LNE94-04.0

X[e] COLLOQUE INTERNATIONAL SUR LA BIOLOGIE DES MAUVAISES HERBESDI-JON SEPTEMBRE 1996

RE-EVALUATING CULTIVATION AND ITS POTENTIAL ROLE IN AMERICAN VEGETABLE WEED CONTROL

JED B. COLQUHOUN AND ROBIN R. BELLINDER

Dept. of Fruit and Vegetable Science, Cornell University, Ithaca, NY 14853

Summary : Alternative weed control strategies are needed to address the recent trend toward restricting herbicide use in U.S. vegetable production. In response to this situation, studies re-evaluating cultivation and its potential role in transplanted broccoli, snap bean, and sweet corn weed control were conducted from 1993 to 1995. Cultivation implements included two flex-tine harrows and three inter-row cultivators (a brush hoe, a spider gang cultivator, and a danish-tine row crop cultivator). Each tool was used individually and the flex-tine harrows were used in combination with each of the inter-row implements. Additionally, banded herbicide applications were integrated with cultivation treatments in snap beans and sweet corn. In transplanted broccoli, individual implements provided adequate weed control without reducing crop yield. Combinations of early-season flex-tine harrowing and an inter-row cultivation, or banded herbicides and row crop cultivation were necessary in snap beans. In sweet corn, preliminary studies (1993) indicated that cultivation alone was not possible due to slow early-season corn growth and competition from weeds within the crop row. Thus, in 1994, banded herbicides were applied over the corn row in all cultivation treatments, effectively minimizing weed-crop competition. While succesful mechanical weed control strategies were identified, several surveyed vegetable growers indicated that increased cultivation was not feasible. Cited drawbacks of extensive cultivation include: 1) greater trained labor and time inputs; 2) cultivator damage in stony soils; 3) delayed cultivation in wet soils, and subsequent risk of weed control failure; and 4) soil erosion and/or compaction resulting from increased tillage.

Introduction

Prior to the advent of synthetic pesticides over a half century ago, cultivation was the primary method of weed control. However, the introduction of herbicides, beginning with the phenoxys in the mid-1940's, drastically increased weed control efficiency, which in turn allowed growers to increase their planted acreage. Herbicide dependence has increased in the past fifty years to the point where there are few viable alternatives in many crops. However, the recent trend toward restricting agricultural pesticide use, coupled with economic concerns of growers and environmental concerns of the public, has led to an interest in reducing pesticide use. Moreover, herbicides constitute 70% of U.S. agricultural pesticide use, and the present Presidential Administration's commitment to having 75% of American farmland under integrated pest management (IPM) by the year 2005 will require the rapid development of alternative weed control strategies.

Alternative strategies are particularly needed for minor crop producers, who are losing the few available herbicide options in current re-registrations mandated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in 1988, and for organic vegetable producers, who have limited weed control options. The increasing number of herbicide-resistant weeds has also stimulated an interest in reducing herbicide dependance in favor of integrated weed control programs that utilize several strategies, including cultivation.

Similar trends in Europe (mid-1980's) stimulated 'innovative' cultivator development for use in cereal crops, however, very few implements have been developed or evaluated for row crops, especially vegetables. In response to this situation, studies re-evaluating cultivation and its potential role in U.S. vegetable weed control began at Cornell University, Ithaca, NY in 1993. The research objective was to identify cultivation tools and strategies that would provide adequate weed control without reducing crop yield, and to integrate these strategies with banded or as-needed herbicides in reduced-pesticide weed control programs. Additionally, practical and economically sustainable cultivation programs in transplanted broccoli, snap beans, and sweet corn were to be identified for immediate grower adoption.

Materials and methods

Studies were conducted in 1993, 1994, and 1995 on Eel silt loam soil (fine-loamy aquatic mixed mesic Udifleuvant), and Howard gravelly loam soil (loamy-skeletal mixed mesic Glossoboric Hapludalf). Plots were moldboard plowed, disced, fertilized (161 N, 71 P, and 27 K kg ha^{-1}), and field cultivated prior to planting. Plots had four-76 cm rows and measured 9 or 12m. Treatments were arranged in a randomized complete block design with three or four replications.

Two broadcast (in- and between-row) flex-tine cultivators, one having round tines (manufactured by Einbock® Co.) and the other having flat tines (Rabe Werk® Co.), a Baertschi® brush hoe, a BHC® spider gang tool, and a McConnell® row crop cultivator were used in all experiments. Each tool was used individually and each flex-tine harrow was used in combination with each of the inter-row implements. Additionally, banded herbicides over the crop row (25 cm width) were combined with the row crop cultivator in snap beans and with all cultivation treatments in sweet corn (1994 and 1995). Weed growth stages at cultivation were: cotyledon, or "white-thread" for flex-tine harrowing (5 to 7 DAP[1]), and 4 true leaves for inter-row cultivation (22 to 27 DAP). Flex-tine harrows were operated at 8 km h^{-1}, with tines set at a 3 to 5 cm operating depth, depending on soil moisture and subsequent crop planting depth. The row-crop and spider gang implements were operated at 4 km h^{-1}, while the brush hoe was used at 2 km h^{-1}. Inter-row cultivation depth was approximately 6 cm. Cultivation treatments were compared with recommended herbicide programs (chemical standard) for each crop, and an untreated check.

The predominant weed species were redroot pigweed, *Amaranthus retroflexus* L. #[2] AMARE; and common lambsquarters, *Chenopodium album* L. # CHEAL. Hairy galinsoga, *Galinsoga ciliata* (Raf.) Blake # GASCI was also prevalent in the Eel silt loam soil.

Weeds were counted by species prior to each cultivation and again 4 to 6 days afterwards. A final weed count and weed biomass were taken at crop harvest. A visual control rating was assigned to each treatment at harvest. All weed counts and biomass samples were taken from four stationary 0.25 m^2 quadrats both in and between crop rows. Crop yield was taken from the center two rows in each plot.

Results

Transplanted broccoli. Cultivation alone provided adequate in- and between-row weed control (Table 1). Using transplants created a natural weed/crop size differential and this allowed for aggressive and effective early-season cultivation. Weed competition did not decrease broccoli yield, even in the untreated check, as broccoli rapidly developed a broad, shading canopy. Therefore, a single use of any of the inter-row implements (row crop cultivator, spider gangs, and brush hoe) 15 to 25 DAP provided excellent between-row weed control and prevented weed seed production before crop harvest. While weed control and yield were comparable when cultivators were used individually and in combination, the combined implements required an additional tractor pass, increasing trained labor and machine inputs. Thus, the second cultivation was not actually necessary. While the flex-tine harrows provided adequate in- and between-row weed control, they injured poorly established broccoli stands in dry years, reducing crop yield.

1. DAP = days after (trans)planting

2. Letters following the symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

Snap beans. Weed control was inadequate and yields were reduced in snap beans, a longer season crop than broccoli, when the cultivation tools were used individually (Table 2). Between-row weed control was inadequate with flex-tine harrowing, and in-row weed control was poor with inter-row cultivators.

During the three seasons, precipitation occuring during the cultivation period varied considerably and influenced weed control. In 1993, precipitation was moderate and well-distributed throughout the growing season and in that season weed control improved when flex-tine harrows and inter-row implements, especially the brush hoe were combined. Precipitation in 1994 delayed inter-row cultivation, and thus, control of between-row weeds was incomplete in all treatments. Early-season precipitation delayed flex-tine harrowing in 1995, and weed control, both in- and between-row, was poor where the broadcast implements were used individually. The banded herbicide application coupled with the row crop cultivator provided maximum weed control in all years.

Sweet corn. Cultivation alone was failed to control weeds in sweet corn due to a combination of slow early-season crop growth and competition from weeds within the corn row (Table 3). Therefore, herbicides were applied in a 25 cm band over the crop row at planting in all treatments. Without in-row weed competition, yields of cultivation treatments and the chemical standard were equivalent. In this case, using combinations of implements was not necessary, as a single cultivation with inter-row tools provided excellent between-row control. Flex-tine harrows, used pre-emergence, provided adequate weed control; however, soil disturbance within the herbicide band may disrupt in-row control by exposing weed seeds to light and moisture required for germination, while diluting the herbicide through soil movement.

Potential for incrased cultivation in U.S. vegetable production

While successful cultivation strategies have been identified in research trials, the applicability at the grower level will determine their ultimate utility in vegetable weed control. In order to fully comprehend potential benefits and drawbacks of cultivation in U.S. vegetable production, one must be acquainted with farm demographics. In NYS, for example, a 1995 extension survey indicated that snap bean and sweet corn growers planted an average total crop acreage of 498 and 396 ha season^{-1}, respectively. Vegetable growers are divided in two groups based on their major markets: processing growers, who plant large acreages under contract for marginal prices; and fresh-market growers, who plant smaller, labor intensive acreages of high value crops.

While cultivation may reduce herbicide use when compared to conventional chemical weed control, several disadvantages have been identified by growers. Mechanical weed control requires greater trained labor, time, and machine inputs, which must be considered relative to other farm practices. Many vegetable growers, for example, also grow forage crops that are harvested during the time for optimum cultivation, increasing competition for machinery and trained operators. While NYS fresh market bean producers cultivate their crop at least once and often twice, only 14% of large processing growers cultivated their beans more than once, and 12% were unable to complete a single cultivation of their planted bean acreage. Thus, farm size and crop diversity, in part, determine the potential for increasing cultivation.

Additionally, soil type must be considered. Many growers cited stony soils and subsequent cultivator damage to crops and breakage as reasons prohibiting extensive cultivation. Replacement parts are often expensive, and the "down-time" when cultivators are inoperable delays weed control. Most surveyed growers, however, cited the risk of weed control failure due to precipitation and delayed cultivation as the primary factors prohibiting mechanical control. Control options are limited for weeds surviving cultivation that not only reduce crop yield, but may also increase the weed seed bank.

Erosion potential and legislation that requires year-round soil coverage prohibit widespread use of mechanical weed control in many regions of the U.S., however, undercutting implements were recently developed for physical control in no-till agriculture. Despite several drawbacks, growers were very interested in the innovative implements used in this research. On-farm cultivator demonstrations have been well attended by both organic and conventional producers and grower interest has stimulated cultivation conferences and articles in popular production journals.

Discussion and conclusions

Several integrated weed control programs, or parts thereof, were identified that require little additional equipment investment or change in current production practices, and thus, can be readily adopted by U.S. vegetable growers. Banding herbicides, for example, reduces herbicide volume up to 67% without compromising weed control, with minimal equipment modification. Additionally, tools such as the brush hoe have diverse and effective uses on small fresh-market and/or organic farms. While environmentally sound, integrated weed control strategies are needed that will maintain productivity without compromising control, Loomis and Connor[3] point out the danger of imposing a poorly researched agricultural theory on society when there is a distinct possibility that this theory may not be an improvement to current practices. The potential for soil erosion and compaction from increased tillage and machinery traffic must be investigated. Moreover, an economic analysis comparing alternative weed control strategies, including cultivation, with conventional weed control are necessary to ensure the economic sustainability of agriculture.

Résumé

Les nouvelles stratégies dans le controle des mauvaises herbes sont indispensables pour aborder la nouvelle tendance qui à reduire l'usage des herbicides dans la production des legumes. En guise de cette situation, des études pour reévaluer la culture et leur rôle pour le brocoli transplanté, le haricot vert, et le maïs doux en vue du contr le de la mauvaise herbe furent entreprises de 1993 à 1995. Comme outil, il y avai deux herses à dent de fourche et trois cultivateurs (une houe avec brosse, un cultivateur "spider gang" et un sarcleur a fourche Danoise pour culturen rang). Chaque instrument fut utilisé séparement mais les herses à dent de fourche furent utiliseés en association avec chaque outil utilisé en culture entre rangée. Enoutre, dans les haricots verts, et le maïs doux, l'application des herbicides fut intregreés avec differents traitements de culture. Les outils utilisés séparement fournirent le meilleur contr le de la mauvaise herbe dans le brocoli transplanté, sans pourtant réduire la productivité. L'association de la herse à dent de fourche pour les cultures précoces et le sarcleule pour culture entre rangeé ou les herbicides et la culture entre rangeé s'avèrent nécéssaire pour l'haricot vert. Pour le maïs doux, des études préliminaires entreprises en 1993 prouvèrent que cette culture fut impossible à cause de la croissance du mais precoce et la competition de la mauvaise herbe dans la même rangeé. C'est pourquoi en 1994, firvent les herbicides ajoutés tous les traitements dans la culture du mais doux, se traduisant une reduction de la competition entre culture et mauvaise herbe. Pendant que les stratégies efficaces pourur bon controle mécanique de la mauvaise herbe etaient mises au point, les resultats des enquêtes realiseés auprès des agricultures indiquèrent que les methodes mécaniques pour le controle de la mauvaise herbe n'etaient pas praticables. Quelques désavantages cites etaient: 1) une main-d'oeuvre qualifieé et le temps investis; 2) dégâts causés aux machines en terrain rocailleux; 3) retard de culture en terrain marecageux et le risque du à l'eche du contrôle de la mauvaise herbe; 4) l'erosion et/ou la compaction du sol due a l'excès de labourage.

3. Loomis, R.S. and D.J. Connor. 1992. Crop Ecology: Productivity and management in agricultural systems. Cambridge, 538pp.

Table 2. Snap bean yield expressed as a percentage of the chemical standard, and in- and between-row weed control, from 1993 to 1995.

	Yield			Weed control					
				In-row			Between-row		
	1993	1994	1995	1993	1994	1995	1993	1994	1995
	%								
Chemical standard	100	100	100	E[1]	E	E	E	E	E
Weedy check	—	84	38	—	P	P	—	P	P
Einbock® harrow	67	84	47	E	F	P	P	P	P
Rabe Werk® harrow	59	74	57	E	P	P	P	P	P
Brush hoe	112	113	84	E	E	F	F	E	E
Spider gangs	74	109	62	F	F	P	E	E	E
Row crop cultivator	102	74	76	P	F	E	E	F	E
Rabe Werk® + brush hoe									
Brush hoe+ Rabe Werk® + spider gangs	112	88	90	E	E	E	E	E	E
Spider gangs Rabe Werk® + row crop cultivator	101	83	67	F	F	P	F	F	F
Row crop cultivator Einbock® + brush hoe	97	81	85	E	E	E	F	F	E
Brush hoebr Einbock® + spider gangs	115	108	85	E	E	E	E	E	E
Spider gangs Einbock® + row crop cultivator	97	110	59	E	F	F	E	E	E
Row crop cultivatorrow rowator Banded herb. + row crop cultivator	79	106	80	F	E	E	E	E	E
Row crop cultivator	—	95	94	—	E	E	—	E	E

[1]E = excellent, F = fair, and P = poor weed control when weed biomass was ≤ 20, $21< x >39$, and ≥ 40 g 0.25 m^{-2}, respectively.

Table 1. Broccoli yield expressed as a percentage of the chemical standard, and in- and between-row weed control, in 1993 and 1995.

	Yield		Weed control In-row		Weed control Between-row	
	1993	1995	1993	1995	1993	1995
	%					
Chemical standard	100	100	E[1]	F	E	P
Weedy check	—	114	—	P	—	P
Einbock® harrow	115	126	E	E	E	P
Rabe Werk® harrow	130	95	E	F	E	P
Brush hoe	143	139	E	E	F	E
Spider gangs	124	126	E	E	E	E
Row crop cultivator	165	136	E	E	E	E
Rabe Werk® + brush hoe						
Brush hoe+	127	113	E	E	E	E
Rabe Werk® + spider gangs						
Spider gangs	133	125	E	E	E	E
Rabe Werk® + row crop cultivator						
Row crop cultivator	125	125	E	E	E	E
Einbock® + brush hoe						
Brush hoebr	114	120	E	E	E	E
Einbock® + spider gangs						
Spider gangs	139	133	E	E	E	E
Einbock® + row crop cultivator						
Row crop cultivatorrow rowator	126	126	E	E	E	E

[1]E = excellent, F = fair, and P = poor weed control when weed biomass was ≤ 20, $21< x >39$, and ≥ 40 g 0.25 m^{-2}, respectively.

Table 3. Sweet corn yield expressed as a percentage of the chemical standard, and in- and between-row weed control, in 1994 and 1995.

	Yield		Weed control In-row		Weed control Between-row	
	1994	1995	1994	1995	1994	1995
	%					
Chemical standard	100	100	E1	E	E	P
Weedy check	96	114	E	P	P	P
Einbock® harrow	92	126	E	E	P	E
Rabe Werk® harrow	94	95	E	E	P	P
Brush hoe	105	139	E	E	E	E
Spider gangs	125	126	E	E	E	E
Row crop cultivator	100	136	E	E	E	E
Rabe Werk® + brush hoe						
Brush hoe+	108	113	E	E	E	E
Rabe Werk® + spider gangs						
Spider gangs	93	125	E	E	E	E
Rabe Werk® + row crop cultivator						
Row crop cultivator	104	125	E	E	E	E
Einbock® + brush hoe						
Brush hoebr	95	120	E	E	E	E
Einbock® + spider gangs						
Spider gangs	111	133	E	E	P	E
Einbock® + row crop cultivator						
Row crop cultivatorrow rowator	104	126	E	E	E	E

[1]E = excellent, F = fair, and P = poor weed control when weed biomass was ≤ 20, $21< x >39$, and ≥ 40 g 0.25 m^{-2}, respectively.