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Corn + white clover intercropping under management of herbicides and nitrogen levels

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Abstract

Intercropping cash crops with perennial pasture legumes can improve crop-livestock systems. In these systems, interspecific competition can affect crop yield, unless suppressed by herbicides. An experiment was carried out to determine whether established stands of white clover pasture, suppressed with herbicides, could be used as living mulch in no-tillage intercropping systems with corn. Treatments were arranged in a completed randomized block design with four replications in a 3 x 4 factorial scheme being three herbicide suppression as follows: (i) broadcast application of Paraquat/Diuron (Gramocil®) + 2,4-D (Aminol®) at rates of 300 + 806 g i.a ha^{-1}, respectively and (ii) glyphosate (Zapp Qi®) + 2,4-D at rates of 1080 + 806 g i.a ha^{-1}, both applied sequentially seven days before and 15 days after corn sowing, and glyphosate + glyphosate (1080 + 1080 g i.a ha^{-1}) applied sequentially 21 days before and 15 days after corn sowing and the 2nd factor four nitrogen rates (0, 60, 120, 180 kg ha^{-1}). The results showed that Nitrogen input is an important element for the optimization of corn + clover intercrop, combined with herbicide suppression to minimize competition effects on the main crop. The corn grain yields ranged from 6.9 to 12.3 Mg ha^{-1} which achieved greatest under the glyphosate + glyphosate (Gly + Gly) treatment. Based on these results, it is possible to use white clover in intercropping systems with corn crop with autogenic clover regrowth after corn harvest.

Keywords: Corn grain yield, Clover suppression, Glyphosate, 2.4-D, Paraquat.
Abbreviations: DAE_days after emergence; Gly + Gly_glyphosate + glyphosate.

Introduction

Although humankind has developed a large variety of agricultural techniques, integrating the different advantages and overcoming limitations remain challenging. One possible solution might be intercropping systems, where one or more crops are simultaneously cultivated on the same field (Thayamini and Brintha, 2010). Such systems are not only more efficient than sole cropping, but also can improve ecological conditions (Culman et al., 2010; Ratnadass et al., 2012).

Intercropped perennial legumes can provide long-term, heterogeneous and stable habitats for insects, herbivores, predators, and microbial populations. Moreover, they contribute to the maintenance of a stable and diverse food web structure, facilitating ecosystem services (Culman et al., 2010; Ratnadass et al., 2012). Consequently, intercropping may decrease yield losses caused by weeds, insects, and pathogens. In turn, this could decrease insecticide and herbicide inputs and; thus, promoting environmentally friendly agricultural practices.

Adding perennial legumes to corn-based cropping systems is considered a good alternative to reduce nitrogen costs and increase corn yields (Thayamini and Brintha, 2010). The nitrogen inputs from symbiotic nitrogen fixation and its effects on the cropping system are considerable leading to a significant reduction of the negative environmental impacts (Jensen, 1996). In these ways, white clover-corn intercropping can effectively promote more sustainable crop-livestock systems (Fedoroff et al., 2010; Herrero et al., 2010).

Corn is a common component in most intercropping systems in the tropics (Ijoyah, 2012) and mainly used as a carbohydrate source for both humans (in the developing countries) and animals (Undie et al., 2012). In cereal-legume intercropping, corn has an advanced growth rate, a height advantage and a more widespread rooting system, allowing it to successfully compete with associated legumes.

White clover is also efficiently used as living mulch intercropped with corn, since its growth rate decreases with increasing temperatures along the growing season, limiting competition for nutrients. Its resistance may allow the use of herbicides for weed control during the intercropping period, limiting interspecific competition. Moreover, clover species may be managed as living mulch in corn, with little or no corn whole-plant or grain yield reduction, as clover recovers a full production within 12 months without replanting (Zemenchik et al., 2000).

The primary concern about living mulch systems is the extent of competition between the primary crop and the mulch. Yield reduction in the main crop, caused by competition with the added cover crop, is a serious problem (Zemenchik et al., 2000). Therefore, it is crucial to minimize this interference through mulch suppression. Furthermore, to be an acceptable alternative for farmers, suppression must be practical and economical.

A number of solutions have been proposed to reduce negative cover crop effects on the main crop. Mechanical and chemical means have been suggested to restrict the growth of the cover crop through a competitive effect on the main crop (Machado et al., 2013; Ijoyah, 2012).

In this context, we evaluated corn-white clover intercropping in terms of herbicide tolerance of white clover, methods to reduce weed competition, nitrogen potential reduction due to the presence of clover, and the clover regrowth potential without replanting.

Results and discussion

Corn development

There was no interaction effect between herbicide management and nitrogen levels on corn plant height. However, corn development, in terms of height, was affected by the clover herbicide management, when measured at 20 and 40 days after emergence (DAE). Final height in the treatment with Gly + Gly was greater than other treatments (Table 1).

According to Kozlowski (2002), the critical period for preventing weed interference in corn is between the growth stages V2 and V7. Thus, taller plants represent a faster initial development, with a greater ability to compete for resources and; therefore, a higher yield potential.

Zemenchik et al. (2000), evaluated glyphosate rates for suppression of kura clover in an intercropping system with corn and reported that a rate of 3.4 kg a.e. ha^{-1} was more effective and resulted in higher corn plants than the treatment with 1.7 kg a.e. ha^{-1}. Corn plants under no clover suppression treatments achieved 44% less than those in the treatment with the higher glyphosate rate. Furthermore, agronomic traits, such as fertilizer application, corn sowing time, and mulch biomass, may significantly affect competition between intercropping species.

Nitrogen levels also affected corn development and height at 20 DAE ($Y = 36.32 - 0.0007222x + 0.0001682x^2$) and 40 DAE ($Y - 103.80 + 0.226037x - 0.00073x^2$), with a quadratic curve as N levels increased (0, 60, 120, and 180 kg ha^{-1}). At this stage, the corn plants may have reached their maximum genetic potential; and therefore, did not respond to increasing N levels. However, they continued responding to N levels throughout the growing cycle, since the final height responded linearly to the N levels ($Y - 255.159 + 0.1440x$).

Adesoji et al., (2013) reported increased corn growth as a result of nitrogen effects that lead to increased cell division, cell expansion and increase in the size of all morphological parts. Lana et al. (2009), evaluated increased rates of N (0, 30, 60, and 90 kg ha^{-1}) as a side dressing on corn and reported a linear increase in plant height, ear insertion height and thousand-grain weight.

Corn yield components and final yield

The corn yield components grains per row, grains per ear, and thousand-grain yield were influenced by white clover herbicide managements (Table 1) as well as by nitrogen levels. In contrast, the number of rows per ear showed an average value of 18.17 (Fig. 1).

Corn yield components such as grains per row, grains per ear, and thousand-grain weight responded linearly to nitrogen levels. The difference between number of grains per ear and thousand-grain weight between the treatment without nitrogen and with 180 kg N ha^{-1} was 95 grains and 50 grams, respectively, directly influencing corn grain yield.

Balbinot Junior et al. (2005) reported that the number of grains per row was the component with the highest correlation (0.586) with corn yield. Combined with the number of rows per ear, these two variables explained 47% of the grain yield variation.

Mohammadi et al. (2003) stated that the number of grains per ear and the thousand-grain weight were the most important components for prediction of corn grain yield. Despite the linear effect of yield components depending on nitrogen levels, obtaining the highest number of grains per area is a function of plant population and the number of ears per plant (prolificacy). This means that corn yield is determined mainly by the number of grains per m^2, which is dependent on plant population. In addition, thousand-grain yield can also determine corn yield (Lopes et al., 2007).

Corn plant population exerts a direct impact on crop yield. Figure 1C shows the close relationship between plant density and corn yield. According to Andrade and Abbate (2005), corn plants have a low plasticity in terms of compensating low plant densities due to a restricted capacity to compensate yield between yield components and low plant population, which might explain the corn yield results.

In relation to the clover herbicide management strategies, corn population under Gly + 2,4-D treatment showed a linear response to increasing N levels. For the other treatments, we observed a quadratic response, depending on the N level. The lower plant density at lower N levels can be explained by clover competition, which suppresses corn plant development and affects the final population. Similarly, clover used only for soil coverage can affect corn plantability by limiting seed deposition depth due to the presence of large amounts of biomass, resulting in a lower plant stand and impaired corn yield potential (Trogello et al., 2013).

Clover management with Gly + Gly resulted in a higher corn plant population in the treatment without N, which explains the higher yield compared with the other treatments. Similar to the treatment with Gly + 2,4-D , corn plantability was favored and plant density was higher.

There was also a difference in corn plant population between the treatments Gly + Gly and Gly + 2,4-D. The largest glyphosate spectrum resulted in a better control of Alexander grass, which appeared in the plots with the 2,4-D

Table 1. Corn plant height (cm) at 20 and 40 days after emergence (DAE), final height, and corn yield components: number of rows per ear, grains per row, grains per ear, thousand-grain weight (TGW), and final plant population (thousand ha^{-1}) in systems intercropped with white clover at different clover management strategies.

Treatments	Height Evaluation periods			Corn yield components				
	20 DAE	40 DAE	Final	Rows	Grains	Grains/ear	TGW	Stand
Gly + 2,4-D[1]	38.08 b	111.8 b	258.6 b	18.28 b	29.4 b	537.2 b	384.5 b	54.982 b
Par + 2,4-D[2]	37.42 b	112.9 b	261.7 b	18.68 a	30.4 b	567.8 ab	409.8 a	57.589 ab
Gly + Gly[3]	39.63 a	120.1 a	283.9 a	17.55 c	33.2 a	582.1 a	410.5 a	61.455 a

[1] Glyphosate and 2,4-D (1,080 + 806 g i.a); [2] Paraquat/Diuron and 2,4-D (300 + 806 g i.a), applied sequentially 7 days before and 15 days after corn sowing and [3] glyphosate + glyphosate (1,080 + 1,080 g i.a,) applied sequentially 21 days before and 15 days after corn sowing. Means with different letters within one column differ significantly by Scott-Knott´s test (p ≤ 0.05).

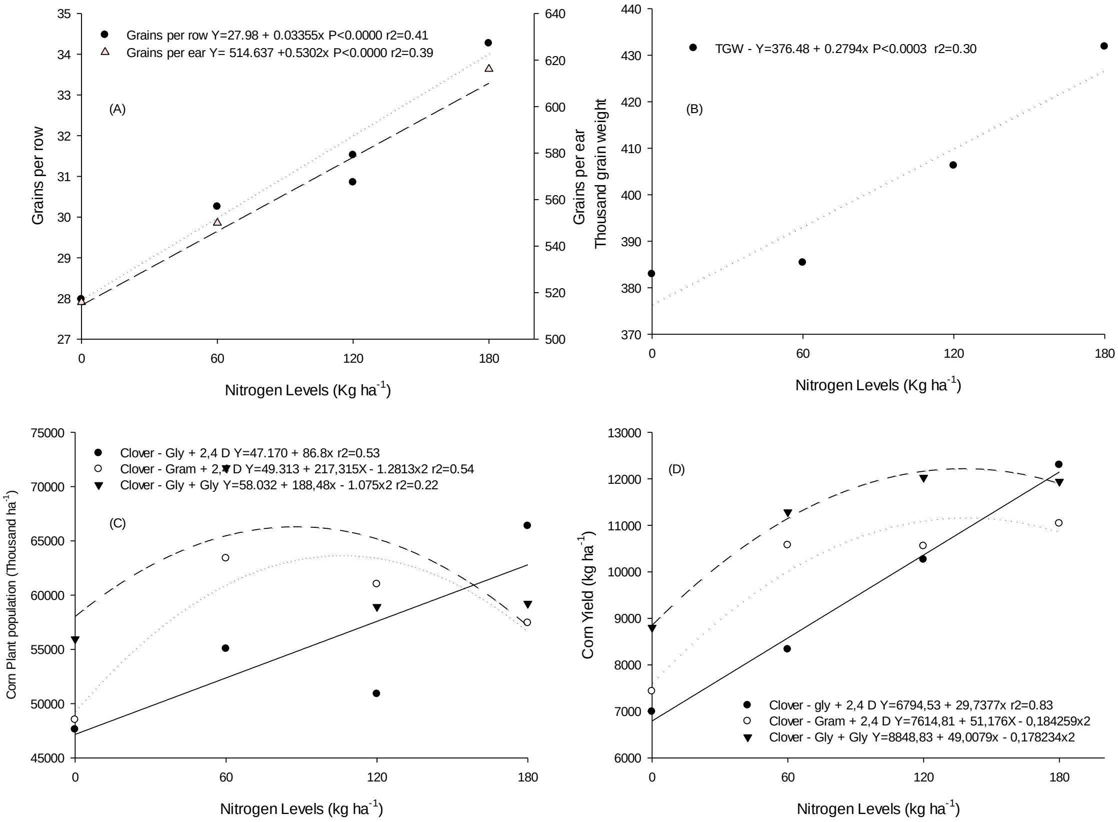

Fig 1. Regression analysis of the number of grains per row, grains per ear (A), thousand-grain weight (B), corn population (C), and corn grain yield (D) in relation to nitrogen fertilization levels (0, 60, 120, and 180 kg ha^{-1}).

treatment, a fact that may have contributed to maximize the difference between these treatments. Even with the difference in plant population between the treatments, the final population was close to 60,000 plants ha^{-1}, which is the technical recommendation of the hybrid holder.

Corn sowed over white clover managed with glyphosate + 2.4-D; Paraquat/Diuron + 2.4-D and glyphosate + glyphosate showed yields of 6.744, 7.116, and 8.840 kg ha^{-1}, respectively, in the treatment without N, indicating a positive influence of white clover and its competition effects at the same time.

Eberlein et al. (1992), studied corn growth in an alfalfa living mulch and reported that grain yields in the partial suppression treatment (application of atrazine) were reduced by 55% when compared with the total suppression-tillage treatment (glyphosate followed by atrazine). Furthermore, when alfalfa was not suppressed, corn grain yields were reduced by 63% or more under irrigated conditions and by 96% or more under non-irrigation. Studies reported the decline in corn yield as a result of competition for water and to a lesser extent, for light and nutrients (Eberlein et al., 1992; Zemenchik et al., 2000).

White clover biomass

At the first herbicide application and at corn harvest (04/25/2015), treatments with Paraquat/Diuron + 2.4-D, glyphosate + 2.4-D, and glyphosate + glyphosate resulted in average living biomass (dry matter basis) levels for the nitrogen levels of 3,445, 3,465, 3,716 and 710, 750, 372 kg ha^{-1}, respectively. On July 31, the average biomass levels for the same treatments were 1,230, 1,050, and 872 kg ha^{-1}, respectively. The white clover plants were present in more than 60% of the area.

It is difficult to estimate the optimal herbicide dose to allow a good white clover development, while at the same time, enabling high crop yields and pasture regrowth in the following growing season. Higher herbicide doses minimize interspecies competition and increase corn yield, but decrease the regrowth capacity of while clover. However, more studies addressed to suppress white clover in corn intercropped systems are needed.

Furthermore, the short-term negative effects of live mulch on crop yield may be offset in the longer term by a positive influence of the legume biomass from the previous year, facilitating grazing without having to replant the species. White clover left in the field after corn harvest acts as a ground cover to protect the soil and provides forage earlier in the season. It has been suggested to intercrop ryegrass into these clover areas to improve soil resource use. Zemenchik et al. (2000) reported that viable meristematic tissue remaining on the rhizomes, enabled white clover to fully recover up to one year after corn harvest.

Materials and Methods

Conduction of study

The experiment was carried out at the Federal Institute of Paraná – IFPR, campus of Palmas, Agricultural Research Station, at 1,115 m above sea level. According to the Köppen classification, the climate is Cfb. White clover cultivar Yi was sown on May 25, 2013, using a no-till seeder and 4 kg of seed per hectare, without seed inoculation or soil chemical correction. Weed control was carried out manually and the area remained fallow until corn (Hybrid DKB 290 PRO3) seeding in November 2014, with a row spacing of 0.7 m at 70,000 seeds ha^{-1}.

The soil showed the following chemical characteristics (0-20 cm): pH (CaCl2) 4.6; V% 44; organic matter 64.33 g dm^{-3}; P-Mehlich 6.35 mg dm^{-3}; Ca, Mg, K e Al 4.6; 0.7; 0.23 and 0.54 $cmol_c$ dm^{-3} respectively; H + Al 7.13, and CEC of 12.76 $cmol_c$ dm^{-3}. As a starter fertilizer, we applied 80 kg ha^{-1} of P_2O_5 in the form of triple superphosphate. Potassium was broadcast applied at sowing, using 200 kg of Kcl ha^{-1}. Nitrogen rates were divided into equidistant values and applied at corn phenological stage of V4 and V8, using urea as a source (45% of N).

Experimental design

Treatments were arranged in a completed randomized block design with four replications in a 3 x 4 factorial scheme, being the first factor the herbicide management and the 2nd factor the nitrogen rates (0, 60, 120, 180 kg ha^{-1}). White clover herbicide suppression treatments were as follows: (i) broadcast application of Paraquat/Diuron (Gramocil®) + 2,4-D (Aminol®) at rates of 300 + 806 g i.a ha^{-1} and (ii) glyphosate (Zapp Qi®) + 2,4-D at rates of 1080 + 806 g i.a ha^{-1}, both applied sequentially seven days before and 15 days after corn sowing, and glyphosate + glyphosate (1080 + 1080 g i.a ha^{-1}) applied sequentially 21 days before and 15 days after corn sowing. White clover herbicide suppression management was established in the main plots and, nitrogen fertilization was performed in the subplots (4.2 x 8 meters).

Traits evaluated

Corn growth and development were evaluated throughout the growing cycle to better explain the effects of treatments on grain yield. Corn plant height was evaluated at 20 and 40 days after corn emergence by measuring the distance from the ground to the insertion of the last fully developed leaf of 10 plants per plot, using a ruler graduated in centimeters. At tasseling, total height was considered.

To determine corn yield components, 10 ears per plot were evaluated and the numbers of grains per row and the numbers of row were registered. In addition, the weight of thousand grains was assessed by manual counting of 400 grains, weighing, and correction for moisture content of 13%, with extrapolation to thousand-grain weight.

Corn was harvested on April 25, 2015, (mean moisture of 17 g kg^{-1}) and corn grain yield was determined by hand-collecting corn ears at physiological maturity from the two center rows, 8 m long, and passing the ears through a stationary small-plot corn sheller. Corn grain yields were adjusted to a moisture concentration of 13 g kg^{-1}. Corn populations at grain harvest were determined by counting and recording the number of plants harvested within each plot.

Aboveground clover biomass was measured at corn sowing, corn harvest (April 25) and at July 31 to obtain an estimate of competition and regrowth capacity. It is important to emphasize that only alive biomass was collected under the white clover live tissue, although there was a large amount of dead plant material. Living vegetation was hand-harvested from two 0.25-m^2 quadrats in each plot and oven-dried at 60°C until constant weight to determine yield per hectare on a dry-weight basis.

Statistical analysis

Analysis of variance was conducted under GLM procedure with Statygraphics 4.1 at $P \leq 0.05$ to test the interaction between herbicide management x nitrogen levels. In terms of an interaction effect, we deployed each herbicide management within the nitrogen levels. When there was no interaction, we performed a mean comparison test for the herbicide managements and regression analysis for the nitrogen levels.

Conclusion

Nitrogen, as a side dressing in corn + with clover intercropping systems increased corn plant height, the number of grains per row, the grains per ear, and the thousand-grain weight. These parameters were optimized when white clover was suppressed by herbicides. Among the evaluated white clover herbicide management strategies, treatment with glyphosate, sequentially applied 21 days before and 15 days after corn sowing, resulted in the best clover suppression and the highest corn yield. We therefore suggest that white clover can be used as living mulch in corn intercropping systems as long as herbicides are applied to reduce interspecies competition, allowing autogenic clover regrowth in the following growing season.

References

Adesoji AG, Abubakar IU, Tanimu B, Labe DA (2013) Influence of incorporated short duration legume fallow and nitrogen on maize (*Zea mays* L.) growth and development in northern guinea savannah of Nigeria. American Euroasian J Agric Env Sci. 13: 58-67.

Andrade FH, Abbate PE (2005) Response of maize and soybean to variability in stand uniformity. Agron J. 97: 1263-1269.

Balbinot Junior AA, Backes RL, Alves AC, Ogliari JB, Fonseca JA (2005) Contribuição de componentes de rendimento na produtividade de grãos em variedades de polinização aberta de milho. Revista Brasileira de Agrociência, 11: 161-166.

Culman SW, Du pont ST, Glover JD, Buckley DH, Fick GW, Ferris H, Crews TE (2010) Long-term impacts of high-input annual cropping and unfertilized perennial grass production on soil properties and belowground food webs in Kansas, USA. Agric Ecosyst Environ. 137: 13–24.

Eberlein CV, Sheaffer CC, Oliveira VF (1992) Corn growth and yield in an alfalfa living mulch system. J Prod Agric. 5: 332–339.

Fedoroff NV, Battisti DS, Beachy RN, Cooper P, Fischhoff DA, Hodges CN, Knauf VC, Lobell D, Mazur BJ, Molden D (2010) Radically rethinking agriculture for the 21st century. Science. 327: 833–834.

Herrero M, Thornton PK, Notenbaert AM, Wood S, Msangi S, Freeman HA, Bossio D, Dixon J, Peters M, Van De Steeg J (2010). Smart investments in sustainable food production: revisiting mixed crop-livestock systems. Science. 327: 822–824.

Ijoyah MO (2012) Review of intercropping research on cereal-vegetable based cropping system. Scientific Journal of Crop Science. 1: 55-62.

Jensen ES (1996) Grain yield, symbiotic N_2 fixation and interspecific competition for inorganic N in pea-barley intercrops. Plant Soil. 182: 25-38.

Kozlowski LA (2002) Período crítico de interferência das plantas daninhas na cultura do milho baseado na fenologia da cultura. Planta Daninha. 20: 365-372.

Lana MC, Woytichoski Júnior PP, Braccini AL, Scapim CA, Ávila MR, Albrecht LP (2009) Arranjo espacial e adubação nitrogenada em cobertura na cultura do milho. Acta Sci Agron. 31: 433-438.

Lopes SJ, Lúcio AD, Storck L, Damo HP, Brum B, Santos VJ (2007) Relações de causa e efeito em espigas de milho relacionadas aos tipos de híbridos. Ciênc Rural. 37: 1536-1542.

Machado D, Lustosa SBC, Baldissera TC, Turok JD, Machado NM, Watzlawick LF, Mendonça CG, Pelissari A (2013) Seletividade de herbicidas em trevo-branco no estádio fenológico de expansão do primeiro trifólio. Ciênc Rural. 43: 2132-2138.

Mohammadi SA, Prasanna BM, Singh NN (2003) Sequential path model for determining interrelationship among grain yield related characters in maize. Crop Science. 43: 690-1697.

Ratnadass A, Fernandes P, Avelino J, Habib R (2012) Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. Agron Sustain Dev. 32: 273–303.

Thayamini HS, Brintha I (2010) Review on maize based intercropping. Journal of Agronomy. 9: 135-145.

Trogello E, Modolo AJ, Scarsi M, Silva CL, Adami PF, Dallacort R (2013) Manejos de cobertura vegetal e velocidades de operação em condições de semeadura e produtividade de milho. Rev Bras Eng Agríc Ambient. 17: 796–802.

Undie UL, Uwah DF, Attoe EE (2012) Effect of intercropping and crop arrangement on yield and productivity of late season Maize/soybean mixtures in the humid environment of South Southern Nigeria. J Agric Sci. 4: 37-50.

Zemenchik RA, Albrecht KA, Boerboom CM, Lauer JG (2000) Corn Production with Kura Clover as a Living Mulch. Agron J. 92: 698–705.