canopy height and light interception for 'Performer' switchgrass as a function of defoliation treatments, including the treatments reported by Bekewe et al. (2018), is presented in Fig. 4. Our results show that the previously reported defoliation regimes (i.e., combining frequency and height of defoliation) that sustained various levels of DM yields for 'Performer' switchgrass (Bekewe et al., 2018) achieved canopy light interception values before harvest of at least 70%. Switchgrass canopy light interception values of at least 70% were achieved with canopy heights before harvest of ∼60 cm tall (Fig. 4).

Weed Infestation

Weed infestation was mainly due to the presence of large crabgrass [*Digitaria sanguinalis* (L.) Scop.] and horseweed (*Conyza canadensis* L.), and it occurred mainly for treatments harvested every 3 and 6 wk (Fig. 5). For treatments harvested every 3 wk, weed canopy cover ranged from 10 to 92%, and it was consistently greater in 2017 than in 2016 across all DH treatments (Fig. 5). For treatments harvested every 6 wk, canopy cover ranged from 4 to 25%, and the

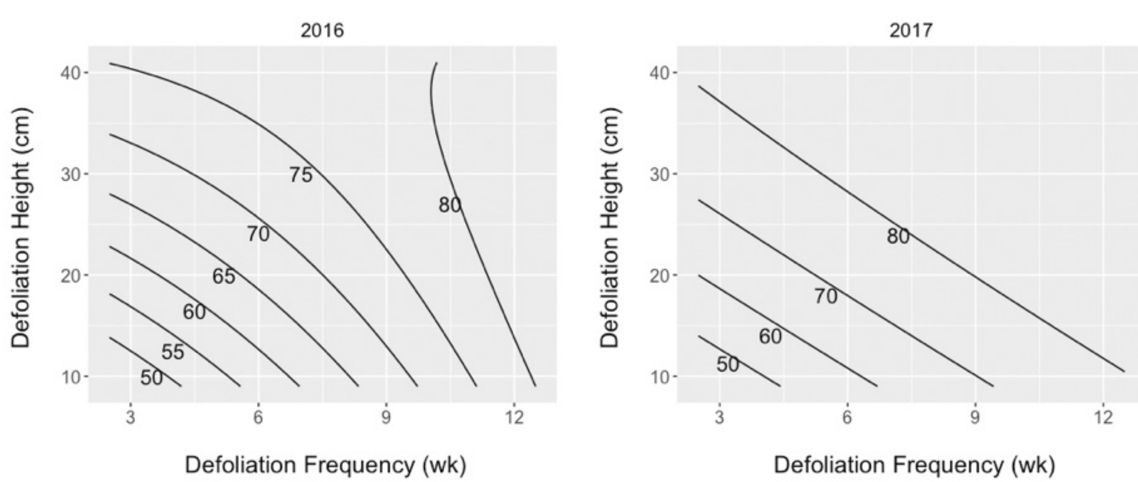

Fig. 3. Light interception before harvest (LIBH) in 2016 (LIBH-16) and 2017 (LIBH-17) as a function of defoliation frequency (DF) and defoliation height (DH). Surface contours were generated using models: LIBH-16 = 20.16 + 4.44 (DF) + 1.73 (DH) – 0.011 (DH^2) – 0.093 (DF × DH), R^2 = 0.86; and LIBH-17 = 3.19 + 7.04 (DF) – 0.145 (DF^2) + 2.78 (DH) – 0.024 (DH^2) – 0.114 (DF × DH), R^2 = 0.86.

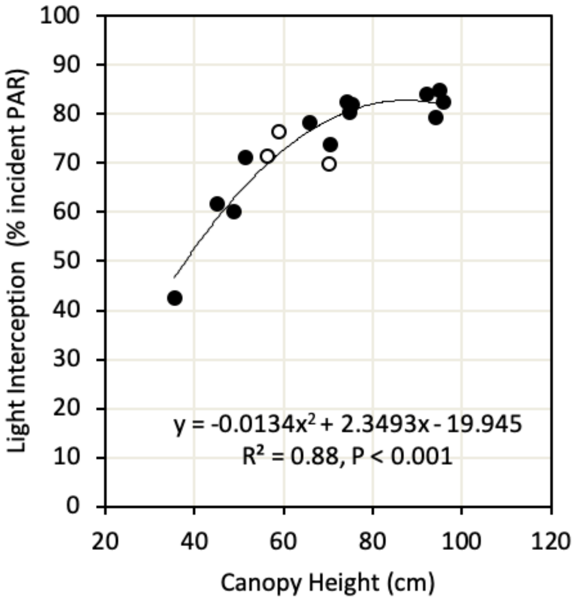

Fig. 4. Relationship between canopy height and light interception, both measured before harvest, for 'Performer' switchgrass. Data are means of 2 yr and four replicates (n = 8). Open circles represent defoliation management thresholds (every 3 wk to 40-cm stubble height, 6 wk to 20-cm stubble height, and 9 wk to 10-cm stubble height) for sustained dry matter yields (Bekewe et al., 2018); solid circles to the left of the thresholds resulted in lower yields and solid circles to the right resulted in sustained yields. PAR, photosynthetic active radiation.

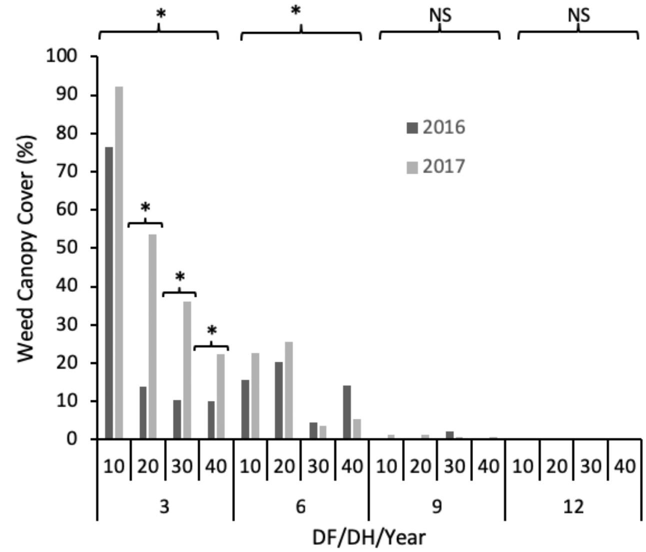

Fig. 5. Weed canopy cover as a function of defoliation frequency (DF), defoliation height (DH), and year for 'Performer' switchgrass. Data are least squares means of four replicates. SE = 3.9. Asterisks (*) denote significant effects at $P < 0.05$. NS, nonsignificant.

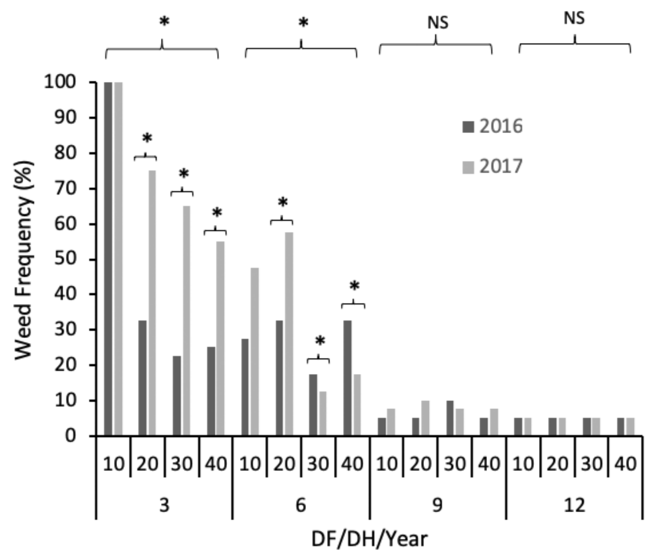

Fig. 6. Weed frequency as a function of defoliation frequency (DF), defoliation height (DH), and year for 'Performer'. Data are least squares means of four replicates. SE = 5.6. Asterisks (*) denote significant effects at $P < 0.05$. NS, nonsignificant.

DH × year interaction effect occurred because there was a trend (P = 0.06) for greater canopy cover in 2016 for DH treatment clipped to 40 cm only. For treatments defoliated every 9 and 12 wk, weed cover was ≤2% in both years (Fig. 5). Greater infestation of crabgrass in 2017 for the more frequently defoliated treatments may be attributed to carryover effects from year to year that resulted in reduced switchgrass stands and productivity (Bekewe et al., 2018) and provided more opportunity for crabgrass establishment and seed development. Bekewe et al. (2018) reported that treatments defoliated every 3 wk to 10- and 20-cm DH were discontinued in 2017 due to loss of the switchgrass stand. Our results indicate that the two previously cited treatments had the greatest weed infestation values (≥54%, Fig. 5 and 6) and the lowest values for switchgrass canopy height (Fig. 1) and light interception (Fig. 2). Working with cultivars 'Cave in Rock', 'Sunburst', and 'Pathfinder', Madakadze et al. (1999) also observed greater weed infestation that resulted in discontinued experimental treatment for switchgrass swards clipped every 2 wk to 15-cm stubble height, and no weed pressure was reported when frequency of defoliation was 4 wk. In 2017, weed canopy cover was <10% for all treatments except DH treatments at 3-wk DF, and the 6-wk DF at 10- and 20-cm DH (i.e., 6 out of 16 treatments).

Weed frequency had greater values for treatments harvested every 3 and 6 wk (Fig. 6). For 3-wk DF, weed frequency in both years was 100% for DH treatment harvested to 10-cm stubble height, and it was greater in 2017 for all the other DH treatments. For 6-wk DF, weed frequency was numerically greater in 2017 for 10-cm DH and greater for 20-cm DH. It is not clear why values for treatments harvested to 30- and 40-cm DH every 6 wk were lower in 2017; however, this response pattern was also observed for weed canopy cover. There were no differences in weed frequency between years for DH treatments harvested every 9 and 12 wk, and frequency values were ≤10%. Overall, weed frequency was <30% for all treatments except for all DH treatments harvested every 3 wk, and DH treatments harvested to 10- and 20-cm stubble heights every 6 wk. (Fig. 6).

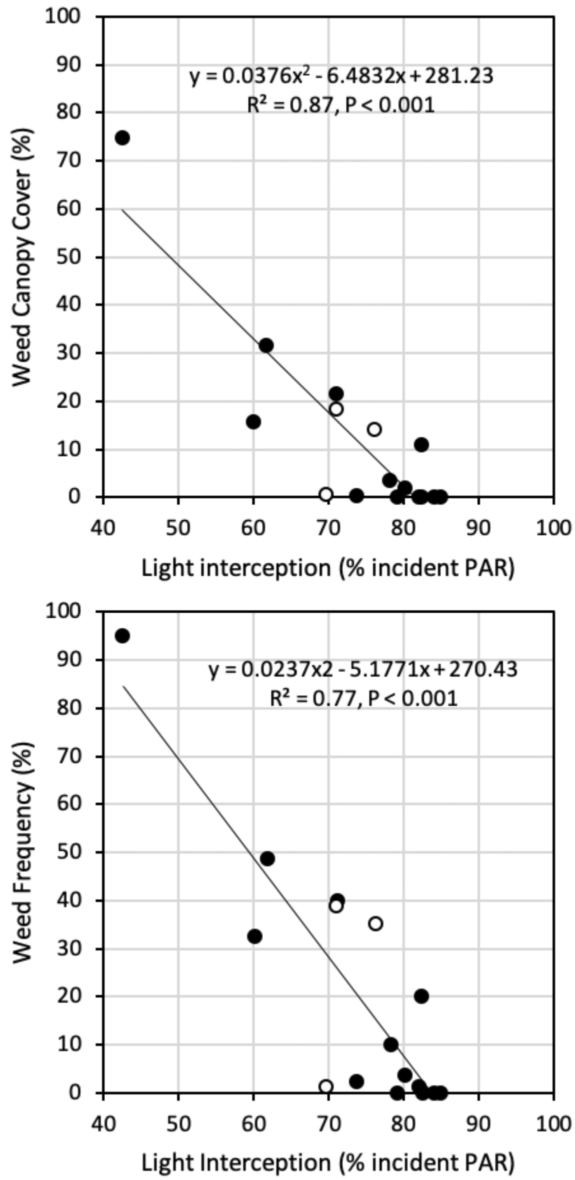

Fig. 7. Weed cover and frequency in relation to light intercepted by 'Performer' switchgrass canopy before harvest. Data are means of 2 yr and four replicates (n = 8). Open circles represent defoliation management thresholds (every 3 wk to 40-cm stubble height, 6 wk to 20-cm stubble height, and 9 wk to 10-cm stubble height) for sustained dry matter yields (Bekewe et al., 2018); solid circles to the left of the thresholds resulted in lower yields and solid circles to the right resulted in sustained yields. PAR, photosynthetic active radiation.

Under the conditions of this experiment, weeds were most prevalent in the 3-wk DF 10-cm DH treatment (Fig. 5 and 6), which coincided with the lowest light interception values (for both before and after harvest) in both years. Lower values for light interception before harvest of the switchgrass canopy resulted in greater weed cover and frequency ($P < 0.001$, Fig. 7). A similar response was reported by Sanderson et al. (2012) for grass–legume mixtures. Crabgrass is a warm-season annual grass, considered a weed problem mainly in row-crop systems due to its rapid growth rate and spreading morphology (King and Oliver, 1994; Teutsch et al., 2005). However, crabgrass has greater nutritive value and is readily grazed by livestock compared with most other warm-season grasses (Beck et al., 2007). Because this trial was conducted under clipping, and due to the value of crabgrass as a forage for grazing livestock that grazes it readily, the results of this trial can only be applicable to clipping as the defoliation mechanism, and it is unclear at this point if the weed infestation by crabgrass or other weeds may differ if the study was conducted under grazing conditions for 'Performer' switchgrass.

CONCLUSIONS

Greater canopy height was associated with greater light interception and lower weed infestation. Treatments harvested to 10- and 20-cm stubble height resulted in greater weed infestation when the harvest occurred every 3 and 6 wk; however, defoliation stubble height had no impact on weed infestation when treatments were harvested every 9 and 12 wk. This result highlights the interaction effect of DF and DH on weed infestation and ultimately switchgrass responses to defoliation regimes. In addition, our results showed that previously reported defoliation thresholds for 'Performer' switchgrass that sustained different levels of DM yield achieved canopy light interception values before harvest of at least 70%. Switchgrass canopy light interception values of at least 70% were achieved when canopy heights before harvest were at least 60 cm tall.

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgments

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