Lessons Learned in Conservation Tillage Vegetable Systems in the Sub-Tropics and Tropics

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INTRODUCTION

Conventional cover crop (CC) management strategies developed and adopted in temperate climates utilize seasonal transitions, plant senescence, and mechanical operations with or without additional chemical termination strategies to ensure effective CC termination. In tropical and subtropical climates, temperate strategies are not practical (due to the cost of inputs), not possible (due to the absence of a killing frost to coincide with crop rotation transitions) and not beneficial to soil quality in the long term. Farmers with low-external-input systems rely heavily on farm-derived resources such as CCs for soil and pest management. Tropical agroecosystems require unique CC management strategies that meet environmental and cultural conditions. The use of reduced tillage practices have been promoted to increase soil conservation and reduce on-farm expenses.

The alternative termination method of rolling/crimping CCs to create surface mulch has gained attention because of the additional agroecosystem benefits it provides. Due to the persistent high temperatures in these climates, assessment of different mechanical CC termination methods is needed to avoid CC regrowth during production of income-producing crops. Cover crop cultural practices including species selection, seeding date and termination strategies, and the manner in which they influence weed diversity and density as well as vegetable crop yield and quality are the primary issues to define.

GOAL

Our overall goal is to develop cover crop technologies in minimum-till vegetable systems that minimize labor and external inputs and ensure competitive vegetable yields.

OBJECTIVES

A series of studies funded by SR-SARE were conducted on St. Croix USVI, Mayaguez PR, and Live Oak FL. Each location utilized RCBD with at least three replications and multiple years. Treatments were specific to study locations. Objectives shared among study locations included:

- Evaluate tropical CC species and identify their suitability for termination with a roller-crimper.
- Assess mechanical roller-crimper CC termination on CC regrowth and weed populations in the following crop rotation.
- Compare in situ CC surface mulch to plastic mulch, hay mulch, and conventional no mulch vegetable systems.
- Determine subsequent cash crop quality and yield.

METHODS

We evaluated tropical CCs for their ease of termination and ability to suppress weeds:

Sunn hemp [(*Crotalaria juncea* cv. IAC-1, Tropic Sun, and an unnamed accession) SH], **Lablab** [(*Lalab purpureus* cv. Rongai) LL], **Velvet bean** [(*Mucuna pruriens* L. DC. cv. Vine 90 and Dwarf) VB], **Jack bean** [(*Canavalia ensiformis*) JB], **Pigeon pea** (Cajanus cajan L. cv. BRS Mandarim) **Sesame** [(*Sesamum indicum* Linn.) SE], and **Sun flower** [(*Helianthus annus* L.) SF].

CC, soil, and weed management treatments included:

Experiment 1: Comparison of standard mechanical termination methods (mow/incorporate and disc/incorporate) to roller crimper termination of erect vs. vining CCs.

Experiment 2: Evaluation of tropical CCs pre and post termination with a roller crimper.

Experiment 3: Evaluation of selected tropical CCs, their response to roller-crimper termination, and the resulting surface mulch's ability to provide ecosystem services in vegetable rotations (pepper, corn, plantain, and banana).

Experiment 4: Comparison of 4 vegetable crop production systems (plastic mulch, cut and carry hay mulch, in situ surface mulch, and conventional no mulch) following SH as a CC.

Data collected included:

1. Cover crop and weed biomass, weed species, and weed density
2. Physical and chemical decomposition of SH and LL residue (litter bag analysis)
3. Post termination CC regrowth and weed biomass, weed species, and weed density.
4. Crop quality and yield of jalapeño pepper (*Capsicum annuum* cv.Tormenta) in Florida and USVI or plantain (*Plantago major*) and corn (*Zea mays*) in PR.

LESSONS LEARNED

Successful systems are associated with:

1. Cover crop species selection that do not exhibit post-termination regrowth traits;
2. Significant cover crop surface mulch that is retained throughout the vegetable crop season; and
3. A reduction in weed establishment leading to reduced weeding frequency.
4. Integrated systems with legume living mulches reduced weeds between plantain rows compared with conventional systems, and resulted in increased plantain height and stalk diameter, and reduced the number of herbicide applications.
5. Fruit and vegetable yields in treatments receiving sunn hemp or sun flower surface sheet mulch are comparable to or greater than yields in conventional systems.

Limitations to the system include:

1. A limited number of cover crop species that respond to roller-crimper termination and
2. The overall additional management effort required relative to traditional vegetable systems.

Future work should include a critical examination of CC germplasm and suitability for meeting specific system objectives.

ACKNOWLEDGEMENTS

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The alternative termination method of rolling/crimping CCs to create surface mulch has gained attention because of the additional agroecosystem benefits it provides. Due to the persistent high temperatures in these climates, assessment of different mechanical CC termination methods is needed to avoid CC regrowth during production of income-producing crops. Cover crop cultural practices including species selection, seeding date and termination strategies, and the manner in which they influence weed diversity and density as well as vegetable crop yield and quality are the primary issues to define.

GOAL

Our overall goal is to develop cover crop technologies in minimum-till vegetable systems that minimize labor and external inputs and ensure competitive vegetable yields.

OBJECTIVES

A series of studies funded by SR-SARE were conducted on St. Croix USVI, Mayaguez PR, and Live Oak FL. Each location utilized RCBD with three four replications and multiple years. Treatments were specific to study locations. Objectives shared among study locations included:

- Identify suitable CC species
- Compare mechanical CC termination methods and assess their effects on CC regrowth,
- Evaluate broadleaf and grass weed suppression, and
- Determine crop quality and yield.

METHODS

We evaluated tropical legume CCs for their ease of termination and ability to suppress weeds:

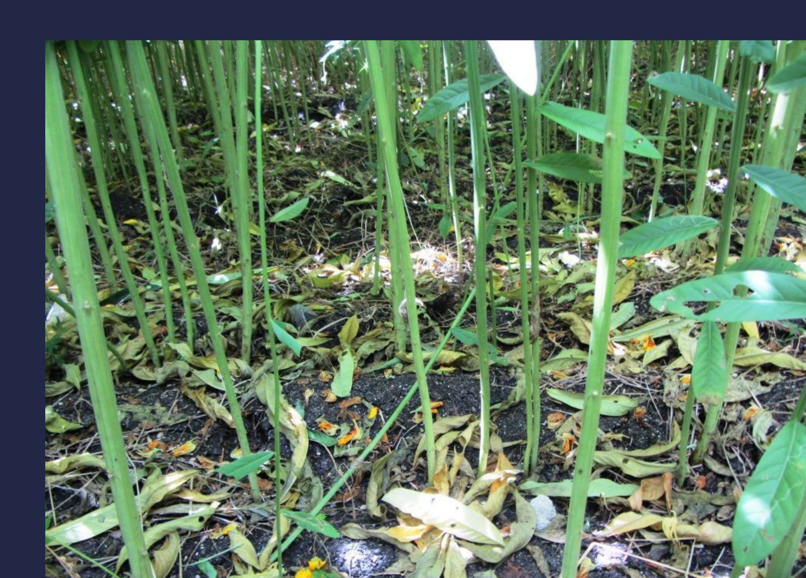
1. Sunn hemp [(*Crotalaria juncea* cv. IAC-1 and an unnamed accession) SH],
2. Lablab [(*Lalab purpureus* cv. Rongai) LL], and
3. Velvet bean (*Mucuna puriens* L. VB).

CC and soil management treatments included:

1. Mow CC and incorporate fully (rotary mower + 3x disc harrow)
2. Mow CC and incorporate minimally rotary mower + 1x disc-harrow)
3. Mow only (rotary mower)
4. Roll down (roller-crimper)
5. Mow CC and incorporate fully followed by application of off-site cereal rye hay (*Secale cereale* cv. FL 401)

Data collected included:

1. Physical and chemical decomposition of SH and LL residue (litter bag analysis)
2. Cover crop and weed biomass, weed species, and weed density
3. Crop quality and yield of either jalapeño pepper (*Capsicum annuum* cv. Tormenta) in Florida and USVI or plantain (*Plantago major*) in PR.



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Limitations to the system include:

1. A limited number of cover crop species that respond to roller-crimper termination and
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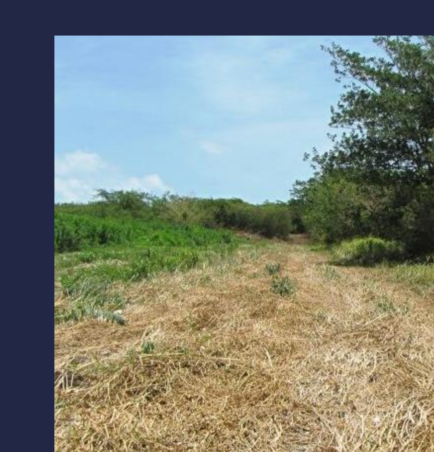
Future work should include a critical examination of CC germplasm and suitability for meeting specific system objectives.



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DUMPLessons Learned in Conservation Tillage Vegetable Systems in the Sub-Tropics and Tropics

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INTRODUCTION

Tropical smallholder farmers operating under low-external-input (LEI) conditions rely upon non-intensive on-farm or locally available inputs for agricultural production; however, conventional resources are limited in the tropics and there is sparse data regarding the sustainability of tropical LEI agroecological systems. Cover crops (CC) provide a range of agricultural and ecosystem benefits which range from soil protection and improvement to pest reduction.

Farmers with low-external-input systems rely heavily on farm-derived resources such as cover crops for soil and pest management. Tropical agroecosystems require unique CC management strategies that meet environmental and cultural conditions. ~~and~~ The use of reduced tillage practices have been promoted to increase soil conservation and reduce on-farm expenses.

Conventional CC management strategies were developed for temperate climates where plant senescence is timed with seasonal transition for effective CC termination. Mechanical cutting followed by full incorporation of CCs in the tropics has been the accepted practice for CC termination but can result in soil decline from hilly production areas. The alternative termination method of rolling/crimping CCs to produce surface sheet mulch has gained attention as a progressive practice that reduces tillage and provides additional agroecosystem benefits. Due to the persistent high temperatures assessment of different mechanical CC termination methods is needed to avoid having CCs become weedy pests. A CC termination study was conducted on St. Croix in the U.S. Virgin Islands to test 4 four mechanical termination methods and their effects on CC regrowth, as well as broadleaf and grass weed suppression.

The primary objective of these studies is to develop tropical cover crop technologies for use as surface mulch in minimum-till vegetable systems to provide alternative weed management strategies and ensure competitive vegetable yields.

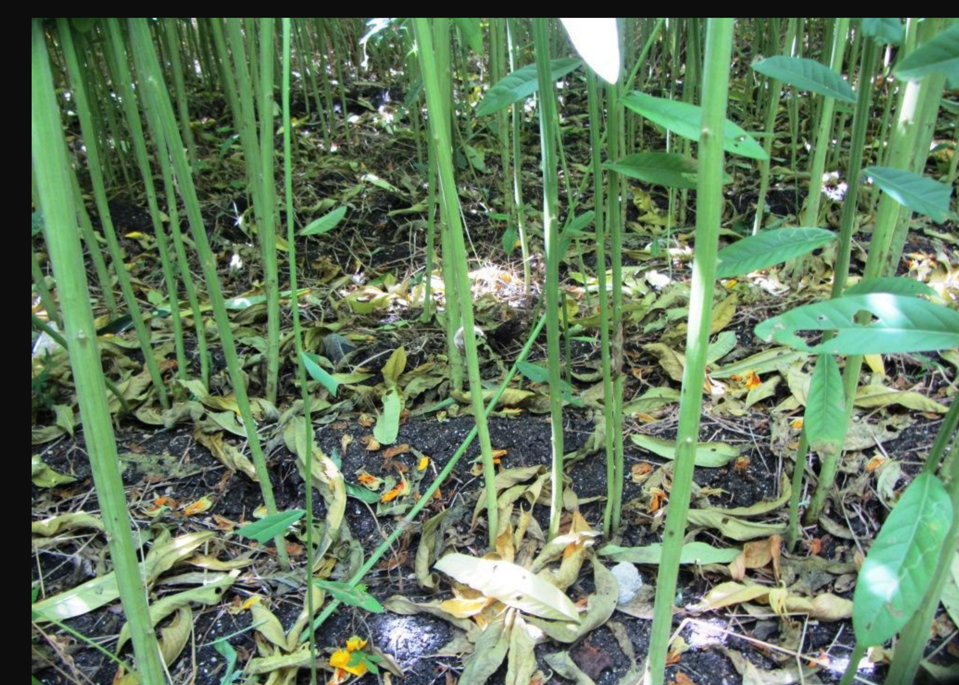
Materials and Methods:

At the University of the Virgin Islands in St. Croix, sunn hemp and lablab were planted on October 3, 2012, evaluated as CCs, and then terminated 120 days after planting. No additional external inputs were applied to the fields.

Termination treatments included: ~~tested consisted of:~~

- 1) Full incorporation with a disc harrow (3 passes),
- 2) Minimum incorporation with a disc-harrow (1 pass),
- 3) Mowing with a rotary brush mower (1 pass),
- 4) Roll down with a roller-crimper (1 pass).

Cover crop and weed biomass were determined prior to termination and subsequent CC regrowth and weed biomass was determined at 6, 9, and 12 weeks post-termination. Weed species were separated by weed class and designated either a grass or broadleaf, no sedges were encountered in this trial. Litter bags containing either SH or LL crop residue were placed in treatments 1 (buried) and 4 (surface) on 1 day ~~1~~ after termination (DAT) and were collected at 28, 42, and 63 days after termination and analyzed for plant chemical properties.



Cover crop (CC), broad leaf (BL) weed, and poacea (GW) weed biomass (kg/ha^{-1}) of Sunn Hemp and Lablab at termination

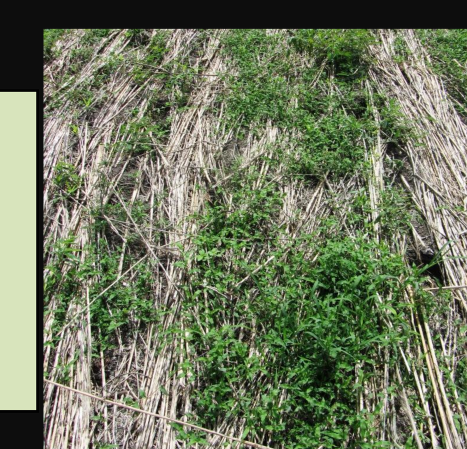
	CC	BL	GW	Total Weeds
Sunn Hemp	6,800 ± 684^{a}	196 ± 130^{a}	413 ± 619^{a}	609 ± 614^{a}
Lablab	3,127 ± 684^{b}	238 ± 130^{a}	1,480 ± 619^{a}	1,718 ± 614^{b}

Values within the same column group followed by different letters differ (p<0.05) according to a least significant range seperation.

Cover crop plant tissue nutrient content (percent) and estimated nutrient contribution (kg/ha^{-1}) for nitrogen (N), phosphorus (P), and potassium (K) based upon total vegetative biomass (kg/ha^{-1})

	Vegetative Biomass	Plant N %	N Contribution	Plant P %	P Contribution	Plant K %	K Contribution
Sunn Hemp	6,800 ± 684^{a}	1.7 ± 0.1^{a}	117 ± 15^{a}	0.09 ± 0.006^{a}	6 ± 0.5^{a}	1.3 ± 0.07^{a}	85 ± 15^{a}
Lablab	3,127 ± 684^{b}	2.3 ± 0.1^{b}	70 ± 15^{b}	0.08 ± 0.006^{a}	2.3 ± 0.5^{b}	2.2 ± 0.07^{b}	71 ± 15^{a}

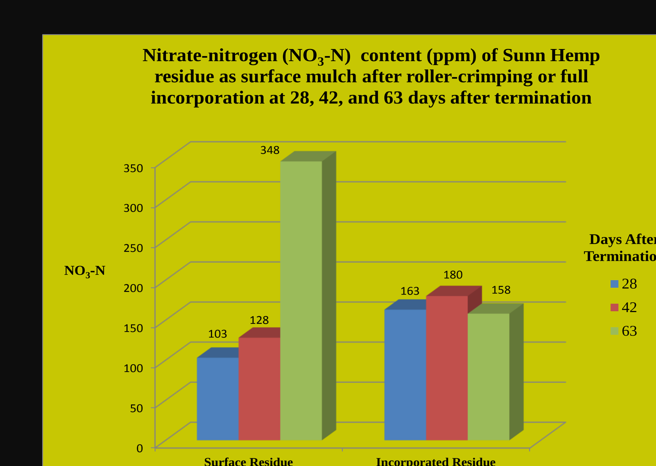
Values within the same column group followed by different letters differ (p<0.05) according to a least significant range seperation.

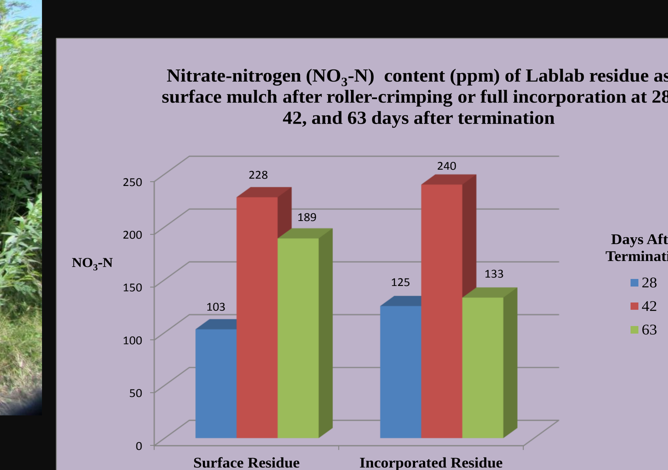


Nutrient content of Sunn Hemp and Lablab vegetative residue at 1, 28, 42, and 63 days after termination

Dayss After Termination	Sunn Hemp N%	Sunn Hemp P%	Sunn Hemp K%	Lablab N%	Lablab P%	Lablab K%
1	1.7 ± 0.2b	0.09 ± 0.03a	1.3 ± 0.05a	See Table 4	0.08 ± 0.01a	2.2 ± 0.1a
38	2.1 ± 0.2a	0.21 ± 0.03b	0.7 ± 0.05b		0.15 ± 0.01ab	1.3 ± 0.1b
42	1.7 ± 0.2b	0.19 ± 0.03b	0.5 ± 0.05c		0.14 ± 0.01b	0.8 ± 0.1c
63	1.7 ± 0.2b	0.2 ± 0.03b	0.6 ± 0.05c		0.18 ± 0.01c	0.8 ± 0.1c

Differences in values observed by week, not by treatment. Values within the same column group followed by different letters differ (p<0.05) according to a least significant range seperation.





Nitrogen (percent) content of Lablab vegetative residue left on the surface or soil incorporated

Days After Termination	Lablab Rolled	Lablab Full Till
1	2.1 ± 0.2^{ac}	2.1 ± 0.2^{ac}
28	2.5 ± 0.2^{abc}	1.9 ± 0.2^{ad}
42	2.8 ± 0.2^{bc}	2.1 ± 0.2^{ad}
63	3.0 ± 0.2^{bc}	2.5 ± 0.2^{bc}

$^{a, b}$ values within the same column group differ and $^{c, d}$ values within the same row group differ (p<0.05) according to a least significant range seperation.

Cover crop regrowth and weed biomass (kg/ha^{-1}) at 6, 9, and 12 weeks after termination

Treatments (TM) Sunn Hemp	6 Week Harvest CCRG	CCVol	BL	GW	TM	9 Week Harvest CCRG	CCVol	BL	GW	TM	12 Week Harvest CCRG	CCVol	BL	GW
1) Full Disc (FD; 3 passes)	0 ± 47^{a}	264 ± 47^{a}	11 ± 47^{b}	0 ± 47^{a}	FD	0 ± 127^{b}	1,111 ± 127^{a}	9 ± 127^{a}	0 ± 127^{b}	FD	0 ± 260^{b}	2,613 ± 260^{a}	631 ± 260^{a}	44 ± 260^{a}
2) Disc (D;1 pass)	0 ± 47^{a}	138 ± 47^{b}	87 ± 47^{ab}	29 ± 47^{a}	D	0 ± 127^{b}	740 ± 127^{b}	482 ± 127^{ab}	0 ± 127^{b}	D	0 ± 260^{b}	2,418 ± 260^{a}	1,084 ± 260^{ab}	1,389 ± 260^{b}
3) Mow (M; 1 pass)	0 ± 47^{a}	102 ± 47^{b}	151 ± 47^{ab}	142 ± 47^{a}	M	84 ± 127^{ab}	362 ± 127^{c}	411 ± 127^{ab}	537 ± 127^{a}	M	0 ± 260^{b}	478 ± 260^{b}	1,613 ± 260^{b}	2,231 ± 260^{b}
4) Roller-Crimp (RC; 1 pass)	0 ± 47^{a}	58 ± 47^{b}	198 ± 47^{a}	38 ± 47^{a}	RC	211 ± 127^{a}	0 ± 127^{b}	696 ± 127^{b}	196 ± 127^{b}	RC	367 ± 260^{a}	67 ± 260^{b}	1,202 ± 260^{ab}	1,967 ± 260^{b}

Lablab	6 Week Harvest CCRG	CCVol	BL	GW	TM	9 Week Harvest CCRG	CCVol	BL	GW	TM	12 Week Harvest CCRG	CCVol	BL	GW
1) Full Disc (FD; 3 passes)	11 ± 198^{b}	0	33 ± 198^{a}	40 ± 198^{a}	FD	264 ± 233^{b}	0	322 ± 233^{a}	7 ± 233^{b}	FD	1,109 ± 288^{b}	0	1,147 ± 288^{b}	878 ± 288^{a}
2) Disc (D;1 pass)	1,229 ± 198^{a}	0	229 ± 198^{a}	118 ± 198^{a}	D	1,756 ± 233^{a}	0	429 ± 233^{a}	604 ± 233^{ab}	D	2,178 ± 288^{a}	0	36 ± 288^{a}	867 ± 288^{a}
3) Mow (M; 1 pass)	91 ± 198^{b}	0	267 ± 198^{a}	302 ± 198^{a}	M	484 ± 233^{b}	0	702 ± 233^{a}	1,113 ± 233^{a}	M	736 ± 288^{b}	0	611 ± 288^{ab}	1,384 ± 288^{a}
4) Roller-Crimp (RC; 1 pass)	498 ± 198^{b}	0	149 ± 198^{a}	869 ± 198^{a}	RC	924 ± 233^{ab}	0	687 ± 233^{a}	411 ± 233^{ab}	RC	1,098 ± 288^{b}	0	431 ± 288^{b}	1,869 ± 288^{a}

Cover Crop Regrowth = CCRG
Volunteer Cover Crop = CCVol
Broad Leaf Weeds = BL
Grass Weeds + GW

Values within the same column group followed by different letters differ (p<0.05) according to a least significant range seperation.

Results and Discussion:

Sunn hemp yielded the highest amount of CC biomass at termination with 6,800 ± 683 kg/ha compared to LL at 3,126 ± 683 (*p=0.002*). Lablab had greater plant tissue nitrogen (N) content than SH at 2.3% ± 0.1 compared to 1.7% ± 0.1~~;~~ respectively. ~~However,~~ Due to the greater SH biomass, total estimated N contribution was greater for SH (117 kg/ha ± 15) than for LL (70 kg/ha ± 15) ($p \leq 0.05$). At 6 weeks after termination, SH had ~~0~~ no regrowth ~~across all~~ within treatments. ~~compared to LL which~~ Lablab had the greatest measured regrowth from treatment 2 (1,229 Units? ± 198) and similar regrowth in treatments 1, 3, and 4 (11 ± 198, 91 ± 198, and 498 ± 198 respectively) ($p \leq 0.05$). At 9 and 12 weeks after termination, SH regrowth was effectively controlled in all termination treatments with the only measurable regrowth occurring in plots terminated with the roller-crimper (Table 2). In contrast, LL had ~~higher~~ greater levels of regrowth ~~across~~ among all treatments for all three post-termination harvests and termination treatments 1, 3, and 4 resulted in similar LL regrowth for each respective post-termination harvest date. Should the previous sentence be two sentences? Results indicate that SH ~~has~~ had a favorable response to all reduced tillage termination methods tested compared to LL, thus, SH may be better suited for use as a CC in reduced tillage tropical agroecosystems. Sunn hemp controlled grass weeds in treatments 1, 2, and 4 through week 9 ~~which~~ and had similar biomass accumulation of grass weeds at week 9 with 0, 0, and 196 ± 127 kg/ha; respectively. At 12 weeks after SH termination, broadleaf and grass weed levels exceeded 1000 kg/ha in all treatments except for treatment 1 which had the lowest levels at 631 ± 260 kg/ha and 44 ± 260 kg/ha~~;~~ respectively ($p \leq 0.05$). Therefore, full incorporation with 3 passes with the disc harrow resulted in the most effective termination and weed suppression method for SH.