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A Review of the Effects of Row Spacing on Weed Management in Corn and Soybean

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Abstract

The adoption of narrow row spacings (rows less than 30 inches in width) in soybeans and corn has primarily been driven by the potential for higher yields in narrow- compared to wide-row production systems. In addition to the potential yield advantages, these systems can have a significant impact on the incidence of weeds within a given agroecosystem and on the approach that producers might take for weed management. A review of row spacing experiments included in this review revealed that narrow row spacings have provided significant reductions in the late-season density of weeds in the majority of soybean experiments but only rarely in corn. This research also indicates that narrow row soybeans are more likely to impact the critical time of weed removal in soybean than in corn. The objective of this article is to provide a brief review of the literature related to the effects of row spacing on late-season weed prevalence and management in corn and soybean and to discuss the implications of these results to current production systems.

Introduction

Prior to 1960, the majority of corn and soybeans produced in the United States were grown in row spacings greater than 30 inches in width. Over the past several decades, however, most corn and soybean producers have gradually moved towards the adoption of narrower row spacings (rows less than 30 inches in width). Narrow row spacings have become particularly common in soybeans but thus far have only rarely been adopted in corn. As just one example, over the past 20 years in Indiana the average row width for soybean has declined from 28 to 12.3 inches while the average row width for corn has only declined from 33.5 to 30.9 inches during this same time period (16).

The adoption of narrow row spacings has primarily been driven by the potential for higher yields in the narrow- compared to the wide-row production systems. Several researchers have reported higher yields in narrow- compared to wide-row systems in both corn and soybean (25,26,28,40). Higher yields in these systems are usually attributed to the more equidistant arrangement of crop plants that decreases the intraspecific competition for water, nutrients, and perhaps most importantly, light (2,39,44,54). Research has revealed that yield increases in these systems are closely linked to increased light interception that occurs in narrow- versus wide-row spacings (2,8,44).

In addition to the potential yield advantages, many producers have found that narrow-row spacings can have a significant impact on weed populations and on their approach to weed management. The objective of this article is to provide a brief review of the literature related to this subject with specific emphasis on the effects of corn and soybean row spacing on late-season weed density and the critical time of weed removal. The effect of crop population on these variables is not discussed in this review and, in most instances, crop population was not a factor under investigation in the literature included within this review.

Influence of Soybean Row Spacing on Weed Management

From a weed management standpoint, perhaps the greatest influence that narrow row spacings have in soybeans is in the reduction in the amount of light that reaches the soil surface and in the reduction in the amount of time that it takes for soybean to reach full canopy closure. Puricelli et al. (43) and Steckel and Sprague (48) have each detected significantly less radiation at the soil surface in narrow- compared to wide-row soybean throughout most of the growing season (Fig. 1). Similarly, Dalley et al. (8) and Yelverton and Coble (56) observed greater light interception in narrow- compared to wide-row soybean throughout most of the growing season. Results from other studies have also revealed that narrow row soybeans reach complete canopy closure quicker than wide-row soybeans (44,45,53). For example, in one of the earliest investigations conducted on the effects of row spacing on weed control, Burnside and Colville (5) reported that soybeans grown in 10-inch rows provided complete shading of the ground 22 days earlier than soybeans grown in 30-inch rows.

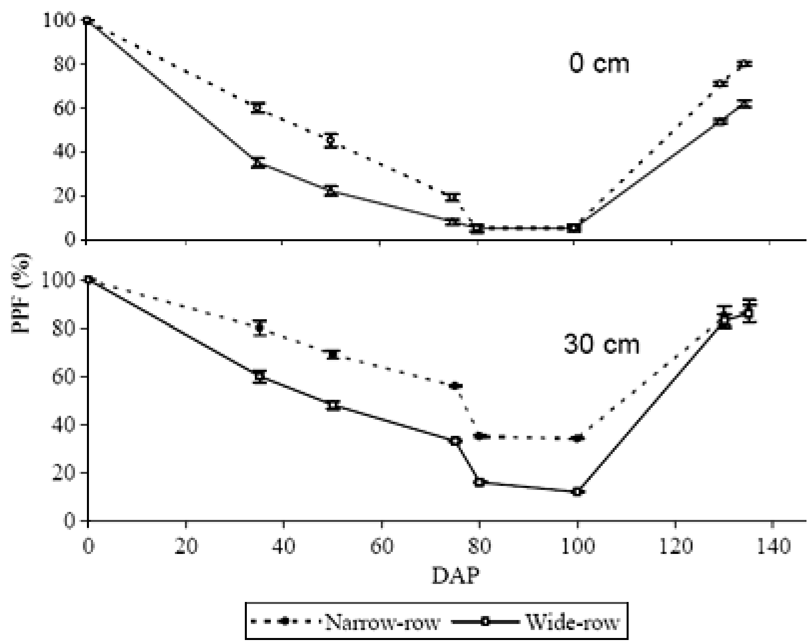

Fig. 1. Percent radiation interception [measured as photosynthetic photon flux (PPF)] in relation to days after planting in narrow- and wide-row soybean 0 and 30 cm from the soil surface. Graph provided by Puricelli et al. 2003 (43).

These reductions in light penetration and time to canopy closure have a profound influence on the likelihood of weed emergence later in the growing season, a phenomenon which Yelverton and Coble (56) first termed "weed resurgence." Weed resurgence has been investigated in a number of studies even prior to the introduction of glyphosate-resistant soybean. In their studies, Yelverton and Coble (56) determined that as row spacing increased, weed resurgence also increased (Fig. 2). In the majority of studies that have been conducted before or since these experiments, similar responses have been observed. For example, a review of row spacing experiments in which an initial weed management practice had been accomplished revealed that in 64% of the cases (72 of 113 site-years), less late-season weed density and/or biomass, or greater late-season weed control, was achieved in narrow- compared to wide-row soybean production systems (Table 1).

Table 1. Summary of literature pertaining to the effects of row spacing on late-season weed control in soybean.

Weed species	**Reference**	**Response**[a] (# site-years/total)
Barnyardgrass	Norris et al. 2002 (36)	2/2
Burcucumber	Esbenshade et al. 2001 (11)	0/2
Common cocklebur	Carey and DeFelice 1991 (6) Patterson et al. 1988 (41)	0/2 2/2
Common lambsquarters	Carey and DeFelice 1991 (6) Mickelson and Renner 1997 (28) Nelson and Renner 1998 (33) Nelson and Renner 1999 (34)	0/2 2/2 2/2 0/1
Common ragweed	Mickelson and Renner 1997 (28) Nelson and Renner 1998 (33) Nelson and Renner 1999 (34)	1/2 2/2 0/2
Common waterhemp	Steckel and Sprague 2004 (48) Young et al. 2001 (57)	3/3 5/5
Eastern black nightshade	Nelson and Renner 1999 (34)	1/2
Giant foxtail	Carey and DeFelice 1991 (6) Nelson and Renner 1999 (34) Young et al. 2001 (57)	0/4 0/2 5/8
Hemp sesbania	Norris et al. 2002 (36)	2/2
Large crabgrass	Norris et al. 2002 (36)	3/3
Redroot pigweed	Légère and Schreiber 1989 (6) Mickelson and Renner 1997 (34) Nelson and Renner 1998 (33) Nelson and Renner 1999 (34)	3/3 0/2 0/2 0/2
Pitted morningglory	Howe and Oliver 1987 (15) Murdock et al. 1986 (30) Norris et al. 2002 (36)	2/2 1/2 3/3
Sicklepod	Buehring et al. 2002 (3) McWhorter and Sciumbato 1988 (27) Nice et al. 2001 (35) Patterson et al. 1988 (41)	2/2 3/3 2/2 2/2
Spurred anoda	Puricelli et al. 2003 (43)	2/2
Velvetleaf	Mickelson and Renner 1997 (28) Nelson and Renner 1999 (34) Young et al. 2001 (57)	6/8 1/1 0/2
Weeds[b]	Burnside and Colville 1964 (5) Chandler et al. 2001 (7) Dalley et al. 2004 (8) Mickelson and Renner 1997 (28) Mulugeta and Boerboom 2000 (29) Peters et al. 1965 (42) Wax and Pendleton 1968 (53) Yelverton and Coble 1991 (56)	2/2 2/2 3/4 0/2 0/2 1/6 2/2 5/5

[a] Indicates number of site-years in which less late-season weed density and/or biomass, or greater weed control, was recorded in narrow- compared to wide-row soybean after an initial weed removal practice had been accomplished.

[b] Indicates experiments where specific weed species responses were not identified, but overall weed response was recorded.

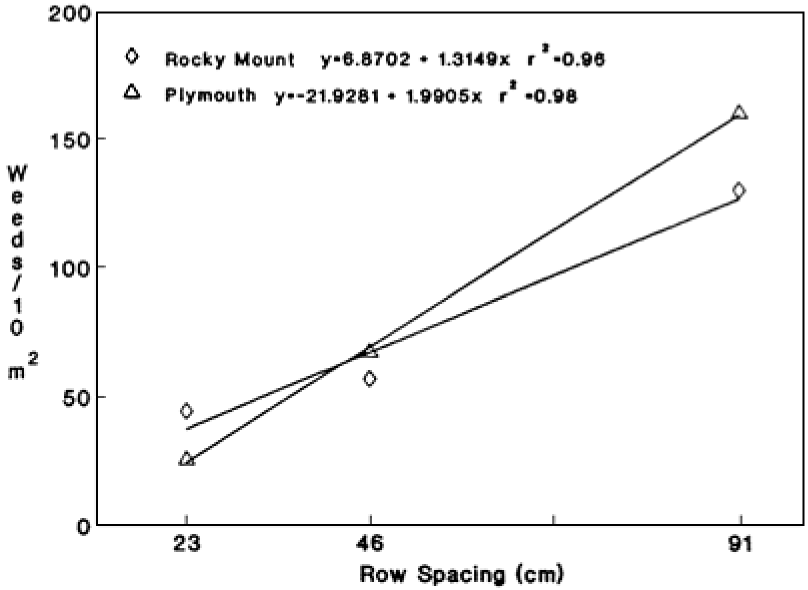

Fig. 2. Influence of row spacing on weed resurgence as indicated by weed density in Rocky Mount and Plymouth, North Carolina. Graph adapted from Yelverton and Coble 1991 (56).

As discussed previously, most authors have attributed this response to the quicker canopy closure and reduction in light penetration that occurs in narrow- compared to wide-row soybean, which subsequently cause reductions in weed seed germination and/or growth later in the season (5,8,24,28,48). Other authors have found that environmental conditions that do not favor rapid canopy closure, such as lack of rainfall, can result in similar late-season weed density in narrow- and wide-row soybean (3,30). This may help to explain the variation in responses observed across site-years within the experiments reported in this literature (Table 1). Additionally, it is highly likely that some of these inconsistencies can be attributed to variations in the type and density of weed species present in these studies from one year to the next.

Based on the available research conducted thus far, it is also difficult to draw any particular conclusion about the types of weeds (e.g., grasses, small-seeded broadleaves, etc.) that are most likely to be impacted by narrow- compared to wide-row spacings. For example, within the literature contained in Table 1, common cocklebur, common lambsquarters, common ragweed, eastern black nightshade, giant foxtail, redroot pigweed, pitted morningglory, and velvetleaf are all weeds that were controlled better in narrow- compared to wide-row spacings in some experiments, but were not influenced at all by row spacing in others. Conversely, barnyardgrass, common waterhemp, hemp sesbania, large crabgrass, and spurred anoda are the only weeds that were controlled better in narrow- compared to wide-row soybean in all of the site-years contained within this literature review (Table 1). One attribute that this latter group of weeds does seem to share, however, is a tendency towards later season emergence. For example, barnyardgrass, common waterhemp, and large crabgrass have each been characterized as having a relatively late-season emergence pattern in previous research (14,32,38). Additionally, optimum germination for both spurred anoda and hemp sesbania was found to be in the 30 to 40°C range (19,47), suggesting that these species are also more likely to emerge later in the growing season. These results indicate that one of the primary benefits of these systems comes through reductions in the germination of late-emerging weed species as a result of the quicker canopy closure and shading that occurs in narrow- compared to wide-row soybeans.

In addition to effects on weed resurgence, row spacing has a profound impact on the critical period of weed control in soybean. The critical period of weed control is an interval of time in the growth of a crop during which it is essential to control weeds in order to prevent unacceptable yield losses (21,58). The beginning of the critical period of weed control is determined by the critical time of weed removal, which is the time at which weeds must be removed because the crop can no longer withstand early season weed competition and will begin to suffer irrevocable yield losses. When investigating the critical time of weed removal across 7.5-, 15-, and 30-inch soybean row spacings, Knezevic et al. (22,23) found that earliest critical time of weed removal occurred in 30-inch row spacings at the V1 stage of growth while latest critical time of weed removal occurred in 7.5-inch row spacings at the V3 stage of growth (Fig. 3). Similarly, Mulugeta and Boerboom (29) found that the critical time of weed removal occurred much earlier in wide- compared to narrow-row soybeans. For soybean producers, results from these studies reveal that planting soybean in wide rows will require implementation of weed removal practices much earlier than in narrow rows.

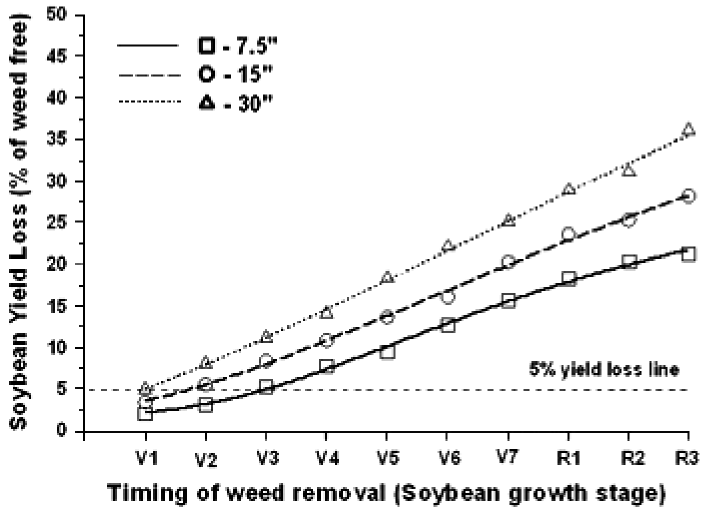

Fig. 3. Influence of row spacing and weed removal timing on soybean yield loss. The horizontal dashed lined indicates the 5% acceptable yield loss level used to determine the critical time for weed removal. Graph provided by Knezevic et al. 2003 (23).

Influence of Corn Row Spacing on Weed Management

Unlike the situation that exists in soybean, differences in light penetration in narrow- compared to wide-row corn production are not always apparent and seem to diminish as the season progresses. Several researchers have observed increases in light interception with corresponding increases in plant populations (31,52), but not necessarily with different corn row spacings. In fact, research conducted by Tharp and Kells (51) revealed that differences in photosynthetic active radiation (PAR) interception between wide- and narrow-row spacings never exceeded 10% throughout the growing season. Additionally, Dalley et al. (8) determined that 64 days after crop emergence, light interception was similar between wide- and narrow-row corn spacings. Westgate et al. (55) and Norsworthy and Oliveira (37) have also reported similar PAR levels in wide and narrow corn row spacings. It should be noted here that, to some extent, these responses should be expected as the typical planting populations and architecture of corn cannot realistically be compared to that of soybean, regardless of row spacing.

These results may help to explain the response, or lack of response, of weeds to different corn row spacings. For example, narrow row spacings have only provided better late-season weed control than wide-row corn spacings in 24% (12 of 50 site-years) of the cases reported within this literature review (Table 2). Therefore, in contrast to soybean, the available research on this subject indicates that the majority of the time narrow-row spacings will provide similar levels of weed control as wide-row spacings in corn. As just one example, Dalley et al. (8) observed similar late-season weed biomass in narrow- compared to wide-row corn spacings in almost every instance throughout four years (Fig. 4). Most authors have attributed this response to the similarities in light interception that exist between wide- and narrow-row corn widths in their research studies (4,8,37). However, in the few instances where lower late-season weed density and/or biomass has been reported, corresponding reductions in light interception in narrow- compared to wide-row spacings have also been observed (1,31,51).

Table 2. Summary of literature pertaining to the effects of row spacing on late-season weed control in corn.

Weed species	**Reference**	**Response**[a] (# site-years/total)
Burcucumber	Esbenshade et al. 2001 (10)	0/2
Common lambsquarters	Tharp and Kells 2001 (51)	2/2
Common ragweed	Johnson et al. 1998 (17)	0/2
Foxtail millet	Anderson 2000 (1)	3/3
Giant foxtail	Johnson et al. 1998 (17) Johnson and Hoverstad 2002 (18)	0/2 1/3
Ivyleaf morningglory	Jones et al. 2001 (20)	0/4
Johnsongrass	Jones et al. 2001 (20)	0/4
Palmer amaranth	Jones et al. 2001 (20)	0/4
Velvetleaf	Teasdale 1998 (50)	0/3
Weeds*	Dalley et al. 2004 (8) Forcella et al. 1992 (12) Murphy et al. 1996 (31) Norsworthy and Oliveira 2004 (37) Shrestha et al. 2001 (46) Teasdale 1995 (49)	0/4 0/3 3/3 0/3 3/4 0/4

[a] Indicates number of site-years in which less late-season weed density and/or biomass, or greater weed control was recorded in narrow- compared to wide-row corn after an initial weed removal practice had been accomplished.

[b] Indicates experiments where specific weed species responses were not identified, but overall weed response was recorded.

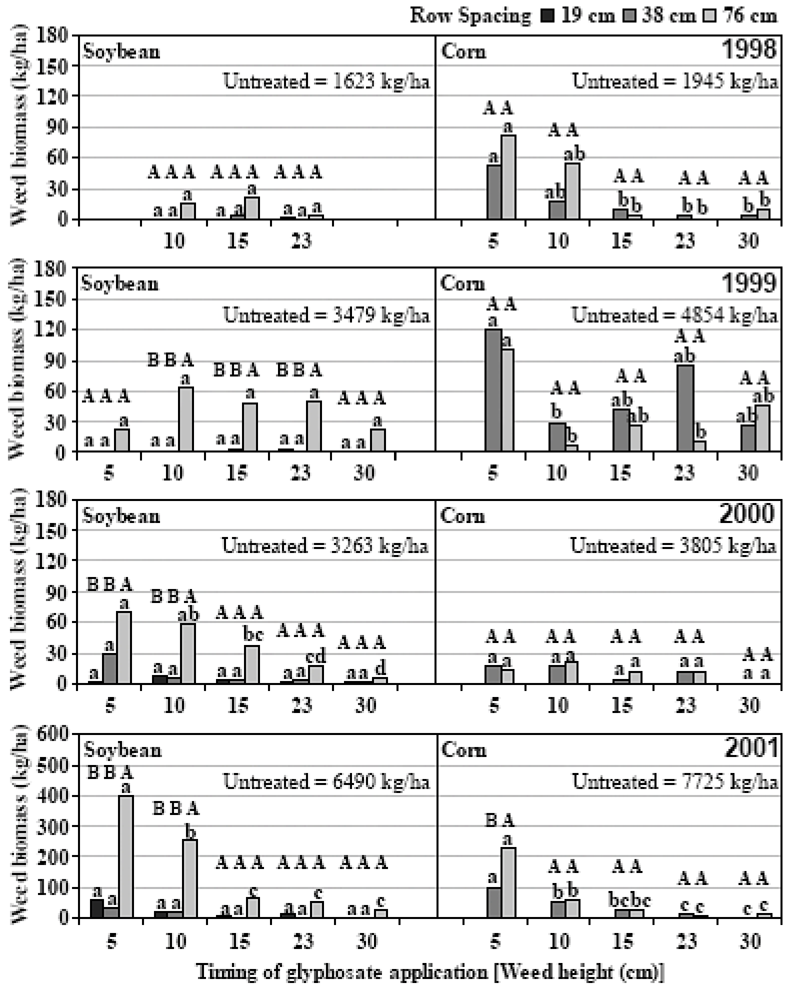

Fig. 4. Biomass of weeds emerging after glyphosate applications in narrow- and wide-row corn and soybean row spacings. Means with different lower-case letters are significantly different ($P < 0.05$) comparing treatment timing within each row spacing. Means with different upper-case letters are significantly different ($P < 0.10$) comparing row spacing within each treatment timing. Graph provided by Dalley et al. 2004 (8).

As in soybean, it is difficult to discern any pattern pertaining to the specific weed species that are most likely to be impacted by corn row spacing. Giant foxtail, common ragweed, palmer amaranth, ivyleaf morningglory, johnsongrass, velvetleaf, and burcucumber are all weeds that were not impacted by narrow- compared to wide-row spacings within this literature review (Table 2). Conversely, foxtail millet, giant foxtail, and common lambsquarters were the only weeds that were controlled better in narrow- compared to wide-row spacings.

Currently, only a small amount of research has been conducted on the effects of row spacing on the critical period of weed control in corn, and the available results from these studies are often conflicting. Norsworthy and Oliveira (37) determined that the critical period of weed control was similar between wide- and narrow-row corn across three site-years. Conversely, Dalley et al. (9) reported that weeds needed to be controlled earlier in narrow- compared to wide-row corn in order to prevent unavoidable yield losses. However, these and other authors (13) have suggested that other factors may play more of a role than row spacing in influencing the critical period of weed control in corn. For example, based on results from light interception measurements at the end of the critical period of weed control in wide- and narrow-row spacings, Norsworthy and Oliveira (37) suggested that the specific weed species and/or density may be more of a determinate of the critical period of weed control than the time to canopy formation in corn. Similarly, Dalley et al. (9) observed differences in weed control and corn yield in narrow- compared to wide-row spacings only in years with below normal rainfall and high weed densities but not in years with adequate rainfall and low weed densities.

Conclusions

The available research conducted to date indicates that under most conditions narrow-row spacings will reduce the likelihood of weed resurgence in soybean. In many studies, this response has been directly correlated with the faster rate of canopy closure and reduction in light interception at the soil surface in narrow- compared to wide-row systems. The available studies also indicate that the critical time of weed removal is most likely to occur later in narrow- compared to wide-row soybeans. In today's production systems, these responses can only be viewed as advantageous, as glyphosate is utilized as the method of weed control on the majority of soybeans grown in the United States and this herbicide has no residual activity to prevent the germination of subsequent weed species. Additionally, based on results from critical period of weed control experiments, it seems that delays in glyphosate application that often occur due to unfavorable environmental conditions, excessive workload, etc. are less likely to cause yield reductions in narrow- compared to wide-row soybean systems.

In contrast to soybean, from a weed management standpoint the available research in corn does not reveal a clear advantage of planting narrow- compared to wide-row spacings. The majority of research indicates that narrow-row spacings usually provide similar late-season weed control as wide-row spacings, and that differences in light penetration are not always apparent and seems to diminish as the season progresses. Only a limited amount of research has been conducted on the effects of row spacing on the critical period of weed control in corn, but results from these studies do not reveal any clear trend and are often conflicting. The lack of a clear weed management benefit may be a contributing factor to the relatively slow rate of narrow-row corn adoption in the United States.

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